AEROBATICS

U.S. NAVY

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U.S. NAVY PRIMARY FLIGHT TRAINING MANUAL

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NAVAL AIR TRAINING COMMAND
CHIEF OF NAVAL AIR PRIMARY TRAINING
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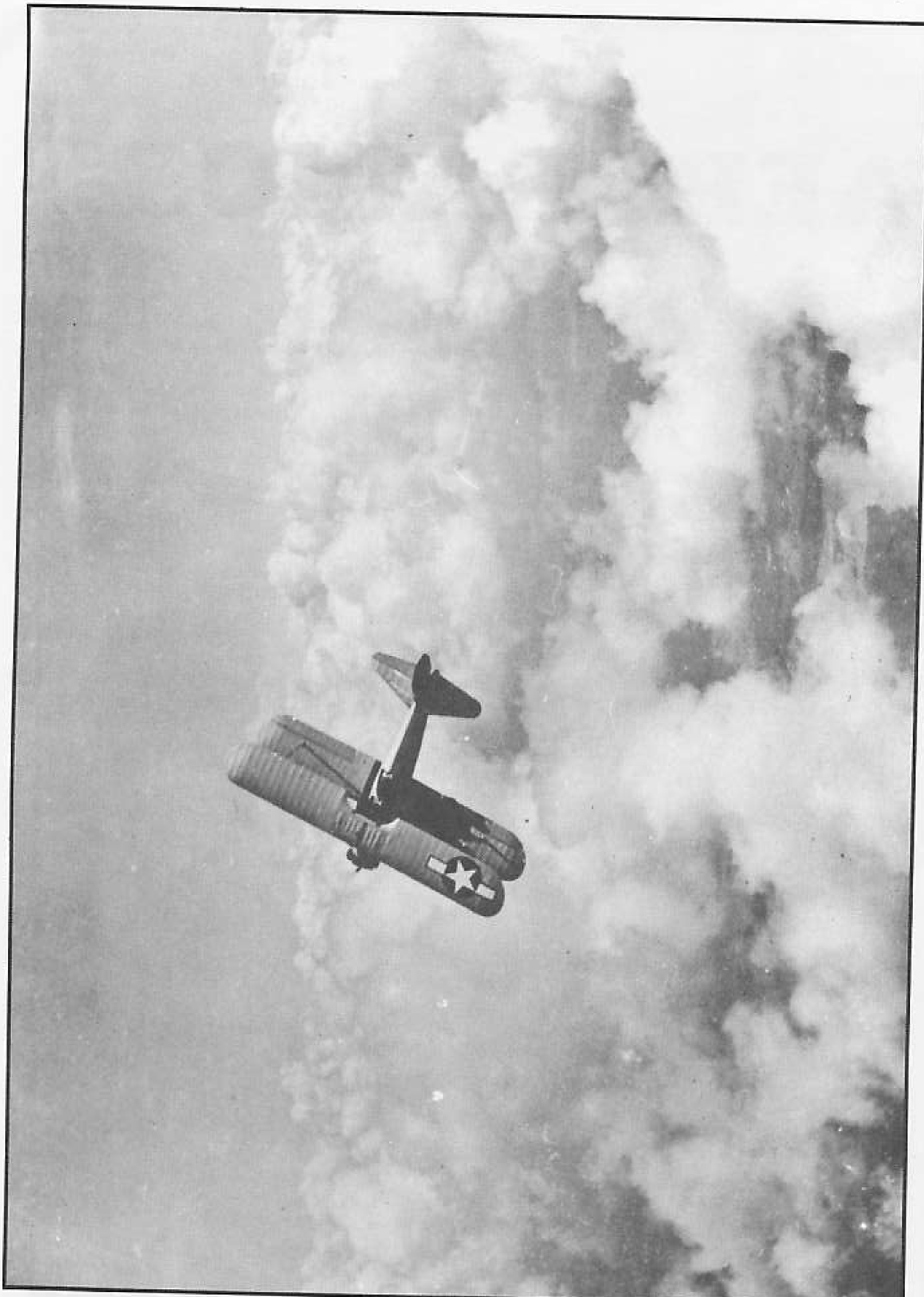


A U.S. Army Stearman PT-17 is shown beginning a slow roll above the clouds at a Primary School in Florida. Photo: U.S. Army Air Corps via K. D. Wilson Collection.

AEROBATICS

You are now ready for that stage in your training as a Naval Aviatior toward which you have been looking forward with keen anticipation, perhaps not unmixed with some feelings of misgiving. Like many before you, you are probably wondering whether or not you can "take it" at the same time laboring under the delusion that the mark of a good pilot is his skill in aerobatics. The answer, of course, is that you **will** be able to "take it", but the question will be whether or not you can "leave it". Too many cadets before you have come to grief in C stage, simply because they were "carried away" by their enjoyment of aerobatics and a desire to become aerobatic experts. They neglected the precision work introduced in A and B stages, forgetting that the Navy does not expect them to become skilled stunt pilots, that even a poor pilot can become proficient in aerobatics and that aerobatic maneuvers are a part of the primary syllabus for only three reasons:

1. To teach a pilot to remain oriented in any attitude which the airplane may assume.
2. Because they require more elaborate and speedier manipulation of the controls, they greatly improve coordination.
3. To increase a pilot's confidence both in himself and in the airplane - only after he is once convinced that he can put the airplane in any possible attitude and recover to normal flight, will he lose his last lingering fear of flying, (if it were ever present).

In C stage you must keep a sense of proportion. Proficiency in the precision flying already taught you, must not only be maintained but improved, for it is this type of flying upon which all your later training is based. Few, very few, of the aerobatic maneuvers you are going to learn have any part in the actual tactics of combat flying. During World War I, certain aerobatic maneuvers were developed by pilots as a means of both attacking and evading enemy aircraft. The design and performance of modern fighters make aerobatics in general less useful in present day combat. However, they continue to be useful in training pilots and, most important, they enable you to recover correctly and efficiently from the many unusual attitudes in which you may find yourself as the result of combat maneuvers.

Aerobatics, in the broadest sense, include all maneuvers not necessary to normal flight. Aerobatic maneuvers are of two basic types; one, those in which the airplane is "**flown through**", (loop, Immelman turn, and slow roll); two, those in which the airplane is in a stalled or partially stalled condition, with the pilot's chief concern that of recovery to normal flight attitude (inverted spins, snap rolls, cartwheel, etc). It will be vital to your success in the performance of these maneuvers that you overcome the natural tendency to think and act in terms of "up" and "down". The sooner you control this tendency, and force yourself to consider control manipulation merely a means of making the airplane pitch, yaw and roll about **you** as a pivot (as described to you in "Effect of Controls"), the more rapidly you will acquire that sense of orientation for which this stage is designed.

Important: Regardless of whether or not a particular maneuver is described in the following pages, you are to practice only those maneuvers demonstrated and prescribed by your instructor in the order presented by the syllabus.

All aerobatics will be completed at least 2,000 feet above the ground.

This is not indicated altitude but actual altitude above the terrain.

Hints for Aerobatics:

1. Your safety belt. It should be fastened snugly, but not so tightly as to interfere with your leg movements. Also check the shoulder harness.
2. Be even more alert in looking for other aircraft in your vicinity. The wingover type clearing turn is preferred as it helps you to clear above and below as well as around you.
3. Once the area is throughly cleared and as soon as your proficiency permits, practice maneuvers in series to conserve both time and altitude.
4. Upon completion of each maneuver or series of maneuvers, concentrate upon regaining as much as possible the altitude you have lost. Convert excess speed into altitude.
5. Be sure your parachute is properly buckled.
6. **Keep your goggles down** and make sure there is no loose gear on the deck or in your lap that might fall out and hit you or foul the controls.
7. Remember altitude and safety go hand in hand. If you fall out of a maneuver you will need more altitude to effect recovery.

CHECK OFF LIST FOR AEROBATICS:

1. Safety belt and shoulder harness.
2. Parachute.
3. Loose gear.
4. Altitude.
5. Traffic.

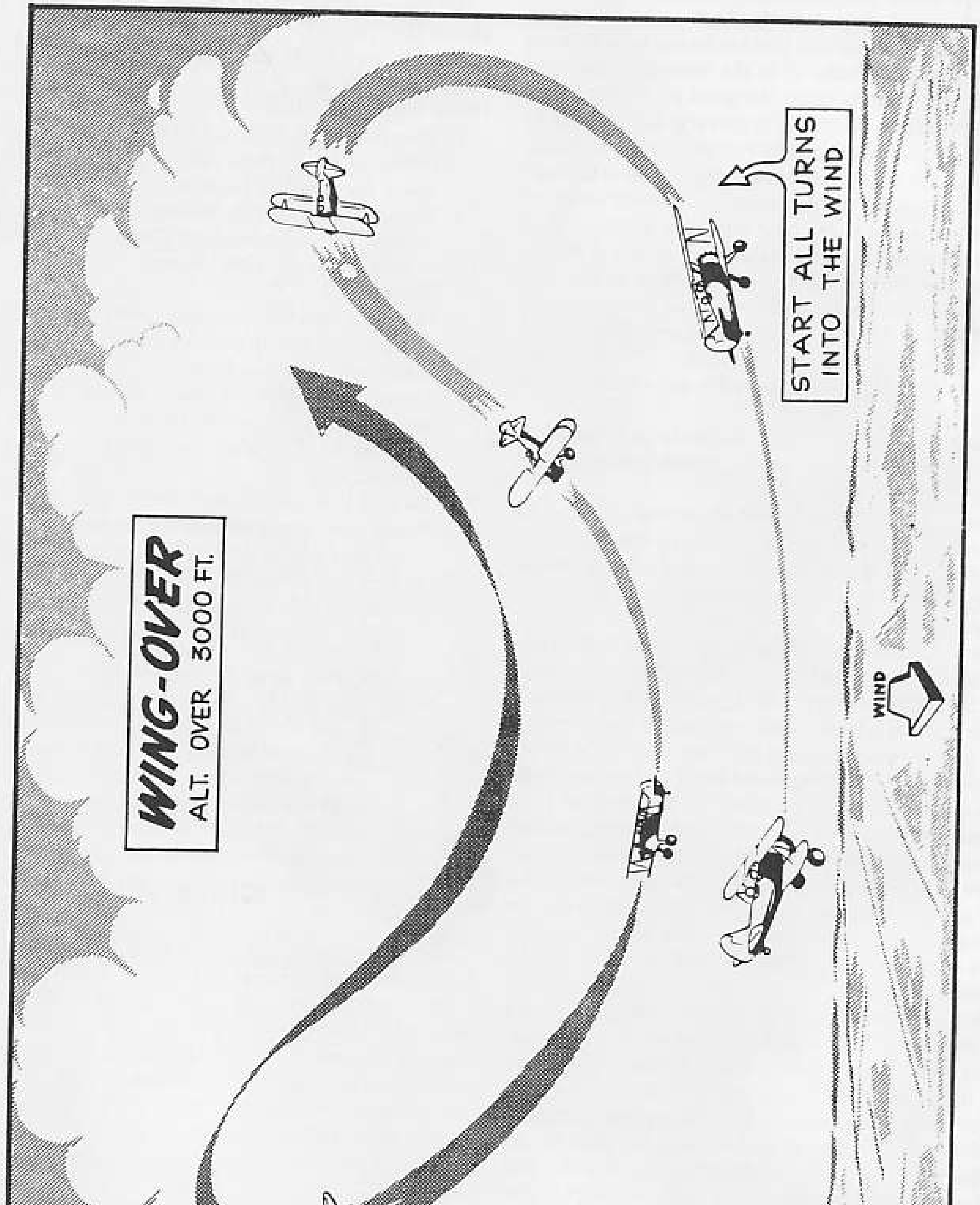
WINGOVER

Definition: A wingover is a climbing turn followed by a diving turn resulting in a change in heading of 180°.

By practicing wingover, you learn to control the airplane smoothly, in balanced flight, through constantly changing attitudes and speeds while maintaining orientation and making desired changes in the direction of flight. The changes in attitude are from wing level or straight flight to steep bank and from a nose-high or climbing to nose-low or diving attitude. Airspeeds vary from slightly above cruising to slightly above stalling.

In addition to this, it helps you to learn the proper combination of all control pressures necessary to attain the attitudes desired and also the recognition, by feel, of varying airspeeds and approaches to stalls.

The wingover is a fundamental practice maneuver that incorporates these elements and it can be seen that there are many variations of the exercise that would also bring them into


WING-OVER
ALT. OVER 3000 FT.
START ALL TURNS INTO THE WIND
WIND

play, perhaps as well. However, so that all instructors will teach and all check pilots will expect the same manuever, certain specifications for the wingover are laid down, which make it a precision maneuver, with a pattern and sequence of attitudes all its own.

When the wingover is introduced to you, it is of primary importance that you first get a visual picture of the path through which the airplane is to be flown and how the airplane appears to you in relation to the ground and horizon as you sit in the cockpit. Once you see this, it is merely a matter of flying the airplane in a balanced condition, (without slip or skid), through this pattern. Visualize that in flying this pattern, the nose describes a smooth semi-circular arc above the horizon and then an equal arc below the horizon.

Execution: The wingover is practiced at an altitude of 3,000 feet or more above the ground.

First orient yourself with respect to anticipated headings and reference points, particularly your present heading, the opposite heading and the point abeam. The nose passes through the horizon only on these three headings. Consequently, they are important reference points and should be anticipated before-hand. At all other points the nose will be either above or below the horizon.

From straight and level cruising attitude and speed, add throttle to approximately between cruising and climbing power for the purpose of completing the wingover or series of wingovers without appreciable loss or gain of altitude.

