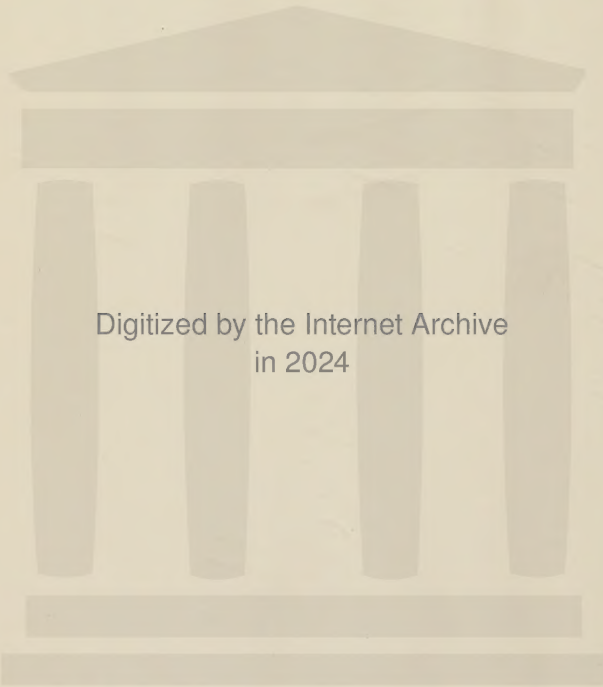




Modern Aerobatics & Precision Flying

**By Champion Harold Krier
with Bill Sweet**



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MODERN AEROBATICS

by Charles
HAROLD KRIEGER

MODERN ABSTRACT ART

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MODERN AEROBATICS

by **Champion**
HAROLD KRIER



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Contents

	<i>Page</i>
Author's Note	7
1. Precision Aerobatics	8
2. Maneuvers	49
3. The Aresti Aerocryptographic System	101
About the Author	Back Cover



Author's Note

Aerobatics are not new, but they have been one of the guarded arts of aviation. Professional acro-pilots, generally, seem reluctant to pass along the fine points they have learned. When I first started my aerobatic career, I often wished that I had some bit of authoritative information to assist me.

So this book is for sport aviation and aerobatic enthusiasts and amateurs—and amateurs who may become professionals. I'll try to remember, and answer here, the questions I wanted to ask someone when I was learning.

I should mention that there are several aerobatic styles or methods, each one correct; but I can speak with authority only about my own. I strive for smoothness and perfection, and the explanations offered here have worked well for me.

Finally, in the "advice" department, I'd like to be there to tell you, personally, each time you take off for a practice session that the best and cheapest insurance you can get is *plenty of altitude*. Acro-flight below 1,500 feet is in violation of the Federal Air Regulations. Professional performers get a special waiver.

1. Precision Aerobatics

Man's first few years in the air were spent improving his new aerial vehicles—which barely flew—and learning merely to remain aloft. Not until 1909, six years after the Wright brothers had first flown, did he reach an altitude above 500 feet. It required another three years for him to produce an airplane that would fly faster than 100 miles per hour.

But the nature of man being what it is, 100 miles per hour (or 1,000 for that matter) did not satisfy him. Nor did merely remaining aloft. It was necessary to bend the airplane to man's will. The flying machine had to be tamed and mastered and made to reflect the will and skill of its creator.

So we forced it to maneuver with precision. We learned to direct our wings through graceful and exact patterns of flight. The wood-and-cloth wings that could so miraculously command the horizon and summon far places could also provide pleasure and excitement and beauty in intricate flight patterns skillfully conceived.

And, as a practical matter, early precision flying was almost the only means there was of earning a living as a professional aviator. The only paying jobs for "aeronauts" prior to World War I were for exhibition flying.

Lincoln Beachey was probably the greatest of these early birdmen. Beachey started as a dirigible pilot. In 1909, Glenn Curtiss taught Beachey to fly, then built several specially designed aerobatic planes for him, the most famous of which was the "Little Looper," a pusher biplane powered with a Gnome rotary engine of 80 h.p. Beachey was killed at San Francisco in 1915 while performing before a huge crowd at the Panama Pacific International Exposition. His plane broke up in the air. He was 29 years old.



Jimmy Doolittle, first known to perform the Outside Loop.

The Twenties produced some real giants in precision flying and aerobatics: Jimmy Doolittle, Al Williams, and Freddie Lund, to name just three. Doolittle, perhaps without equal as an airman (and with few equals as a man), was not only one of the greatest aerobatic pilots of his time, but also a top racing pilot, transcontinental record holder, pioneer in instrument flight, etc. He left the Air Force a Lt. General and today is an official of a company that produces rocket engines for our big space vehicles. Jimmy Doolittle performed the first outside loop on May 27, 1927 (the first inside loop had been accomplished in 1913 by the Frenchman, Pegoud). At the National Air Races of 1929, held at Cleveland, Doolittle's Hawk P-1 pursuit plane shed its wings during the preliminaries to his exhibition. He bailed out, climbed into another plane, and completed his aerobatic routine.

