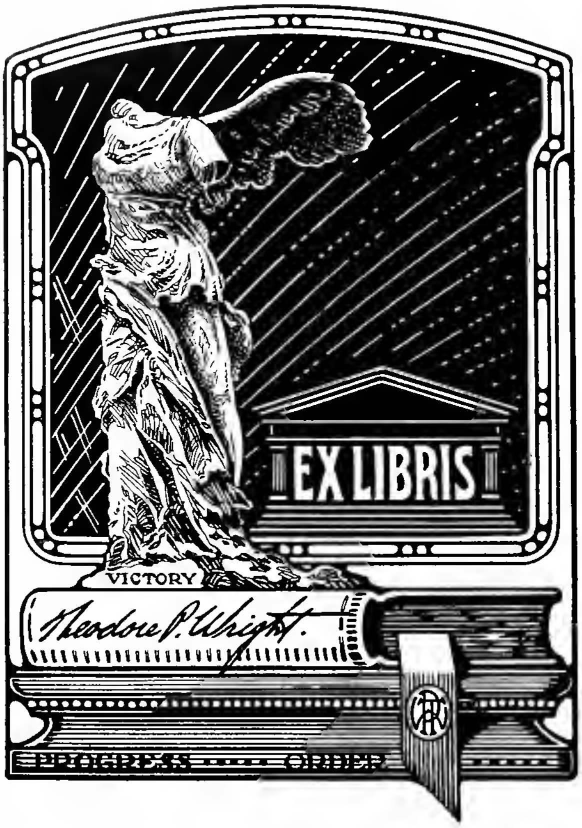
AEROBATICS

BARBER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AEROBATICS

By

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PREFACE

Before the commencement of the war it was a generally accepted theory that a first-class pilot of an aëroplane could not be produced under a minimum of a year. Under present conditions the average young man can learn to handle an aeroplane and put it through all the known tricks of looping, rolling, nose-dive spins, side-slips, etc., after a period of instruction of approximately no more than from twenty to thirty hours of actual flying.* That is a most extraordinary advance and it is in but slight part due to the improvements in engines and aëroplanes. Rather, it is almost entirely due to (1) the knowledge we now have as to how to execute aërial manoeuvers or "aerobatics"; (2) the improved methods of acquiring such knowledge, and (3) the confidence which we now know a pupil may have in attempting feats which, in the past, were looked upon as dangerous and as mere circus tricks.

This book is an attempt to explain in simple form, and for the benefit of novices, the general rules calculated to turn a raw pupil into an expert pilot in the shortest possible time and with the greatest possible degree of safety to himself and his aëreplane. Written during short periods of leave and at odd moments when off duty, I have not had the time to amplify it as fully as I should have liked; however, all it contains is based upon the hard lessons of practical experience and I feel that the rest to be learned can only be acquired in actual practice. If what I have written assists the pupil to approach his work in the air with intelligence and confidence, then half his battle is won before he begins and this little work has not been in vain.

Various technical subjects such as the theory of flight, meteorology, aëro-engines, aërial navigation, etc., have an important bearing upon the subject of aerobatics. The prospective aviator should have a sound if elementary

*I do not suggest that practise in formation flying, aerial fighting, 'cross country flying, etc. can be included within the twenty to thirty hours.

knowledge of such subjects and I have been tempted to include them in this work. Each subject, however, would demand a volume in itself unless treated in a casual way which would be of no real value, and I have therefore confined myself to the practical work in the air. Moreover, having regard to the intricacies of the subject and the opposite factors of brevity and simplicity required by the novice for whom I write, I have further confined myself to the *fundamental* evolutions of aerobatics, confident that once the student has learned to accomplish them he will have no further need of a text-book to assist him in perfecting himself in a higher degree.

June, 1918.

PART I

PART I.

ELEMENTARY FLYING.

The Ultimate Object. It is as well to commence with the ultimate object well in one's mind. That object is to learn to fly as if to the instinct born so that one may give practically all one's attention to other things than merely flying the machine. Those other things are many and require attention impossible to give unless the pilot can carry on his flying, including all aerobatic evolutions, as easily and automatically as the city man navigates a crowded sidewalk. There are the reading of maps, the reconnaissance of the country, etc., below, notes and sketches to be made, photographs to be taken, artillery observation, signalling, bombing, the outwitting of hostile aircraft, aërial gunnery, etc., all of which call for concentration apart from the flying of the machine. The pilot must, therefore, learn to handle his machine as if it were part of himself. He must be able instantly and almost instinctively to throw his machine into any desired position. That is the ultimate object as far as mere flying is concerned.

Confidence. As in the practical application of most things, *confidence* is one of the first essentials. Without that nothing can be accomplished. The novice may hear a lot about the danger of flying and feel his confidence shaken. Nearly all that kind of talk is fallacious. Flying is remarkably safe, given a good nerve and average intelligence. It's just as safe as driving a high-powered car at a smart pace along Fifth Avenue. But a few would never learn to drive that car. That's right, and there are a few who are, by temperament, unfitted to fly. Such unfitness is, however, at once discovered by a test flight as a passenger. Then let the prospective aviator experience a flight as his first preliminary. If he enjoys it then all's well, and the great majority enjoy it. If he is frightened then he had better not go any farther. But, Mr. Expert Pilot, it's not fair to put him through it too severely. There are limits to all things, and there is such a thing as spoiling a pilot in the making by forcing the pace too much at the start.

Theory. A pupil should have a thorough grasp of the elementary principles of flight, stability, and control, before going into the air. Without that groundwork it is impossible for him to approach his practical work intelligently. But he should not overdo it. The mathematical side of the theory of flight and aëroplane construction is not going to help him in the air. There's no time for abstruse calculations there. About all the pupil really needs is a thorough grasp of how it is that an aëroplane flies, the reasons why its attitude must be so and so during certain manoeuvers, what will happen if the correct attitude is not maintained and *the reason why*: the operation of the controls, what will happen if they are used wrongly, and *the reason why*. This elementary knowledge he can assimilate by carefully reading one or two of the best and simplest books on the subject, and by discussing points with pilots. He should also, of course, have an elementary knowledge of the internal combustion engine—elementary, but thorough as far as it goes. Lastly, he should gain a practical knowledge of the control of the engine he is going to fly, and this should be done before he thinks of ascending. He cannot be too thorough or painstaking in this.

In penning that which follows, I assume that the reader has passed the elementary stage of ground instruction outlined above, and that he is ready for his first lesson in the air.

The First Lesson in the Air.

In the early days of aviation there were no such things as lessons in the air, for machines capable of carrying two persons had yet to be designed and built. The novice was then his own instructor and took weeks and even months to learn that which a year or two later he was taught in a few hours. Then came more powerful engines capable of carrying two persons, and with two sets of control levers linked together. The pupil could then, by means of this system of "dual control," learn to handle his machine, confident that any mistake he made would be rectified by his pilot-instructor. That was a considerable advance but there was still this difficulty: that speech between the instructor and pupil was impossible owing to the noise of the engine and the rush of air. Much time was lost in descending to explain mistakes. All that is now avoided by the use of a speaking tube, and this little matter of the speaking tube or "aero-telephone" is probably the greatest advance of all where instruction in flying is concerned. By this means the instructor and pupil can converse all the time, and with the greatest ease. All the different manoeuvers, from the simplest to the most complicated, may be explained to the pupil during their execution; questions can be asked and answered; mistakes on the part of the pupil can be instantly rectified by orders from his instructor; and *the controls can be left entirely to the pupil,* although they can, of course, be instantly commanded by the instructor in case of emergency. The point italicised is most important, as nothing shakes the confidence of a pupil so much as doubt as to whether he or his instructor has command of the controls.

The best machine for instructional purposes is, without doubt, a fairly high-powered tractor aeroplane with a high margin of lift and a rather sensitive rudder—a large lift to minimize the effect of the pupil's errors in arriving at the proper gliding, climbing and banking angles, and a rather sensitive rudder to prepare him for the necessarily very sensitive one of the faster and more quickly controllable pursuit type of machine he must fly before long.

I am going to assume that the pupil learns to fly upon such a machine, fitted with the necessary telephonic apparatus, and that his instructor is one of the new school who never touches the controls except in case of emergency or for purposes of demonstration, who makes a study of his pupil's temperament and never rushes him but always insists upon each step being learned thoroughly before passing on to the next, and who, at the same time, is always teaching and never merely joy-flying.

The Rudder.

When the instructor has taken the machine off the ground, the pupil must first of all learn to keep the machine on a straight course by means of the rudder. He should learn this before touching the other controls. This is the kind of conversation which will then ensue:

Instructor: "I am now going to give you the control of the rudder. If you press your left foot ever so little forward the machine will turn to the left. If you press with the right foot the machine turns to the right. Have you got your feet on the rudder bar?"

Pupil: "Yes."

Instructor: "Notice that hill on the horizon. The nose of the machine is heading for it. Now press your left foot forward. That's right. The nose has now moved to the left of the hill. Now press your right foot gently and hold it there until we point to the hill again. That's right. Now centralise the rudder-bar and just ever so little the mo-

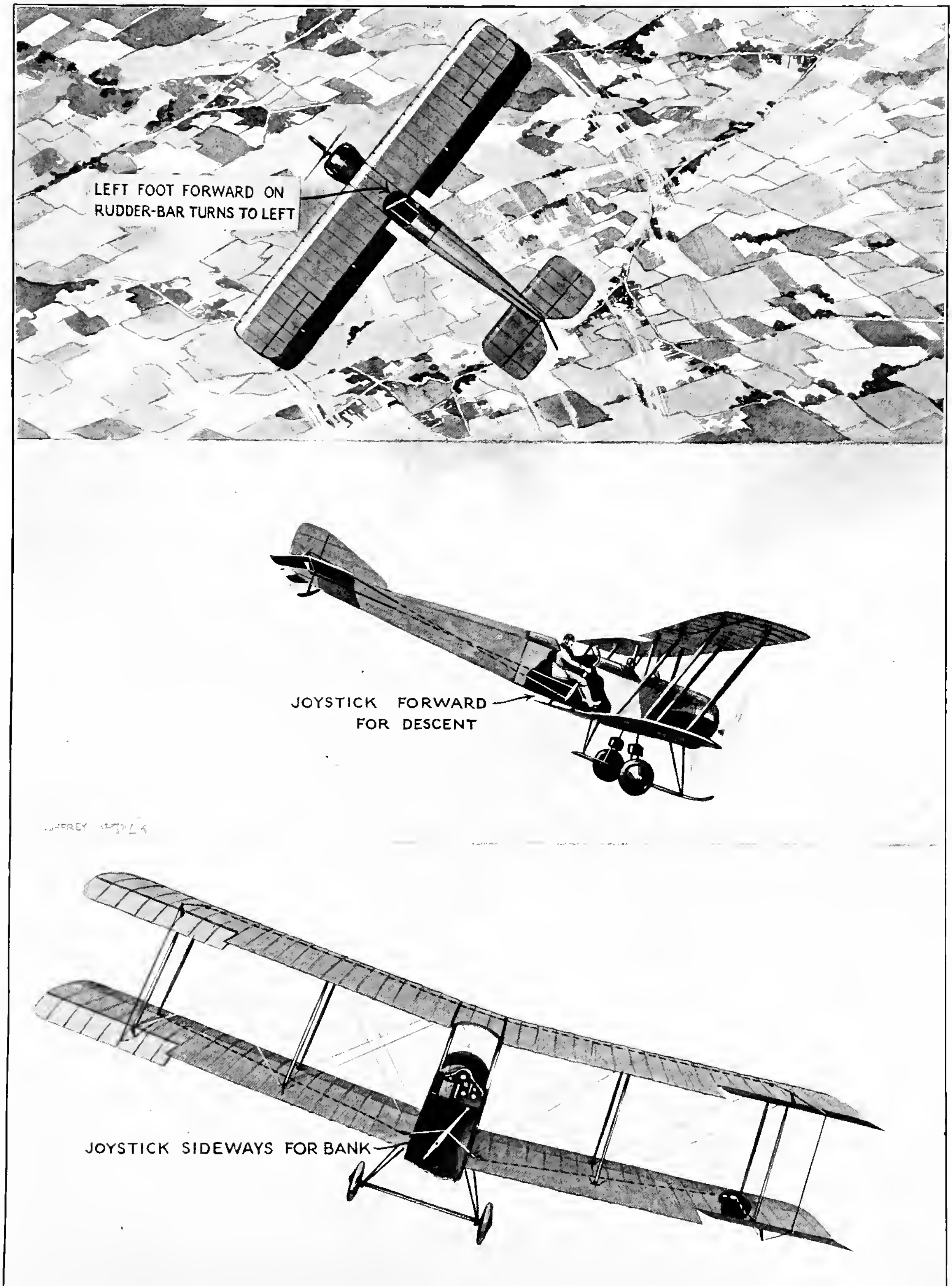

Plate 1.

The operation of the controls.

mentary left rudder to counterbalance the momentum of the turn or we shall continue to turn to the right.

"That was not bad but you must *press more gently.* The slightest pressure is sufficient. Now try the same thing but start with right rudder."

The pupil practises this sort of thing for a few minutes, until he has the feel of the rudder control, and then:

Instructor: "Now you know how the rudder works. What's that you say? 'Rudder very sensitive, and difficult to avoid too great pressure of foot?' You'll soon get used to that. If not, you will have to fly with boots off for a bit. Now see if you can keep the machine straight for that hill."

If, after five to ten minutes' practice the pupil cannot keep a fairly straight course, the chances are he will never make a pilot.

The Elevator

Now for the elevator control.

Instructor: "I'll take the rudder now. Put your hand on the joy-stick in front of you, and *don't grip hard,* or you will never acquire the necessary 'touch.' If you push it forward the machine descends. If pulled back, it ascends. The nose is normally about a foot above the horizon. Push the stick forward *gently* until the nose is level with the horizon. That's right. Now pull back until the nose is about two feet above the horizon. That's right. Go on doing that until you have the feel of it."

Within a minute or two the pupil has got the touch, and then:

Instructor: "Now keep the nose in its normal position for straight flying, that is, about a foot above the horizon."

A few minutes of this, and the pupil should have no difficulty in keeping the machine level longitudinally. Now he should take control of both rudder and elevator, and in about ten or fifteen minutes he should be able to keep a straight course, and a level flight path.

The Ailerons. Now for the third and last control; that of the ailerons hinged to the wing-tips, and which keep the machine level laterally.

Instructor: "I will take the rudder and elevator. Keep a light hold of the joy-stick. If you press it to left or right the machine tilts that way. Now practise it until you have got the touch."

In a minute or two the pupil has learned how much to move the stick sideways to secure a corresponding sideways tilt of the machine. He should then take command of all three controls and practise straight flying in which the rudder will give him his directional course, the elevator his longitudinal attitude, and the ailerons his lateral position. It is really absurdly easy, and the movements quickly become practically instinctive. Left or right with rudder. Push the nose down or pull it up with the stick, and push down the rising side with the stick. Within sixty minutes after first ascending (two lessons of about thirty minutes each) the average pupil should be flying straight and level.

Second Lesson. *Turning.*—The pupil now knows the effect of the controls, can fly straight and level, and must learn to make easy turns. His ground instruction has taught him that, in order to turn correctly, the machine must be tilted sideways to avoid side-slip outwards, and that it must not be tilted or "banked" too much for the turn, or it will side-slip inwards. Flying straight, he hears his instructor as follows:

"We will first do a gentle turn to the left. Bank the machine to the left by pressing the stick in that direction. About a 30 degrees angle. As soon as it banks put on a little left rudder—very little. Keep the nose a little above the horizon." (See Plate 2.)

The pupil obeys. He probably puts on too much or too little bank or rudder. He is quickly put right *via* the telephone and, in a very short time, he is making moderate

Plate 2.

A moderate turn to the left. The rudder makes the turn, the elevator maintains the longitudinal attitude, and the ailerons effect the bank.

turns in good form. For every turn to the left he will do well to make one to the right, for, otherwise, he may be come "one-sided" as many of the old time pilots were, and that would never do for modern flying and the aerobatic tricks he will be called upon to perform very shortly. He should practise moderate turns and increasingly steep banks up to angles of 45 degrees, until he can hold his machine steadily upon such turns and without side-slip inwards or outwards of the center of the turn. Such slip is quickly borne in upon him by the side draught of wind it sets up. The instant he feels such side-draught he should press the stick sideways *away* from the direction of the draught. He should make his turns sufficiently perfect to avoid any side draughts. Many pupils will complete this stage in one lesson of thirty to forty minutes, but some will require an additional lesson before passing on to more advanced flying,

The Third Stage.
Sharp Turns.

Sharp turns and steep banks. This third stage, as in the case of Euclid, may be well described as the *pons asinorum.* It is more difficult than anything gone before, but it should certainly be within the capacity of the average pupil and, after it has been passed, his confidence should be greatly increased. A thorough grasp of "the reason why" of the inherent difference between moderate turns with banks of no more than a 45 degrees angle and sharper turns with banks up to the vertical should materially assist him in passing this stage.

Plate 2 shows a machine making a moderate turn to the left necessitating a slight bank. It is obvious to anyone having but an elementary knowledge of flight that the ·udder is turning the machine to the left and that the elevator is controlling the longitudinal attitude of the machine. The ailerons are ,of course, being used as may be necessary to give the correct bank which, if too steep, would cause a side-slip inwards—and, if not steep enough, would cause a side-slip outwards.

In Plate 3 is illustrated a machine making a sharp turn necessitating an almost vertical bank.

It will be observed that, while the rudder and elevator are still turning the machine about the *same axes of the machine,* they have changed their functions one with the other as follows: The elevator is now making the turn relative to the earth, and the rudder is maintaining the longitudinal attitude, that is, controlling the ascent or descent of the nose of the machine which the pilot with feet and eyes must hold on a definite course.

The joy-stick is pulled hard back to make the machine turn—and the rudder is operated to keep the machine in the desired longitudinal attitude. The ailerons, controlled by the side movement of the joy-stick, are used to hold the machine in the correct bank.

During the first few such turns the great difficulty the pupil has to contend with is the altered aspect of the earth, horizon, and sky. Everything appears to be in a state of mad chaos, which is accentuated by the increased air pressure upon the control surfaces, especially the elevator, the operation of which needs much more force.

It will save time and avoid a lot of trouble if he asks his instructor to take command of the controls and to continue such turns until he is somewhat used to them and can keep his eye on the rapidly revolving horizon and his mind upon the sharpness of the turn and angle of bank. The rapidity with which the horizon races by the nose of the machine is at first somewhat amazing and disconcerting, but one very soon gets used to it and finds out that the greater such rapidity the more finished the turn. Given a horizon only twenty miles away and a turn completed in six seconds, the speed with which the horizon moves past the nose is 1,200 miles a minute; however, one soon become acustomed to it.