Then lower the nose to increase the speed to slightly above cruising and bring it back up to the horizon. At this point immediately begin a smooth climbing turn. Increase the bank and the climb simultaneously. The increase in bank should be planned so that approximately a vertical bank is reached when the airplane has turned to the point abeam of the original heading. The climb should be planned so that as much altitude as possible is gained, and to allow the nose to lower through the horizon on this abeam heading with just sufficient speed above stalling, to provide smooth control.

At this point in the wingover, the airplane will have reached its maximum bank and the nose momentarily intersects the horizon on its way down.

To maintain smooth balanced flight at this point in a right wingover, it may seem that you have to apply excessive right rudder pressure, because of the torque effect, plus the slipping tendency due to the extreme bank. Whereas in a left wingover, considerably less left rudder is needed as these two effects act against each other.

As the nose intersects the horizon on its way down, begin to shallow the bank immediately, so as to recover from the turn on the selected heading. This is important. Do not allow the airplane to progress into its dive, while still in a steep bank, or air speed control will be difficult.

The rate of the dive shall be controlled so that, upon completion of the turn at this desired heading, the airplane will have returned to level flight (nose on the horizon), at the same airspeed used for entry (slightly above cruising).

As the nose comes up to the horizon, immediately start another wingover in the opposite direction. They are practiced in a series.

The maneuver is best performed in a series of four, (two in each direction, alternately). This enables you to develop a feeling of the control pressures and the rhythm of the maneuver.

HINTS AND COMMON ERRORS:

Wind direction has absolutely no effect on the performance of wingovers except as it drifts the airplane over the ground. Solely for this reason it is advisable to start your series of wingovers headed crosswind and make the turns into the wind to offset wind drift.

Airspeeds in the wingover vary from just above cruising to just above stalling. For the N2S, speeds just above cruising are considered to be in the 85-90 knot range. You should learn to complete a wingover at the same speed used for entry, whatever it may be, within the authorized range. Speeds just above stalling can vary between 45 and 50 knots. It is best to judge a satisfactory speed above stalling entirely by feel.

Since you are learning to fly the airplane in a predetermined pattern, keep your eyes out of the cockpit, in order to keep track of the airplane's attitudes in relation to the ground and horizon. Instruments are only for an occasional reference, to check your other sensory impressions.

In the beginning, it will be helpful to use a long road or section line to help orient yourself in the 180° change of direction.

The trim tab should be used to trim the airplane for normal straight and level flight before starting the wingover, so that you will feel the true pressures on the controls throughout the manuever. If you find that you are consistently too slow or too fast in the diving turn, the trim tab may be adjusted to assist you in applying correct pressures on the stick.

The nose should always move at a constant rate as it describes an arc, first above and then below the horizon.

Throttle setting may be varied to compensate for a noticeable loss or gain in altititude during the series of wingovers.

The wingover is a relatively slow, deliberate maneuver. Do not rush it, but maintain regular rhythm.

Keep your bank and rate of climb or dive changing in proper proportion, to attain the correct attitude at your abeam and reverse headings.

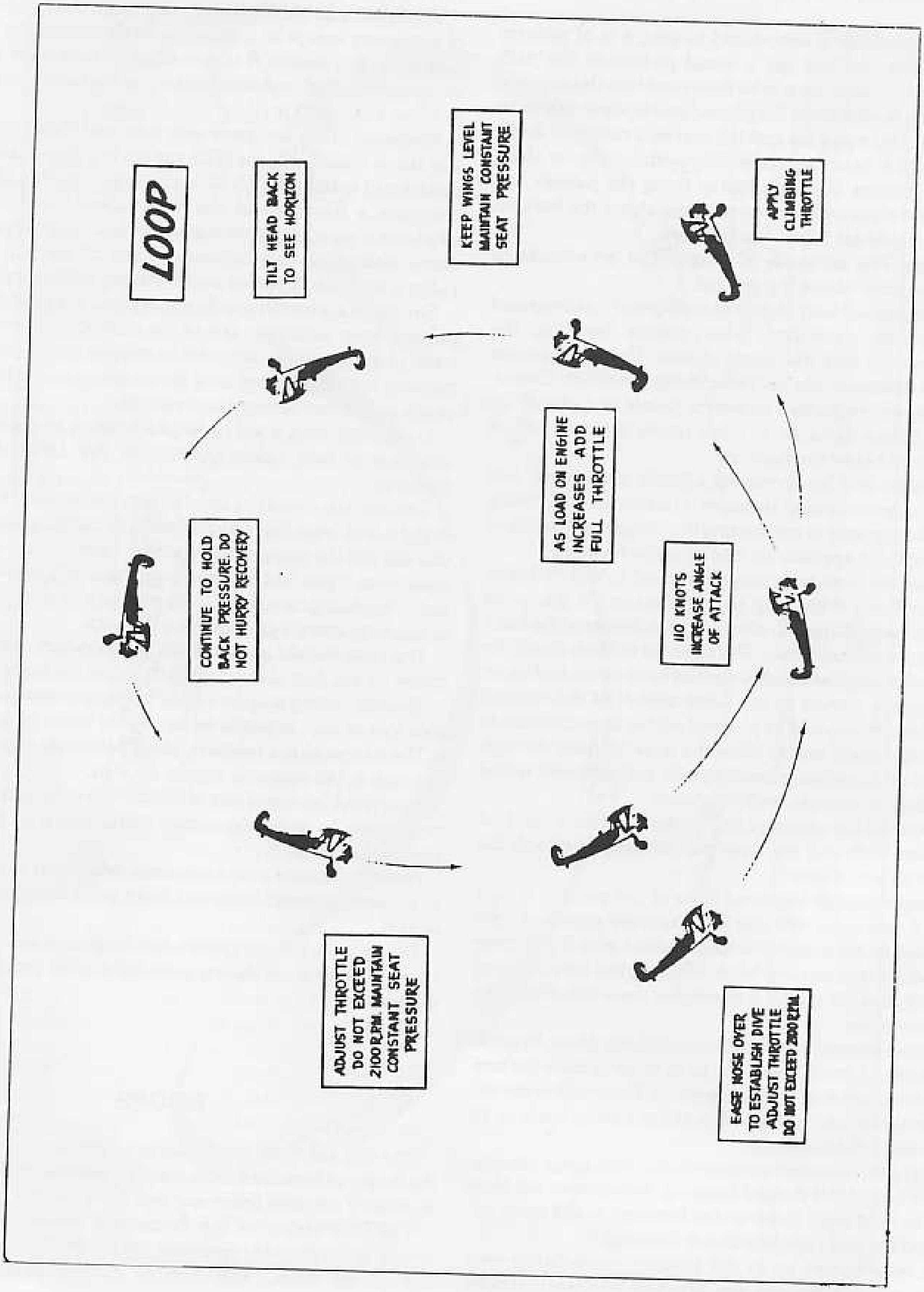
Apply sufficient control pressures, **whatever they may be,** to maintain smooth balanced flight at all times, with no slip or skid.

Do not practice wingovers too long or continuously, but come back to them during your flight, after practicing other maneuvers.

LOOPS

The first aerobatic maneuver to be introduced in C stage is the loop, not because it is the simplest or easiest to execute, but because it requires fewer and less rapid control movements.

The loop is one of the fly-through maneuvers. In other words, when properly executed, the airplane is under full control at all times, with normal control reactions in all attitudes.


LOOP
TILT HEAD BACK TO SEE HORIZON
KEEP WINGS LEVEL MAINTAIN CONSTANT SEAT PRESSURE
APPLY CLIMBING THROTTLE
AS LOAD ON ENGINE INCREASES ADD FULL THROTTLE
110 KNOTS INCREASE ANGLE OF ATTACK
CONTINUE TO HOLD BACK PRESSURE. DO NOT HURRY RECOVERY
ADJUST THROTTLE DO NOT EXCEED 2100 R.P.M. MAINTAIN CONSTANT SEAT PRESSURE
EASE NOSE OVER TO ESTABLISH DIVE ADJUST THROTTLE DO NOT EXCEED

Technically, a loop is the pattern described by the airplane as it is flown through a closed circular path in a vertical plane. In as much as the loop is executed in a single plane, the elevator and throttle are the basic controls. The ailerons and rudder are used merely as balance and directional controls.

At an altitude of 3000 feet or more above the ground, fly along a straight road, or similar landmark, in straight and level cruising flight, then ease the nose over to establish a dive. In the N2S, dive the airplane until it reaches an indicated airspeed of approximately 110 knots, adjusting the throttle as necessary so as not to exceed the maximum allowable r.p.m. (2100).

When this speed is reached, start a straight climb holding a straight flight path in the vertical plane and keeping the wings level. When you begin to feel and hear the increased load on the engine, as the nose comes up through the horizon, apply full throttle.

To execute the best loop, sufficient back pressure should be used to maintain a constant seat pressure and to keep the nose moving at a constant rate.

The back pressure will be approximately constant but, as the airspeed diminishes, greater movement of the stick will be necessary to attain this desired result.

When you can no longer see the horizon ahead of you, tilt your head backward so that you can see the horizon in the opposite direction as soon as possible. Thus you can check, and if necessary, correct your wing level attitude and directional heading.

Continue to hold the back pressure and fly the airplane through the opposite horizon.

As the nose passes through the horizon, you should feel and hear the engine begin to speed up as the load on it diminishes. At this point retard the throttle, (so as not to gain excessive r.p.m.), and maintain the same seat pressure throughout the dive and pull-out.

As the nose comes up through the horizon, apply climbing throttle and gain as much altitude as possible, before returning to straight and level cruising flight.

COMMON ERRORS:

1. Poor directional control, as the result of failure to make corrections for torque effect which varies throughout the maneuver.
2. Initial pull-up too fast. This is caused by increasing the angle of attack too rapidly and results in unnecessary loss of airspeed, and a possible stall at the top of the loop. Too fast a pull-up can be detected by excessive seat pressure.
3. The initial pull-up is too slow (you will feel little seat pressure) which results in dissipating too much airspeed in the initial climb, with the same result of poor control and possible stall at the top of the loop.
4. Applying additional back pressure to hurry the nose down when in the inverted position, as airspeed and control effectiveness diminishes. This aggravates, rather than remedies, the approaching stall condition.
5. Failure to start the maneuver with wings level, and failure to maintain directional control throughout the maneuver.
6. Failure to maintain a wing-level attitude, resulting in poor directional control.
7. Failure to adjust back pressure in last half of loop to compensate for changes in control effectiveness as speed is regained in dive. Also failure to adjust throttle to prevent overspeeding of engine in dive.
8. Failure to bring the stick straight back. There is a common tendency to bring it back to the right.

NORMAL SPINS

In a spin, the airplane is completely stalled and is falling toward the ground nose-low, following a corkscrew path through the air.

When there is plenty of distance between you and the ground, and you know the simple rules for recovery, there is nothing to worry about. A spin is one of the most easily performed maneuvers. It puts no excessive loads on the airplane when properly performed.

You will practice spins and their recovery for two reasons. First, the practice will enable you to recover promptly and automatically from unintentional spins, besides giving you confidence in your ability to recover. Second, it will serve as introduction to the aerobatics, which you will do later, and teach you to orient yourself in unusual attitudes of the airplane.

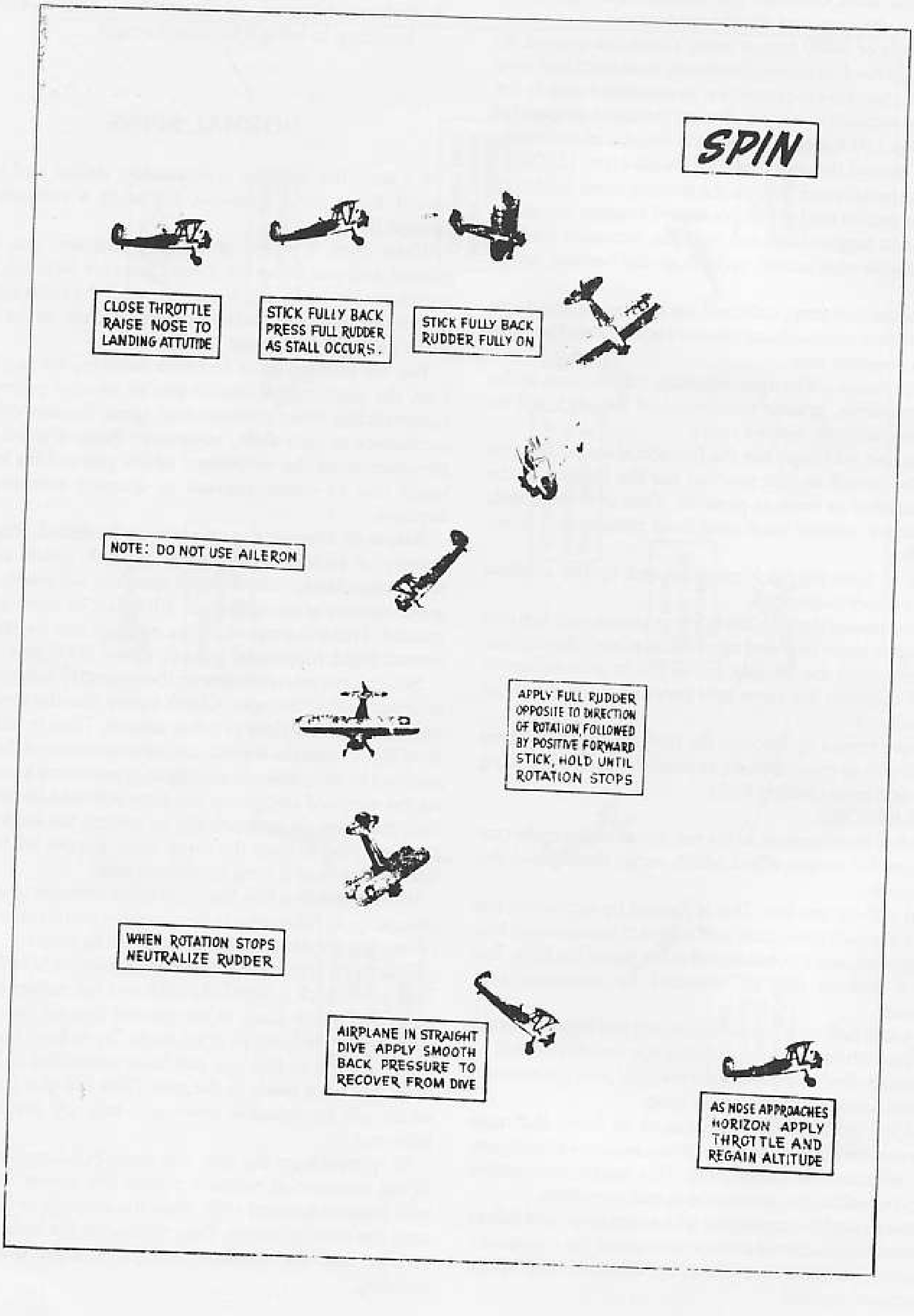
Before an airplane can spin it must be stalled, either intentionally or accidentally. A complete stall, unless recovered from immediately, will result in a spin. You will practice normal spins, starting at an altitude of 3000 feet or more above the ground. This will insure that the airplane can be returned to normal flight, fully under control, above 2000 feet.