Al Williams's was the U.S. Navy's top racing and precision aerobatic pilot during the years that Doolittle filled this role for the Air Corps. There was a keen rivalry between these two that undoubtedly spurred each to his ultimate effort. Williams grew up in the Bronx, N. Y., and was signed by the New York Giants baseball club after leaving school. World War I then intervened and he became a Navy aviator. His Curtiss Gulfhawk was familiar to millions during the Thirties. Appearing in hundreds of air shows, his specialties were outside and inverted loops, inverted spins, and a vertical figure S. Williams employed recording instruments to provide engineers with their first definite information on load factors during all forms of aerobatic flight, and he is generally considered the father of dive-bombing. He died at his home in North Carolina five years ago.

Freddie Lund was a pilot and wing-walker for the legendary Gates Flying Circus, the greatest aerial show on earth (or above it) during the Twenties. He was billed on the colorful posters as "The Man Without Nerves." And, after the aerial circuses passed, along with the barnstorming era, Lund's fame continued to grow. He was the first to equip his red, white, and blue Waco Taperwing with a smoke-generator



AJ Williams and his famed GULFHAWK.



Paul Mantz, whose life was devoted to aerial showmanship.



Stinson sisters, Marjorie (L) and Katherine, were top female exhibition flyers before World War I. Plane is a Wright Model B.

device so that the spectators could follow the course of his flight and the perfection of his maneuvers. He was also the first civilian aerobatic flyer to perform the outside loop. His wife, Betty, was the top woman aerobatic pilot of that day.

Freddie was killed in the fall of 1931 during a closed-course race at Lexington, Kentucky, as a result of a mid-air collision with a competing plane.

Freddie was honored for many years at the Miami, Florida, All-American Air Races, where the Freddie Lund Memorial Trophy was awarded for precision aerobatics. The best of the pros competed for this award. Some of the winners were: Tex Rankin, Roger Don Rae, Joe Mackey, Len Povey, "Squeak" Burnett, and Mike Murphy.



Tex Rankin, champion aerobatic and movie flier of the thirties; once performed 131 outside loops in 131 minutes.

This brief account of yesterday's greats is incomplete, of course. There were others, great and near-great. And their shoes are hard to fill.

But each generation seems to produce another crop of exceptional men. Today, we have such masters as Rod Jocelyn, Bevo Howard, Roy Timm, Charlie Hillard, and Woody Edmunson. There are others. In fact, there may be more unusually skilled precision and acro-pilots today than ever before.

It has been my privilege to know all of these men and to work with them. I've learned something from each. And I've copied, as I'm sure all of us do. For example, the inverted ribbon pick-up with which I usually end my exhibition, I borrowed from Bevo Howard. I only hope that I do it as well.

But what prompts a man to become an acro-pilot? This is a question I've heard many times. While it is true that one takes pleasure in being recognized and applauded, this form of reward did not occur to me back in the late Forties and Fifties when I began those long hours of practice in my Clipwing Piper Cub.

As operator of the Garden City, Kansas Airport, one of my chief commodities was student instruction. This, plus my



Harold Johnson loops six-ton Ford Trimotor from ground level. He once performed this maneuver on two engines.



"Fearless" Freddie Lund performs in his Waco Taperwing, 1929.



Wasp-powered Boeing "100," flown by aerobatic ace Milo Burcham prior to WW II.



Another famous Early Bird akro-pilot was Matty Laird (L), shown with his 12-hp "homebuilt" Baby Biplane in 1915. At prop is Buck Weaver, one of original founders of WACO.

ingrained obsession for perfection, sent me off in my Clipwing Cub at every opportunity to improve my own flying and thus make myself a better instructor. I logged between 300 and 400 hours of aerobatic practice—all of it at a safe altitude, I might add.

By this time I had become interested in aerobatics as an end in themselves. In 1956 I appeared as a free-lance solo performer in several small air shows flying a Clipwing Cub. And looking back, I can see that these exhibitions were a bit ragged at the edges. Practice is essential; but it's essential to practice the right things.

Then I had an opportunity to join Ray Doan's Sky King Air Shows, and this threw me into close contact with some of the best aerobatic pilots then performing. I learned a lot watching Merle Torrance, for he had a Great Lakes similar to mine. Art Davis, who flew a Waco Taperwing, gave me tips as did Ray Henry, whose ship was a 450-Stearman (very much like the one Bill Adams flies today). And there was Roy



Kobelt-Ryan Special, flown by acro-pilot, the late Bill Kobelt.



The writer with Betty Skelton. Betty's plane was the Pitts Special, "Li'l Stinker," which she flew to three consecutive women's aerobatic championships.



Frank Price, BUCKER JUNGMEISTER

Timm, one of the smoothest “3-D flight” exponents in the business. We toured the midwest with a really good show. Howard Libersky was our stunt man—wing-walker, plane-changer, parachutist—and he was without peer.

My first big chance came in 1958 when, with Bill Sweet’s help, I was hired to perform at the National History of Flight, which took place at the airport at Connellsville, Pennsylvania during the July 4th weekend. I hope the spectators got as big a thrill from my performance as I did in sharing the billing with Beverly (Bevo) Howard. During the rest of this year, I flew as a free lance. At Ottumwa, Iowa, I won the National AAA Aerobatic Championship, an event that was then sponsored by the Antique Airplane Association. Frank Price took second place, and Roy Timm placed third.