After about a dozen sharp turns the following is the conversation to be expected:

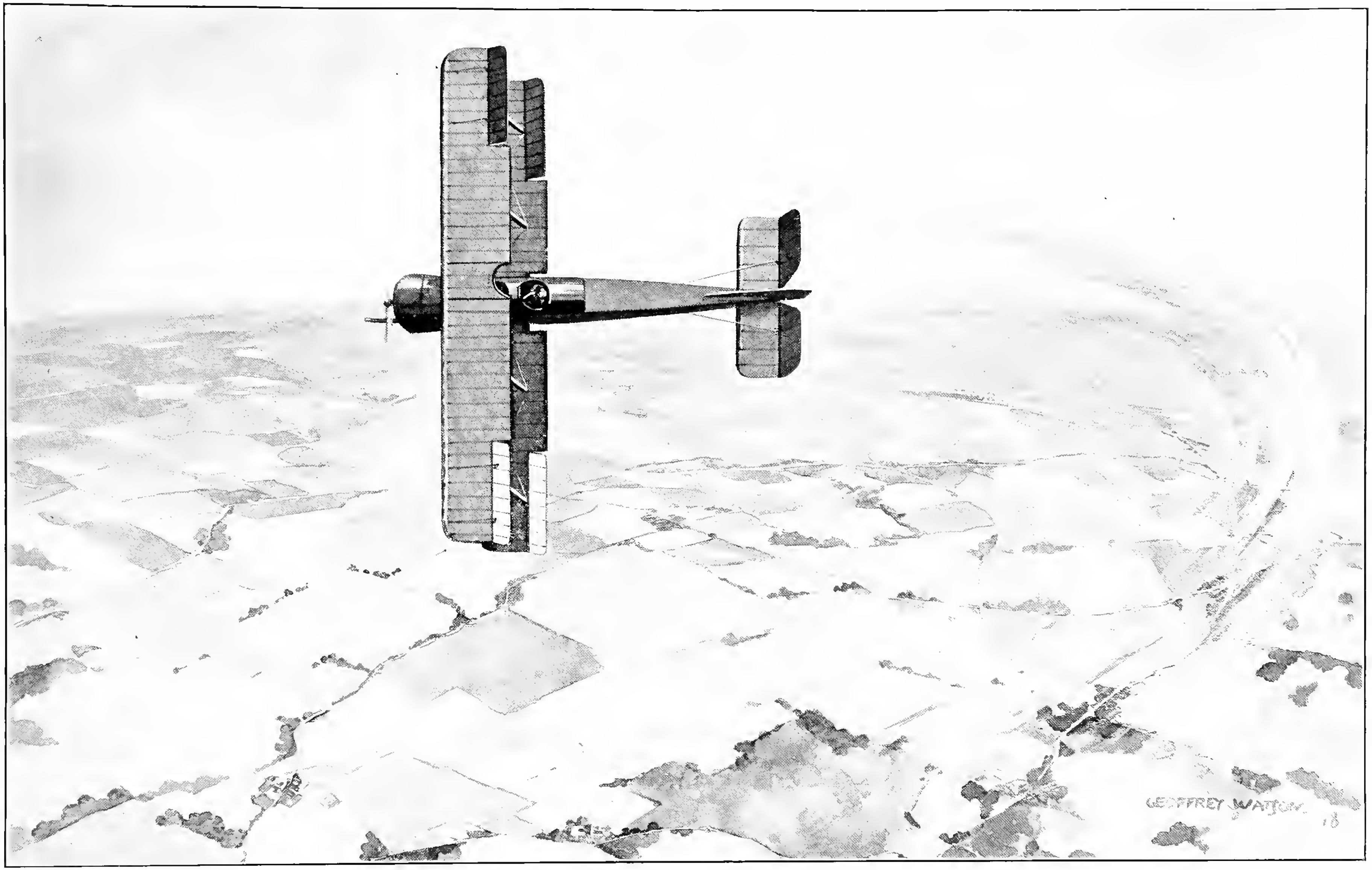

Plate 3.

A sharp turn with vertical bank. The elevator makes the turn, and the rudder controls the longitudinal attitude. The ailerons maintain the correct bank.

Instructor: "Getting used to it now?"

Pupil: "I couldn't tell whether I was inside out or upside down at first, but I could keep my eye on the horizon the last four or five turns."

Instructor: "Well, you had better have a shot at it now. Begin with a moderate turn and gradually increase it. After you increase the bank to over 45 degrees pull the stick back, and use the rudder to keep the nose a little below ordinary flying level—about level with the horizon. Try a left hand turn and remember that it is always *bottom rudder* (that's your lowest foot) forward *to depress nose,* and top rudder for *reverse effect.* The steeper the bank the sharper must be the turn, and consequently the more you must operate the elevator by pulling the stick back until it is right against your stomach. If she banks too much, take it off by pressing the stick sideways against the rising side."

Pupil: "How about getting out of the blessed turn when once I'm in it?"

Instructor: "Sufficient for the day, my boy. I'll get you out of it and you shall learn that after you can turn correctly. One step at a time is our system. Now take charge."

Pupil: "I've got her at about 45 degrees now. Is this where I start this new stunt?"

Instructor: "Yes. Now bank a bit more by pressing the stick sideways. Begin pulling the stick back, for the elevator must now do the turning. That's right. Go on pulling it back—more—more. A little more back. That's splendid. Keep the nose on the horizon—it's too high now, and needs a little bottom rudder; not too much, old fellow, or you'll have the nose down and we don't want a spinning nose-dive. No—don't overdo it; keep the nose on the horizon. If it goes up too far we shall do a stall and side-slip tail first. Pull the stick back; keep on pulling her round the turn. All right—give me the controls now."

The instructor puts the machine on an even keel and straight course again, and the pupil listens for his comments.

"That wasn't half bad," he says, and the pupil feels a glow of confidence and gratification. "It was a bit wobbly, but you'll find it easier next time. But you *must* pull the stick back more when you get a steep bank on—otherwise the machine side-slips inwards and you will know that by the side draught of air. There is no side draught if it is done properly. Now try a right hand turn."

The pupil should practise sharp turns both to the left and to the right, until he can hold his machine steadily in its correct attitude. He should go on doing this until he has attained a fair degree of perfection. It is the first great step towards the all-important feats of aerobatics and a thorough grounding in sharp turns should be completed before anything more ambitious is attempted.

The most surprising thing about a sharp turn with a vertical bank is, in my mind, the fact that, where most machines are concerned, little or no altitude is lost. Given that the planes are really vertical and therefore securing no reaction from the air directly opposed to gravity and that the propeller thrust is horizontal and not hauling the machine upwards, then all the principles of flight dictate loss of altitude. Yet no appreciable loss occurs! It is very puzzling and this very day before writing this, I ascended to put it once more to the proof. I made four consecutive turns with vertical bank and horizontal thrust at an altitude of 2,500 feet and at the finish the altitude was still the same. The nose was pointing slightly downwards during the first part of the bank, and also during the recovery, so the lift could hardly have been produced during those stages of the evolution. It seems that my observation must have been at fault somewhere but, at any rate, the maintenance of altitude during sharp turns is very surprising. If the turn is not sharp enough for the bank (i. e., the stick not pulled back enough) the machine side-slips at once and altitude is lost. The maintenance of altitude dur-

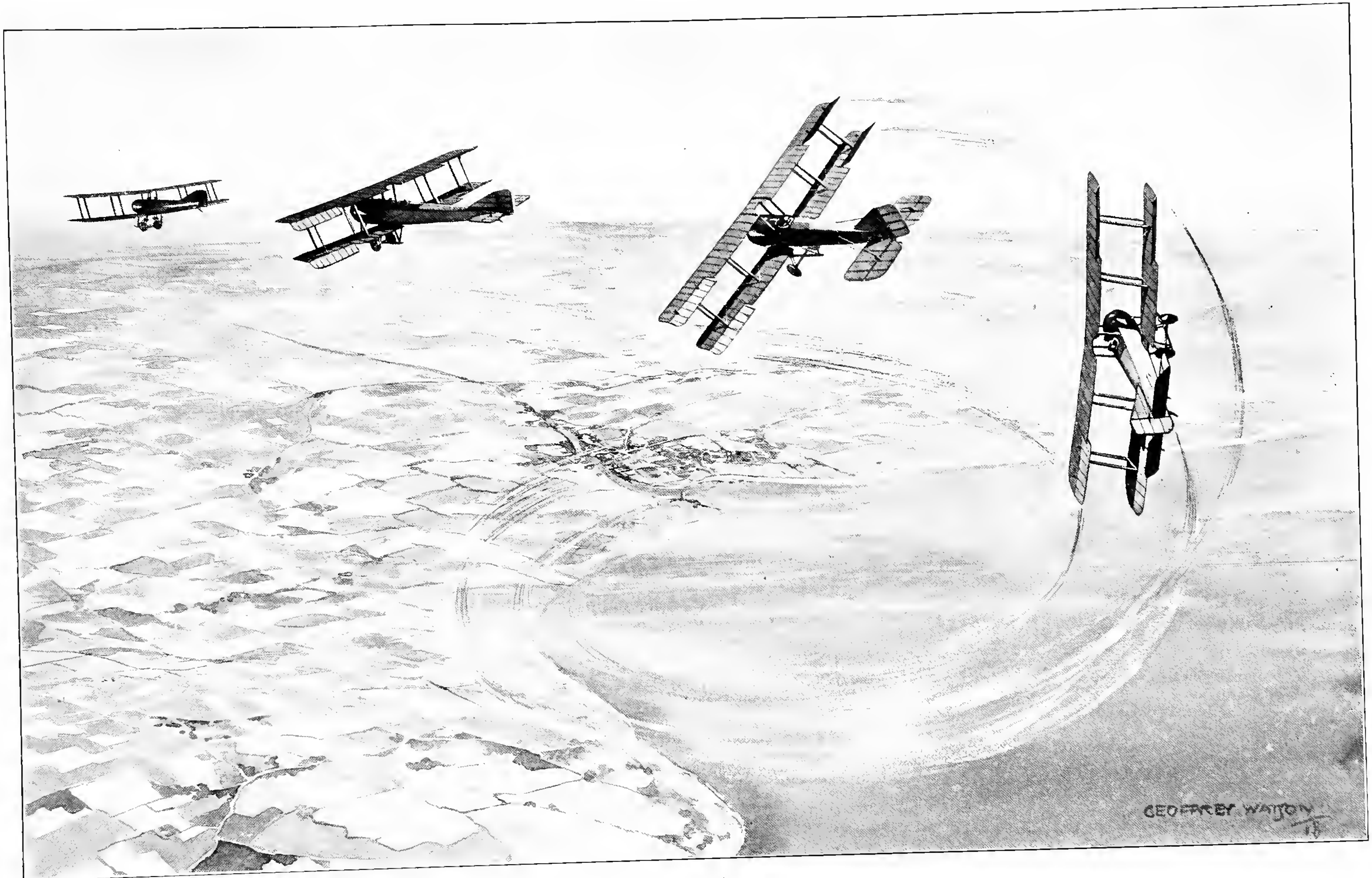

Plate 4.

Recovering from a sharp turn.

ing a vertical bank then appears in practice to depend upon the turn being sufficiently sharp. I have to confess that on this point I am unable to produce my old friend "The Reason Why."

Recovery from sharp turns should be learned at this stage, and after the pupil begins to feel at home in turning.

Recovering From a Sharp Turn.

Plate 4 illustrates the path taken by the machine in recovering from a sharp turn and vertical bank. The positions of the controls are shown at different stages and they are, of course, only approximate as they differ slightly with different types of aeroplanes. The stick must be gradually pushed forward to widen the turn, and pushed sideways to operate the ailerons and take off the bank. Only practical experience can teach the comparative forward and sideway movements. At the same time, the rudder must be operated to keep the nose of the machine a little lower if anything than during the turn—this to gain greater speed and consequently air reaction in order to offset the tendency of the machine to side-slip inwards owing to its banked up position.

This operation of the controls continues until the bank has been decreased to about 45 degrees—the critical banking angle from the point of view of the operation of the rudder and elevator. Now the rudder can be used as in normal straight flying; that is, for continuing to straighten out the turn to a straight flight—the elevator can be used to maintain the correct position of the nose relative to the horizon; that is, by pushing forward to descend and pulling back to ascend—and the pupil will continue to use the ailerons to level the machine laterally.

After the banking angle has been decreased to less than 45 degrees a little top rudder may be used to assist in leveling the machine laterally. In Plate 4, top rudder is right-hand rudder and causes the machine to turn to the right. Thus, the left wings are made to travel faster than the right wings, and therefore gain more lift, consequently helping to lift the left and low side. But this must not be overdone or it will result in a side-slip towards the lower wings.

It may take some time for the pupil to acquire a friendly acquaintance with the critical banking angle of about 45 degrees, to hold his machine steadily and confidently upon turns of various degrees, and to recover from sharp turns without side-slipping. As regards the last point his usual mistake in first trying to get out of a sharp turn is to use his rudder as he would in normal straight flight. That, of course, since the machine is in a sideways attitude to the earth, causes the nose to rise and results in a stall and consequent side-slip with tail down, as illustrated in Plate 5.

Climbing Turns.

Climbing turns (Plate 6) are just as easy as any other forms of turning, but they must not be overdone; that is, the turn must not be so sharp as to necessitate a steep bank, or the result will be descent instead of ascent. The reason of this lies in the fact that the lift depends upon the speed *and* the span of the lifting surfaces as viewed when standing under the machine and looking directly upwards. Both these factors decrease on a climbing turn. The air-speed always drops when climbing, and, owing to the turn, the machine must be banked, thus decreasing the plan view, i. e., the horizontal equivalent, of the planes. The lift must then decrease and, if the climb and-or the bank pass a certain limit of steepness, the lift will become less than the weight and the machine must consequently lose height.

The maximum angle of climb and the sharpness of the turn, with consequent bank, depend entirely upon the margin of lift the machine possesses. In a machine having only just enough lift to get off the ground, and therefore no margin of lift, a climbing turn would be impossible.

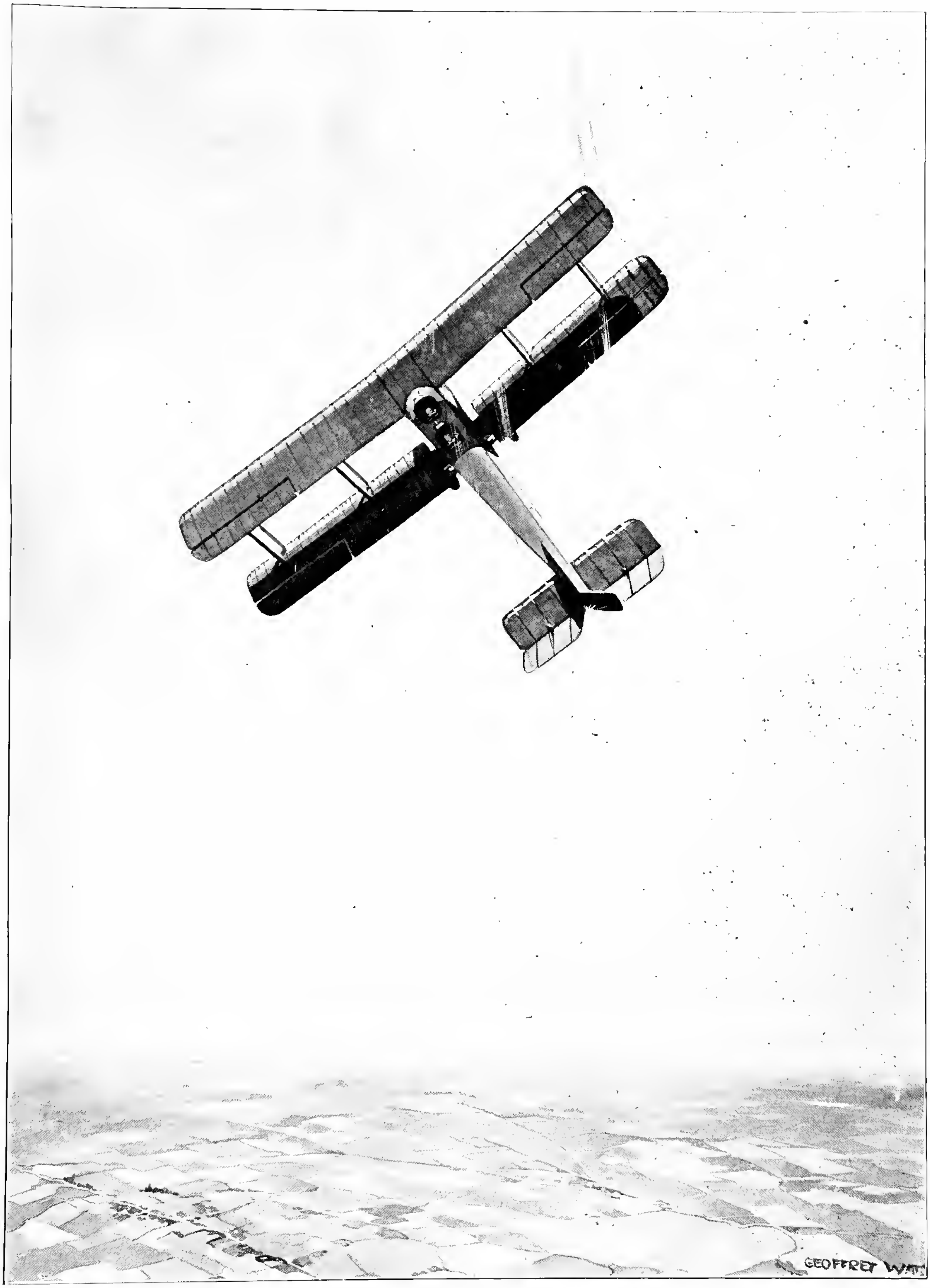

Plate 5.

A combination of side-slip and tail slide, the result of using top rudder instead of elevator to recover from a sharp turn.

Where present day machines are concerned there are few capable of making climbing turns at angles of bank over 45 degrees; unless, indeed, the turn is preceded by a dive to gain greater than normal speed when a short climbing turn at over 45 degrees angle of bank may be secured.

Climbing turns may at times be very useful and the pupil should therefore practise them in order to find out exactly what his machine can do in this respect.

There is a good deal more to be said about turning, but nothing, I think, that is not best left to be learned at a later stage. The above should be quite enough for the pupil to know before starting and, if well-known to him, can hardly fail to assist him in his elementary flying, and to augment his confidence.

Flat Spins.

Flat spins are the result of turning with insufficient bank, i. e., of using the rudder without banking. The rudder causes the machine to turn and the centrifugal force of the turn causes the machine to skid outwards from the center of the turn. If there is no bank to offset the skid the latter acquires considerable velocity. The direction of the flight path is then the resultant of the propeller thrust force and the centrifugal force of the turn and the machine travels in a more or less sideways attitude through the air. Owing to it not being streamlined for such direction of travel it quickly slows up and the controls become inoperative. The nose then falls and the machine dives. It may dive some way before it is possible to pull it out of it by means of the elevator, so that if a flat spin occurs near the ground it may mean a disastrous dive. More bad crashes are caused by flat spins at a low altitude than by any other cause. The moral of this is to be sure and bank enough when turning, especially at a low altitude. It is far better to over-bank than not to bank enough, as over-banking merely causes a side-slip inwards which is instantly rectified by pushing the stick sideways towards the rising wing. A flat spin is illustrated at the top of Plate 18.

The Flight and Glide Angles.

The next stage should be that of learning to maintain the best climbing angle, the minimum and maximum flying angles, the correct gliding angles, and of thoroughly learning the difference between the foregoing and the stalling and diving angles. Landings should not be attempted until this stage has been passed. (See Plate 7.)

Climbing.

Every machine has its best climbing angle. At this angle its air-speed, as registered on the air-speed indicator, is usually about 75 per cent. of its normal speed in horizontal flight. While the indicator may occasionally be of use to the trained pilot, it is better for the pupil to make no use of it, or he may learn to rely upon it for his correct climbing and other angles, and that would never do since he will have other use for his eyes.

The instructor now puts the machine into its best climbing attitude, and begins using the invaluable telephone.

Instructor: "Now we're climbing. There's not so much wind in your face, is there?"

Pupil: "That's so, but why?"

Instructor: "You ought to know that from your ground instruction. The air-speed is less when climbing and consequently there is less air-pressure; also, and for the same reason, there is less air-pressure upon the rudder, ailerons, and elevator. Wobble them and see."

Pupil: "The ailerons are certainly easier to move, and the elevator easier to push forward. The turning effect of the rudder and ailerons does not seem to be so quick."