Select some reference line on the ground to help you remain oriented during the spin. Check to see that the area around and below you is clear of other aircraft. Then in straight and level flight, close the throttle and raise the nose of the airplane to about landing attitude, exactly as in practicing a normal stall. As the airspeed decreases, the nose will tend to drop. Try to hold the nose up by gradually increasing the back pressure, remembering to keep the wings level. Do not fail to use carburetor pre-heat if icing conditions exist.

When the stick is fully back, just at the moment when the stall occurs, apply full rudder in the direction you want to spin. This causes the airplane to fall off and start to rotate.

During the spin, maintain the controls in the full ON position. That is, the stick is kept fully back and full rudder pressure is held. Don't look down at the ground directly over the nose. Look out at the horizon, at an angle. Try to keep track of your reference line so that you can have some idea of how many turns you have made in the spin. (This will give you practice which will be valuable when you take up precision spins later on.)

To recover from the spin, first apply FULL rudder opposite to the direction of rotation. Follow this almost immediately with positive forward stick. Hold the controls in this position until the rotation stops. Then neutralize the rudder, making certain that the airplane is in a straight dive, without skidding.


SPIN
CLOSE THROTTLE RAISE NOSE TO LANDING ATTUTIDE
STICK FULLY BACK PRESS FULL RUDDER AS STALL OCCURS.
STICK FULLY BACK RUDDER FULLY ON
NOTE: DO NOT USE AILERON
APPLY FULL RUDDER OPPOSITE TO DIRECTION OF ROTATION, FOLLOWED BY POSITIVE FORWARD STICK, HOLD UNTIL ROTATION STOPS
WHEN ROTATION STOPS NEUTRALIZE RUDDER
AIRPLANE IN STRAIGHT DIVE APPLY SMOOTH BACK PRESSURE TO RECOVER FROM DIVE
AS NOSE APPROACHES HORIZON APPLY THROTTLE AND REGAIN ALTITUDE

To recover from the dive, gradually and smoothly apply back pressure on the stick. As the nose approaches the horizon, apply throttle so that you will gain as much altitude as possible. Recovery from the dive must be gradual, especially if your airspeed has become excessive. Remember that you can best estimate the sharpness of the pull-out from the feeling of how much you are pressed down in the seat. Too abrupt a pull-out will result only in stalling the airplane again and it will probably enter into a progressive spin, which will be even more violent than the first.

Regardless of the types of airplane you are flying, recovery from a normal spin is always accomplished in precisely the same manner.

1. Apply positive opposite rudder (opposite to the direction of rotation), followed almost immediately by,
2. Positive forward stick.

NOTE: The amount of forward stick, and the length of time stick and rudder pressures must be held varies from one type of airplane to another. Hold the rudder just long enough to stop the rotation, and hold forward stick just long enough to regain flying speed. If you hold forward stick too long, you will lose too much altitude and pick up too much speed in the dive, making the recovery difficult.

CAUTION: In the N2S type airplane, aileron is never to be used in the entry to or recovery from spins. During the recovery from the spin itself, your control movements should always be brisk and positive. Slow and cautious control movements not only will cause you to lose too much altitude before recovering, but may have no effect at all on the spin. Be sure to read the T.O. on spin recovery.

ACCIDENTAL SPINS

As you know, an airplane cannot spin unless it has first been stalled. All accidental spins, therefore, result from unintentional stalls. Regardless of whether the spin has been entered intentionally or not, however, recovery is the same as in normal spins.

Accidental spins at low altitudes are dangerous because there is usually insufficient altitude for safe recovery. Since the spin is not expected, the pilot is not prepared for an immediate recovery, and hence, it takes him longer to start applying the controls properly.

Accidental spins are demonstrated to you so that you can learn to recognize the signs of an approaching spin, and learn to effect recovery before the spin actually develops. They also provide practice in spin recovery so that, if the spin should actually develop, you will be able to effect complete recovery with a minimum loss of altitude.

Accidental spins may occur as the result of any of the following situations:

1. Climbing turns:

   If, through carelessness or for some other reason, the nose of the airplane is held too high in a climbing turn, the angle of attack is increased too much, causing the airplane to stall. If proper corrections are not made immediately, the result will be a spin.

   Accidental spins out of climbing turns are likely to be "over the top". Instead of falling off and spinning in the direction of the low wing (as you would expect), the high wing stalls first and the airplane whips over into a spin in that direction. This may be due to the fact that just before the stall, the airplane slips toward the low wing which results in a partial blanketing of the air flow about the high wing or it can be the direct result of misuse of the rudder (in this case, top rudder).

2. Excessive skidding in turns:

   When the airplane skids in a turn, it loses airspeed and the nose tends to drop. Your reaction is to try to keep the nose up by increasing the back pressure on the stick, thus increasing excessively the angle of attack. If the proper corrections are not made, the airplane stalls. This stall, plus the rudder pressure (which caused the skidding in the first place) usually results in an accidental spin.

3. Spins from too shallow glides:

   If you hold the nose of the airplane too high in a glide, the airspeed decreases and the nose tends to drop. The natural tendency of the beginner is to try to raise the nose again by pulling back on the stick. This greatly increases the angle of attack and the airplane stalls in complete readiness for an accidental spin.

4. Spins from gliding turns:

   As you already know, the airplane will stall at higher airspeeds in a gliding turn, than in a straight glide. If the nose is held too high in a gliding turn, the airspeed decreases and the nose then tends to drop. As in the glide which is too shallow, the beginner usually tries to raise the nose again by increasing the back pressure on the stick. This decreases the airspeed still more and greatly increases the angle of attack. Under these conditions, the airplane stalls and is ready for an accidental spin.

The recovery from an accidental spin is exactly the same as the recovery from intentional spins which you have already practiced: apply full opposite rudder followed almost immediately by positive forward stick.

There is, however, one important difference which has already been mentioned: since you are not expecting the spin, it will take some time for you to realize what is happening. In other words, you won't be "all set" to make the recovery. During the time it takes you to recognize the spin and its direction, you may have lost considerable altitude. This is the basic reason why accidental spins are so extremely hazardous if they occur near the ground. Add to this the probability that such spins are likely to be entered with power on, which increases the violence of the entry, and you have all the ingredients for trouble.

However, note this: if you should ever get into an accidental spin at low altitude, the application of full throttle will enable you to recover with less loss of altitude and may prevent a crash. Practice this type of recovery at a safe altitude and check


ACCIDENTAL SPIN – "OVER THE TOP"
USUALLY OCCURS IN A STEEP CLIMBING TURN ON TAKE OFF WITH NOSE IN EXCESSIVELY HIGH ATTITUDE — ALMOST ALWAYS FATAL BECAUSE OF INSUFFICIENT ALTITUDE FOR RECOVERY

your altimeter to see how much less altitude you lose than with power off throughout the recovery.

It is obvious that, by the time you have recognized that the airplane is either entering a spin or already is in one, you have waited too long to take the necessary corrective measures. The time to prevent the spin is during the approach to the stall which always precedes it.

Remember these rules:

1. If you ever think you are climbing too steeply in a turn, **lower the nose with forward stick.** (Decreased angle of attack.)
2. If the controls seem to become "mushy" during a glide or a gliding turn, **lower the nose with forward stick.** (Decreases angle of attack.)
3. Keep all your turns balanced - don't skid or slip.

INVERTED SPINS

An inverted spin is very similar to the normal spin except that the airplane is stalled when inverted and spins in the inverted position, i.e., you are on the **outside** of the cork-screw path it follows.

The inverted spin in the N2S trainer is somewhat flatter and also slower than the normal spin. Therefore, the maneuver is less violent than you might expect.

Like all spins, inverted ones are dangerous only if insufficient altitude is available for recovery. Start them at 5000 feet or more above the ground and recover by at least 3500 feet. Be sure your safety belt is snug, the shoulder harness fastened, and that the seat is low enough to allow full throw of the rudder.

You will enter an inverted spin by beginning a normal loop at approximately 110 knots. As you reach the top of the loop with the nose on the horizon or slightly above, close the throttle and apply forward pressure on the stick to keep the nose in this attitude. Keep the wings level as you do this. As you continue your forward pressure on the stick to keep the nose up, the speed will become slower and slower and finally, the airplane will stall, with all the usual symptoms. Hold the stick full forward and apply rudder in the direction you desire to spin. Maintain your orientation the same as in normal spins by observing the direction the nose moves around the horizon.

Don't look at the ground directly beneath or behind you, because by looking beneath or behind, the pilot gets a false indication of his direction of rotation. Only by looking over the nose are you able to determine the direction of rotation. This is done by observing the movement of the nose to your right or left against the horizon.

Remember, an airplane will not spin **inverted** if the stick is held all the way back.

Recover by applying full opposite rudder, (opposite to the rudder applied on entry and opposite to the direction of the movement of the nose on the horizon), then apply positive back pressure on the stick. **Ailerons are not used.** As soon as rotation has stopped, neutralize rudders and, as flying speed is regained, complete the recovery by executing the last half of a loop.

The throttle is not opened until after normal flight is resumed and the oil pressure has returned to normal.

You are not likely to get into unintentional inverted spins, but during the practice of your aerobatics you may become stalled in the inverted attitude; of course, if the proper controls are not applied for recovery from the stall, an inverted spin will result. If you find yourself in an unintentional inverted spin, remember to take the following five steps immediately:

1. Close the throttle
2. Apply full rudder against the spin rotation.
3. Pull the stick back.
4. Neutralize rudders as rotation stops.
5. Recover to normal flight with a half loop.

Due to the fact that the rudder is not blanked out in an inverted spin as much as in a normal spin, recovery is effected more easily and more positively. Experience gained from inverted spins will enable you to immediately recognize the stall attitude which precedes the spin and to recover from it, before the spin actually develops.

An inverted spin can always be recognized by the feeling of being thrown away from the seat and against the belt. It is also difficult to keep your feet on the rudder pedals. If you should ever lose the pedals completely, you can recover merely by applying full back stick. Be sure you pull **back** on the stick - you may think you are pulling back when you are actually only pulling out on it.

PROGRESSIVE SPINS

A progressive spin is a spin resulting from improper recovery from a previous spin.

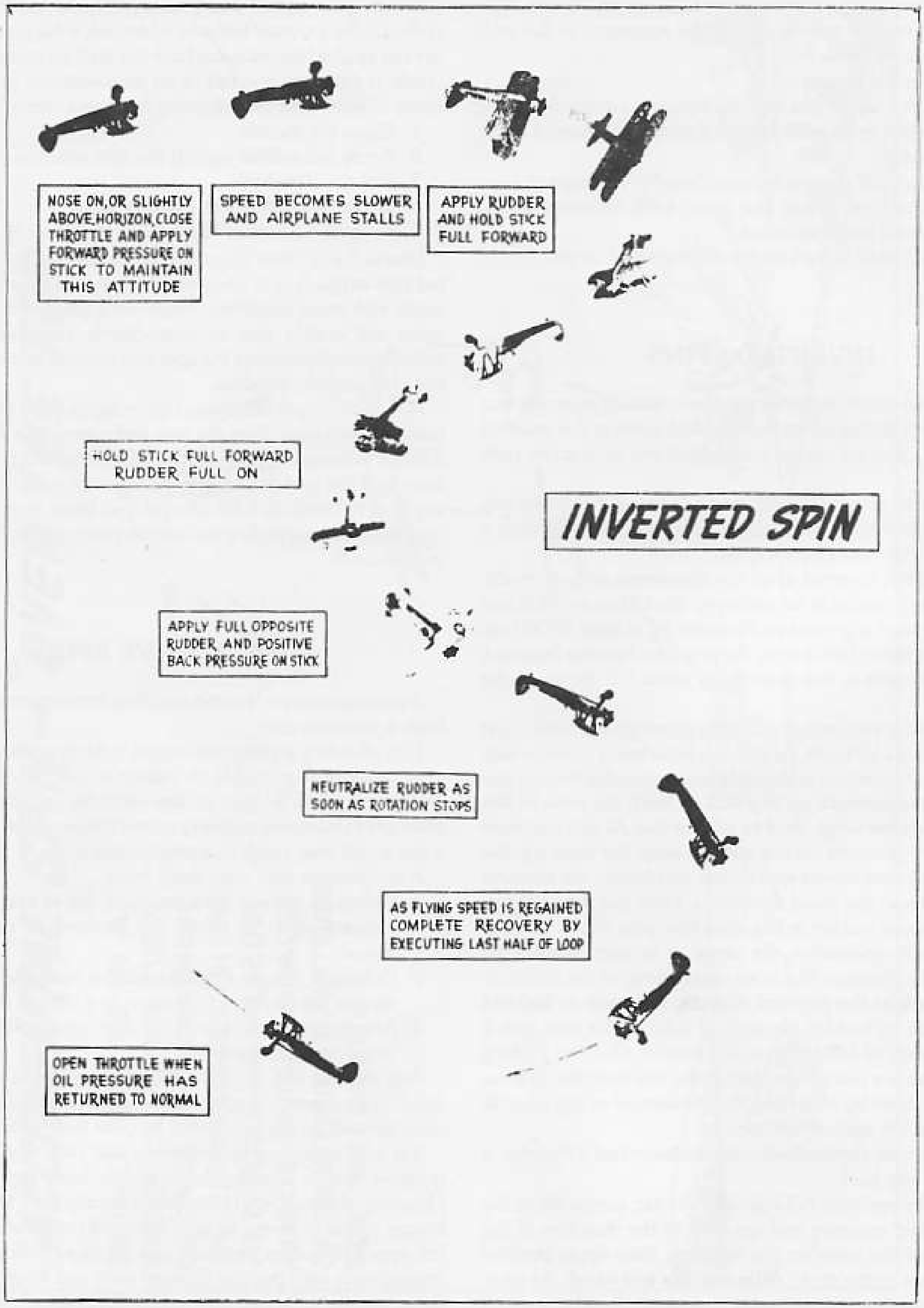
Like all spins, a progressive spin is dangerous unless sufficient altitude is available to permit a safe recovery. When recovering from a spin at low altitudes, a pilot naturally attempts to hurry the recovery as much as possible, but rushing it too much may result in a progressive spin.