In 1959, I joined Bill Adams, Red Grant, and Bill Sweet in the National Championship Air Show. About midsum-



Joe Mackey's Waco Taperwing

mer Joyce Case came to work with us. Joyce is the daughter of veteran Dean Case, who is now a corporation pilot. Petite and feminine, and with a smile as ready as a puppy's tail-wag, Joyce was a pleasure to work with. Her aerobatic plane was a Great Lakes Biplane at that time. She was just 21 years old, but her performance was always of professional calibre.

We appeared at Ottumwa again in 1959, and I won the aerobatic championship for the second time. Again, Frank Price was second, Bill Adams took third, and Joyce's neat hesitation rolls and Cuban-8's won the Women's National Championship for her.

In the spring of 1960, Bill Adams left our group to return to work full time for Cole brothers. Charlie Hillard replaced him, and we also regained another topnotcher, Rod Jocelyn, to help with this very successful 40-show season. At Doylestown, Pennsylvania, CBS-TV filmed our show and I flew my exhibition with a camera mounted on the top wing of the Great Lakes biplane which had become my regular mount. At Ottumwa, the National AAA Aerobatic Championship, sponsored by the Antique Airplane Association, was won for the third time by Harold Krier. This retired the trophy. Bill Adams was second and Charlie Hillard was third. Joyce Case again won the Women's Championship, this time in a saucy little homebuilt aerobatic craft called "Joy's Toy," which Dean had built for his daughter during the spring and summer.

This contest ended the Antique Airplane Association's sponsorship of the National Aerobatic Championship for professionals. This fine organization now sponsors a similar contest each year for amateurs.

In 1961, CBS-TV again filmed our show, this time at Crawfordsville, Indiana, near Indianapolis. Our group of the year before remained intact until June when Grant left us and was replaced by Reds Diget. Red is a small man, but he's one of the coolest stunt men I've ever seen. In the car-to-plane transfer he always times himself perfectly, and his complex parachute routine never seems to misfire.



Joyce Case Funsch, Women's Aerobic Champion 1959, 1960, 1965 and her Pitts
Special "Joy's Toy." (Don Wigton photo).



The late Bill Adams at controls of his Wasp-powered Boeing Special.



Former acro champ Joe Mackey (R) shares chuckle with America's top WW I ace, Capt. Eddie Rickenbacker.



Dean Case points a playful finger at photographer while Bill Sweet "pitches the action" at an air show.

Also about this time, Joyce Case left the show to accept a job with Beech Aircraft Corporation. Dean sold "Joy's Toy" to Don Pittman of Sapulpa, Oklahoma; Don took it to the first Amateur AAA Aerobatic Championship in 1962 and won first place with it.

The first major event of 1962 was the EAA International Aerobatic Championship—sponsored by the Experimental Aircraft Association—held at Phoenix, Arizona, in mid-January. There were 17 entries, and the aircraft entered ranged from clipped-wing T-Craft and Cubs to Darts, homebuilts, and a Beech T-34.

Duane Cole took first place, Rod Jocelyn was judged second, Rolly Cole third, and Krier fourth. Each contestant was allowed five minutes to perform.

The Coles are a real air-show family. The original Cole Brothers Air Show was made up of four brothers, Duane, Marion, Arnold, and Lester.



**Bucker Jungmeister flown by European aerobatic champ Alex Papana;
rebuilt and now owned by Bevo Howard.**



Charles Hillard performs outside loop in his clipped-wing Cub.



Rodney Jocelyn, who pilots jetliners for Pan Am, has won national aerobatic championship twice.



Woody Edmondson, 1948 national aerobatic champion, and his clipped-wing Monocoupe.



Bevo Howard. Nuff said.

Although I did no better than fourth at this EAA-sponsored event, I was very glad to see the EAA revive its interest in this phase of aviation. The Experimental Aircraft Association, which is headed by Paul Poberezny, was organized back in 1953 primarily for the benefit of the homebuilt-plane buffs. But it has done so much to further sport-flying in general, that its 25,000 members include racing fans, antiquers, aerobatic-types, and just plain Sunday pilots who like good company.

The EAA has an annual International Fly-in and Convention at Rockford, Illinois, during the first week of August. And if you like airplanes—any kind of airplane—this is an event you shouldn't miss. It always draws hundreds of homebuilts, along with almost equal representation in the antique and "store-bought" plane departments.

In 1962 at Rockford, Bill Adams won the Modern Aircraft Series Trophy for aerobatics, while Pete Myers and I received



Mike Murphy, former Freddie Lund Trophy winner, served as judge at the 1962 international contest in Hungary.

similar awards for our performances from Cessna Aircraft and the Sitka Spruce Lumber and Manufacturing Company. Bill Sweet was honored with an award from Beech Aircraft Corporation for his many years of aviation promotion.

Also in 1962, the United States sent a team to Budapest for the World Aerobatic Championship meet. These pilots were Lindsey Parsons, Rod Jocelyn, and Duane Cole. I was unable to go because of air-show contracts here. And although this was the first time American pilots had participated in this event, the U.S. team won fourth place and Lindsey Parsons finished in fifth. This was a real tribute to Lindsey's flying, because European contest procedures are somewhat different and we expected to see our people place well down the list until the American team gained some experience in this competition.