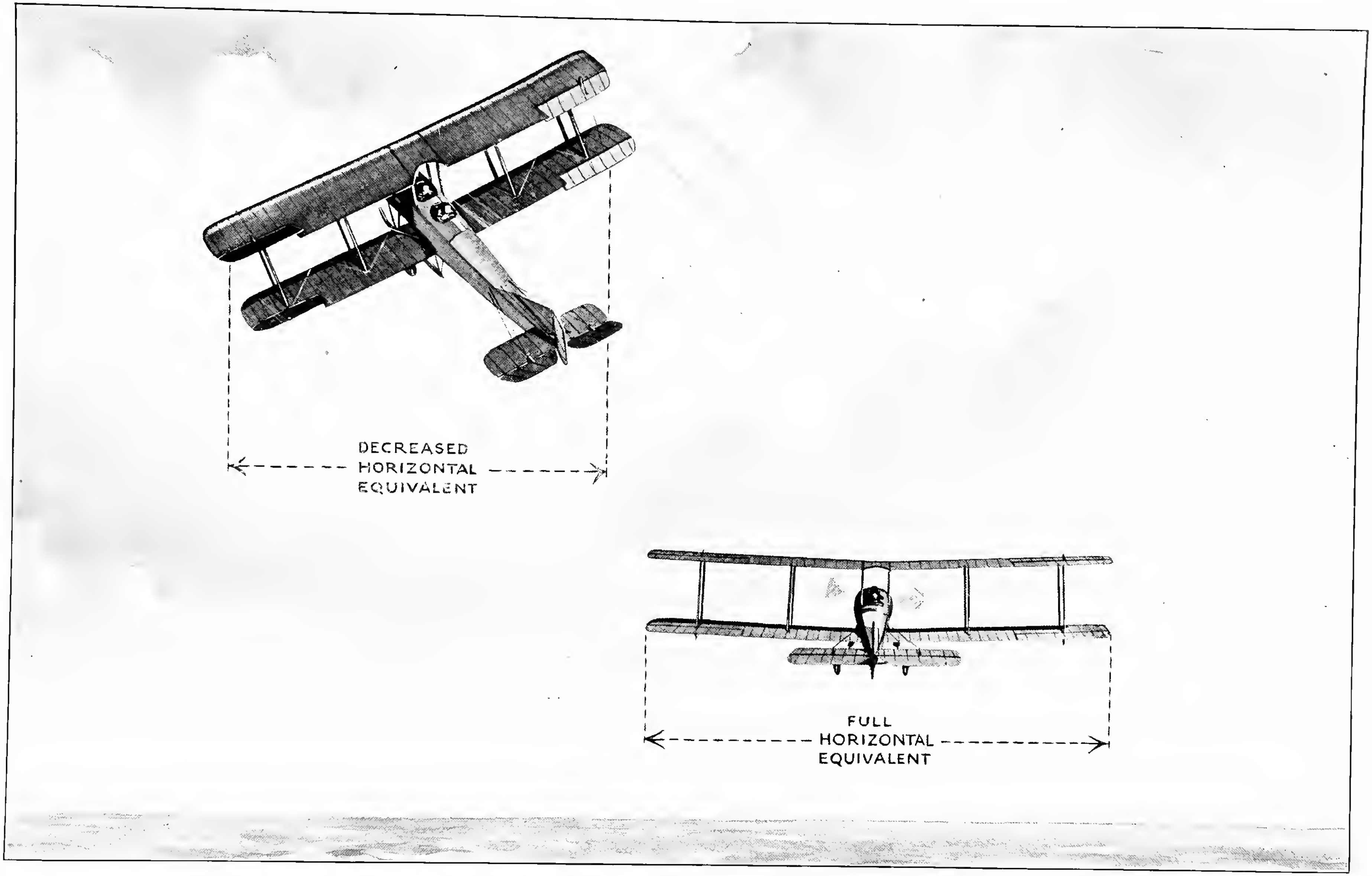

Plate 6.

A climbing turn. Note the decrease in the horizontal equivalent of the span of the planes due to the bank.

Instructor: "That's right, and the greater the climbing angle, the more exaggerated those conditions become. The less the angle the less they are experienced. Now take the controls and keep climbing.

"Don't wobble the elevator like that. We're not going upstairs. Keep the stick back. It looks strange at first to see the nose so high, but you'll soon get used to it. That's right. Hold her there.

"Now we'll descend a couple of thousand feet and try it there. After that you shall practise climbing above those clouds."

Pupil: "Why not go on with it here?"

Instructor: "You have got to learn this at various altitudes and above the clouds; otherwise you may be sure of the correct angle at only one altitude."

The tendency is to learn to know the angle from the attitude of the machine relative to the earth, and this must be avoided or the aviator will find it impossible to maintain the best angle when above the clouds or in thick weather. He must learn to know it from the air pressure and the feel of the controls.

Maximum Angle and Stalling.

Instructor: "The machine is now at its best climbing angle. Pull the stick back a little—just a little more—now hold it there. This is what's called the 'maximum angle.' The air-speed has decreased to such an extent that we have only just enough lift to maintain our height. Any greater angle and, the air-speed decreasing still more, our lift becomes less than our weight and we fall. That's stalling. Now pull the stick back and see what happens."

The machine assumes a still greater angle, the air-pressure dies away, the controls become practically inoperative, and the pupil wonders much what happens next.

The machine begins to fall, there is an upwards draught of air (here's the origin of "wind-up," by the way), and the instructor cuts off the engine. The machine is now, in effect, nose-heavy and the nose begins to fall quicker than the tail. Soon it is pointing downwards in a moderate dive and the controls becoming operative, the orders of the instructor are again heard.

"Pull the stick a little back of neutral. Not too much. Pull her out of the dive gently. Now we are out of it. Switch on the engine."

Pupil: "Why did you cut off the engine?"

Instructor: "To render the machine more nose-heavy, thus assisting the nose to fall downwards out of the stall; also to eliminate the propeller thrust and so minimize the dive. Now keep on doing stalls. Do them entirely by yourself and make each one steeper than the last. Note each time—this is important—how much altitude you lose in recovering the normal flying position. That will teach you how near the earth you can stall safely. When you have learned to do it properly up here you must practise it lower down—also among the clouds where you can't see the horizon."

A machine can also be stalled by using too much top rudder when on a sharp turn with steep bank. Owing to the sideways attitude of the machine relative to the earth the operation of top rudder causes the nose to rise. (See Plate 5.)

Stalling during a glide is dealt with under the head of *Gliding*.

The Minimum Angle.

The Minimum Angle is the smallest angle at which an aeroplane can maintain horizontal flight, and it is also the angle at which greatest speed is attained apart from diving. The pupil should take every opportunity of practising the maintenance of this angle as upon it depends the shortest and most rapid flight, an important consideration where long distance flights are concerned. If the angle is not closely maintained then the flight path becomes undulating and consequently of greater length.

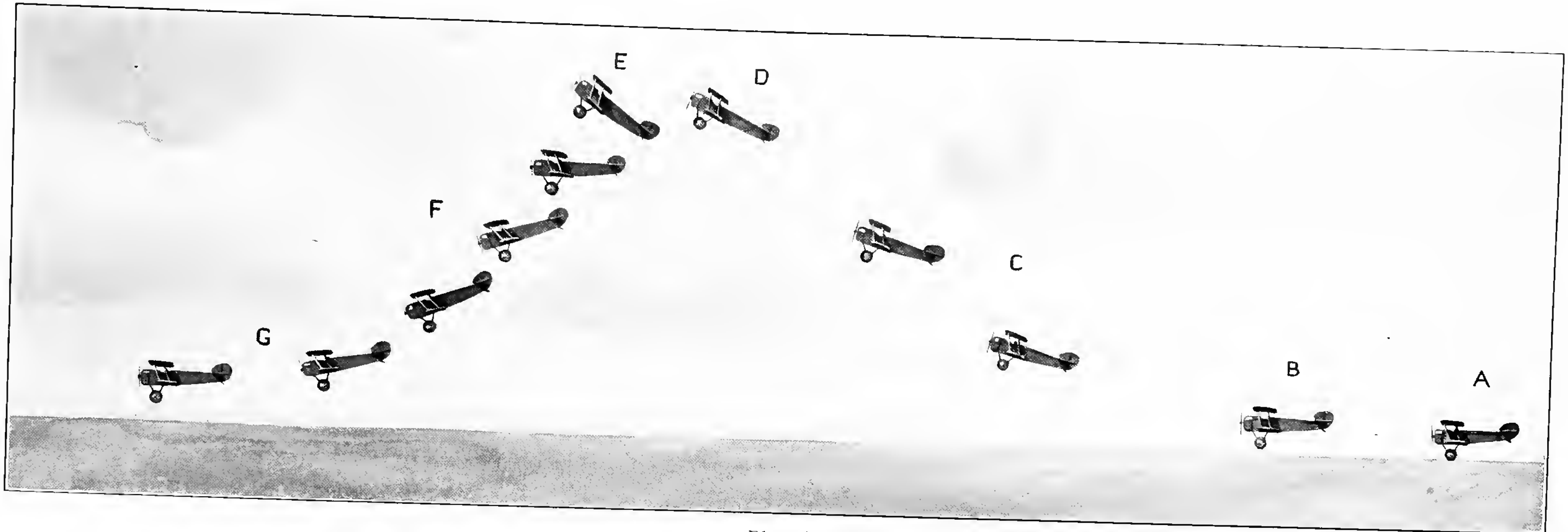

Plate 7.

A. *Minimum angle*, which gives greatest speed apart from diving.
B. *Optimum angle*, (propeller thrust horizontal) at which a slight ascent is maintained provided that not less than normal flying speed is also maintained. Called "Optimum" because at this angle the efficiency of the aeroplane (i.e., the proportion of lift + speed to air-resistance) is at its best.
C. *Best climbing angle*, at which ascent is quickest.
D. *Maximum angle*, the greatest angle at which horizontal flight can be maintained.
E. *Stalling angle*, which must result in descent.
F. *The Dive*, resulting from stalling. If the engine is throttled down the dive will be minimized.
G. *The Recovery*, effected by gently pulling the stick back.

Note.—The angles as illustrated are approximate (with the exception of the optimum angle) as they vary with different types of aeroplanes.

Gliding. If the engine is stopped or throttled down and the machine held in its climbing attitude or upon a horizontal flight path it will quickly stall, that is, fall owing to the lift decreasing with the decreased air-speed. In order to avoid a stall the nose must be deflected by means of pushing the stick forward. Gravity then takes the place of the propeller thrust in pulling the machine along its downward gliding path. The steeper the glide the faster the air-speed upon which the operation of the rudder, elevator and ailerons depend. The pupil should possess a thorough grasp of gliding and gliding turns before he attempts landings, for without that he is asking for trouble. If we could be put through to the pupil's aero-telephone we should probably hear something like this:

Instructor: "This machine can do eighty miles an hour and it glides nicely at fifty-five. I shall now throttle down and put it into a fifty-five mile an hour glide—now we're gliding—take the controls and try to keep a steady glide."

The pupils sights the nose of the machine against some object on the earth and steers steadily for it. As he continues to descend he unconsciously gradually flattens out the glide in keeping the nose sighted against the far distant object and the next instant the machine stalls. It falls and then, the nose dropping owing to the machine being in effect "nose-heavy" when the engine is throttled down, it takes on a dive and the instructor pulls it out of it. (Plate 8.)

Pupil: "What was wrong? I seemed to be gliding straight for that building."

Instructor: "That was just where you were wrong. In a steep glide it might be all right, though, in such a case, probably you would find that you would overshoot your mark. In the case of a slow glide such as we were doing we fall a little all the time and it is impossible to reach the object you sight at the beginning of the glide; especially if the wind is against you. If the nose is kept pointing for it the gliding angle decreases and a stall must occur."

Pupil: "Well, since I am not allowed to observe the air-speed indicator how am I to keep the machine at its fifty-five mile glide?"

Instructor: "By noting the 'feel' of the air-pressure at that speed and by the different 'touch' of the controls. You will have to practise this at various altitudes, and also above the clouds where you cannot see the earth. You must become sufficiently perfect to enable you to glide without stalling or diving when you are in thick weather or clouds.

"When the horizon is visible it is easy to maintain your correct gliding angle by keeping the nose pointing a certain distance (in this machine about a foot) below the horizon, but that's rule-of-thumb flying, and since the horizon is not always visible, you must learn to do without its aid. Now try it again."

Gliding Stalls and Recoveries.

He practises it again and again, the instructor often disturbing the gliding angle to give him experience in recovering it. Then at various altitudes, above the clouds, and, last of all, in cloud mists from which the earth can hardly be seen. Then practice in stalling and recovering. This is practically the same as the lesson he has already had in stalling with engine on, but the difference to be learned is *the smaller angle* at which the gliding machine stalls. This is all important from the point of view of landings as, if the machine stalls just before landing, there will not be the height necessary for recovery and a crash must result.

Diving Glides.

Diving glides near the earth are also useful in teaching the pupil the great landing speed they result in, and the latter is, of course, to be strictly avoided owing to the following disadvantages: (1) the large extent of landing

Plate 8.

A gliding stall due to continuing to sight the nose against a distant object during a slow gliding descent. A is the correct gliding path. B is the decreased angle of path which results in a stall. C is the dive resulting from the stall.

ground necessary, (2) the great skill necessary to prevent the machine touching ground too early in which case it will probably bounce up and come down with a crash.

Gliding Turns. The pupil should now pass on to gliding turns which, since the machine is descending, form spiral descents. The rules to be observed are very much the same as in the case of turns with engine on. The main difference lies in the fact that the nose must be kept pointing down at an angle sufficient to ensure the necessary air-speed, otherwise a stall will result. Also, owing to the comparatively slow speed of gliding, the controls will experience less air-pressure and must be used more coarsely than in the case of turning with engine on. For some abstruse reason most pupils have a tendency to underbank when making a gliding turn. This results in a side-slip outwards with consequent side-draught of wind which will warn him to put on more bank. The side-draught will, however, be much less than in the case of the engine being on as, owing to the lesser air-speed, and consequently lesser momentum, there is less centrifugal force tending to pull the machine outwards from the center of the turn.

The correct angle of glide when turning is perhaps rather more difficult for the novice to learn than is the correct longitudinal attitude in the case of a turn with engine on. This is so because in the former case the nose is too far below the horizon for it to be a good guide. An imaginary circle on the earth, some distance below the horizon, must be visualized against which the nose must be sighted and held as the machine turns—held by the elevator at angles of bank below about 45 degrees and by the rudder at steeper angles. Just before starting the turn and while the machine is still on a straight gliding path the pupil should notice the distance the nose appears to be below the horizon. Let him now slightly increase the gliding angle (this to increase the speed and consequently the air-reaction in order to offset the loss of lift which will occur when he banks for the turn—otherwise he will side-slip inwards) and the point the nose then points at is on the imaginary circle. As the machine descends nearer and nearer to the earth the imaginary circle must be correspondingly decreased in diameter, but it remains the same distance from the horizon since the circumference of the latter decreases with descent. (See Plate 9.) In very sharp gliding turns the gliding angle need not be so steep as in the case of moderate turns, and the diameter of the circle may therefore be greater.

Gliding S Turns.

S turns should now be practised. Their value lies in the fact that, when descending, the pilot can keep his landng ground always within view, which is not the case where a spiral descent is concerned unless it is made directly over the landing place which is not advisable having regard to the problem of approach. They also give him more time to observe his landing ground and to decide upon the best way of approaching it than is afforded by a straight glide. Again, an S turn or turns is a necessity if, owing to miscalculation, he finds that his straight glide will overshoot the mark if persisted in. (See Plate 10.)

Side-Slipping.

It is not so long ago that side-slipping was regarded as a dangerous performance. We now know that, done properly, there is no danger, and that this manoeuvre has distinct advantages in securing a quick descent with a minimum forward speed, the latter point being invaluable where landings on small areas are concerned. It is also useful (as explained elsewhere) in offsetting drift when it is necessary to land with the wind on the beam. Our pupil must learn to side-slip for these reasons and also so that

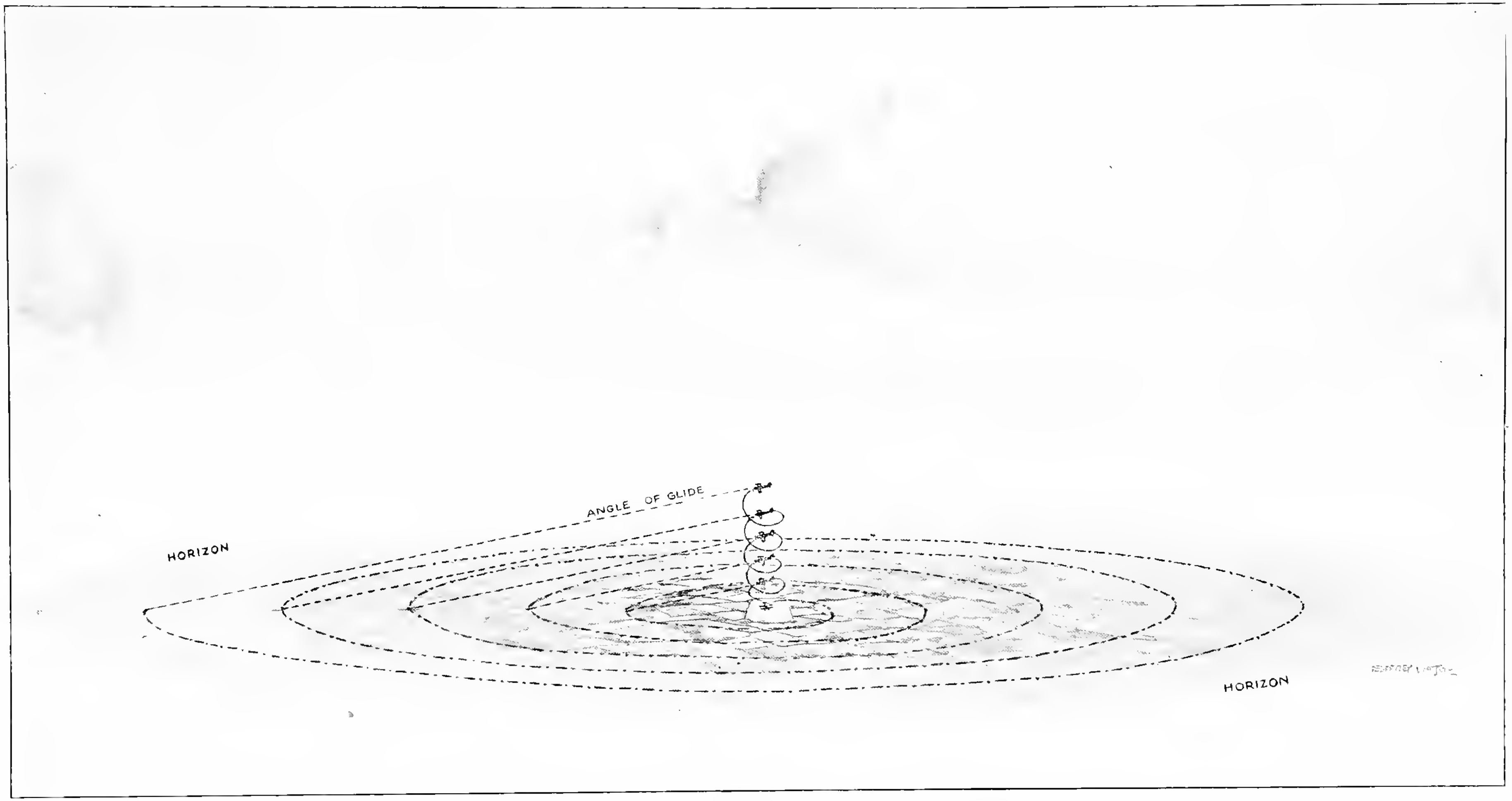

Plate 9.

The above illustrates a spiral gliding descent and the imaginary circle against which the nose of the machine must be sighted. Throughout the descent the imaginary circle remains at the same distance from the horizon since the latter decreases proportionately to the descent.

he may know how to recover from an involuntary side-slip. Let us follow his first lesson.

Instructor: "Now we'll make a side-slip descent on that mark in front of us. No, not yet. We happen to be flying with the wind, so we must pass it first and then turn to and against the wind as otherwise our landing speed would be excessive. Also, remember always to side-slip into the wind rather than the other way or, owing to the sideways speed of the slip plus the speed of the side wind, you may land with a sideways momentum and wipe off your undercarriage. Now take the controls and bank over fairly steeply. That's right. Now we're slipping. Hold the bank there."

Pupil: "There's a dickens of a side draught. Where do I keep the nose pointing?"

Instructor: "The side draught is all right, but *don't forget your forward speed.* You must keep steerage way on or the controls won't work. Keep the nose down—about half way between the horizon and the normal gliding point. That's too high. Bring the nose down with a little bottom rudder. That's right. The lower the nose the greater the forward speed, and the steeper the bank the faster the side-slip."

Pupil: "We're getting rather near the ground. How do I act?"

Instructor: "Wait until the lower wing-tip is about forty feet from the ground. Now we are there. Push stick sideways towards the high side, and level her up."

The machine instantly levels and lands with a normal glide.

Pupil: "Wasn't that rather near the ground to take the slip off?"

Instructor: "After a little practice you will be able to wait until the wing-tip is within a few feet of the ground. The machine will always level the instant you push the stick sideways. The important point is to keep sufficient forward steerage way on by keeping the nose down to the right degree, but don't overdo that or you will land with undue forward speed, and one of the principal objects of this manoeuvre is to land in a small area and stop quickly. Now we'll do it again." (See Plate 11.)

Taking Off, Landings and Taxying.

The pupil is still far from being an aerobatic pilot but, by this time, he should know enough to take a lone command of his machine in the air. Landing is, however, a very different matter and he should not attempt a solo flight until he has been thoroughly instructed in landings, and also in taking off.

Taking Off.