A progressive spin may result from:

1. Failure to release back pressure, (or to apply sufficient forward stick), to allow the airplane to regain flying speed.
2. Failure to release opposite rudder in recovering, which causes the airplane to recover in a violent skid.
3. Attempting to pull out of the dive too quickly, (this is the most common cause).

Any one, or any combination of these three errors, may result in a progressive spin, but the last one, which is the most common will be demonstrated by your instructor.

It is very important to remember that recovery from a progressive spin is exactly the same as from a normal spin. However, the recovery controls will usually have to be held on longer, in the recovery, to stop the more rapid rotation. Apply full opposite rudder, (against spin rotation), followed almost immediately with positive forward stick and throttle to regain flying speed. As the airplane regains flying speed, recover from the dive as in a normal spin recovery.


NOSE ON, OR SLIGHTLY ABOVE HORIZON, CLOSE THROTTLE AND APPLY FORWARD PRESSURE ON STICK TO MAINTAIN THIS ATTITUDE
SPEED BECOMES SLOWER AND AIRPLANE STALLS
APPLY RUDDER AND HOLD STICK FULL FORWARD
HOLD STICK FULL FORWARD RUDDER FULL ON
INVERTED SPIN
APPLY FULL OPPOSITE RUDDER AND POSITIVE BACK PRESSURE ON STICK
NEUTRALIZE RUDDER AS SOON AS ROTATION STOPS
AS FLYING SPEED IS REGAINED COMPLETE RECOVERY BY EXECUTING LAST HALF OF LOOP
OPEN THROTTLE WHEN OIL PRESSURE HAS RETURNED TO NORMAL

Even though you begin to spin at a high altitude, if you find the airplane again spinning on each attempted recovery, you are likely to attempt increasingly rapid pull-outs each time and thus spin on in.

REMEMBER - You are to practice progressive spins with your instructor only.

PRECISION SPINS

Precision, as applied to spins at this stage of your training, refers to your ability to orient yourself sufficiently to start the recovery when the airplane will have completed exactly one and one-half turns of the spin.

Execution: At an altitude of at least 3,000 feet above the ground, fly along a road, section line or some other prominent straight landmark. Ascertain that the area around and below you is clear of other aircraft, then enter a normal spin, as was demonstrated in the preceeding stage. The fact that you have a straight line on the ground to use for visual reference, will aid you in orienting yourself by counting the turns the airplane will make against this reference line.

Enter the spin flying on a heading directly down a reference line. Watch for the line to come around again. When you see it-count "one-half"; when it appears again, "one" and the third time "one and a half". As the airplane reaches this one and one half-mark, start the spin recovery by positive opposite rudder followed almost immediately by forward stick. Complete the recovery as previously instructed, regardless of the heading.

COMMON ERRORS:

1. Improper entry or recovery from spin.
2. Failing to count the turns.
3. Concentrating on precision heading, thus forfeiting positive recovery.

EDITOR'S NOTE

The Stearman originally was equipped with small triangular wooden strips which were attached to the leading edges of all four wings which were designated as spin strips. These spin strips are commonly called stall strips by many pilots today. Deed Levy, the Chief Experimental Test Pilot for the Stearman Aircraft Co., has related that these spin strips were installed to facilitate rapid recovery from prolonged spins. Without the spin strips installed, the Stearman is un-predictable in spin recovery from prolonged spins. Deed has warned that if you do not have the spin strips installed on your Stearman - **do not do prolonged spins.**

TECHNICAL ORDER #113-44

30 August 1944

STALLS AND SPINS

(Of paramount interest to flying personnel - to be read by all pilots)

INTRODUCTION

1. This Technical Order is issued at the request of the Deputy Chief of Naval Operations (Air).

2. This Technical Order supersedes Technical Order 8-43 and Technical Order 133-43, which are hereby cancelled. This Technical Order does not alter, modify or supersede any existing instructions or orders which prohibit the spinning of certain models of airplanes.

3. The purpose of the Technical Order is to consolidate information on normal spins, stalls in accelerated flight, and inverted spins. Although considerable correspondence has been issued by the Bureau of Aeronautics from time to time regarding stall characteristics of aircraft and methods of spin recovery, avoidable accidents attributable to the lack of understanding of this subject continue to recur with such frequency as to necessitate a review and practical approach to this problem.

4. All student aviators shall read this Technical Order prior to solo.

NORMAL SPINS

5. For many years naval pilots were taught to push the stick forward and then kick opposite rudder to recover from a spin. It appears that certain pilots are still attempting to recover from spins using this old technique which, if carried out in certain modern airplanes, will cause the spin to flatten out, (due to the blanketing effect of the elevators on the rudder), and may produce a spin which will not only require a considerable period of time from which to recover, (even after proper technique is applied), but may even make recovery impossible.

6. The National Advisory Committee for Aeronautics and the Flight Test Department, NAS Patuxent River, have extensively investigated the question of recovery from spins. They recommend the method of spin recovery described below, which is equally satisfactory for both old and modern airplanes and **should be adopted as standard procedure by all naval pilots.** While the technique of recovery is described, it is desired to emphasize that airplanes should be prevented from developing spins by judicious use of the rudder, elevator, and throttle controls. The sudden realization that a stall is imminent should be followed immediately by a brisk forward movement of the elevator control to decrease the angle of attack. An increase in engine power will also assist. If the stall is not circumvented before the spin develops then, to recover:

(a) Use full rudder **hard** and with **positive** motion **full** against the spin and hold.

(b) After about one-quarter to one-half turn, move the elevator controls **full** forward with a **positive** motion.

(c) Keep ailerons in neutral, unless required otherwise for a particular model.

(d) Hold controls in this arrangement **positively** and **long enough** for them to take effect. It is advisable to judge the lapse of time by the number of turns made. In the event of a vicious spin, applied controls for recovery should be held for at least five turns before attempting any other means for promoting recovery.

7. The recovery technique outlined in paragraph 6 above should be modified as may have been determined by previous experience to be desirable for a particular model of airplane.

8. The proper technique of aileron control in spin recovery cannot be definitely set forth. The consensus is that aileron control is not necessary for spin recovery and lacking specific instructions for a particular model that the aileron controls should be left in neutral. However, in certain models, the use of aileron control, while perhaps not being necessary to effect eventual recovery, will expedite the recovery from a spin. Also, whether the aileron should be applied with or against the spin depends on the particular models of airplane and on the distribution of load at the time of spinning. Tests have indicated that as the proportion of load carried within the fuselage is reduced and the proportion carried in the wings is increased (or vice versa) the effect of aileron setting on the spin recovery characteristics may be reversed.

Since a large proportion of the weight may be carried in the wings in the form of fuel, ammunition and bombs, and may be expended in flight, aileron control movements that are beneficial for one instantaneous flight loading condition of a given model airplane may prevent recovery for another instantaneous loading condition. The best general rule appears to be as follows:

(a) Do not use ailerons to assist in spin recovery unless definite information is available that such procedure is desirable. In this event apply the ailerons in the direction applicable for the model and distribution of load at the time of spinning.

(b) Spin-tunnel experience indicates that with monoplanes the aileron effects are generally larger and more consistent than with biplanes. This emphasizes the fact that the **wrong** use of the ailerons is likely to have serious consequences. Generally speaking, if the ailerons are used with monoplanes, they should be set **with** the spin for improved recovery, not **against** as would appear normal.

9. In case an airplane is known to have bad spinning characteristics it may assist in recovery (altitude and other factors permitting) if, before attempting to recover, the controls are placed so as to develop a normal spin, that is, place rudder full with the spin, elevators all the way back, and ailerons in neutral. The movement of the controls from this position to recovery position as outlined in paragraph 6 carries them through the full arc of their throw and accordingly will exert maximum recovery forces.

10. Slow and cautious movement of the controls during recovery is to be avoided. In certain cases it has been found that with a slow and cautious reversal of the rudder and elevators, spinning will continue indefinitely; whereas, brisk and positive operation of these controls would have effected recovery.

11. The proper use of the elevator tab control is decidedly important. It is obvious that in order to promote ease of recovery from a spin the tab should be set so as to make the plane nose-heavy for normal spinning. Under normal conditions, where the spin is entered inadvertently, it is thought that the tab setting will be in the near-neutral position, and, unless stick forces are very high and recovery very difficult, it will be unnecessary to readjust the elevator tab setting to complete recovery.

12. Use of the throttle in an attempt to recover from a bad spin, although effective at times, is very poor practice and generally should be considered as a measure to be tried only as a last resort.

13. In addition to outlining the latest information on the technique of spin recovery, it is desired to emphasize the following factors which have a direct bearing on preventing spins:

(a) Many airplanes and **especially tapered-wing monoplanes** will stall without any "sluggish control" warning. Pilots should insure sufficient "above stall" speed in these airplanes at all times.

(b) As the airplane is banked, the stalling speed increases due to the increase in applied acceleration. It is, therefore, essential that as the angle of bank is increased, sufficient flying speed be maintained to prevent stalling.

(c) In certain models of aircraft fitted with retractable landing gear, recovery from prolonged spins with the wheels in the down position may be slow if not impossible. Prolonged spins in such models with the wheels in the down position, are, therefore, prohibited and no intentional spins with the wheels in the down position are to be attempted.

(d) Care should be exercised in the opening of cowl flaps when the airplane is near stalling speed as such flaps may have an adverse effect upon stalling characteristics.

(e) The same airplane may develop different types of spins, depending upon the method of entry, control positions and movements, the load distribution and other conditions.

(f) Consideration should be given to the likelihood of losing fuel pressure and engine power in a prolonged spin.

(g) It is absolutely necessary for pilots of medium or short stature to be so positioned in the cockpit that full control throws may be obtained when desired. In addition, the possibility of high reversal of elevator and rudder forces in unusual types of spins cannot be overlooked, when the full strength of both hands, or even a foot, is needed to push the elevator control forward.

14. The higher the altitude at which a plane is spun the more difficult it will be to bring it out, as an increase in altitude has the same effect as an increase in wing loading. However, deliberate spins should not be started at an altitude lower than 10,000 feet in types whose spinning characteristics are unknown or of doubtful character. Pilots are advised (subject

to restrictions of paragraph 2) to become familiar at safe altitudes with the stall characteristics of the type of airplane they are flying; stick and rudder forces; distinctive warnings of approaching stall; recovery characteristics; roll and pitch action; effects on stall of cowl flaps, cockpit enclosure positions, power, propeller pitch setting, balance tab settings, retractable landing gear up and down, landing flaps; stick movement to produce stall; altitude loss for recovery. In general those airplanes which are difficult to spin may also be difficult to bring out of a spin. In the larger and heavier types of airplanes, the initial stalls should be reached only after slow approach; with a second pilot prepared to assist in overcoming unusually heavy control forces; with crews secured by safety belts; and with all loose gear properly secured.

15. When any doubt exists regarding the recovery characteristics of an airplane, a familiarization method consisting of trials of recoveries at various stages of the transition from straight flying to a steady spin should be employed.

16. Attention is invited to the fact that for a particular model of airplane the Pilot's Handbook often contains valuable information on spin-recovery technique.

STALLS IN ACCELERATED FLIGHT

17. The speed at which any given aircraft stalls is a function of the wing loading. Wing loading increases in direct proportion to the acceleration, "g", placed on an aircraft either in a turn or pull-out. Stalling speed increases directly as the square root of the applied acceleration or "g". In a steady turn at constant altitude, the acceleration is equal to the natural secant of the angle of bank and therefore the stalling speed varies as the square root of the natural secant of the angle of bank. Stalling speed rises sharply in turns as the angle of bank is increased beyond 50-60 degrees. In dive bombing or strafing if pilots continue their dives or glides beyond the safe recovery altitude they are forced to pull out quickly causing considerable acceleration to be placed on the aircraft and sometimes resulting in stalls and spins at very high speeds. Records show that stalls in accelerated flight **at low altitudes** account for a large majority of spin crashes. An aircraft which normally stalls at 70 miles an hour will stall at 210 miles per hour if a load factor of 9 "g" is experienced during a pull-out; or if the same airplane is flying in a steady horizontal turn banked 60 degrees, the square root of the secant of the angle of bank is 1.414 and the stalling speed accordingly is 99 miles per hour.