I wound up the 1962 season with a total of 38 exhibitions which had been staged, literally, coast to coast. These in-



Caro Bayley, women's international acro-champ '51 & '52, in her Pitts Special, "Black Magic."

cluded the first reunion of the pilots of the World War I Lafayette Escadrille; Joe Durham's and Dave Martin's fabulous fly-in at Fairview, Oklahoma, which is a real ball each November 11th; and Midland, Texas—another big one every year, and Battle Creek, Michigan, where CBS-TV filmed us for the third time for their Sunday Sports Spectacular. This pattern continued through the 1964-5 seasons, with air shows growing in size and number.

This, then, is a quick run-down on how it goes. From April to November we seldom have a weekend at home. I'd rather do it than anything. The people I work with are like people everywhere; most of them are nice.

Of course, there are several trophies and championships that I haven't mentioned. I omit detailing these, not because I want to slight any of the sponsors which are, after all, the *raison d'être* for any air show, but merely because of the repetitious nature of such accounts.



Mary Aikins of Wichita won 1964 Womens Aerobatic Championship in her Pitts Special, "Dinah-Mite." Contest sponsored by Antique Airplane Association.



Charles Hillard (R) is one of America's top aerobatic pilots.



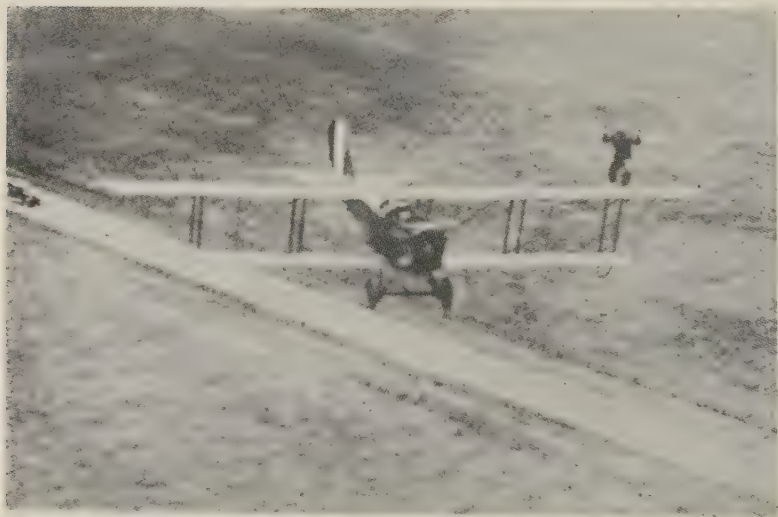
The Joc-Par Special, designed and built for aerobatics by Rod Jocelyn and Lindsey Parsons.

When I first discussed this book with Jae Greenberg and Joe Christy at the fly-in at Rockford, it occurred to me that novice aerobatic pilots might have nearly the same questions and curiosity about 3-D flying that had at first puzzled me. What does a guy think about, hanging by his seat belt, 20 feet above the ground at 160 m.p.h.? How do you judge control movement during a "gray-out" at high G-loadings? Do you rely on your altimeter, or do you just guess at your height during low-level work? You know, things like that; some important, some silly.

Well, climb aboard, and fly my exhibition with me at Rockford.

We've taxied the Great Lakes to the left of the East-West intersection of the North-South runway at Greater Rockford Municipal, and are waiting for the flag that will announce the start of our routine before 50,000 air-show fans.

Cockpit check is completed. A final check for full and free



So, what else is new? In 1921 this daredevil was walking the wings of a Jenny over Ft. Sill, Oklahoma.

movement of all controls. We're a bit tense—anxious to move. There's the flag!

Roll into the center of the runway, make a last check for other traffic, and ease power to the 185-Warner up ahead until she holds us against the seat-back with acceleration. This is a quiet engine—you seem to feel its power rather than hear it.

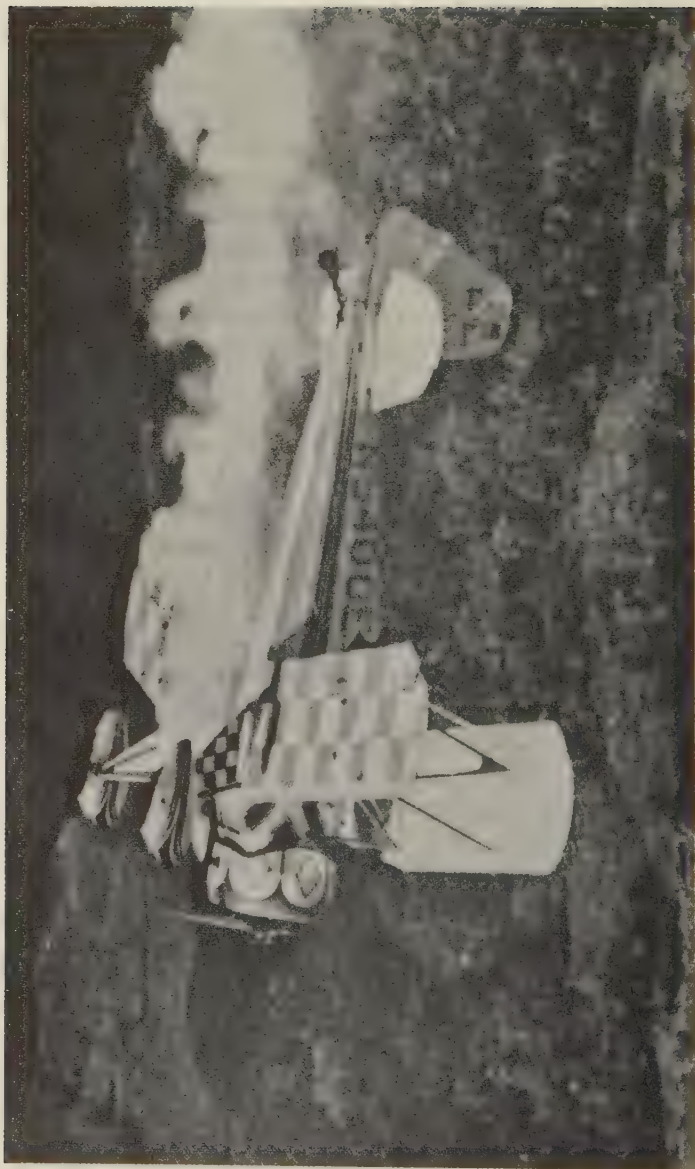
Now a quick glance at the instrument panel: oil pressure, 85 pounds; fuel pressure, 11 pounds; manifold pressure, 28 inches; r.p.m., 2,350. Okay. By now, Bill Sweet, at the microphone, has begun to focus crowd attention on the Great Lakes. That's fine; we won't keep them waiting very long.