"Taking off," i. e., ascending from the ground, is an easy matter compared to what it used to be. A few years ago aeroplanes were so underpowered that considerable skill was necessary in order to secure, within a reasonable length of run, the necessary speed to rise. The nose had to be deflected to just the correct point in order to give the planes the best angle for minimum air resistance, and, therefore, maximum speed; and, when pulling the stick back for ascent, great care had to be taken to avoid giving the planes too great an angle or the result would be nothing but a spasmodic hop. Now, owing to greater engine power and consequently a higher margin of lift, the same degree of nicety is not strictly necessary. The pupil will do well, before attempting his first ascent and while sitting in the machine, to get someone to lift the tail of the machine up until it is in normal flying position, and to do this half a dozen times. He may then carefully note the flying position which is the maximum angle at which the preliminary run should be made. Any greater angle will increase the air resistance of the planes and result in an excessively long run. A slightly less angle is permissible, but care must be taken to avoid too small an

Plate 10.

A descent by means of S turns.

angle or he may stand the machine on its nose. (Plate 12.)

Ascents should, it seems almost unnecessary to say, *always* be made in the face of the wind. This is to minimize the length of the run and also to secure a good control of the machine as early as possible. Until the machine has got its air-speed the controls are naturally comparatively sluggish, and it helps matters to start with the air-speed of the wind. In getting off with a following wind the machine may gain considerable ground speed before the controls become efficient and this may easily lead to it becoming unmanageable and crashing.

Immediately the machine moves the stick should be pushed forward until the nose is in normal flying position: and, as the air-speed and consequent air-pressure upon the elevator increase, the stick must be gradually pulled back to about neutral position or the tail will get up too high with possibly disastrous results. *Directly* the tail rises from the ground the rudder should be used to maintain a straight course. The latter is, where some machines are concerned, rather tricky at first but, after a few attempts the average pupil should manage it. Until flying speed is attained the rudder will not be fully efficient and must be used coarsely. Any tendency of the nose to swing sideways must be checked by *instant* application of the rudder.

As soon as the air-speed is sufficient for ascent the stick should be pulled back *gently* and it is not advisable to place the machine at its best climbing angle until one is quite sure that full air-speed has been secured, otherwise a stall may occur. It is sometimes necessary to take off with the wind on the beam owing to difficulties of the ascending ground. In such cases the ailerons must be used to preserve lateral balance. However, practice in this does not occur at this stage of the pupil's career.

Landings. A perfect landing is one in which the machine is (1) stopped at the desired point, (2) when near the ground glides but a short distance and then pulls up quickly on the ground, and (3) lands without shock.

In order to achieve this it is necessary (1) to descend slowly as otherwise a fast and *long* glide near the ground will result, and (2) to stall the machine near the ground in order to increase the air-resistance and thus brake the speed.

The glide should therefore be a slow one, and the pilot should begin flattening out by gently pulling the stick back when about fifteen feet from the ground. By the time the wheels are about three feet from the ground the attitude of the machine should be a little nose up. This attitude should be held until the wheels have descended to about one foot from the ground, and then, *when the speed has decreased sufficiently to render ascent impossible in the event of the elevator being used,* the stick should be pulled right back. The machine will then stall and come to rest without shock and with a very short run along the ground. If the stick is pulled back too early and before the speed has slackened sufficiently the machine will rise and then come down with a bad bump. If it is pulled back too late the undercarriage may be wiped off or the machine may complete its run in a series of hops. In a landing done perfectly the wheels and tail-skid will touch ground simultaneously. Such landings demand a very nice judgment and take practice to perfect. Perfection is a necessity having regard to forced landings in bad country and the pupil will do well to use every landing he makes an opportunity of perfecting himself in this respect. Before long he will make perfect landings almost instinctively. (See Plate 13.)

Accuracy of Landings.

The next thing to learn is to come to rest at a definite point. This may not seem very important to the pupil at this stage as he probably has a large aerodrome at his disposal, but he should never forget that very soon he will have to spend most of his time in the air far from good

Plate 11.

A side-slipping descent. Note the forward movement in the descent. Upon this depends the efficiency of the controls. The ailerons are shown in position for recovery at the bottom of the descent.

landing places. In order to do this he must learn to judge height, and the distance his glide will take him across country, from *various altitudes* and in *different velocities and directions of wind*. The distance his machine will glide relative to the earth depends upon the conditions italicised and he should take every opportunity of carrying out gliding descents and landings from various altitudes and under various conditions of wind. It is easy enough to learn to hit off the landing mark from one altitude in calm air. That is the first thing to be learned but the rest must be learned, and thoroughly, if crashes are to be avoided.

In the matter of making slow landings without shock and of landing on the mark much useful knowledge can be gained in using spare time between flights in observing the efforts of other pupils and noting their mistakes.

Landing Across Wind.

Landing across wind should now be practised as the pupil will in the future sometimes be confronted with forced landings in small fields and may find it impossible to land against the wind owing to trees or other obstacles. If he should attempt to land with the ordinary straight glide, the wind drifting his machine sideways will result in the wheels of the undercarriage getting a sideways shock on landing with the almost certain result of a crash. Means must then be taken to take the drift off. As a rule this can be done by side-slipping in the direction the wind is coming from. The side-slip should be persisted in until the lowest wing-tip is within a fraction of touching the ground when the machine should be levelled up by means of the ailerons. The flattening out of the glide and the following stall must, of course, be attended to in the ordinary way. In this way a moderate drift may be offset by the opposite speed of the side-slip. In the case of a rapid drift this may not be sufficient and, after levelling up the side-slip near the ground, it may be well to make a flat turn towards the direction of the wind, while making the final stall. This may sound a rather complicated manoeuvre but a few preliminary demonstrations on the part of the instructor will show the pupil how it is done and he will soon get used to it.

Forced Landings.

Forced landings can now be practised in fields adjacent to the aerodrome. In making a forced landing the considerations are (1) to choose the landing place as early as possible and never to lose sight of it, and (2) to make sure of the direction of the wind. As regards the first point, the pupils should remember the value of S turns, each turn being made *towards* the landing place. In this way he can keep it in sight all the time. As regards the wind, if he has any doubt as to its direction he may find the following tips useful. Smoke or the moving shadows of clouds on the ground, or the ripples on water—remember that the water on the windward side of a pond or river is usually calm compared to the lee side. If these indications fail he will have to wait until he is low enough to detect his drift relative to the ground. Having decided upon the direction of the wind he must now make up his mind as to the approach the factors governing which are the direction of the wind. obstacles such as trees, and the size and topography of the landing space. Assuming lack of landing space he must use every endeavor to land as near the approach side as possible, so that the landing run may not carry him into the opposite boundary of the field. By means of S turns he can keep outside the approach boundary until there is just enough height to hop over it. Then, if there is a sideways drift, he should side-slip in order to offset it and land as explained elsewhere.

Forced landings should be practised from various altitudes and in different places if they are to be of real value.

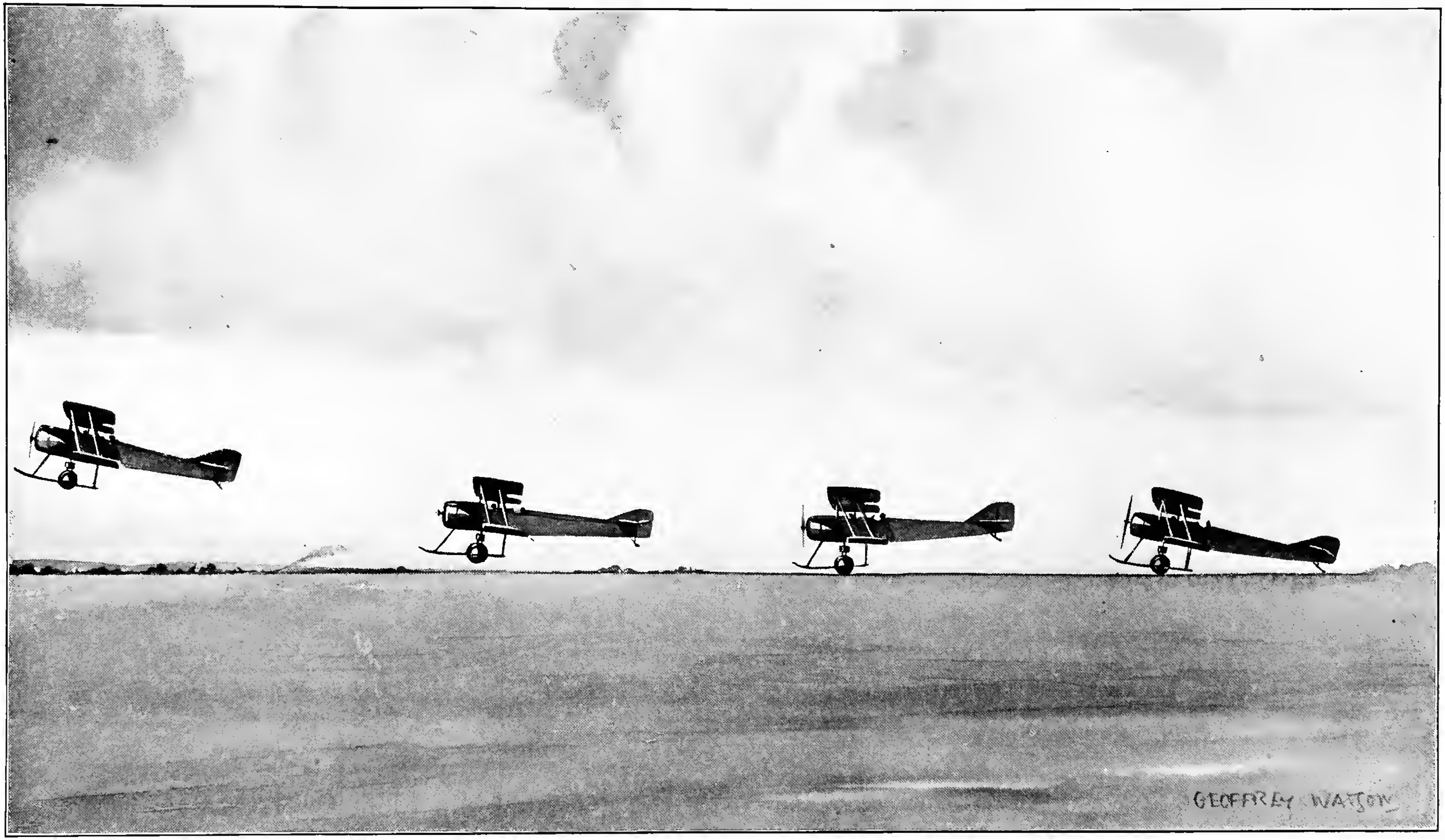

Plate 12.

Getting off. The machine should not be put into its climbing attitude until the pilot is quite sure that normal flying speed has been attained; otherwise a stall and bumpy descent will result.

Taxying. By "taxying" is meant the control of the machine while it is running along the ground under engine power. In the bad old days of learning to fly taxying was the first thing attempted and many pupils would taxy scores of miles before attempting a hop. We now know that it may be left until the last thing before solo flying.

Very slow taxying is only possible in the case of a machine with a steerable tail-skid. In such a machine the tail-skid is connected by wires to the rudder-bar and acts as a land rudder. In other machines it is impossible to steer the machine on the ground unless there is sufficient air-speed to enable the rudder to do its work. Such air-speed is secured by driving the machine along the ground at a certain speed to be learned by the pupil, and by the slip-stream from the propeller. The latter can be momentarily increased without materially affecting the ground speed by opening wide the throttle for an instant at a time.

The pupil should learn to taxy as slowly as possible having regard to good control of the machine. In order to do this he must learn to use his ailerons as subsidiary rudders. The stick should be pushed *the opposite way to the turn desired.* This depresses the ailerons of the wings on the inside of the turn and they, acting as air-brakes, retard that side and assist the turn. (See Plate 14.)

Owing to the low air-speed the controls are very sluggish and the rudder-bar and joy-stick must be used coarsely. In straight taxying many machines have a tendency whereby the tail tries to swing sideways. This must be checked *instantly* by full application of the rudder or the machine becomes unmanageable. This instant checking by means of the rudder is the first thing to learn.

Some machines have a tendency to turn in one direction owing to propeller torque. The machine tries to turn over sideways in the opposite direction to which the propeller revolves and this results in one wheel taking a greater stress than the other. That wheel then tends to lag behind and a turn results unless corrected by the rudder.

In such a case as illustrated in Plate 15, left rudder should be applied as soon as the machine moves forward, and it may be advisable to supplement the rudder control by means of deflecting the ailerons on the left-hand wings (pushing stick to right) until sufficient air-speed is gained to render the rudder control sufficient.

Where heavy machines are concerned it is necessary to use the elevator to get the tail off the ground or almost off it; otherwise, the friction and bumping of the tail-skid on the ground will render directional control impossible. In the case of light machines it is better to keep the stick back and the tail on the ground, as otherwise the latter tends to swing sideways too much.

In addition to the above the following tips may be worth remembering.

In calm air the machine turns easiest in the opposite direction to which the propeller revolves.

With a side wind the machine turns easiest towards the wind.

In a high wind *don't taxy* unless necessary. If it must be done try to keep head to wind, and it may be well to keep the tail well off the ground so that the planes present a minimum angle to the wind thus lessening the effect of the gusts upon them.

In taxying with the wind considerable ground speed is necessary to secure sufficient air-speed to render the controls efficient. That means momentum which, assisted by the wind, may cause the machine to roll a long way before stopping. Therefore, in taxying with the wind great care should be exercised if there are any obstacles on the ground.

Turn *slowly* when taxying or the centrifugal force of the turn may result in upsetting the machine, crashing the wheels, or taking the tires off.

Expert taxying will not be learned all at once, but fifteen minutes' practice should be sufficient at this stage, and the pupil should take every opportunity in the future to perfect himself.

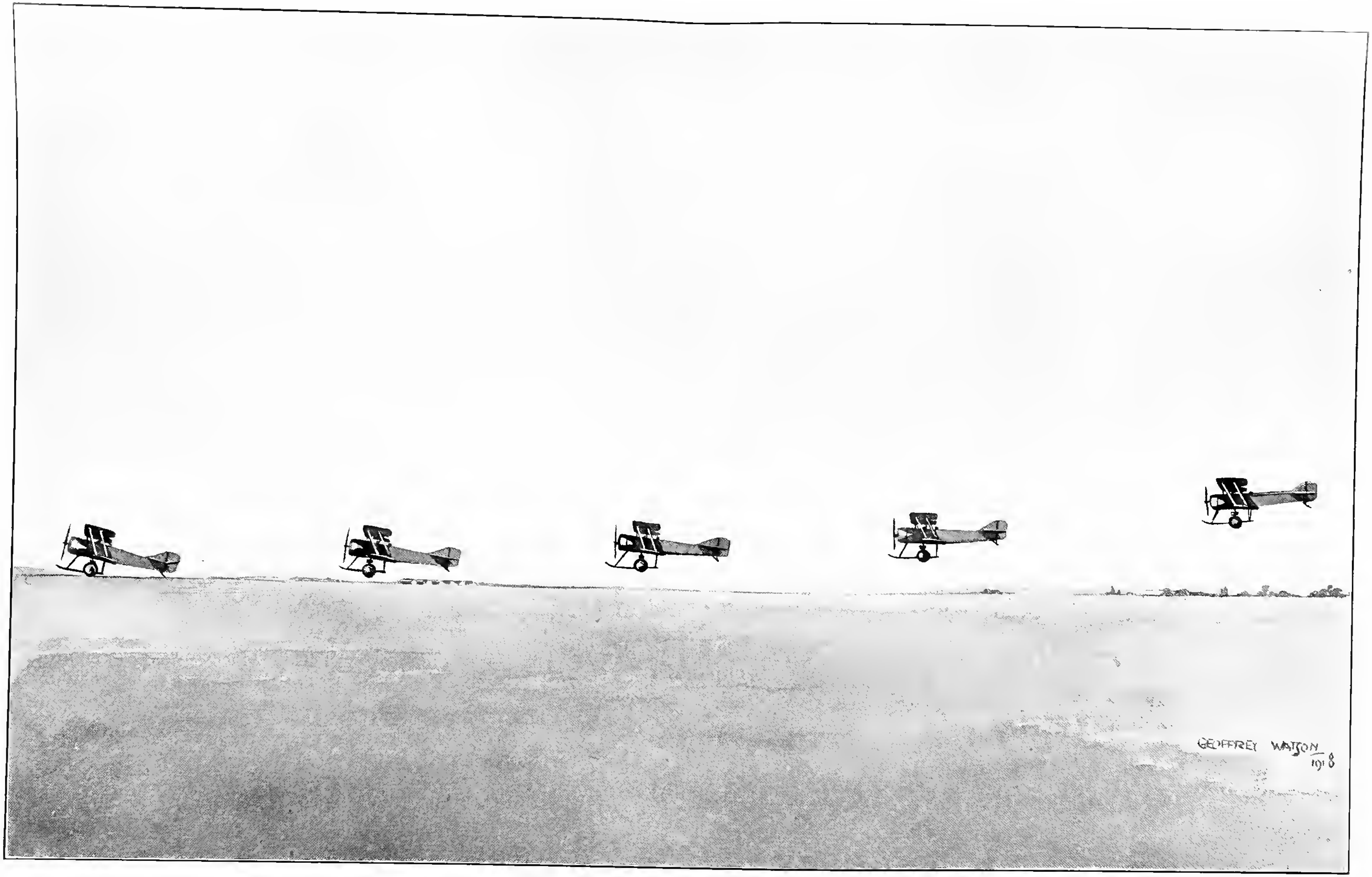

Plate 13.
Landing.

The average pupil has now spent eight or ten hours in the air, and should be ready for his first solo flight.* He has done more than the average pilot of not long ago dared to do after a year's experience, and he knows, or should know, far more than that pilot, for his trained instructor has given him "the reason why" for everything he has done. He feels confident, is already rather bored with the telephone, and he is ready to spread his own wings.

The First Solo.

Solo flying at this stage should be confined to perfecting the various evolutions already learned. The time necessary should not be more than from five to eight hours in the air altogether, according to the ability and temperament of the pupil. In my opinion the two main points to be observed are as follows. Firstly, *to make the first solo in fairly windy or "bumpy" weather.* If the pupil does this it is unlikely that he will ever fear rough weather but, on the contrary, he will enjoy the exercise of the skill necessary to control his machine in bad weather. If this stage of his flying is carried out in calm air he will learn to perfect the manoeuvres he has learned under dual instruction in unusually peaceful conditions and when, later on, necessity causes him to ascend in bad weather and execute more advanced flying he will not feel at home and may easily learn to dislike "bumps." That is how the fair-weather pilot is produced and the only way to avoid such an inefficient and unhappy condition is to commence solo flying in fairly bumpy weather and to seize every opportunity of perfecting himself in *increasingly* rough weather. This is

*Opinions as to when the first solo flight should be made are very diverse. I have placed it later than some instructors do. It seems to me that the more the pupil knows before attempting solo flying the greater will be his confidence and skill when first left to rely upon himself. Against this is the time lost if he fails to make good as a soloist. On the other hand how many pilots in the making have been spoiled by pushing them into the air at too early a stage. And how many crashes have resulted from the same cause?

really a most important point and if only civilian schools would evince more enterprise in this direction they might lose the reputation so many of them have had in the past of turning out only fair-weather pilots.

The second point is to *always ascend with a definite job in view.* Flying round and round the aerodrome, or making long straight flights is no use at all, and merely wastes valuable time and resources in petrol, oil and life of the machine. Before ascending the pupil should make up his mind as to the manoeuvre he is going to execute and he should stick to that with no wasted flying until he has perfected it.

If, after a few trials, he finds himself unable to carry out his object—sharp turn with vertical bank or side-slip, for instance—let him come down and ask his instructor the reason why; and if, after a further trial, he cannot manage it, let him at once ask his instructor to give him another short dual instruction lesson. He should not hesitate to take the latter course for it saves valuable time and may prevent him from learning to execute certain manoeuvres in a slightly wrong fashion. Unless every manoeuvre is perfected from the beginning he may easily get into bad habits and never become a really finished pilot. This solo stage of elementary flying is perhaps the most important stage of all for it is the necessary foundation upon which is based the advanced flying to follow.

At the expiration of five to eight hours' solo the average keen and intelligent pupil should be able to execute with confidence all the tricks he has so far learned under dual instruction. I have known a pupil to put up perfect loops, rolls and side-slips on his first solo flight. That is, of course, exceptional and going too fast for the average man, but it shows what can be done.

Before passing on to the subject of advanced flying or "aerobatics" it may be well to summarize the foregoing in the form of a progressive syllabus.