18. Consideration must also be given to successive spins, (previously called progressive stalls). When a pilot recovers from a spin, particularly an inadvertent spin, he is likely to be in too great a hurry to regain normal flight and consequently will apply an unwarranted amount of "g" on the aircraft during recovery. In addition to this unnecessary application of "g", the pilot will probably bank the airplane in the opposite direction to his previous rotation, due to confusion and, unless experienced or careful, he may fail to neutralize rudder. The increased stalling speed resulting from the excessive "g" load coupled with opposite bank and possible failure to neutralize the rudder frequently results in successive spins, usually in the opposite direction. On one occasion a pilot recovered at least five consecutive times from inadvertent spins before finally crashing. It is apparent that this pilot each time desired to pick up more airspeed than was employed in the previous recovery, but also became more anxious to recover each time and pulled the stick back harder, which resulted in progressively increasing his stalling speed. Failure to neutralize the rudder after rotations ceased aggravated the recurring spin tendency.

19. There are two sets of physiological facts which should be given consideration in any attempt to analyze pilot reaction to spinning. The first of these is the action of the "balance mechanism" of the inner ear, which largely controls pilot reaction to a spin when flying on instruments. A human who is whirled rapidly in a given direction, without visual reference, as in instrument flying, will feel, when this turning movement is arrested, that he is being whirled in the opposite direction and his natural attempt at correction of this sensory illusion tends to cause him to re-enter a spin in the same direction as the original spin. The second of these considerations is the normal ocular reaction to spin when there is a visible horizon or visual reference point. Under these circumstances, the ocular stimulus outweighs the control of the "balance mechanism" of the inner ear. Therefore, when not on instruments, and when the rate of rotation is sufficiently rapid or sufficiently prolonged, a jerking movement of the eyeball occurs characterized by a slow movement of the eyeball in the direction of the original spin and a jerky recovery in an attempt to fix upon a visual reference point. Consequently, if the spin be to the **right,** and then arrested, it is followed by a slow movement of the eyeball to the right which component creates the illusion that the horizon is rotating to the left. In the inexperienced pilot there would be an involuntary tendency to try to catch up with his horizon, with the result that he would attempt to place his plane in a left bank or left spin. To summarize:

(a) When flying on instruments, the physiological tendency is to re-enter a spin in the same direction as the original spin.

(b) When flying by visual contact, the physiological tendency is to enter a spin in the opposite direction to that of the original spin.

20. Recovery technique for spins entered from stalls in accelerated flight is the same as that for recovery from normal, intentional spins. However, it must be remembered that spins entered during accelerated flight, will usually be much faster due to the greater speed at entry. Therefore, there is more need for rapid and positive application of recovery controls and also the controls may need to be held in the recovery position for a longer period of time. In summary, to recover from a spin entered in accelerated flight:

(a) Employ prompt recovery controls, as previously outlined in discussion on normal spin recovery, and hold these controls until rotation stops.

(b) Neutralize rudder after rotation ceases.

(c) Level wings.

(d) Pull out at such a rate as to avoid placing excessive "g" on the aircraft, thus avoiding another stall.

All flying personnel must take cognizance of the fact that in recovery from a difficult situation in a stalled attitude, due consideration must be given to the progressive increase in stall speed which results from an increase in load on the wings.

INVERTED SPINS

21. A study of previous literature on the subject gives the impression that the inverted spin is a somewhat dangerous and unfamiliar maneuver and the correct technique for recovery therefrom is slightly obscure. The fact is, however, that the general precautionary measures involved in the inverted spinning of any airplane parallel those applying to normal spinning. The most cogent considerations in the spinning of any airplane are:

(a) Any airplane which is difficult to spin may also be difficult to bring out of a spin.

(b) The higher the altitude at which the plane is spun, the more difficult it will be to bring it out, as an increase in altitude has the same effect as an increase in the wing loading.

(c) The pilot's ability to place all controls on "full" in all directions is essential. In an inverted spin the pilot is thrown away from the controls, and unless a conscious effort is made he will find himself hanging onto the stick rather than actually moving it back and forth; the inexperienced pilot thinks that he is pulling the stick **back** when in reality he is probably trying to pull it **out** of its socket.

(d) In order to promote ease of recovery from an inverted spin the tab should be set so as to make the plane tail-heavy. Note that this is opposite to the nose-heavy tab setting that promotes ease of recovery from normal spin, paragraph 11. Under normal conditions, where the spin is entered inadvertently, it is thought that the tab setting will be in the near-neutral position, and, unless stick forces are very high and recovery very difficult, it will be unnecessary to readjust the elevator tab setting to complete recovery.

(e) The inexperienced pilot is apt to have difficulty in recognizing the early stages of the inverted spin when first entered. If power is on, the spin is apt to develop very rapidly and lead to confusion, but the sensation of being thrown away from the controls is a certain indication that the spin is inverted rather than normal. This uncertainty will completely disappear after several practice inverted spins.

22. The inverted spin has been carefully studied by engineers and pilots with practical experience in recovery from this maneuver. The results of these studies indicate that recovery from the inverted spin is often more rapid and certain than from the normal spin for the following reasons:

(a) In the inverted position the wings of the airplane have less lift and greater drag, thus acting to retard autorotation.

(b) Practically all aircraft have greater throw of up-elevator than down-elevator, thus giving greater control for recovery from an inverted spin than from a normal spin.

(c) The average airplane is designed so that the airflow impinges more directly on the elevators when set for recovery from inverted spins than from normal spins.

(d) Due to the relative position of the horizontal tail plane to the rudder, there is less tendency for the horizontal surfaces to blank the rudder in the inverted position.

23. The best method of entering the inverted spin is from the half-loop position. As the plane approaches the inverted horizontal, the stick is eased forward to maintain this attitude, and just before the plane stalls the stick is pushed completely forward and hard rudder applied. The average plane will then whip off into an inverted spin in the direction in which the rudder is applied. If the plane stalls completely with the stick all the way forward and then rudder is applied after the nose has begun to fall, it very probably will not spin but will slide off into a skidding inverted spiral and lose altitude much more rapidly than if a normal inverted spin develops. Practical experiments have indicated that no inverted spin has ever developed with the stick pulled back, regardless of the attitude of the airplane.

24. The following technique, fundamentally parallel to that for recovery from normal spins, will produce rapid and certain recovery from the inverted spin:

(a) Cut the gun.

(b) Kick hard opposite rudder against the direction of rotation. The nose follows the rudder in all attitudes. The pilot's impression of the direction of rotation is correct only as long as the line of vision goes along or in relation to the nose of the airplane, and if, while in an inverted spin the head is thrown back and the line of vision goes straight down to the ground, the direction of rotation is apparently reversed. It **is therefore mandatory that a visual determination of the direction of rotation be made by reference to the nose of the airplane. The turn indicator will show the true direction of rotation in either normal or inverted spins.**

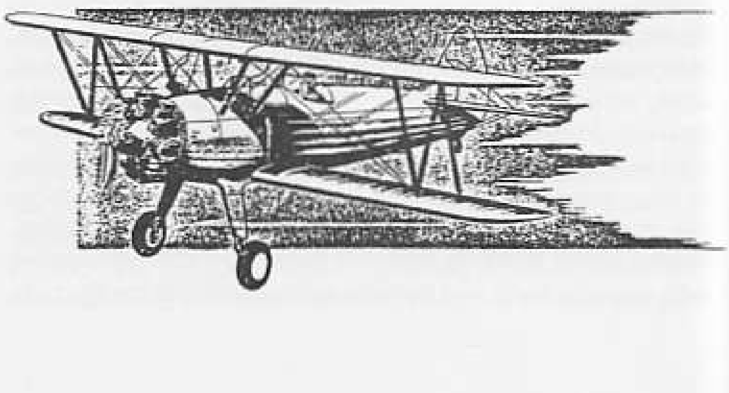
(c) Pull the stick all the way back, neutralizing the ailerons.

(d) As soon as autorotation ceases, complete the recovery from the inverted position by either rolling out with the ailerons or completing the loop or a combination of the two.

(e) Ease the throttle on very gradually to prevent engine bearing damage, as during the evolution oil pressure will probably have been lost.

/s/ L. B. RICHARDSON

L. B. RICHARDSON
Rear Admiral, USN
Acting Chief of Bureau



THE SLOW ROLL

The slow roll is a maneuver in which the airplane is rolled about its longitudinal axis, through 360°, chiefly by use of the ailerons. Rudder and elevators serve merely to maintain the direction in which the nose was pointing at the time the maneuver was begun. This conception (ailerons the major control) is important as most of the errors committed during the performance of the maneuver are due to attempting to force rotation by means of the rudder or elevators.

The slow roll is included in the Primary Syllabus for several reasons:

1. To improve your coordination, timing and orientation in unusual attitudes.
2. To aid you in getting over any tendency to apply controls in terms of "up" and "down".
3. To give you an understanding of the use of controls in inverted flight.
4. To furnish you the most efficient recovery, (minimum loss of altitude), in case you ever find yourself inadvertently in an inverted position.
5. To furnish you an effective means of bailing out, (from the inverted position), should the need ever arise.
6. To help you overcome any aversion you might have to inverted flight.

Referring to your aerobatic check off list, in the slow roll it is particularly important to be sure that your safety belt is snugly fastened. Even a small amount of slack gives an unpleasant dropping sensation in the inverted position and may interfere with effective application of controls. Keep your seat low and be sure the adjustment lever is locked. To have the seat slip a few notches while inverted will surprise you, to say the least. The low position of the seat will enable you to have full throw of the controls in the inverted position.

Be sure your goggles are down and fastened securely, (helmet also). There is no excuse for losing them while in the inverted position. Moreover, keeping the goggles down over your eyes is protective insurance, for in spite of your check for possible loose gear on the deck, small particles of dust, oil etc. are usually present in the cockpit of the airplane and may get in your eyes while you are inverted.

As for altitude, slow rolls must not only be begun, but also completed at more than 3000 feet above the ground.

Before going up with your instructor to learn how to do a slow roll, make a careful study of the two illustrations. The illustrations represent 360° of rotation. The angles are necessarily approximate and the procedure should not be allowed to become mechanical as a result of attempting to follow the figure too closely. It should, however, be useful in getting the general idea, especially if you use a model. The airplane can be rolled in either direction; the left slow roll will be described here.

The slow roll is executed as follows: After clearing the area and while flying straight and level, line the airplane up with a point well out on the horizon. With cruising throttle, nose the airplane down until you have a speed of 90-95 knots. Raise nose slightly above the horizon, add throttle and start the roll immediately.

Begin the roll by applying coordinated pressures to the left on the stick and rudder, as in the beginning of a turn. Increase the aileron pressure in order to obtain the maximum rotation, with minimum tendency to change direction. Full aileron pressure is then applied throughout the entire maneuver, and removed only as the airplane completes the roll and resumes straight and level flight.

As the airplane begins to roll, ease off the pressure on the left rudder and gradually apply pressure on the right rudder. This pressure on the right rudder is continued until the aiplane has rolled past the fully inverted position and is just sufficient to keep the nose in position while the airplane is banked. From the vertical bank position to well past the fully inverted position, hold the nose above the horizon by applying forward stick pressure as necessary. As the airplane passes the wing level inverted position, ease the pressure from the right rudder and apply gradually increasing pressure on the left rudder, **still holding the stick forward**. Continue left rudder and left aileron pressures until straight and level flight is resumed, but from the position of approximately 45° before the wings are level, begin easing the stick back and, at the same time, slowly ease off the left rudder pressure, as the airplane approaches normal flight.

It may be necessary to apply slight opposite aileron to stop the roll exactly in the wing level position.

USE AILERON FOR ROLL—RUDDER AND ELEVATOR FOR DIRECTIONAL CONTROL.

The importance of the full use of the ailerons in the slow roll can best be demonstrated by placing your feet on the deck and executing the roll with aileron alone. The result will be an old fashioned "barrel roll", i.e., the airplane will move through a circular path in the vertical plane at the same time it rotates around its longitudinal axis.