As the controls come to life, we hold the airplane on the runway a bit longer than usual. We're going to need that extra speed. Now, slight right-stick. The left wheel leaves the runway, and then the right one. Back slightly on the stick, with a little left rudder—and watch the right lower wing tip as it clears the runway. As we roll past vertical, feed in slight forward-stick and, at the 20-foot level, we are in inverted flight. You may be fairly sure that everyone is watching now.

Just as we reached the inverted position, we flicked the smoke valve beside the throttle and our flight path is being traced by a filmy white ribbon of smoke.

We will remain inverted, about 20 feet above the white runway, until we pass Bill Sweet at the mike (actually, a matter of a few seconds). We feel the Aeromatic prop change for a normal climb and inverted traffic pattern out (our right turn out is to our left in this attitude). Now, a bit more forward trim to reduce the stick load, and the white concrete gets narrower as we climb away.

Back there on the taxi strip, waiting for the flag, we mentally noted the placement and spacing of our first three or four maneuvers. The sequence is always the same; but different airport layouts and spectator areas require that we prolong or shorten certain maneuvers for maximum crowd viewing. And everything must be planned so that the airplane is never pointed at the spectators.



Krier Kraft aerobatic plane, designed and built by author, is now owned by Champion Charles Hillard of Ft. Worth, Texas.



Author performs snap-roll at tree-top level in Krier Kraft.

As our inverted climb reaches about 400 feet, we turn 90 degrees away from the announcer's stand. We continue upward another 100 feet then begin a series of slow rolls through a 270-degree turn. We will thus complete this maneuver back on our original course above the runway. (It is very difficult to roll with a given rate of turn. I always roll and turn together; ease into a shallow bank, establishing rate of turn and rate of roll which I hold throughout the maneuver.) We roll five times to complete the 270-degree turn.

We nose down toward the runway and half slow-roll to inverted to start the first leg of the Outside Horizontal-8 (formerly called the Cuban-8). The inverted dive position increases our air speed, and the runway above our head begins to widen. At 140 m.p.h. we apply forward-stick and trim and immediately begin to feel the outside G-load as the nose arcs skyward through the outside loop. Excessive G-loads in this kind of flight, with centrifugal force pushing beneath your seat and sending blood to your head, sometime cause a slight tight feeling in the top of your head. This is a warning signal that I never ignore. When this happens I immediately loosen up the maneuver—even if it means sacrificing a perfect arc. Another warning signal you are probably familiar with is “gray-out,” occurring as a result of an excess G-load, which forces blood from your head. This sometimes happens on inside maneuvers, dive recovery from a Split-S, etc. Again, do not allow this condition to progress. Anytime that you are literally blind, you are out of control.

By immediately heeding these signals, you not only remain in complete control at all times, but you also insure against structural failure of the aircraft. In other words, never overload yourself and you won't overload the airplane either.

For an instant, at the top of the first half of the Outside-8, we are upright, but we continue to press the nose away from us and half-roll the plane into a 45-degree inverted dive. She picks up to 140 m.p.h. again. Trim is now full forward. Additional forward-stick pressure is applied and we swing into the second half of the Horizontal-8, another outside loop op-



Reds Diget rides the top wing during a series of low level aerobatics.
(Don Wigton photo).

posing our first one. We've planned this one so that we return to normal flight just before reaching the announcer's stand. We pick up speed for a turn around at the south end of the N-S runway, and we'll use a Split-S to accomplish this from a cruising speed of 110 m.p.h.

The nose is pulled up into a climb of about 45 degrees and the plane is on-half slow-rolled into inverted position. Just above stall, the stick is eased back and the plane allowed to Split-S out at about 100 feet above the runway; airspeed—130 m.p.h.

Now, we begin a *slow* slow roll that will require about three-quarters of a mile to complete. Through this maneuver, the plane is rotated to the right: right stick, slight back-pressure, slight left rudder, and the plane starts a roll to the right to establish a rate of roll that will be constant. The nearer we get to vertical, the more left rudder we apply. As the plane is rolled past vertical, feed in slight forward-stick. We pass the announcer's stand as we reach inverted position—still about 100 feet above the runway and continue our roll to the right. Stick is now well forward, rudder is neutral but changes to right rudder as we roll to vertical again. Recovering to normal flight from vertical attitude, we ease off right rudder and apply straight back-pressure on the stick.