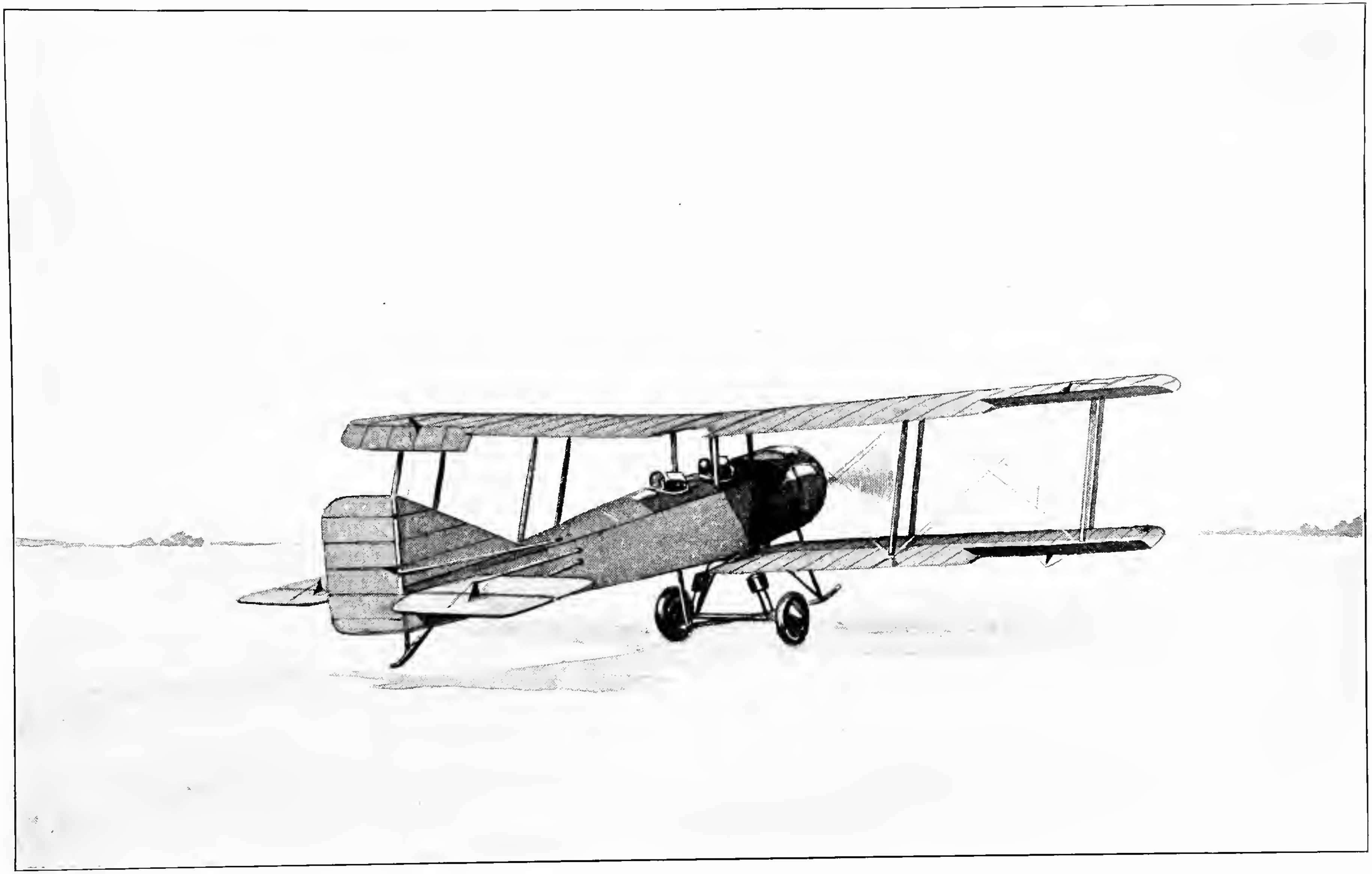

Plate 14.
Ailerons assisting a turn to the left. Stick held over to the right.

Theory. *The Aeroplane.* The history of aviation—the elementary principles of flight, stability and control—technical terms—types of aircraft and their comparative advantages—rigging—propellers—inspection and maintenance—instruments—navigation.

The Engine. Elementary principles—types—tank systems—ignition—carburration—thorough course on engine to be first flown including faults and remedies, and practice in running engine on test bench until the pupil can manage it satisfactorily with instruments out of sight.

Practice Rudder—elevator—rudder and elevator combined—ailerons—rudder, elevator and ailerons combined.

Moderate turns.

Sharp turns and steep banks.

Recovering from sharp turns.

Climbing—minimum and maximum flying angles—gliding.

Climbing and gliding turns.

Stalling with engine on and gliding stalls—diving.

Gliding S turns.

Side-slipping.

Flat spins and recoveries at a good altitude.

Taking off—taxying—aerodrome landings from different altitudes and in different conditions of wind.

Forced landings outside aerodrome and from different altitudes and in different conditions of wind.

Solo flights in *increasingly rough* weather until the above mentioned evolutions have been perfected, and sandwiched with additional dual lessons as necessary.

GENERAL REMARKS.

Always learn from the pilot's seat when under dual instruction as otherwise you may not feel at home on your first solo.

Ask your instructor "the reason why" of everything that's done, and steer clear of rule-of-thumb flying.

Before ascending for dual control instruction be sure to have a definite arrangement with your instructor whereby you may be quite sure when you have sole control of the machine. Also make sure of the telephone by conversing with your instructor during the preliminary run of the engine.

Be thoroughly informed as to bad landing spots on the aerodrome.

Don't be afraid of using the controls. Learn to throw the machine about from the beginning.

Make sure of the direction of the wind before ascending, and of the orders for the time being as to the direction of circuits near the ground.

Get used to altitude as soon as possible.

Keep clear of cloud, mist or fog at a low altitude.

Never stunt near the ground however confident you feel until you have passed the stage of aerobatic flying.
down. *Don't* underbank.

When turning near the ground it is better to have too much air-speed than not enough; therefore keep the nose

Always consider every landing as forced and do not rely upon the engine.

If a crash appears inevitable switch off the ignition and then cut off the petrol in order to avoid the risk of fire.

If a manoeuvre goes wrong and you are in doubt as to how to use the controls, then centralise them and the machine should right itself.

Take every opportunity between flights of noting mistakes in pupils' flying and landings, and, if in doubt as to the reason why, always ask your instructor.

Always take sufficient time to make yourself perfectly comfortable in your seat before ascending—and, if in doubt about anything, do not hesitate to ask your instructor.

Keep a sharp look-out for other machines from the time you take your seat until you leave it.

Plate 15.

The propeller is revolving to the left and the machine consequently has a tendency to turn over sideways in the opposite direction. The right wheel then bears more weight than the left one. It retards the right side of the machine which therefore tends to turn to the right. This is offset by left rudder.

Keep on asking your instructor all about everything. That's what he's there for, and he likes it. Keep on asking questions of those who know. Don't waste time in futile arguments with those who don't know.

Flying is no game for recklessness. The qualities which go to make a finished pilot are, in the order of their importance, about as follows: Keenness, physical and mental fitness, caution, alertness, sensitiveness of touch, thoroughness in details. Slackness, ill-health, recklessness, heaviness of touch, or a casual attitude where details are concerned make good flying impossible.

Keep fit by playing games requiring physical exercise and quickness of hand and eye; and, when on leave, forget all about flying.

PART II

PART II.

AEROBATICS.

Looping. Looping, while one of the most spectacular evolutions, is perhaps the simplest and easiest aerial trick to perform. One good loop accomplished the pupil will have no difficulty in continuing to loop in increasingly finished style.

Now let us imagine the pupil at an altitude of about four thousand feet. His instructor has looped him a number of times; and he has now given him command of the controls so that he may essay his first loop.

Instructor, while the machine is flying level: "Push the stick forward and dive until the speed is about 25 per cent more than normal flying speed. Be sure and keep a straight flight path and the machine level laterally." (See Plate 16.)

Pupil: "Is this fast enough?"

Instructor: "Yes. Now pull the stick back and fly over the loop. Keep straight with the rudder and level with the ailerons."

The pupil pulls the stick back too violently, with the result illustrated in Plate 17.

Instructor: "If you are out for collapsing your wings that's the right way to do it. You pulled the stick back so violently as to suddenly give the planes an enormous angle of incidence at which the air-flow over the top of them broke up into turbulent eddies, and the undersides of the planes met the air with a tremendous shock. The result was sudden loss of speed and lift and we consequently stalled. You must pull the stick back fairly gently and fly over the loop. Now try it again. By the way, there's a cloud over us with one side of it parallel to the horizon. As you fly upwards use that side as you would the horizon to guide you in keeping the machine level laterally."

The pupil now tries it again and, the machine rearing up, he hears his instructor's voice again.

"Now we are vertical. Pull the stick right back. Keep straight with rudder. Left foot (or right as the case may be) forward. That's right. Look at the horizon on each side of you. Keep each wing-tip the same distance above the horizon. Push the stick sideways *towards the lowest wing-tip*. Now we are at the top. Throttle down the engine."

The machine has now lost most of its speed, but the nose commences to fall and an upside down glide commences.

Instructor: "Now we are getting up speed again. Keep the stick a little back of neutral and, as soon as you feel air-pressure on the elevator, begin evenly and *gently* pulling her out of the dive. Keep steering straight and laterally level.

"Now we are in a normal position again. Open up the engine, and put the nose into normal flying position."

Pupil: "Why throttle down the engine at the top? Wouldn't it have helped to pull us over the back of the loop?"

Instructor: "Once the top is reached gravity pulls the nose down which is all that is wanted. If the engine were not stopped our forward speed would be greater and the loop correspondingly enlarged. In looping the endeavour should be to keep the circle as small and 'tight' as possible without undue air-pressures which mean unfair stresses on the machine. Again, if the engine were left on then the dive would be greatly accentuated and recovery retarded. Now try it again and without the cloud to help you."

Now for a synopsis of the operations.

1. Dive to increase the normal speed by about 25 per cent. (A. in illustration.)

2. Pull the stick back gently. Fly straight and laterally level (B.).

3. Pull the stick right back as a vertical attitude is approached. (C.) The machine now begins to turn on its back. Observe the horizon on each side in order to pre-

Plate 16.

The Loop.

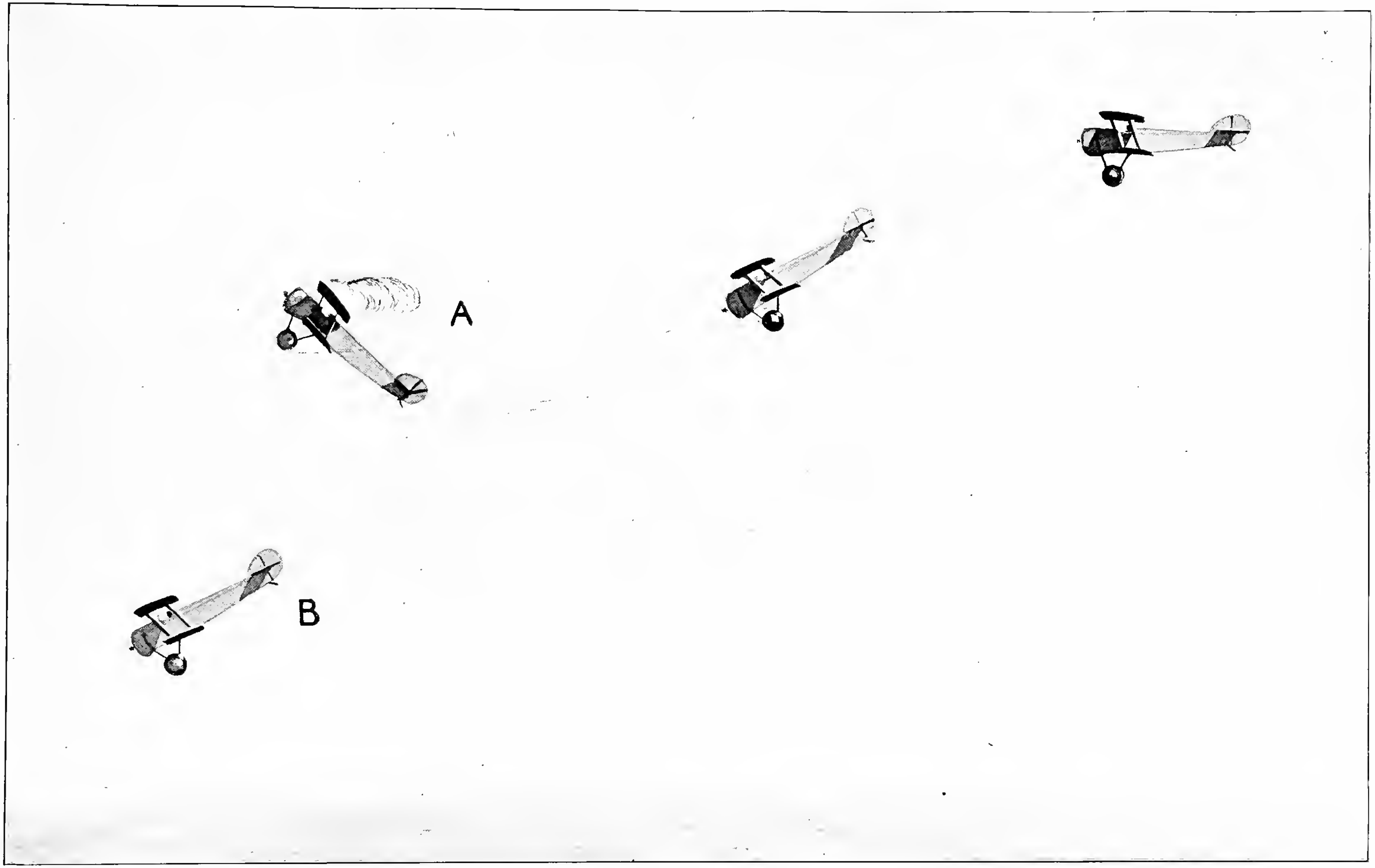

Plate 17.

Result of commencing a loop with stick too far back. A. the resultant stall. B. the dive following the stall.

serve lateral balance. Push the stick sideways towards the lowest side (D).

4. Throttle down the engine at the top (E).

5. *The nose commences to fall and the speed increases.* Stick a little back of neutral (F). Pull her out of the dive *gently* (G). Steer straight and keep laterally level.

6. *The machine assumes a normal attitude.* Throttle on, and put the nose into normal flying position (H).

The first mistake usually made is in pulling the stick back too violently at the commencement of the loop.

The second error is usually in not steering straight with the rudder. That causes a turn in which the wing on the outside of the turn travelling quicker than the inside wing gets a correspondingly greater lift with the result that at the top of the loop, if not before, the machine is no longer flying level, but is tilted over side-ways. A side-slip then results and the loop is spoiled.

The third error is in throttling down the engine too early and while the nose of the machine is pointing skywards. That results in the machine failing to go over the top, instead of which it falls back into a tail-slide from which it levels up, the nose falling and a dive and-or side-slip resulting from which recovery may be secured as explained elsewhere.

Tail-slides should be avoided as the resultant air-pressures throw unfair stresses upon the controlling surfaces and their fittings.

The only way to loop is to commence by flying over gently. When vertical pull the stick right back, and *steer straight* all the time. Don't throttle down until at the top and upside down.

In the case of a very wide loop there is a distinct tendency to leave the seat when upside down. In the case of a very "tight" loop the pilot is jammed hard into his seat by the centrifugal force. The perfect loop is, to my mind, neither of those, but one in which one seems to fly right round the circle with no jamming into the seat tendency, and no tendency to fall out of it. A gentle hold of the joy-stick should be all that is sufficient to hold the pilot comfortably in his seat. There are then no undue stresses on the aeroplane.

In some machines, especially some fitted with rotary engines, the machine has a tendency to turn over sideways directly the engine and propeller slow down at or near the top of the loop. The "reason why" of this is that some machines have their wings rigged at a varying angle to offset propeller torque. When the engine is throttled down the torque disappears and, owing to the wings on one side being rigged with a greater angle of incidence (and consequently having greater lift) than those on the other side the machine tends to turn over sideways. In others not so rigged the pilot when in normal flight instinctively and without thought operates his controls to offset the torque and keep the machine level, but when first looping the conditions are so different from normal flight he may fail to omit the slight correction he is used to maintaining when the engine is running. At the top of the loop he may continue to operate his controls to correct a torque which is non-existent since the engine is throttled, and such operation of the controls results in the machine banking.

Some machines therefore require a certain amount of one-sided rudder and-or ailerons control during the loop. The habit of every type of machine is in this respect well-known, so all that remains is for the pupil to make sure of it by enquiry before essaying his first loop. In any case the worst that can happen is a side-slip from the top of the loop and that, in itself, will teach him the control necessary to keep the machine laterally level during the loop.

Spinning.

Spinning is a very necessary evolution to learn, not only from the point of view of its utility in securing a quick descent and a safe get-away from a foe, but also for the equally important reason of learning how to recover from it.

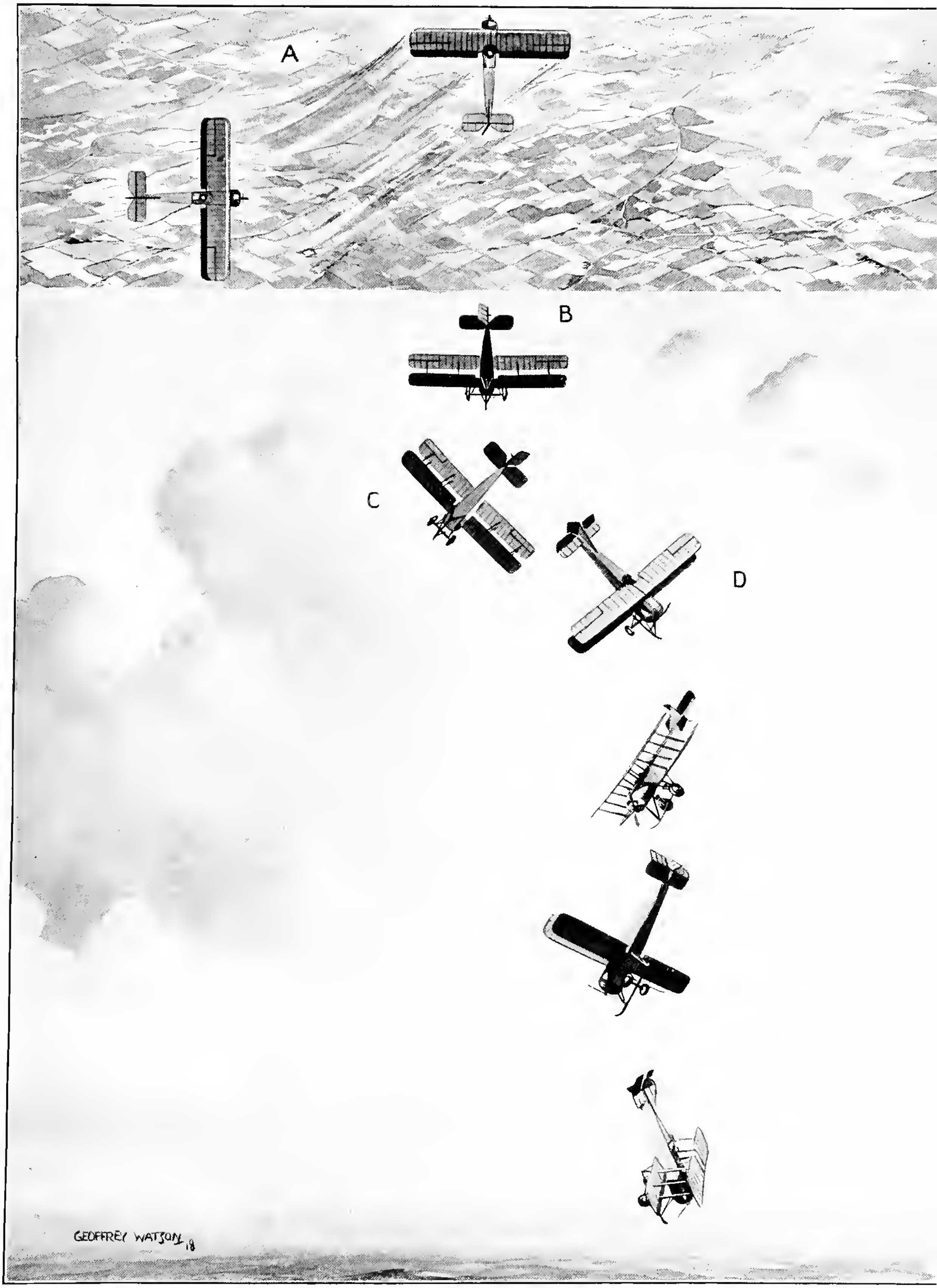

Plate 18.