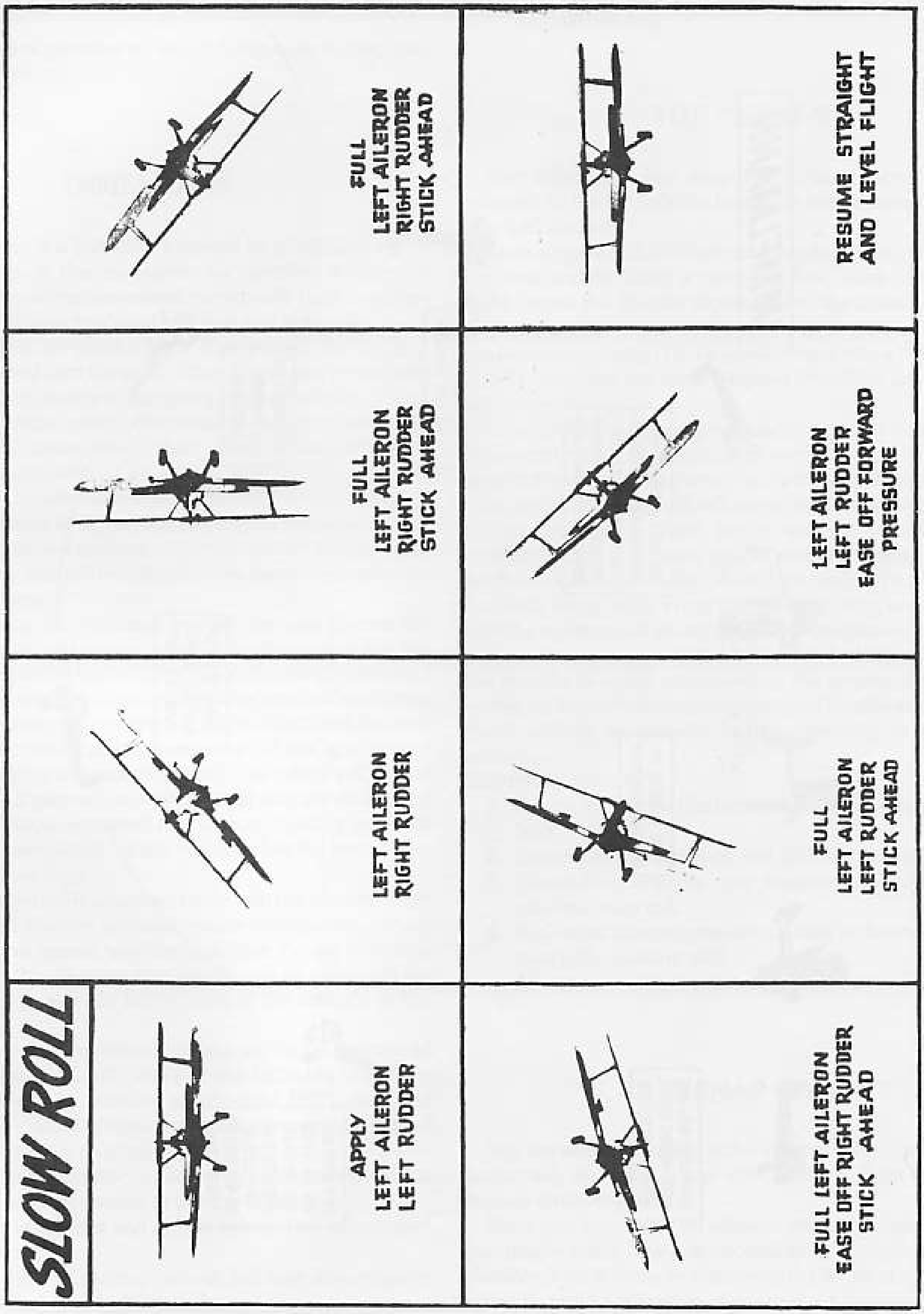
If you divide the roll in half, i.e., stop for a moment in the inverted position you can obtain a better understanding of the stick movement and position necessary to hold the nose slightly above the horizon. The oil pressure will drop if the plane remains inverted for any length of time. If this happens, **close the throttle immediately** and roll to the upright position. Even in a continuous slow roll, the engine may miss a few times while inverted but will pick up again as the roll is completed.

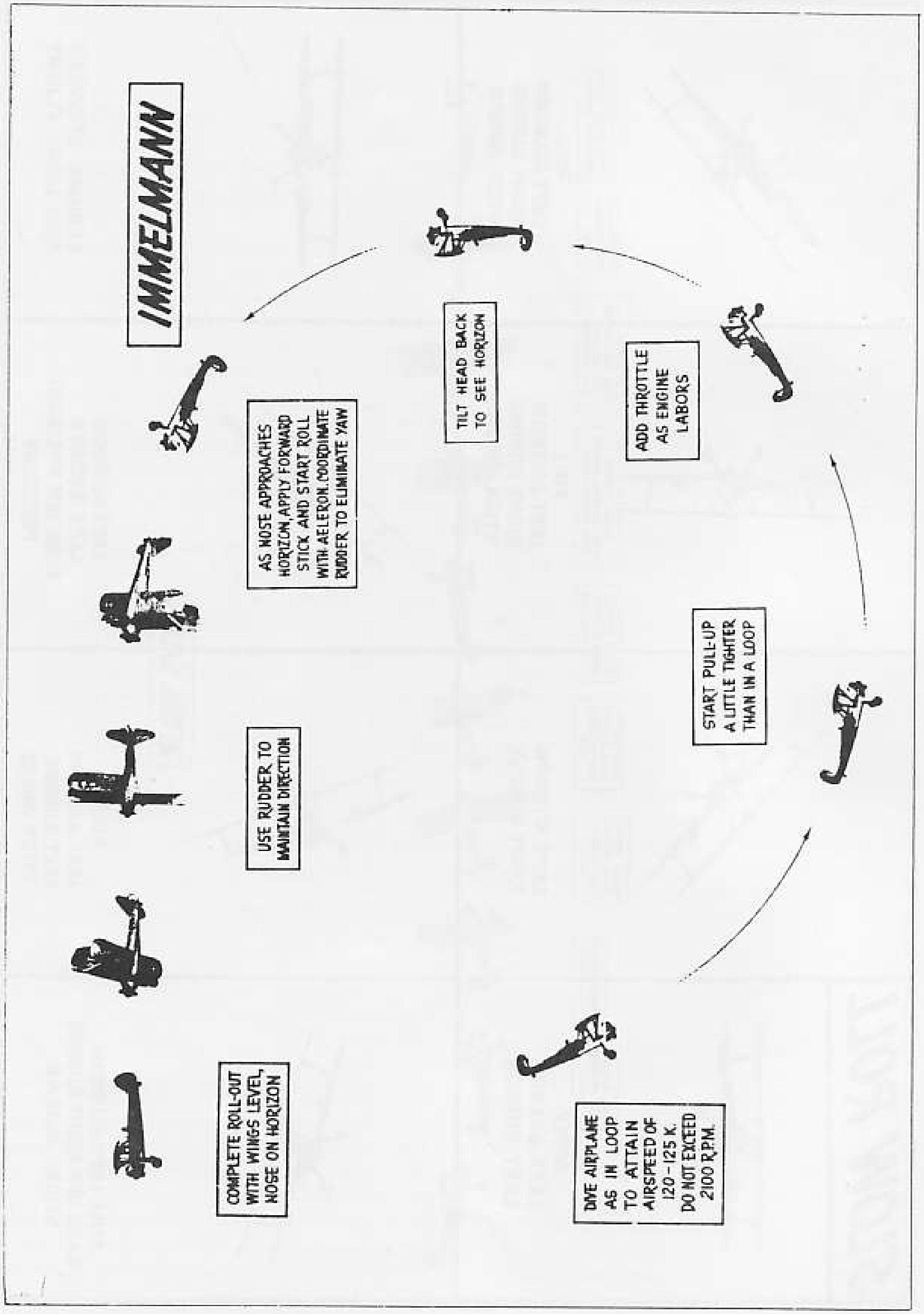
If at any time while in the inverted position the engine ceases firing, close the throttle to protect the engine from the detrimental effect of the sudden surge of power resulting when the engine picks up again.

COMMON ERRORS:

1. Relaxing aileron pressure before roll is completed.
2. Failure to select a definite point for use in orientation.
3. Failure to hold the heading throughout the maneuver.
4. Failure to apply full aileron throughout the roll, which tends to markedly slow up the maneuver.
5. Failure to maintain forward stick pressure when inverted, or too much forward stick while inverted resulting in stall.
6. Overcontrolling with rudder.


SLOW ROLL
APPLY LEFT AILERON LEFT RUDDER
LEFT AILERON RIGHT RUDDER
FULL LEFT AILERON RIGHT RUDDER STICK AHEAD
FULL LEFT AILERON RIGHT RUDDER STICK AHEAD
LEFT AILERON RIGHT RUDDER STICK AHEAD
FULL LEFT AILERON EASE OFF RIGHT RUDDER STICK AHEAD
LEFT AILERON LEFT RUDDER EASE OFF FORWARD PRESSURE
FULL LEFT AILERON LEFT RUDDER
RESUME STRAIGHT AND LEVEL FLIGHT


SLOW ROLL
APPLY LEFT AILERON LEFT RUDDER
LEFT AILERON RIGHT RUDDER
FULL LEFT AILERON RIGHT RUDDER STICK AHEAD
FULL LEFT AILERON RIGHT RUDDER STICK AHEAD
FULL LEFT AILERON EASE OFF RIGHT RUDDER STICK AHEAD
FULL LEFT AILERON LEFT RUDDER STICK AHEAD
LEFT AILERON LEFT RUDDER EASE OFF FORWARD PRESSURE
RESUME STRAIGHT AND LEVEL FLIGHT


IMMELMANN
DIVE AIRPLANE AS IN LOOP TO ATTAIN AIRSPEED OF 120-125 K. DO NOT EXCEED 2100 R.P.M.
START PULL-UP A LITTLE TIGHTER THAN IN A LOOP
ADD THROTTLE AS ENGINE LABORS
TILT HEAD BACK TO SEE HORIZON
AS NOSE APPROACHES HORIZON, APPLY FORWARD STICK AND START ROLL WITH AELERON. COORDINATE RUDDER TO ELIMINATE YAW
USE RUDDER TO MAINTAIN DIRECTION
COMPLETE ROLL-OUT WITH WINGS LEVEL, NOSE ON HORIZON

7. Delay in starting roll with resulting unnecessary loss of airspeed.
8. Starting roll with back pressure on the stick, thus losing directional control.
9. Applying forward pressure on the stick too early in the roll.
10. Apply back pressure on the stick too early during final part of the roll.

IMMELMANS

An Immelman is a half loop, followed by a half slow roll at top of the loop. In this maneuver, the direction is changed 180°. Execution of the Immelman merely calls for a combination of the principles practiced in loops and slow rolls.

At 3,000 feet or more above the ground, fly along a reference line and start the entry with a dive as you would for a loop, except that, since you are going to do a half slow roll on top and need more control effectiveness, you must enter the Immelman with more speed than a loop, (120-125 knots indicated airspeed without exceeding maximum r.p.m)

NOTE: To conserve as much of this additional airspeed as possible for control in the roll out, you should make the pull up a little more rapid and the loop a little tighter than before. If you do this properly, you will feel slightly more seat pressure than in the ordinary loop.

As in the loop, tilt your head back so that you can see the opposite horizon, as soon as possible. As the nose of the airplane approaches the horizon, slow down its rate of movement by applying forward stick and at the same time, without delay or hesitation, start a roll in either direction. Slight rudder pressure will be necessary here in starting the roll out, to eliminate yaw away from the direction of the roll. The rate of roll should be constant and planned, so that it blends with the downward movement of the nose toward the horizon in such a way, that the half roll is completed , as the nose reaches the horizon for straight and level flight.

Remember the roll is executed solely with the ailerons while the rudder and elevator are used only to maintain the correct heading. For this reason, you can anticipate the use of aileron in the roll, but the other controls should not be used until the need for them is actually felt or seen in the attitude of the airplane.

Hints and common errors include all those mentioned under loops and slow rolls, and also the following hints:

1. To assist you in attaining an accurate 180° change in heading, you should practice this maneuver along a road or other similar reference line.
2. Acquire and maintain sufficient speed to complete the roll-out with full control at the top of the loop.
3. Do not use elevator and rudder before their actual need is apparent.
4. Do not delay in starting roll-out, but take advantage of airspeed before it is dissipated.
5. Do not relax aileron pressure too soon, prior to completion of the half roll and do not try to complete roll-out with rudder.
6. Remember, it is the ailerons that cause the airplane to roll. Use them for that purpose.
7. Use the rudder and elevator only to maintain the desired heading.

THE "SPLIT-S"

The split-S is a half snap roll to the inverted position, followed by the last half of a loop. The airplane changes direction 180 degrees.

At an altitude of 3,000 feet or more above the ground, clear the area and fly along a reference line. From straight level flight, retard the throttle slightly below the cruising position, and raise the nose so as to allow the airplane to slow down to a speed below cruising (70-75 knots). Since only a half snap roll is to be executed, the initial airspeed should be less than for a full snap roll.

Execute the roll by applying full rudder in the desired direction, together with firm back pressure on the stick. No aileron is used in the entry of this maneuver. At the instant the airplane is fully stalled, the snap roll will occur in the direction in which rudder has been applied. Begin recovery immediately, by applying positive opposite rudder and firm forward pressure on the stick to stop rotation, in order to reach an inverted position with wings level. From this inverted wing level position, with the rudder neutralized, apply back pressure on the stick to execute the recovery as in the last half of the loop and regulate the throttle to avoid overspeeding the engine. As the nose comes up through the horizon, apply full throttle and regain as much altitude as possible before returning to a cruising attitude.