This stretched-out slow roll has taken us to the north end of the N-S runway, so we make another climbing Split-S to head us south again with plenty of speed. On this pass we will do 6-point and 8-point hesitation rolls at 100 feet. We've planned this so that the 6-point roll will be completed above the announcer's stand, or at the halfway mark.

These maneuvers are accomplished in a manner similar to the slow roll, except that the plane is stopped and started—in its rotation—at six or eight points during the roll. A well-executed hesitation roll should give the illusion of a giant wrench turning the airplane about its longitudinal axis. It requires a lot of bold aileron movement. (In all roll maneuvers, of course, the ailerons are the chief activators; rudder and elevators are merely trimming devices—the ailerons do the rolling.)



Bill Sweet telling the crowd nice things about us. Charles Hillard (L), and Bill Adams (R). (Don Wigton photo).

At the south end of the runway, we will do an Immelmann turn to reverse our course. This is a pretty maneuver and gets us headed back to the spectator area before losing the crowd's attention. But it costs air speed, so we dive almost to the ground to get about 120 m.p.h. to begin it. We climb

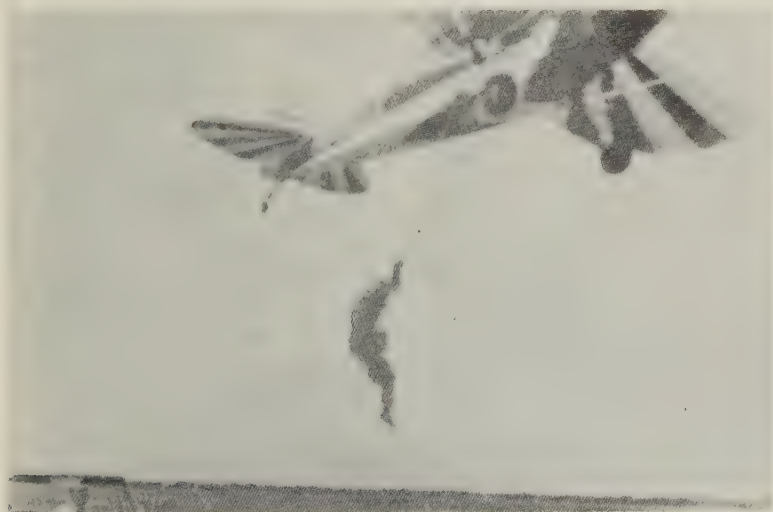


Moment of pride.

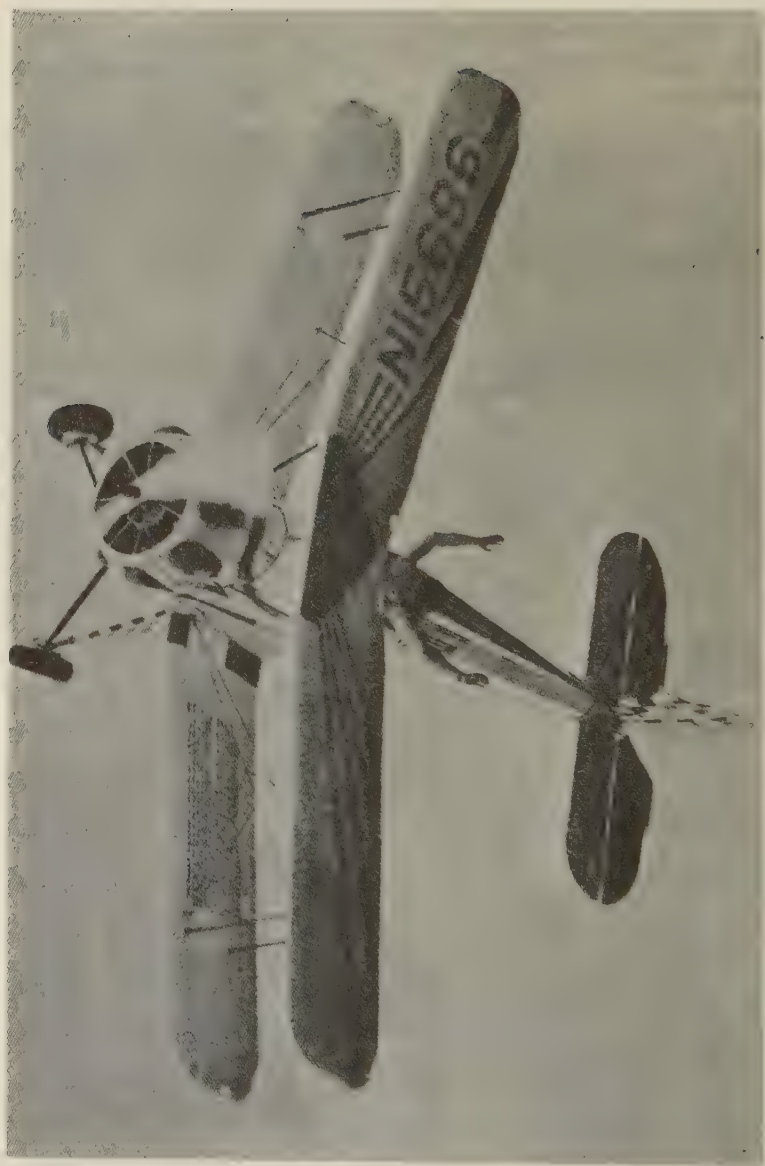
upward—wings level—and over, past vertical to inverted. Then, just as the horizon appears, we do a one-half slow roll. The roll is accomplished while still climbing, so that the roll is completed just as level flight is attained to execute the Immelmann.