A spin commencing with a flat spin. The flat spin is illustrated as a plan view. The following movements are illustrated as a side view.

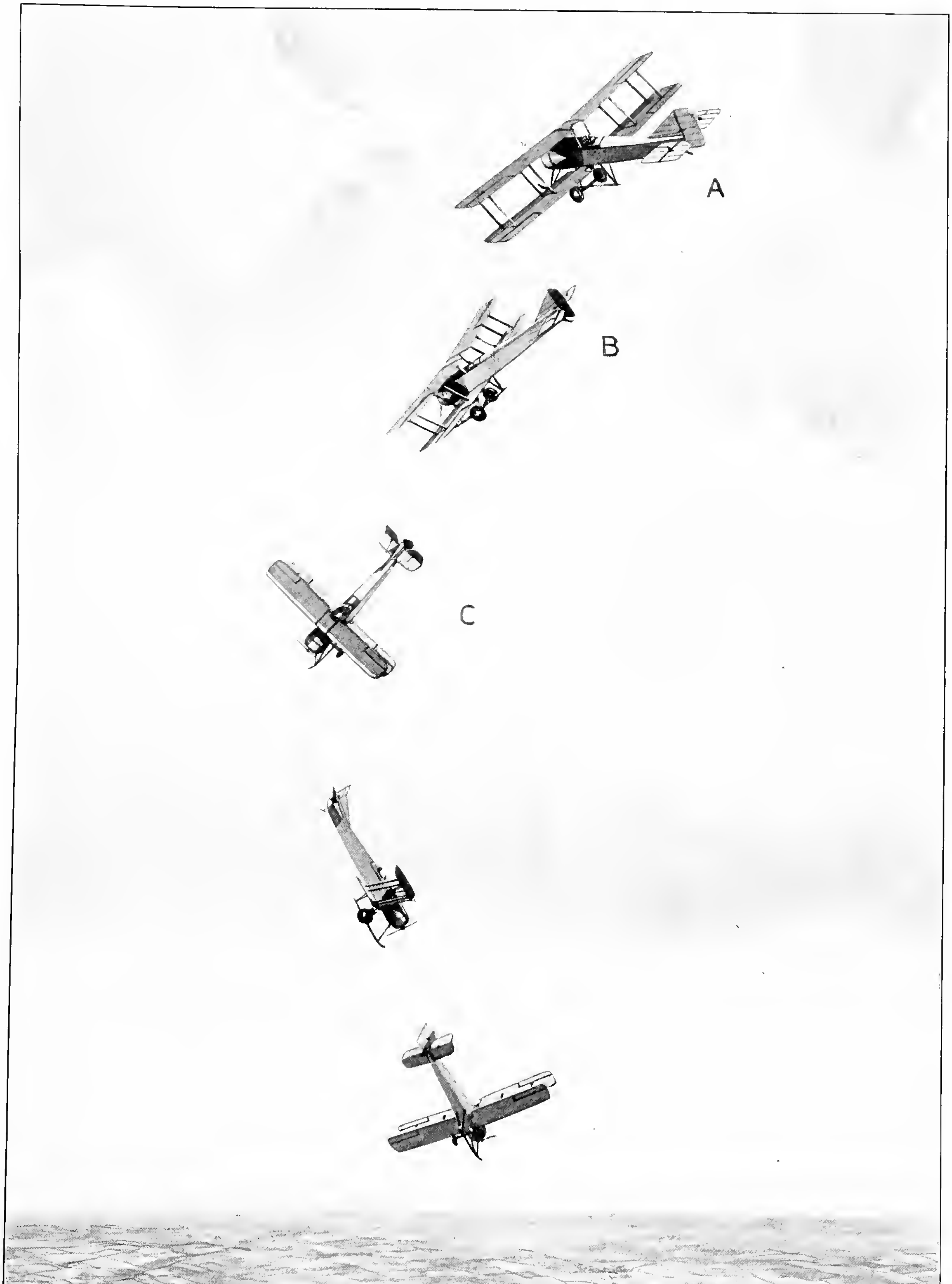

Plate 19.

A method of entering a spin without a preparatory flat spin.

There are various methods of commencing a spin, the usually accepted one (See Plate 18) being to throttle down the engine and put hard rubber on, following that by pulling the stick back. The operation of the rudder (without bank) causes the machine to enter on a flat spin (A) and the nose consequently drops, as already explained elsewhere, (B). The nose now pointing downwards, the continued application of the rudder (left rudder in the illustration) causes the machine to swing sideways, and it is thus placed in a position (C) whereby bottom rudder (right rudder in the illustration) keeps the nose down and the stick, if pulled back (D), causes the machine to turn into a spin.

The more coarsely the rudder and elevator are used the more acute the spin and the quicker the descent. The less they are operated the milder the spin and the slower the descent.

The descent is extremely rapid but a very quick recovery is possible, so much so that a finished pilot may spin down to within about 200 feet of the earth in safety. However, until the pupil is expert in recovering the normal position .he should confine his efforts to a good altitude, say three to five thousand feet.

During the first few spins the rapidity of the revolutions may seem rather disconcerting, but the pupil's confidence will be augmented if he will remember that all he has to do to secure a recovery is to centralise the rudder and push the stick forward. The machine will then fall into a straight dive, from which it should be brought out of by *gently* pressing the stick backwards.

Another Method.

The above methods of securing the spin and recovering from it are perhaps the easiest way for the novice, as they demand the operation of merely the rudder and elevator, and do not call for the combination of all three controls—rudder, elevator, and ailerons. Another method, and one which results in a quicker entrance to the spin and also a quicker recovery since the final dive is eliminated, is as follows. (See Plate 19.)

1. Throttle down the engine and bank the machine steeply by pressing the stick sideways. Centralise the stick as soon as the bank is secured (A).

2. Full bottom rudder to put the nose down. Keep the rudder on (B).

3. Pull the stick back to operate the elevator and secure the turning effect. Keep the elevator on. (C.)

Quick Recovery.

To recover quickly and without a dive (See Plate 20) the operations are as follows:

1. Top rudder to bring the nose up (A). Neutralize rudder as the nose approaches the horizon.

2. Stick forward to operate the elevator and straighten out the turn, and stick sideways to operate the ailerons and level the machine laterally (D).

Operation 2 is maintained until the angle of bank has decreased to about 45 degrees (C) when further recovery is accomplished in the ordinary way.

With a little practise a surprisingly quick recovery—almost instantaneous—may be effected. It should, however, be appreciated that the rapid movements which are incidental to such a quick recovery set up severe stresses which only a strong and well-built machine can safely take. Some rather flimsily built machines are not suitable for such severe handling.

The coarse application of rudder with stick well back will always result in a spin.

Before getting into a spin the engine should always be throttled down, as otherwise the speed and consequent air-pressures might be too much for the construction of the machine to bear.

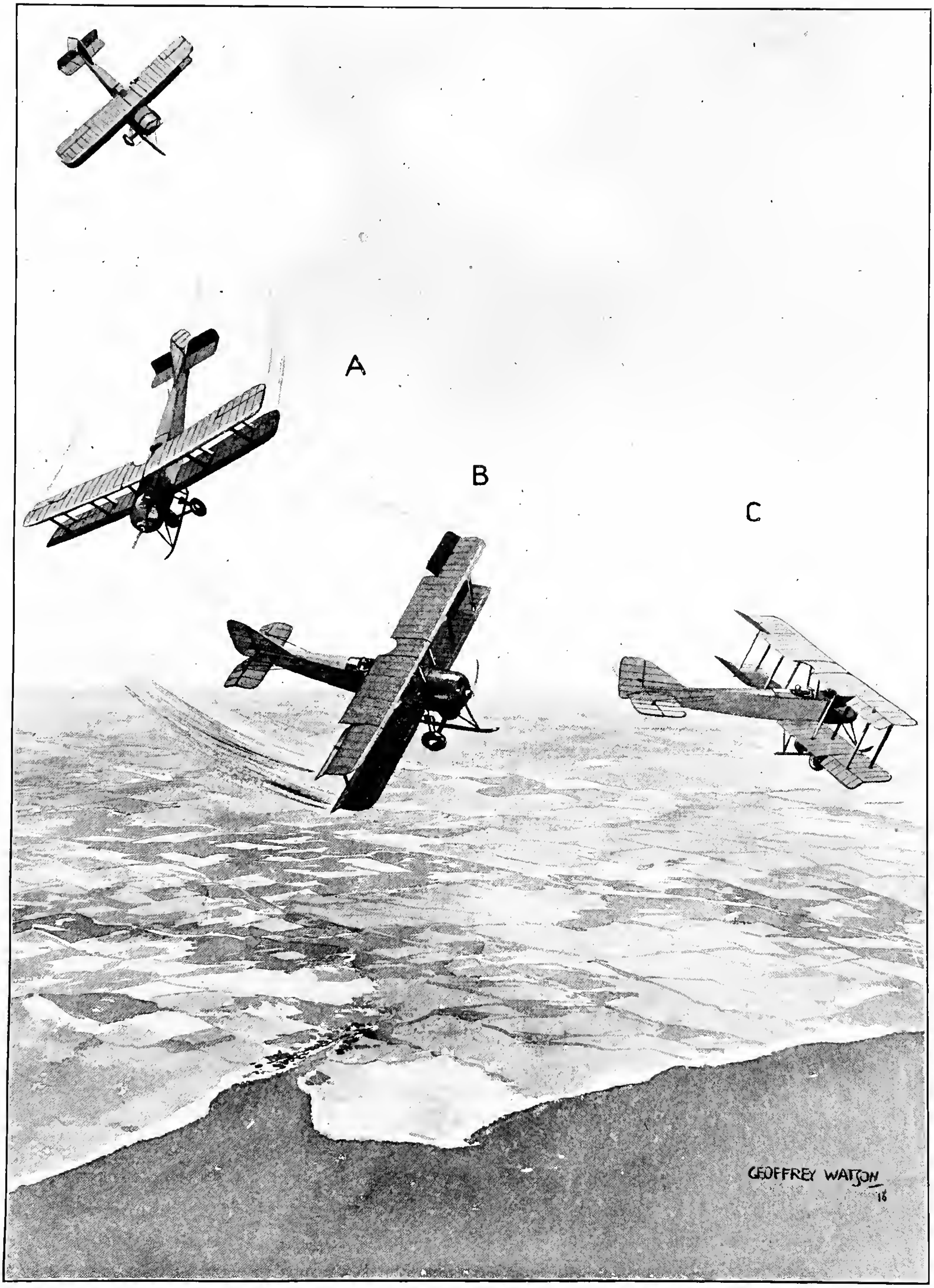

Plate 20.

Recovering from a spin quickly and without a dive.

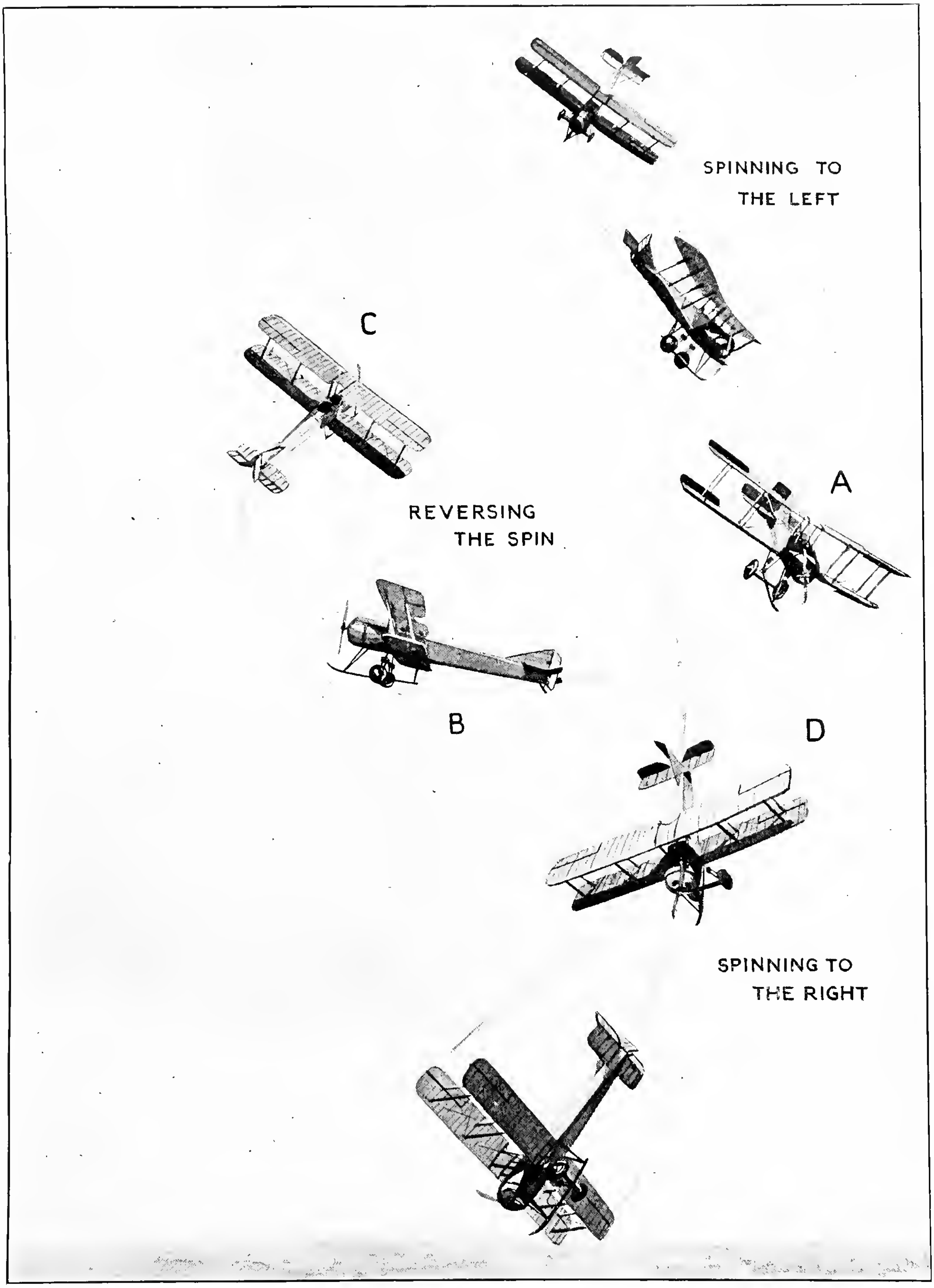

Plate 21.

Reversing a spin.

Involuntary Spins.

Nearly all involuntary spins are caused by misuse of the rudder, that is, by turning with insufficient bank. That, as explained elsewhere, results in a flat spin. A stall occurs, the nose falls, and, very likely, the machine, for some reason or other, tilts over sideways. The pupil makes the mistake of trying to pull the nose up by means of the stick but, owing to the sideways tilt, the pulling back of the stick causes the elevator to put the machine into a turn, and, the nose already pointing downwards, a spin is the natural result.

Moral: Always bank sufficiently when turning, especially when near the ground.

The pupil should practise spins of various degrees of sharpness, each time noting the *altitude lost* and the *time and space taken by the recovery.*

He should gain a thorough knowledge of the points italicised before spinning under two thousand feet altitude.

Reversing a Spin.

A spin may be reversed as illustrated in Plate 21. It is accomplished by putting on full top rudder and pressing the stick sideways in the same direction (A). The operation of the rudder causes a turn whereby the lower wings, being on the outside of the turn, secure much greater speed and consequently greater lift than do the higher wings. The machine then tends to level laterally, and this is assisted by the ailerons, as the stick is held over sideways. The stick is pulled back as the machine levels laterally (B). A stall then occurs (C) which finishes, as all stalls do, by the nose dipping. The position (D) is now correct for a spin, which at once takes place, and its direction of rotation is opposite to that of the preceding spin.

When first putting on top rudder to reverse the spin care should be taken to use it fairly gently. If it is kicked on, the sudden change in the attitude of the machine coupled with the sudden change in air-pressure and the great momentum may very likely break the wings. This evolution at its best sets up very severe stresses and it demands a strongly built machine and a smooth operation of the controls.

If the pupil has any tendency towards air-sickness, spinning will discover it. One soon gets used to the motion, however, and, with a little persistence, he is almost sure to find that any symptoms of nausea will soon wear off, just as in the case of seasickness.

The Half-Roll.

The half roll and recovery (See Plate 22) may be accomplished as follows:

1. Put the nose down to the horizon in order to secure greater speed and consequently more effective controls (A).

2. Bank smartly (B).

3. Continue banking, and, as the bank approaches vertical, kick bottom rudder on (right rudder in illustration C of Plate 22). This has the effect of causing the machine to turn (to the left of the pilot in the illustration) thereby speeding up the wings on the high side and securing a greater air-reaction (sideways lift relative to the earth) for them than that possessed by the lower wings—thus again assisting the roll (C).

4. When the upside down position is secured, throttle down the engine, and recover as in the case of a loop (D).

The above method, unless executed smartly, may result in the final dive materialising before the upside down position is secured, the evolution becoming a quarter roll followed by a combination of a dive and side-slip, as illustrated in Plate 23.

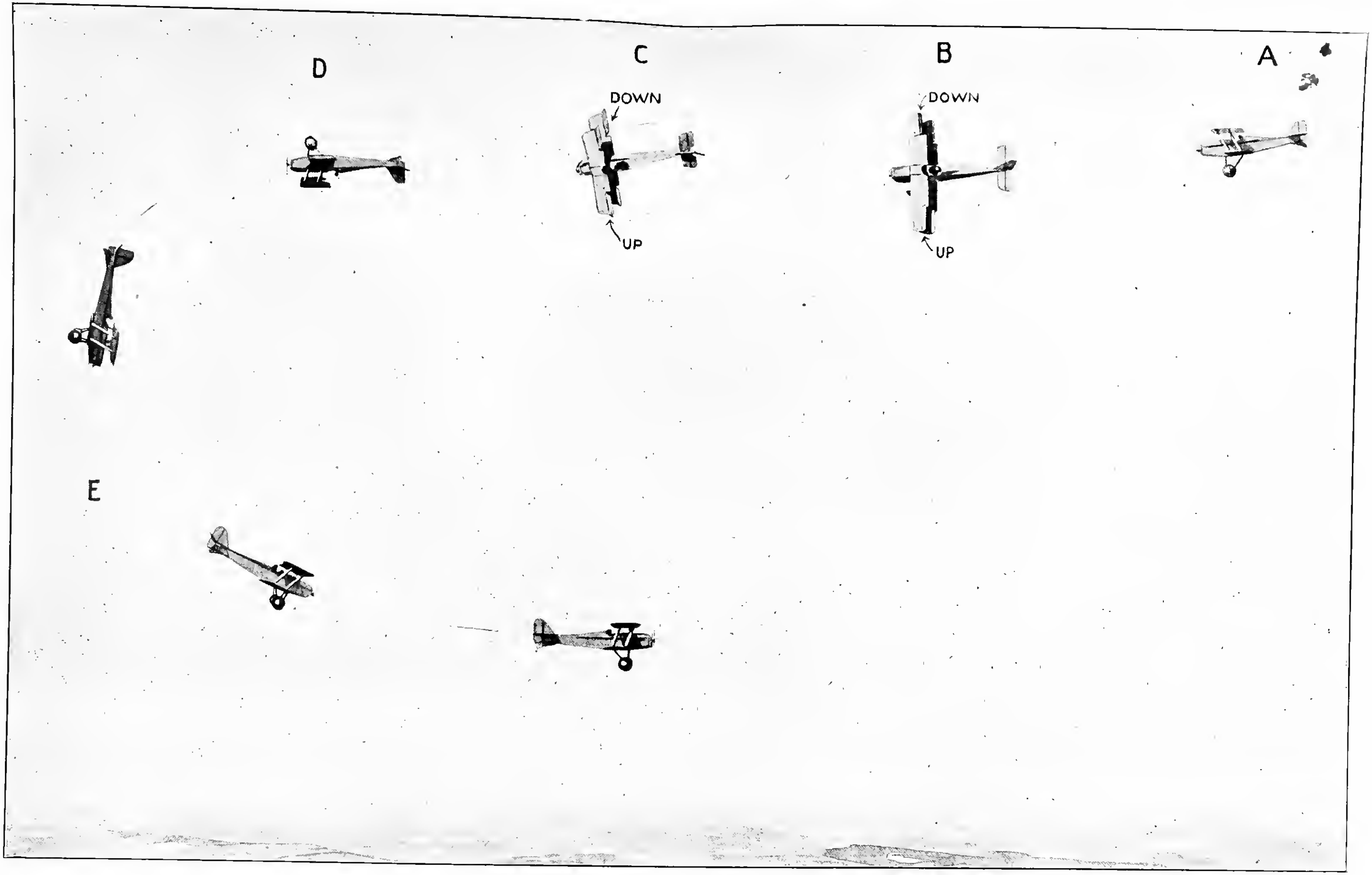

Plate 22.
The half roll and recovery.