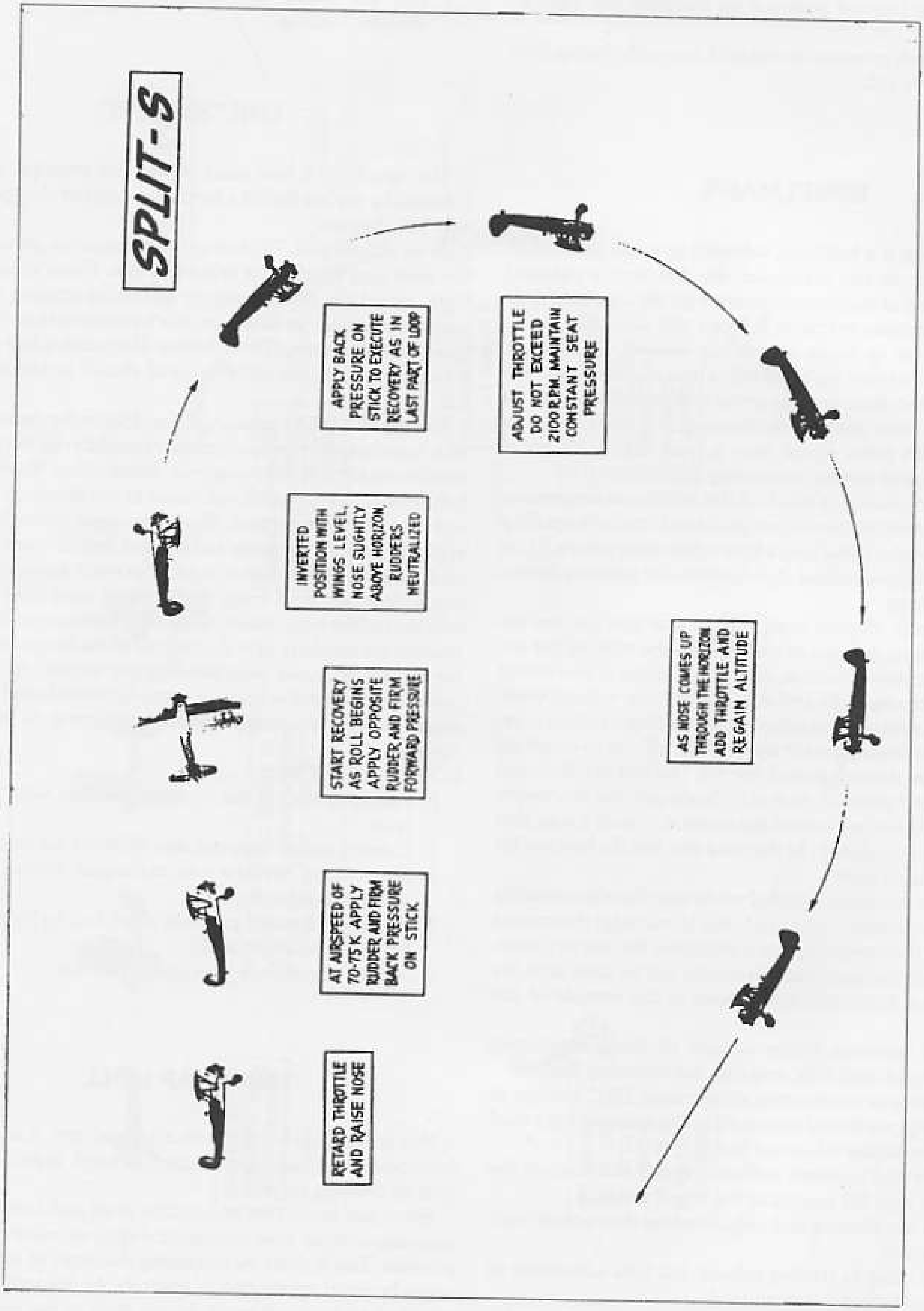
COMMON ERRORS:

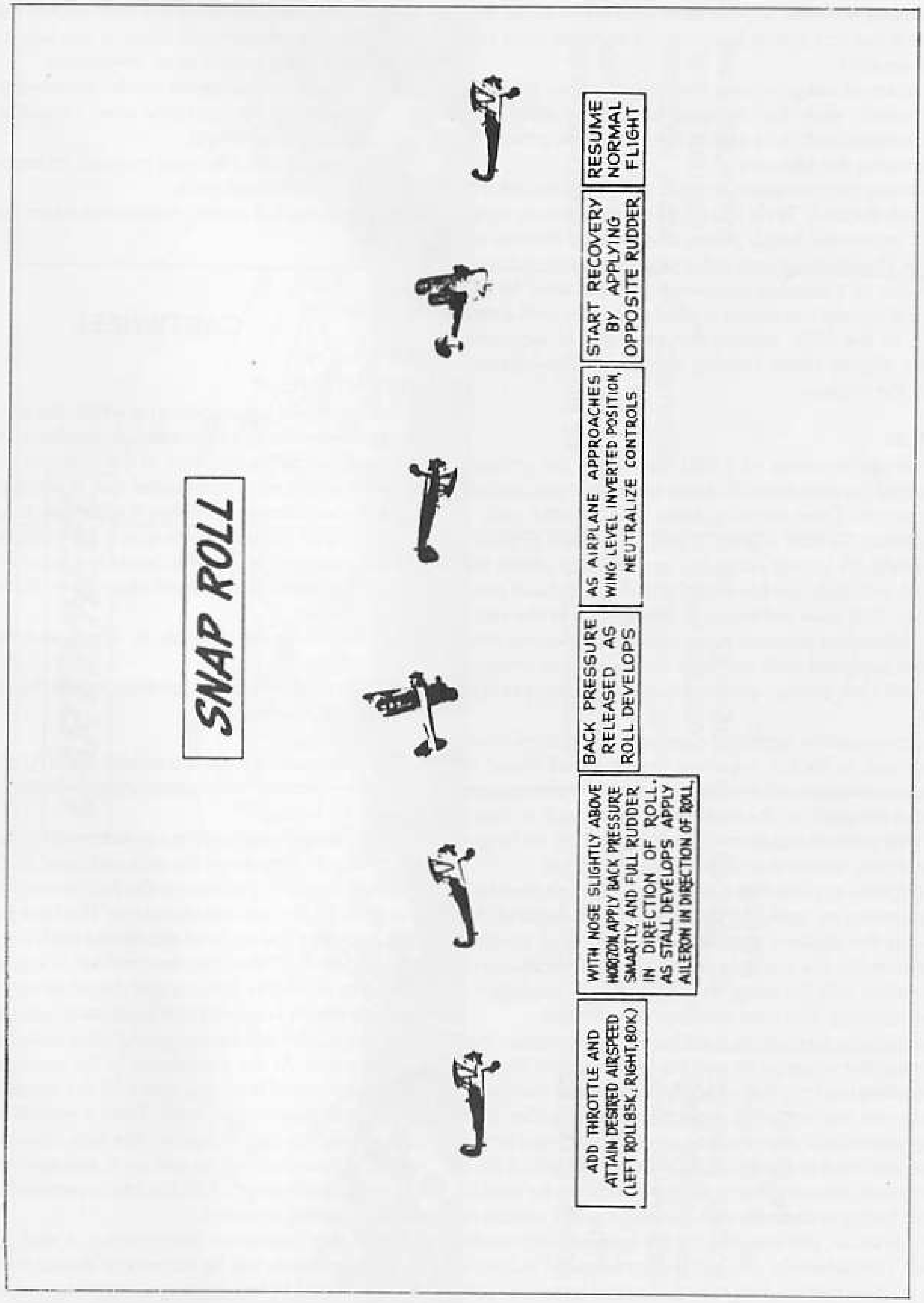
1. Failure to stop in the inverted position, with the wings level.
2. Gaining excess airspeed and RPM on the recovery.
3. Slow-rolling airplane into maneuver instead of using one-half snap roll.
4. Prolonged forward pressure on stick in the inverted position, with resultant stall.
5. Abrupt use of back pressure in pull-out.

THE SNAP ROLL

You are already familiar with a normal spin. A snap roll is a horizontal, one-turn power spin, in level flight at approximately cruising speed.

Since you know that an airplane must stall before it spins, you may wonder how a horizontal spin, at cruising speed, is possible. This is done by increasing the angle of attack of the wings by rapid application of controls. As this stall is brought about at an airspeed much higher than in the normal slow


SPLIT-S
RETARD THROTTLE AND RAISE NOSE
AT AIRSPEED OF 70-75 K APPLY RUDDER AND FIRM BACK PRESSURE ON STICK
START RECOVERY AS ROLL BEGINS APPLY OPPOSITE RUDDER AND FIRM FORWARD PRESSURE
INVERTED POSITION WITH WINGS LEVEL, NOSE SLIGHTLY ABOVE HORIZON, RUDDERS NEUTRALIZED
APPLY BACK PRESSURE ON STICK TO EXECUTE RECOVERY AS IN LAST PART OF LOOP
ADJUST THROTTLE DO NOT EXCEED 2100 R.P.M. MAINTAIN CONSTANT SEAT PRESSURE
AS NOSE COMES UP THROUGH THE HORIZON ADD THROTTLE AND REGAIN ALTITUDE


SNAP ROLL
ADD THROTTLE AND ATTAIN DESIRED AIRSPEED (LEFT ROLL 85K, RIGHT, 80K)
WITH NOSE SLIGHTLY ABOVE HORIZON APPLY BACK PRESSURE SMARTLY, AND FULL RUDDER IN DIRECTION OF ROLL. AS STALL DEVELOPS APPLY AILERON IN DIRECTION OF ROLL
BACK PRESSURE RELEASED AS ROLL DEVELOPS
AS AIRPLANE APPROACHES WING LEVEL INVERTED POSITION, NEUTRALIZE CONTROLS
START RECOVERY BY APPLYING OPPOSITE RUDDER
RESUME NORMAL FLIGHT

speed stall which you have practiced, it is referred to as a high speed stall.

As in a normal spin, rotation results from application of rudder. Even though stalled, the airplane retains its forward momentum and the nose will not drop until some of the forward speed is lost and gravity becomes the stronger force acting on the airplane.

Snap rolls are of value because they improve your ability to remain oriented, while the airplane undergoes rapid and extensive changes in attitude and, at the same time, providing training in timing the recovery.

In performing this maneuver, it is not necessary to kick the rudder or jerk the stick. To do so results in an extremely rapid and violent maneuver, which places unnecessary stresses on the airplane. The pressure snap roll is just as effective and even more valuable as a training maneuver. It is executed by the application of rapidly increasing control pressures until a stall is reached. In the N2S, starting the snap roll at airspeeds greater than slightly above cruising also causes unnecessary stresses on the airplane.

EXECUTION:

At an altitude in excess of 2,000 feet above the ground, determine that the area around, above and below you, is clear of other aircraft. From cruising flight, add throttle and, if necessary, lower the nose slightly to gain the desired airspeed, (approximately 85 knots). Raise the nose slightly above the horizon and, with only one hand on the stick, apply back pressure smartly, (this does not mean violently), and at the same time apply full rudder pressure in the direction of desired rotation. Do not apply full back pressure on the stick in bringing about the stall. Only enough pressure necessary to cause a stall is needed.

As the airplane stalls, apply full aileron in the desired direction of roll, and, as the roll develops, ease the stick ahead to neutralize the elevators, still holding full aileron. It is necessary to exert back pressure on the stick only long enough to cause the stall. After rotation has started, back pressure is no longer necessary; it only makes the recovery more difficult.

As the airplane approaches a wing-level position inverted, start the recovery by applying opposite rudder, (against the roll). Now, as the airplane approaches a wing-level up-right position, neutralize the controls, or use them as necessary to stop the rotation with the wings level and with the airplane on the proper heading. You then resume normal flight.

In analyzing your own errors, it will be well to remember that if, on recovery, the wings go on past the level position, you are probably waiting too long before applying opposite rudder for recovery, or you are not using enough recovery rudder. If, in recovering, the nose of your airplane consistently drops below the horizon and back pressure on the stick will not hold it up, it is very likely that you are either pulling the stick too far back in the entry or failing to ease the stick forward toward neutral as the plane rotates, or, you are entering the snap roll with too little airspeed. (Occasionally, you will find an airspeed indicator that gives an incorrect reading - too fast in this instance - and when you suspect this to be the case, try increasing your entry speed about five knots.)

COMMON ERRORS:

1. Rough and abrupt use of controls, resulting in a extremely rapid and violent maneuver.
2. Failing to apply controls sufficiently, or rapidly enough to effect a stall, resulting in a slow aileron roll.
3. Effecting recovery too soon or too late, as the result of poor timing and/or poor orientation.
4. Failing to neutralize the rudder in recovery, resulting in a violent skid, (similar to the effect caused by holding rudder in spin recovery).
5. Excessive use of forward pressure on recovery, resulting in a nose-low attitude.
6. Not using full control movement when necessary.

CARTWHEEL

DEFINITION:

The cartwheel is a maneuver in which the airplane is stalled and spins over the top from a steeply banked turn in one direction to a steeply banked turn in the opposite direction. It is a partial snap roll, or an interrupted spin, in which the nose of the airplane describes an arc above the horizon, the size of the arc depending on the manner in which the controls are applied.

This maneuver is valuable because it teaches:

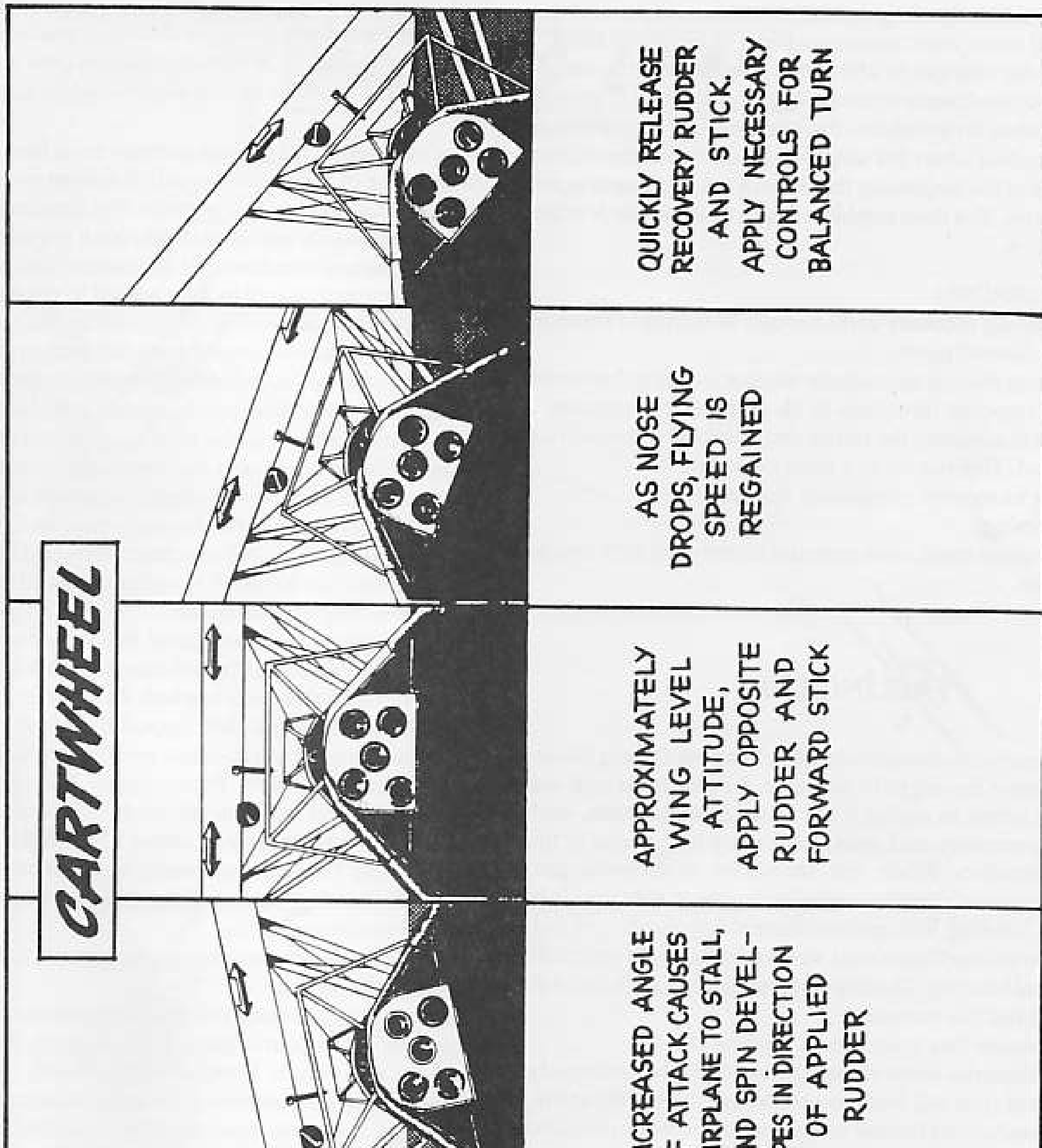
1. Orientation during rapid changes in the attitude of the airplane.
2. Application of controls to effect sudden changes in attitude.
3. Correct timing of the controls, rather than impulsive and erratic reactions.