On this pass, at 400 feet, we'll do an 8-point back-to-back roll. It consists of the first half of a 4-point hesitation roll to the inverted flight position, which is then "backed-off" to original or beginning position. Then the last half of the 4-pointer is performed and it, in turn, is similarly "unwound" again.

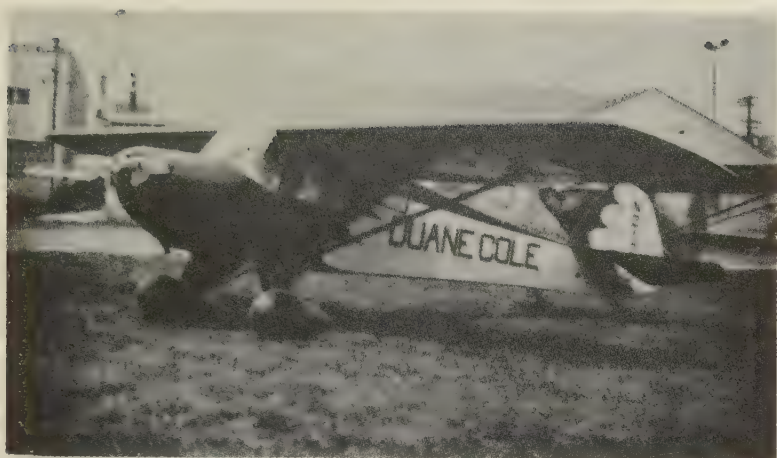
This has taken us to the north end of the field once again, and now we'll do a climbing turn away from the crowd to gain altitude for a series of loops. At 600 feet, we dive toward the announcer's stand, level off at about 100 feet, and start the first half of a loop. As we reach inverted, we snap-roll the plane violently, recovering in the inverted position, and apply back-pressure to the stick to recover from the loop at 100 feet. We continue back-stick pressure, and, up, arc over into a graceful, normal loop. Then, recovering again at 100 feet, we do a square loop.



No air show seems complete without a car-plane transfer.



Beverly (Bevo) Howard demonstrates low level hands-off flight while inverted.



Duane Cole's clipped-wing T-Craft.

This is how the square loop is accomplished. At 140 m.p.h., back-stick is applied abruptly. Then, as the plane reaches vertical, just above stall, it is pulled onto its back. We hold inverted position until we've covered approximately the same distance (600 to 700 feet) as we did in the first side of our square loop, then again back-stick to dive (throttle off, smoke off), after which the final quarter of the square is completed at 100 feet.

We finish our series of loops at the south end of the field. A maximum climbing turn is executed to gain altitude, and we make ready for a loop with a double snap-roll at the top and bottom.

We start this one at 1,000 feet. Nose pointed at the runway and held there until we have 150 m.p.h. indicated. Now up in a graceful arc until we go past vertical to about a 45-degree inverted climb position. Now full back-stick as the plane breaks at stall and abruptly snap-roll—that is, full right rudder and one-half aileron to the right. Full back-stick will hold plane in stall position through two complete rotations. When the stick is eased forward, left rudder applied and ailerons neutral, the plane halts rotation in the inverted position. Then the stick is eased back once again to complete

the loop—at the bottom of which, we perform another double snap-roll, though this one will begin and end in an upright position.

And so it goes. You're too busy to catalog the sensations. This job demands lots of concentration. And never was it more true that you must think ahead of the airplane. Nor can I overstress the importance of being in good physical condition if you choose this means of earning a living. Low level aerobatics provide no room for mistakes. The least you can do for yourself is perform only with a clear head and when you are in top condition.

A below-par physical condition will show up quickly under the repeated G-loadings of aerobatic flight. Each time I perform, I experience a succession of such forces, up to about 5 G's negative and 7 to $7\frac{1}{2}$ G's positive (although the Great Lakes is stressed and has been tested to 9 G's).

My complete aerobatic routine is as follows:

1. Take-off $\frac{1}{2}$ roll to inverted flight; low inverted flight and inverted traffic pattern out, followed by a series of slow rolls through a 270-degree turn.

(Note: The turn maneuvers used at each end of the aerobatic zone vary as necessary to maintain position and are not listed.)

2. Outside horizontal-8 (formerly Outside Cuban-8).

3. Slow roll; 6-point slow roll, 8-point slow roll, and 8-point back-to-back slow roll.

4. Chain loop series: loop with snap-rolls at top and bottom; 8-point loop, square loop.

5. Starting from knife-edge flight position: $\frac{1}{2}$ outside snap-roll and $\frac{3}{4}$ snap-roll. Then $1\frac{1}{4}$ snap-roll, knife-edge, to normal flight position.