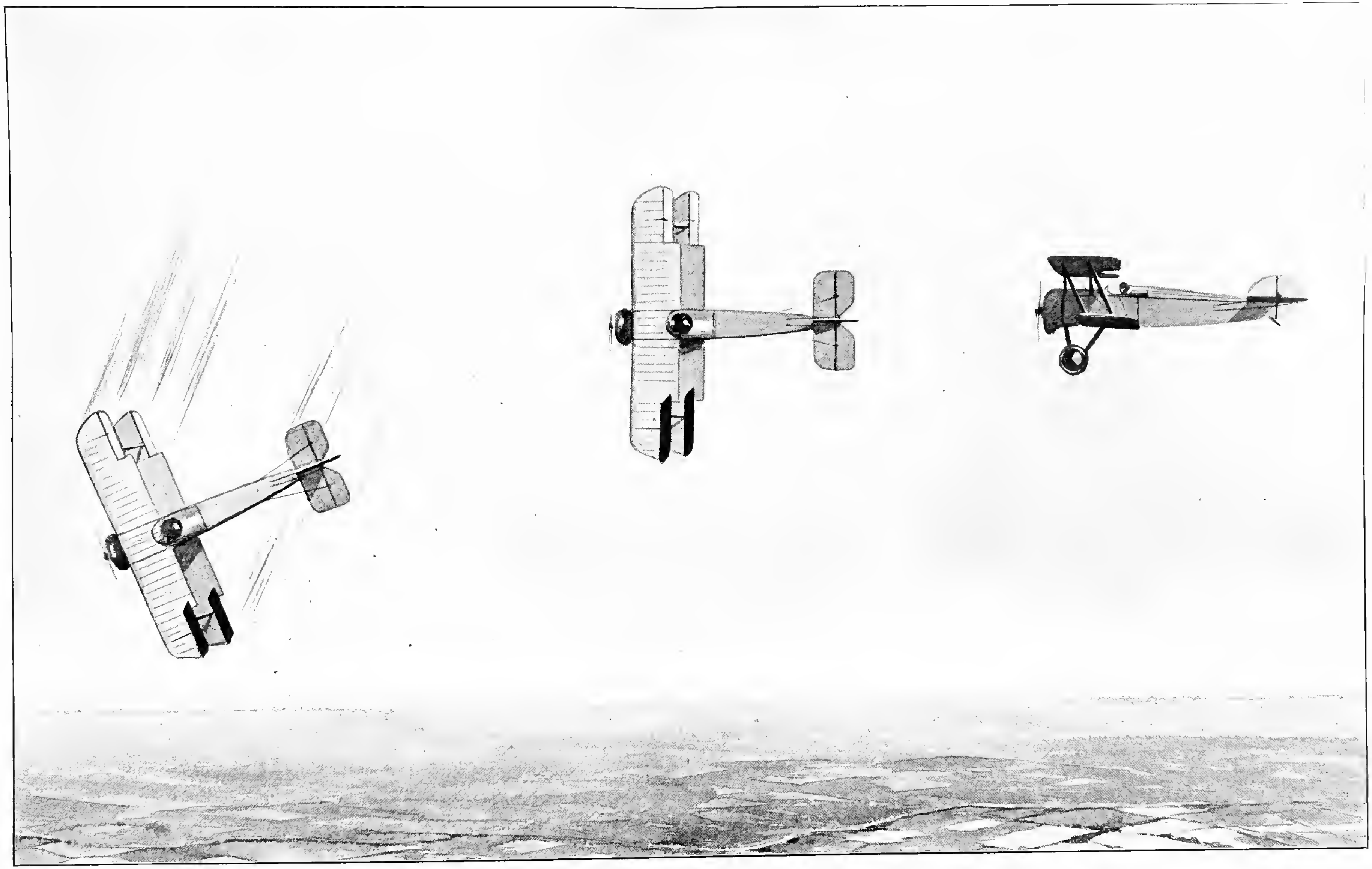

Plate 23.

A combination of dive and side-slip, commencing with a quarter roll. The result of not carrying out smartly an attempt to roll.

Another Method.

Another method is as follows. It aims at getting the nose well up before starting the roll so that the upside down position may be secured before the final dive commences. (See Plate 24.)

1. Put the nose down rather more steeply than in the case of the first method described in order to secure speed for the following climb, and efficiency of controls (A).

2. Put the nose up (B).

3. As the nose rises put the bank on (C).

4. As the bank approaches vertical kick bottom rudder on (D).

5. When the upside down position is secured throttle down the engine and recover as in the case of a loop (E).

Unless the machine is one which responds particularly quickly to the controls the latter method is advisable, and, in any case, it is the best method for the pupil to tackle first, as there is less likelihood of the final dive arriving before the half roll is accomplished.

The Complete Roll.

The expert pilot who is out to make a series of complete rolls will commence each roll by means of the first method described (Plate 22) as, otherwise, each evolution will commence with pulling the nose up, thus spoiling the smooth and continuous effect of the series of rolls.

The first half of the roll having been described I will continue the evolution from the upside down position (See Plate 25). The engine is kept running all the time.

1. By means of the elevator keep the nose pointing a little downwards towards the horizon or a little below it in order to maintain forward speed and consequently efficiency of controls (A).

2. Continue to bank by pushing the stick sideways in the direction of the roll (B).

3. The wings are now vertical. Continue operation 2 and, if necessary, increase the speed and therefore sideways lift of the lower wings by a little top rudder which

will cause the nose to rise and the lower wings to travel faster than those on the high side (C).

If the machine is blessed with quick controls and the operations are carried out smartly a series of four or five consecutive rolls may be effected without appreciable loss of height. If the evolution is carried out slovenly then some side-slipping will probably occur at those times when the wings are vertical or nearly so. The pilot should aim at carrying the machine over the vertical positions as *smartly* as possible in order to avoid side-slipping.

Should a side-slip occur when the wings are more or less vertical and the pupil desire to secure a normal position instead of persisting in the attempt to roll, all that is necessary is to keep the nose down to the horizon by means of the rudder and to pull the stick right back, when the machine will enter the sharp turn with steep bank which he has learned all about in his first lessons in the air; or neutralise all the controls and the machine should right itself.

The Immelman Turn.

The object of the *Immelman turn* is to quickly effect a complete turn with gain of height. Thus, if closely pursued by another machine at the same altitude, such a turn may place the pursued in the position of the pursuer with the additional advantage of greater height. (See Plate 26.)

The evolution commences with a sharp climbing turn. This has the effect of gaining height and completing the first part of the complete turn desired. The climbing turn (A) may be preceded by a slight dive to gain speed and lift. As the top of the climbing turn is approached the following operations should be carried out simultaneously. (B.)

1. Bottom rudder to put the nose down to the horizon; otherwise, a stall and side-slip inwards will occur.

2. Stick well back as, owing to the severe bank, the elevator must complete the turn.

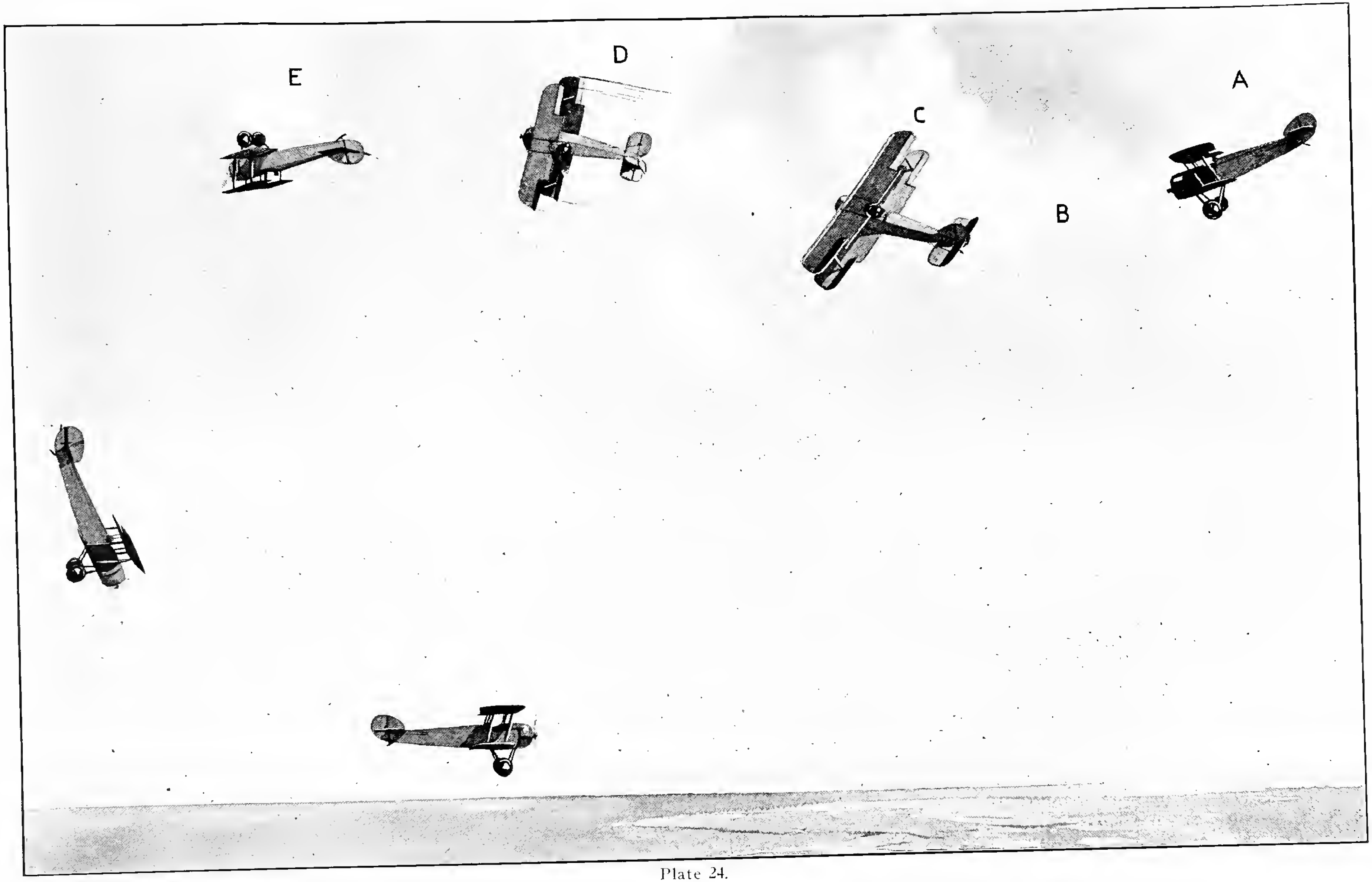

Plate 24.

Commencing the roll with a slight climb.

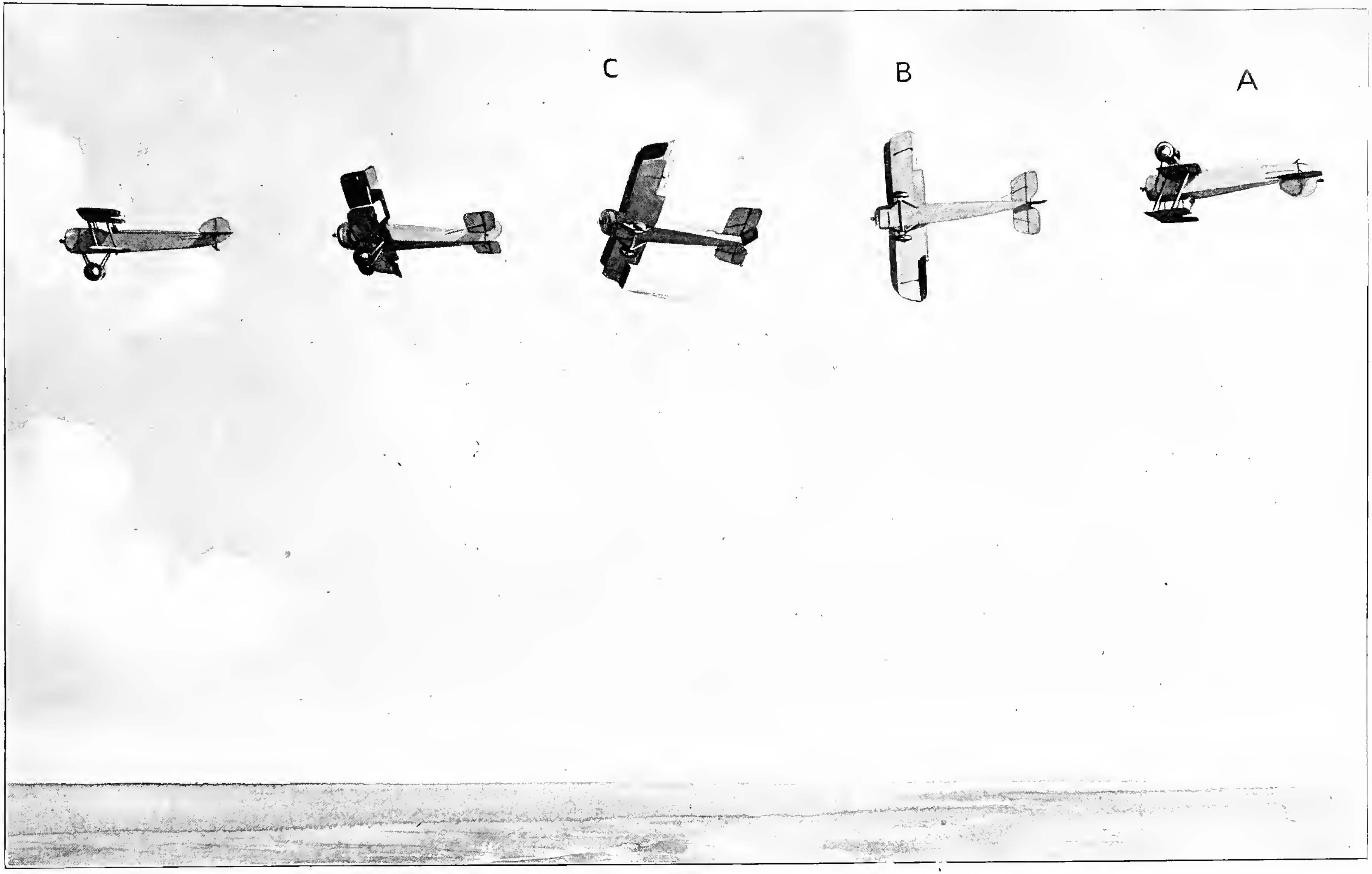

Plate 25.

The second half of the complete roll. The first half is illustrated in Plate 22.

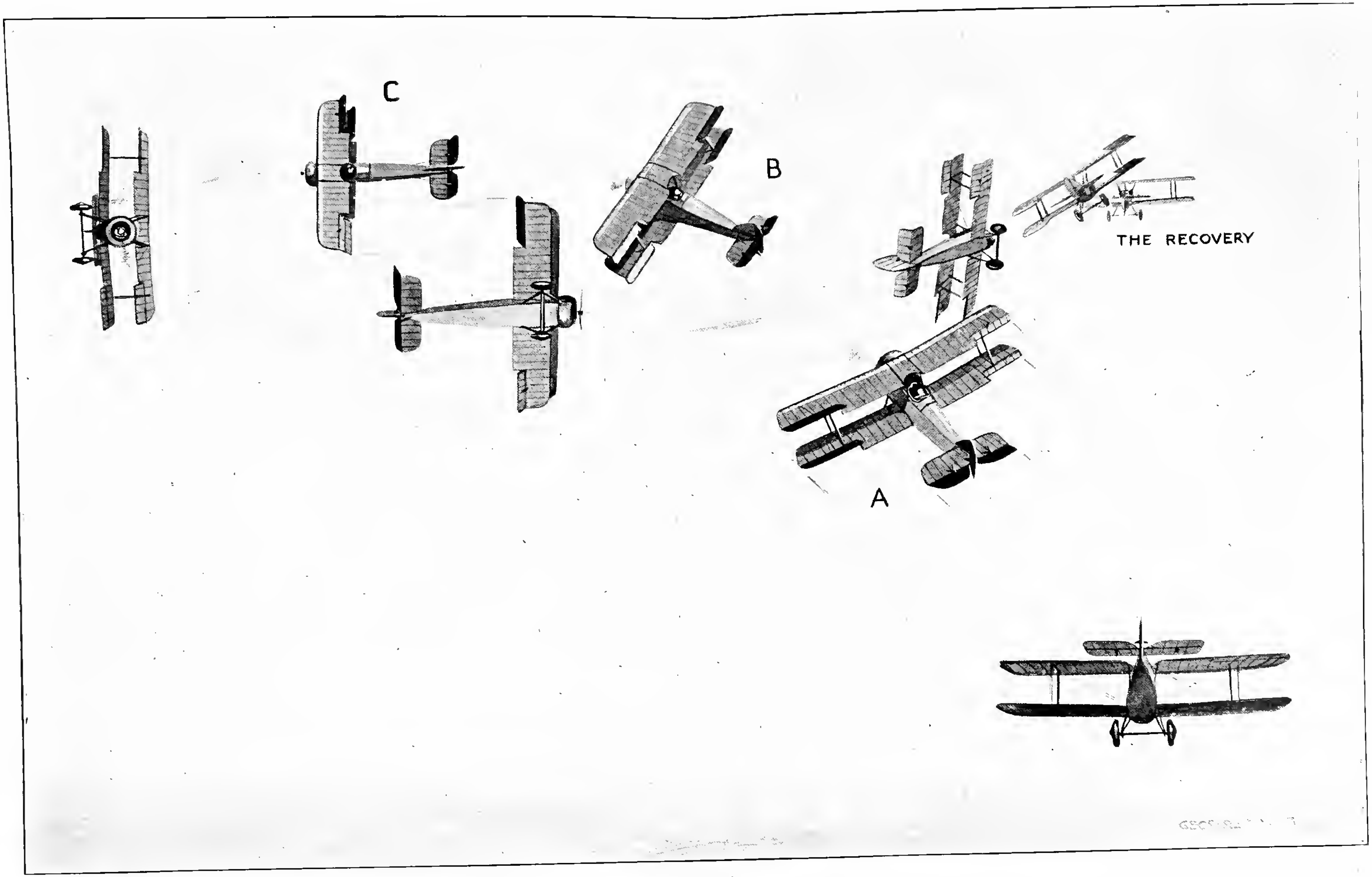

Plate 26.

The Immelman turn.

3. Stick sideways towards the high side in order to prevent over-banking. There is a distinct tendency to over-bank due to the operation of bottom rudder which causes the nose to descend, whereby the high wings travel faster than those on the low side and thus secure an abnormal sideways lift relative to the earth, consequently tending to over-bank the machine.

The above operations having been carried but the result is a sharp turn with vertical bank (C). The bank may even be a little over the vertical, i. e., the machine may for a moment be in a slight degree upside down. That, however, is bad business, as it tends towards loss of height. As the nose approaches the former direction of flight, recovery of a normal flying attitude should be effected as explained elsewhere under the heading of "Recovering from a sharp turn."

A dive may follow the completion of the Immelman turn, but it is not necessarily part of that evolution.

The above is one way of making the Immelman turn. There are other slightly different methods, all of which may be described as Immelman turns, provided (1) height is gained, (2) a complete turn is possible of accomplishment, if desired, and (3) the evolution is rapid enough.

The Falling Leaf.

This evolution, while spectacular, holds no practical utility beyond accustoming the pilot to every possible position in the air.

The operations (see Plate 27) are as follows;

1. Throttle down the engine, and hold the machine upon an even keel (A).

2. As the speed slackens, bank sideways and side-slip steeply (B). Provided the machine has its wings set at a dihedral angle and-or has more keel surface in effect above the longitudinal turning axis than there is below it, a recovery from the side-slip will occur naturally (C). This is due to the lower wings securing an upwards pressure

from the air through which they descend, and the wings on the high side securing an opposite pressure *and or* the excess of keel surface above the longitudinal axis securing from the air through which it descends a reaction tending to right the machine. (See Plate 28.)