EXECUTION:

This maneuver is started at an altitude of 3,000 feet or more above the ground, after establishing a level turn at approximately 70 knots.

You now stall and spin the airplane over the top by applying straight back pressure on the stick and rapid, but smooth, pressure to the rudder, opposite to the direction of turn. No aileron is used in the entry of this maneuver. The back pressure on the stick increases the angle of attack and stalls the airplane. The airplane spins in the direction rudder is applied. The nose comes up above the horizon and describes an arc. Just before the nose reaches the peak of this arc, start recovery by applying opposite rudder and forward stick to stop the spin, and recover from the stall. As the nose drops to the horizon, the airplane will be recovered from the spin with the wings banked in the opposite direction from entry. Then a smooth well-balanced turn should be established in this new direction by quickly releasing recovery rudder and stick, and applying controls as necessary for the turn. Add throttle to prevent loss of altitude, while regaining airspeed.

Since this maneuver incorporates a stall, your airspeed upon completion will be somewhat slower than upon entry. Consequently, before starting a second cartwheel in the other direction, it will be necessary to continue the turn until approximately 70 knots is regained.


CARTWHEEL
NORMAL BALANCED TURN (AIRSPEED 70K) STEADLY INCREASING BACK PRESSURE AND RUDDER OPPOSITE TO DIRECTION OF TURN
INCREASED ANGLE OF ATTACK CAUSES AIRPLANE TO STALL, AND SPIN DEVEL-OPES IN DIRECTION OF APPLIED RUDDER
APPROXIMATELY WING LEVEL ATTITUDE, APPLY OPPOSITE RUDDER AND FORWARD STICK
AS NOSE DROPS, FLYING SPEED IS REGAINED
QUICKLY RELEASE RECOVERY RUDDER AND STICK. APPLY NECESSARY CONTROLS FOR BALANCED TURN

When you first practice this maneuver, you may enter it from, and recover to, a medium banked turn, since the control movements need not be so rapid. However, as you progress, you must execute the cartwheel from a steeply banked turn, to a turn of equal bank, using the more rapid movement of the controls and more exact timing required in the steep bank.

Visualize the changes in attitude in this way. At the start of the maneuver the nose is on the horizon in a balanced turn and it then describes an arc above the horizon. The high point of the arc is reached when the wings are level. At the conclusion of the arc, as in the beginning, the nose of the airplane is again on the horizon. You then establish a turn of equal bank in the other direction.

COMMON ERRORS:

1. Not starting recovery early enough to stop spin rotation at the desired point.
2. Checking the roll too early or too late, causing the banks in the opposite directions to be of unequal steepness.
3. Failure to continue the turn immediately after the roll has stopped. This results in a nose high slip.
4. Failure to recover completely from stall.
5. Poor timing.
6. Holding too much back pressure on the stick, with resultant spin.

FALLING LEAF

This maneuver, as the name implies, involves stalling the airplane through a zig-zag path similar to that followed by a leaf falling from a tree. In reality, it is a series of spin entries, each followed by recovery and immediate entry into a spin in the opposite direction. When this maneuver is properly performed, the nose of the airplane will swing from side to side of the original heading. With proper alternate application of rudder, the nose will oscillate about an equal distance to each side of the original heading. The airplane remains in a stalled condition throughout the maneuver.

This maneuver has four distinct training values:

1. It develops the sense of recognition of the beginning of a spin and thus will help you recognize accidental spins.
2. It re-emphasizes the use of **opposite** rudder in checking the rotation in a spin.
3. Like all aerobatics, it helps develop the ability to remain oriented while undergoing rapid attitude changes.
4. It develops a sense of timing. Although the maneuver looks like a falling leaf to a person on the ground, you will find it does not feel nearly as lazy and graceful as it looks. Actually the aiplane is moving through a considerable space in each of the zig-zag oscillations and the changes of directions are quite sudden.

Since the falling leaf dissipates altitude very rapidly, be sure to begin it well above 3000 feet (above the ground). Pick some object on the horizon as a reference point to be used throughout the maneuver. The throttle is closed and remains fully closed until recovery.

Obviously this maneuver is entered from a stall. The type of stall (either wing level or from a slip) is optional but in any case for successful directional control, the stall must be gentle with the nose only slightly above the horizon. Entry from a nose-high gentle slip is preferred. Such an entry benefits you in two ways: (1) it predetermines the direction in which the airplane will first spin, and (2), it further develops your appreciation of the feel and reaction of the airplane when is stalls out of a slip.

Let us assume that you are going to enter from a left slip. Put the airplane in a shallow slip, with the nose slightly above the horizon. Maintaining this attitude and heading, stall the airplane by gradually applying steady back pressure on the stick as the airplane slows down. At the instant the low wing (in this case left) starts to rise of its own accord in spite of aileron pressure against it, apply full opposite rudder (in this case left) and neutralize the ailerons, maintaining full back pressure. The low wing will come up "over the top" and the airplane will fall off to the right, until the airspeed increases sufficiently for the left rudder to take effect and the right wing will start to come up. As the wings again approach the horizontal position, apply full opposite rudder (in this case right) to prevent a spin to the left. During this time, of course, the stick must be held full back in order to maintain a stalled condition. Also, and important, after the initial stall has occured, no aileron control is to be used at any time during the maneuver.

If the airplane is to be stalled from a wing-level attitude, application of either rudder will cause the first fall to start in the direction that rudder was applied. As soon as the wing drops apply immediate and full opposite rudder. When speed increases, the nose will then rise and the airplane will fall off in the opposite direction. Again apply full opposite rudder immediately and continue through as many oscillations as desired. (Be sure to recover above 2000 feet).

If you hold the stick hard back, no appreciable dive or airspeed will develop, making it possible to proceed at once with the next oscillation.

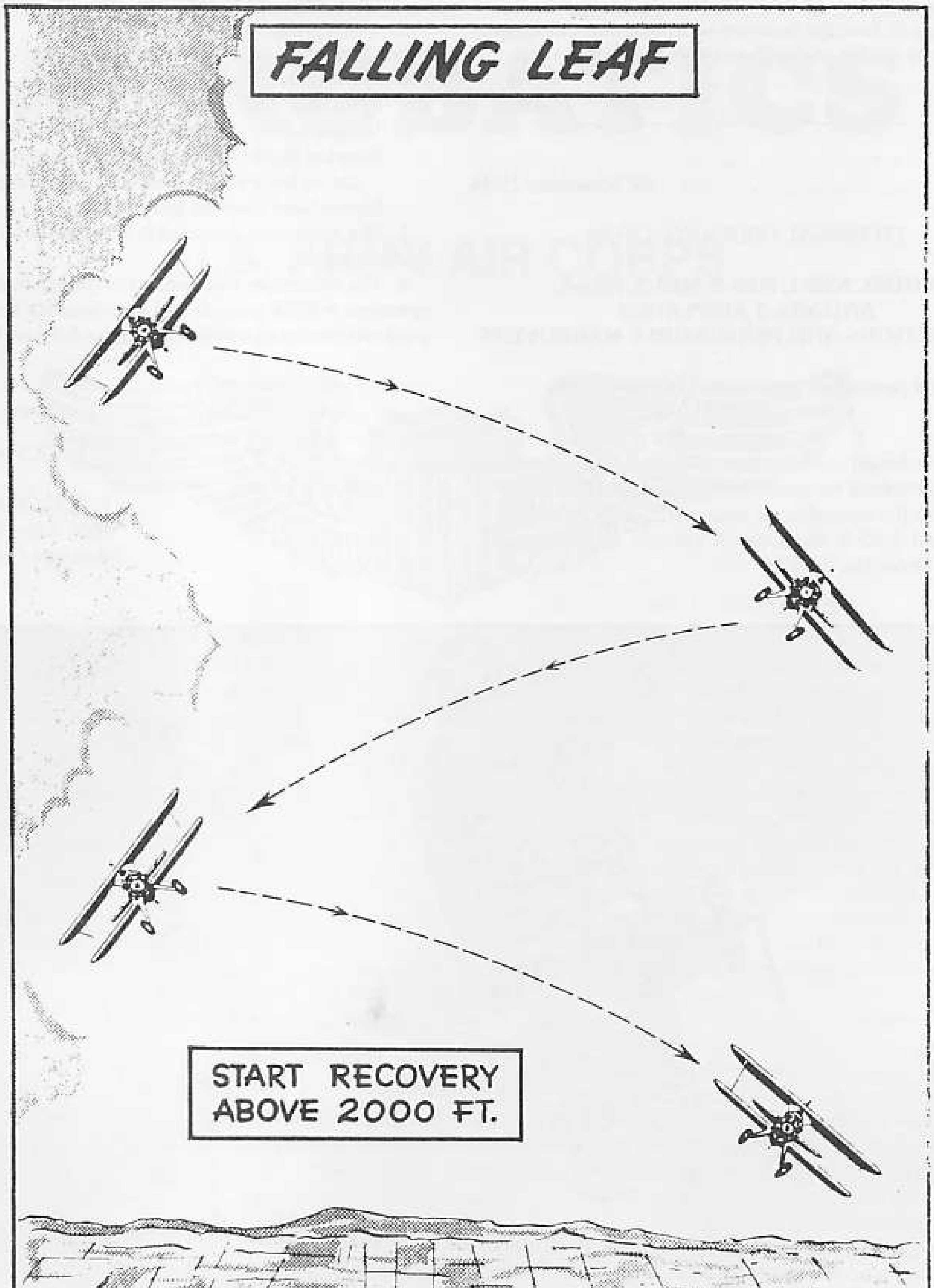
Each time the nose comes up on recovery, it should point to the original heading.

Recovery is extremely simple: merely neutralize the rudder. As you return to your original heading apply throttle and forward stick to regain flying speed. You will be expected to recover reasonably near to your entry heading.

Caution: there are cases on record of pilots having carried this maneuver lower than was intended. Possibly, this was the result of the hypnotic effect produced by the rhythmical oscillations. It is, therefore, advisable not only to plan to recover above 2000 feet, but also to have a pre-determined number of oscillations in mind before entering the maneuver. Usually three or four will suffice to demonstrate effective control.

COMMON ERRORS:

1. Entering the maneuver from an attitude so nose-high that a violent stall results, with consequent loss of directional control.
2. Not applying full opposite rudder, or not applying it soon enough with the result that a spin actually develops.


FALLING LEAF
START RECOVERY
ABOVE 2000 FT.

3. Applying opposite rudder too quickly, i.e., not allowing the oscillation to develop.
4. Failure to hold the stick all the way back, permitting the airplane to regain flying speed between successive stalls.
5. Failure to time the recovery so as to come out approximately on the original heading.

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22 November 1944

TECHNICAL ORDER NO. 139-44

MODEL N2S-1, N2S-2, N2S-3, N2S-4, AND N2S-5 AIRPLANES RESTRICTIONS AND PERMISSIBLE MANEUVERS

(Of paramount interest to flying personnel; to be read by all pilots.)

1. This technical order sets forth the permissible maneuvers and the restrictions on speed, weight, and acceleration to be observed in the operation of model N2S-1, N2S-2, N2S-3, N2S-4, and N2S-5 airplanes. It cancels and supersedes Technical Order No. 82-42.

2. The permissible maneuvers are the following:
   Loop
   Aileron roll - at speeds not over 108 knots (124 mph) indicated
   Snap roll - at speeds not over 92 knots (106 mph) indicated
   Chandelle
   Immelman turn
   Wing over
   Vertical turn
   Inverted flight (For a few seconds only; must be discontinued before oil pressure drops to zero.)
   Normal and inverted spins.

3. The maximum permissible airspeed is 163 knots (186 mph) indicated.

4. The maximum recommended gross weight for normal operation is 2850 pounds and the allowable accelerations at gross weights up to this value are plus 5.8g and minus 2.8g.

/s/ L. B. RICHARDSON

L. B. RICHARDSON
Rear Admiral, USN
Assistant Chief of Bureau

An Aviation Cadet flips his Stearman trainer into a snap roll as part of his aerobatic training.
Photo: U.S. Army Air Corps via K. D. Wilson Collection.