3. The machine righting itself, the momentum of the rolling movement should carry it over on to the opposite bank and another side-slip should occur, and so on (D).

4. While the above described movements have been going on the forward speed of the machine has been decreasing. Eventually a stall (E) occurs and the nose drops. A moderate dive (F) results, out of which the machine is pulled in the ordinary way (G) after which the pilot may, if he wishes, perform the trick again (H).

In the case of a machine having its wings rigged with no dihedral angle and possessing no excess of keel surface above the longitudinal axis, there would be no natural tendency to recover from the side-slip. It would, therefore, be necessary to maintain a gliding angle in order to secure the forward speed necessary to render the ailerons effective, the latter being used in the ordinary way for the purpose of effecting the side-slips and of recovering from them. The evolution would then consist of a slow glide, with a side-slip first on one side and then on the other side, and would, perhaps, hardly merit the term of "falling leaf."

The Cart-Wheel.

The Cart-wheel, like the falling leaf, has no direct practical utility. It may be accomplished as follows: (See Plate 29.)

1. Execute a sharp climbing turn. It may be well to precede the turn with a slight dive in order to gain speed and lift (A).

2. As the top of the climbing turn is approached, put on bottom rudder to bring the nose down, and press the stick

Plate 27.
The falling leaf.

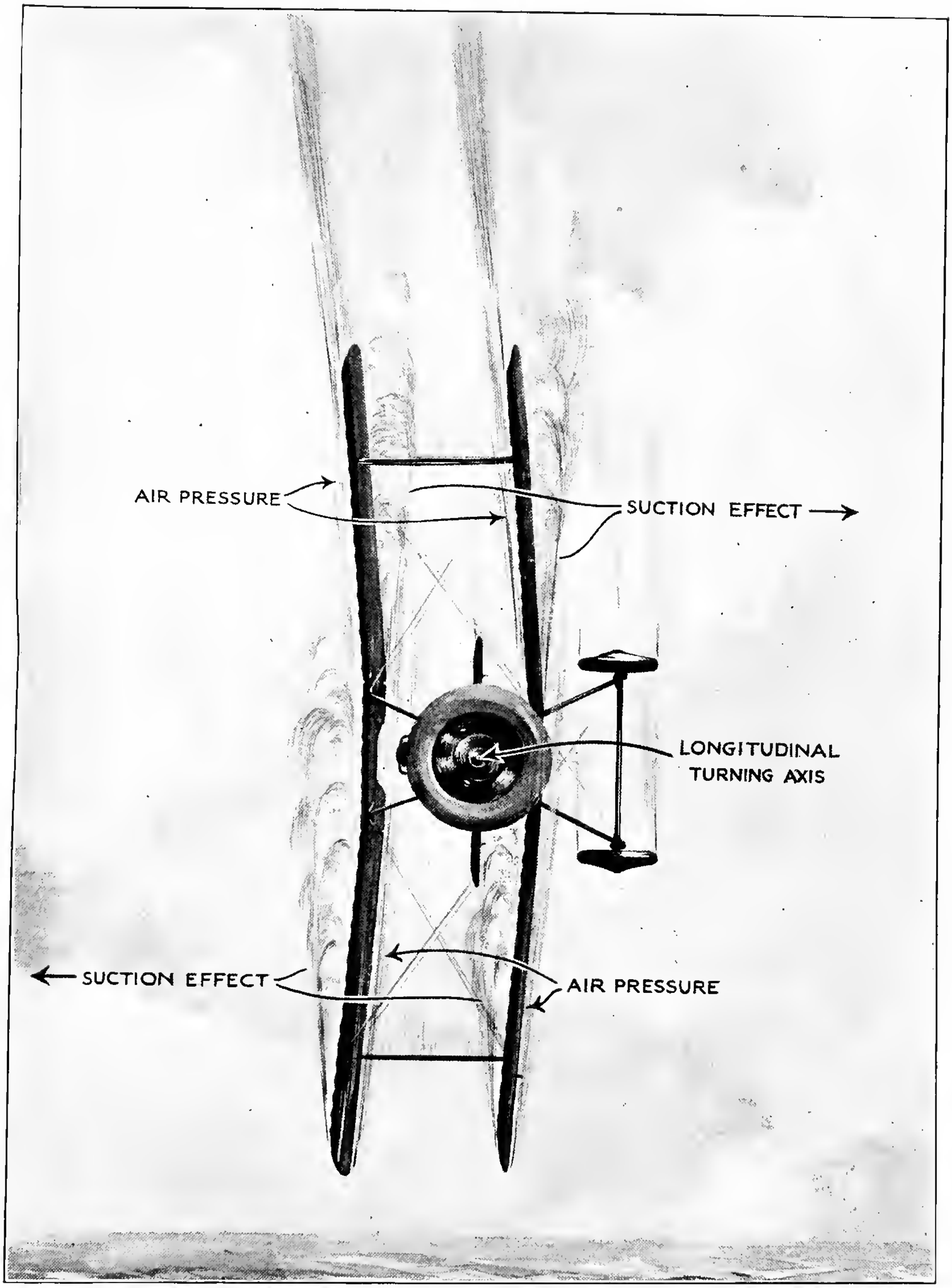

Plate 28.

The air-pressures tending to recovery from a side-slip.

It is not possible in an illustration of this size to show the upwards air-pressures on the keel surface. The struts, wires, side of the fuselage, etc., constitute the keel surface and if there is more surface in effect above the longitudinal axis (to the left of the axis in the illustration) than there is on the other side then the upward pressure upon it must tend to raise that side and right the machine.

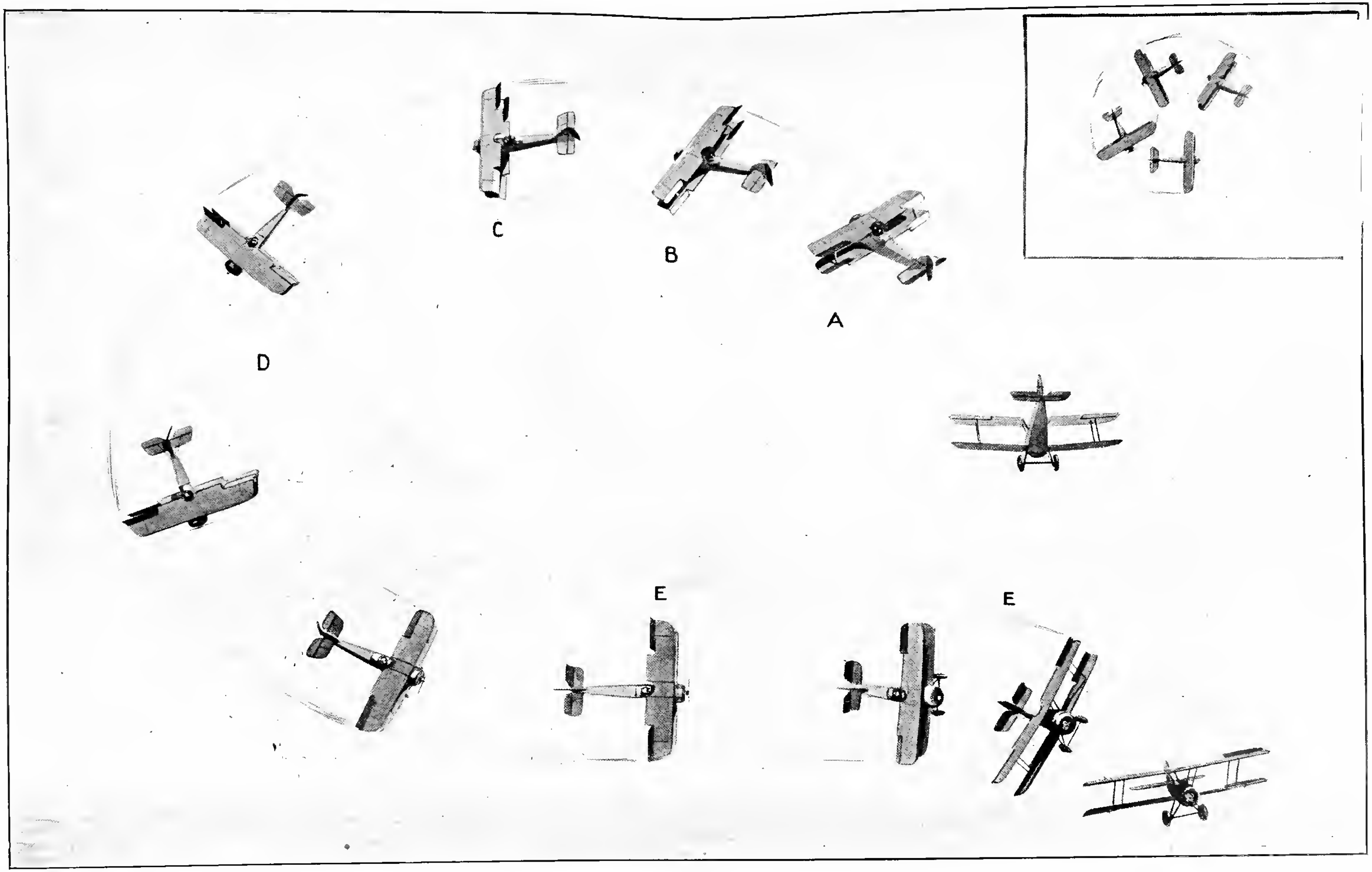

Plate 29.

The Cart-wheel.

The small illustration at the right-hand top corner shows the appearance of the evolution. In the large illustration the flight-path has been enlarged beyond reality in order to make room for the illustrations, as otherwise they would cover one another.

sideways towards the high side to prevent over-banking (B).

3. When the nose points towards the horizon throttle down the engine; otherwise, a lengthy dive will shortly occur (C).

4. Keep on maintaining operation 2, and, as the nose falls, it may be well to pull the stick back just a little in order to offset the tendency to dive. Maintain this operation until the "cart-wheel" is completed (D).

5. Recovery may now be made by using the rudder to keep the nose on the horizon, and by pulling the stick back when the machine will come into a sharp turn from which the final recovery may be effected in the ordinary way (E).

Another way of effecting recovery may be accomplished by using the ailerons to take off the bank, at the same time being careful to keep the nose down to the horizon or a little below it in order to secure forward speed and consequently efficiency of controls.

The difficulty is, of course, to avoid side-slipping during the latter part of the evolution and the recovery.

The pupil has now spent some twenty to thirty hours in the air and, thanks to dual instruction and the telephone, he knows as much as, or more than, the crack flier of three years ago. He should now know all there is to know about the management of his first machine, and he is ready to pass on to fast single-seater scouts. Their name is legion, and each type has its own peculiarities. Four or five hours' practise in the air should be sufficient to familiarise him with any type. The main points for him to remember when passing on to a faster machine are:

(1). The rudder control may be more sensitive. He must therefore be careful to get the tail well off the ground, steer straight and *instantly* check tail-swinging when making the run along the ground preparatory to ascent.

(2). The momentum is greater than in the case of his first machine. When in the air he must then steer straight, and bank adequately for turns; otherwise, side-slips outwards or flat spins with resultant nose-dives will occur.

(3). The landing speed may be greater than that which he is used to. He must not be tempted to touch ground too early or he will land with a series of hops and bad bumps. The machine should be held off the ground until the speed has sufficiently decreased to render ascent impossible even though the stick is pulled right back, and then it should be stalled in the usual way when landing.

(4). Before taking up a machine of a type new to him he should secure from his instructor (not another pupil) particulars of its peculiarities. When first ascending he should *steer straight* at a *moderate climbing angle* and wait until he has arrived at a safe height before turning. Also, he should climb to several thousand feet altitude before commencing to practise aerobatics.

(5). Every evolution he has learned on his first machine will demand a little different treatment in the case of every other type of machine. It is not enough to take up a machine of a type new to him, to make a short flight, and then be satisfied that he knows it. He should put it through every possible evolution and combination of evolutions and perfect himself in their accomplishment before passing on to a still more advanced type; otherwise, he will be proceeding too fast for thoroughness and his style, when he reaches the most advanced type of machine, will probably lack finish.

All other aerobatic evolutions are slight modifications of those I have described, or combinations of them. Once the pupil has learned to accomplish the manoeuvres I have tried to explain he will, without doubt, invent his own combinations and begin to express in them his individuality as a pilot

It would be easy to produce a large volume by describing all the slightly different ways of accomplishing the evolutions I have dealt with and dwelling upon the various combinations of two or more of them. I feel, however, that if this little work is to be of practical value to the novice it should be as short and simple as possible, and I am sure that if the reader learns to accomplish the fundamental evolutions I have explained he will have no further need of a text-book.

As the reader finishes this little book I can hear him say, "It can never be done in twenty to thirty hours' flying." But it can be done, and it is being done every day. Of course, there are many who take much longer, and others who will never shine as aerobatic pilots though they may make perfectly sound pilots for other and tamer kinds of flying. But the average pupil among those possessing the making of expert pilots may certainly do all that I have described after about twenty to thirty hours in the air, *provided* he attacks the game in the right way. Too many seem to think that the preparatory ground instruction is of comparatively little importance—just so many examinations to be scraped through. That's a mistake to begin with, for the more thorough the theoretical knowledge the easier it is to grasp the practical lessons in the air. When that commences there should be no misunderstandings and time lost due to the pupil's ignorance of the elementary principles of flight, stability and control, the management of the engine, the instruments, technical terms, etc. Also, in order to secure the best results where *time* and *flying form* are concerned it is necessary to strictly conform to a syllabus of which each detail is *progressive,* and to use every minute in the air (and on the ground) in pursuing the next detail to be learned. Flying is a game in which casual and haphazard methods are fatal.

One last word to the novice. Years ago there was no such thing as instruction in aeronautics and aviation. That which we learned we had to teach ourselves, and we did that by using every moment and every opportunity, however small, of digging for knowledge. Nothing sticks like knowledge gained by digging for it oneself. I think that there is now a tendency among many pupils to imagine that all that matters is the passing of so many tests, and that there is nothing left to be done outside of the classrooms and the flying hours. Yet a keen fellow may perhaps learn more outside of the prescribed hours of technical instruction than within them—and the knowledge so gained is never forgotten! Aviation and the instruction connected with it are in their infancy, and there is everything to be gained by the pupil who is not content to be spoon-fed, but who uses initiative in search of knowledge. I have noticed again and again that those who are keen in this way never fail to make their mark.

GLOSSARY OF TECHNICAL TERMS EMPLOYED IN THE BOOK.

Aeronautics. The science of aerial navigation.

Aerofoil. A rigid structure, of large superficial area relative to its thickness, designed to obtain, when driven through the air at an angle inclined to the direction of motion, a reaction from the air approximately at right angles to its surface. Always cambered when intended to secure a reaction in one direction only. As the term "aerofoil" is hardly ever used in practical aeronautics, I have, in this book, used the term SURFACE, which, while academically incorrect, since it does not indicate thickness, is the term usually used to describe the cambered lifting surfaces, i. e., the "planes" or "wings," and the stabilizers and the controlling aerofoils.

Aerodrome. The name usually applied to a ground used for the practice of aviation. It really means "flying machine," but it is never used in that sense nowadays.

Aeroplane. A power driven aerofoil fitted with stabilizing and controlling surfaces.

Angle of Incidence. The angle at which a surface attacks the air.

Angle of Incidence, Maximum. The greatest angle of incidence at which, for a given power, surface (including detrimental surface) and weight, horizontal flight can be maintained.

Angle of Incidence, Minimum. The smallest angle of incidence at which, for a given power, surface (including detrimental surface) and weight, horizontal flight can be maintained. This angle gives the greatest speed apart from diving.

Angle of Incidence, Best Climbing. That angle of incidence at which an aeroplane ascends quickest. An angle approximately half-way between the maximum and optimum angles.

Angle of Incidence, Optimum. The angle of incidence at which the lift-drift ratio is highest.

Angle, Gliding. The angle between the horizontal and the path along which an aeroplane, at normal flying speed, but not under engine power, descends in still air.

Angle, Dihedral. The angle between two planes. Thus, if the wings of an aeroplane are inclined upwards towards their wing-tips they are said to be rigged at a dihedral angle.

Air Speed Indicator. An instrument used for measuring air pressures or velocities. It consequently indicates whether the surface is securing the requisite lift for flight. Usually calibrated in miles per hour, in which case it indicates the correct number of miles per hour at only one altitude. This is owing to the density of the air decreasing with the increase of altitude and necessitating a greater speed through space to secure the same air pressure as would be secured by less speed at a lower altitude. It would be more correct to calibrate it in units of air pressure.

Air-Screw. (Propeller.) A surface so shaped that its rotation about an axis produces a force (thrust) in the direction of its axis.

Aileron. A controlling surface, usually situated at the wing-tip, the operation of which turns an aeroplane about its longitudinal axis; causes an aeroplane to tilt sideways.

Aviation. The art of driving an aeroplane.

Aviator. The driver of an aeroplane.

Bank, to. To turn an aeroplane about its longitudinal axis (to tilt sideways) when turning to left or right.

with shock absorbers, situated under the tail of an aeroplane in order to support it upon the ground and to absorb the shock of alighting.

Stream-Line. A form or shape of detrimental surface designed to produce minimum drift.

Torque, Propeller. The tendency of a propeller to turn an aeroplane about its longitudinal axis in a direction opposite to that in which the propeller revolves.

Tail-Slide. A fall whereby the tail of an aeroplane leads.

Thrust, Propeller. See "Air-Screw."

Velocity. Rate of displacement; speed.

Weight. Is a measure of the force of the earth's attraction (gravity) upon a body. The standard unit of weight in this country is 1 lb., and is the force of the earth's attraction on a piece of platinum called *the standard pound*, deposited with the Board of Trade, in London. At the centre of the earth a body will be attracted with equal force in every direction. It will therefore have no weight, though its mass is unchanged. Gravity, of which weight is a measure, decreases with increase of altitude.

Wing-tip. The right or left-hand extremity of a surface.

Work. Force x displacement.

Lift, Margin of. The height an aeroplane can gain in a given time and starting from a given altitude.

Momentum. The product of the mass and velocity of a body is known as "momentum."

Reaction. A force, equal and opposite to the force of the action producing it.

Rudder. A controlling surface, usually hinged to the tail, the operation of which turns an aeroplane about an axis which is vertical in normal horizontal flight; causes an aeroplane to turn to left or right of pilot, if the angle of bank is not above 45°. At steeper angles it controls the attitudes of ascent and descent.

Right and Left Hand. Always used relative to the position of the pilot. When observing an aeroplane from the front of it, the right hand side of it is then on the left hand of the observer.

Rudder-Bar. A control lever moved by the pilot's feet, and operating the rudder.

Surface. See "Aerofoil."

Surface, Controlling. A surface the operation of which turns an aeroplane about one of its axes.

Span. The distance from wing-tip to wing-tip.

Stall, to. To give or allow an aeroplane an angle of incidence greater than the "maximum" angle, the result being a fall in the lift-drift ratio, the lift consequently becoming less than the weight of the aeroplane, which must then fall.

Stress. Burden or load.

Side-Slip, to. To fall as a result of an excessive "bank" or "roll."

Skid, Tail. A piece of wood or other material, orientable, and fitted

Chord. Usually taken to be a straight line between the trailing and leading edges of a surface.

Centrifugal Force. Every body which moves in a curved path is urged outwards from the centre of the curve by a force termed "centrifugal."

Control Lever. A lever by means of which the controlling surfaces are operated. It usually operates the ailerons and elevator. The "joy-stick."

Drift. The resistance of the air to a moving body.

Drift, to. To be carried by a current of air; to make leeway.

Dive, to. To descend so steeply as to produce a speed greater than the normal flying speed.

Elevator. A controlling surface, usually hinged to the rear of the tail-plane, the operation of which turns an aeroplane about an axis which is transverse to the direction of normal horizontal flight. Causes the aeroplane to assume an ascending or descending attitude when the angle of bank is less than about 45°. At steeper angles of bank it controls direction in a plane more or less parallel to the earth.

Flight. The sustenance of a body heavier than air by means of its action upon the air.

Gravity. Is the force of the earth's attraction upon a body.

Horizontal Equivalent. The plan view of a body whatever its attitude may be.

Joy-Stick. See "Control Lever."

Keel-Surface. Everything to be seen when viewing an aeroplane from the side of it.

Lift. The vertical component of the reaction produced by the action of driving through the air a surface inclined upwards and towards its direction of motion.