6. Inside horizontal-8 with 4-point slow roll on each half, followed by inverted climbing turn.

7. Roller coaster: hammerhead stall with outside and inside recoveries.

8. Series of inside and outside snap-rolls (from single to $2\frac{1}{2}$ snaps).



Captain Tomas Castano of the Spanish Air Force flew this Czech-made Zlin (Z-326TM) during world contests at Bilbao, Spain, to become World Aerobatic Champion for 1964-1965.

9. Series of outside loops: outside loop from normal flight; square outside loop from normal flight, and two slow rolls in square outside loop ($1\frac{1}{2}$ roll on each side).
10. Spin series: from inverted flight, $2\frac{1}{2}$ turn outside spin with outside Immelmann recovery, then a $2\frac{1}{2}$ turn inside spin with normal Immelmann recovery followed with a "falling leaf."
11. Low level inverted flight with hands outside of cockpit.
12. Pass under ribbon; check wind conditions.
13. Three-fourths of a normal loop to inverted flight recovery and a 90-degree inverted turn.
14. Inverted ribbon pickup between 20-foot cane poles.
15. Inverted traffic pattern and half slow-roll to upright position just before landing.

My Great Lakes trainer is powered with a 185-h.p. Warner engine, as previously mentioned. This craft was originally built at Cleveland, Ohio, in August, 1932, and fitted with a 90-h.p. Cirrus 4-cylinder in-line engine. I bought it in 1955

and, with the help of my brother Larry (Krier Brothers Aircraft), completely rebuilt it. Lower wing span is 24 feet, 6 inches; upper wing span 26 feet 8 inches. It's 18 feet, 6 inches long and weighs, 1,120 pounds empty. It cruises at 110 to 115 m.p.h. and it has logged more than 3,200 hours of acrobatic flight.



Krier-Kraft in a slow roll to the left. Photo by John Zimmerman

2. Maneuvers

A revised list, prepared by R. F. Jocelyn for the NAA, contains 87 aerobatic maneuvers. Variations of these will run the total well past 350. But there isn't much point in detailing the control handling required to perform all of them. A roll is a roll. Master it in all its moods and changes and it will give you command of a significant portion of this list.

I know of no quick-and-easy way to become a precision flyer. I'm not sure I know what the "talent" is, or if any is needed. Skill, of which a great deal is required, is easier to define. And whatever my own degree of skill, I'm sure it came almost exclusively from a single source: practice—and more practice. I'm also sure that it will be the same with you. So I'll describe the techniques that have worked well for me; the practice—the true accomplishment—will be yours. Let's start with a few safety tips.

Make sure that the airplane is mechanically and structurally sound and that it is stressed for the type of maneuvers you have in mind. Most of today's off-the-shelf lightplanes are approved for only limited and relatively gentle maneuvers. Remove all tools and loose equipment from the airplane and baggage compartment.

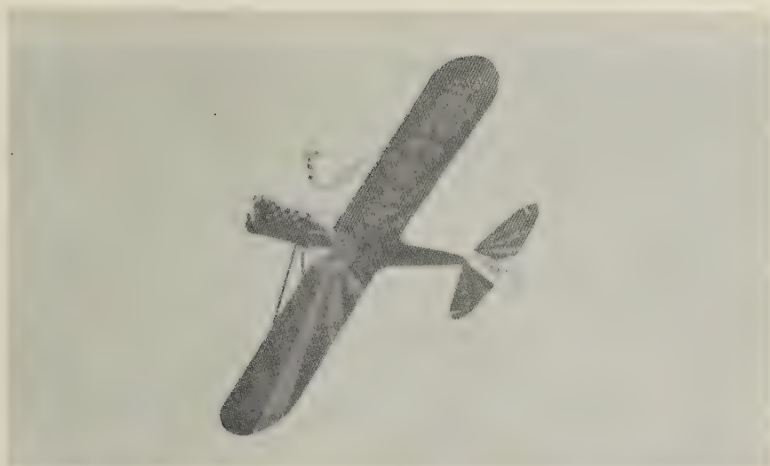
Check condition of safety belts (two are recommended in case one of them is accidentally opened). The safety belts should be tightly adjusted, and when so adjusted must not interfere with your normal control movements.

Parachutes are not required for solo aerobatics, but use one anyway. Make sure it fits well and that its inspection label is current.

Select and plan your maneuvers in advance, and be certain that you have a clear understanding of each maneuver and the manner in which you intend to execute it.



Popular Pitts Special aerobatic plane was designed by **Curtiss Pitts** of **Homestead, Florida**



Gene Griffin's clipped-wing Piper P-2 in an outside loop.

Once again, your physical condition is important. If you're not up to par, don't engage in aerobatic flight. And, finally, it's a good idea to take along a qualified aerobatic instructor.

Also, for the record, an aircraft is considered to be in aerobatic flight any time it exceeds a roll or bank of 60 degrees or a pitch (climb or dive) of more than 30 degrees.

1. Chandelle

The chandelle is a maximum performance climbing turn producing an exact 180-degree change of direction. Enter this maneuver in a shallow dive at cruising power or slightly better. You'll want approximately 20 per cent speed increase above normal cruise. Begin a coordinated climbing turn from the entry point. Your nose-up attitude should become steeper at a constant rate until your 180-degree change of direction is complete. The degree of bank also becomes steeper as the nose continues to rise and the air speed falls off. Your bank should reach its steepest—about 60 degrees—exactly halfway through the turn.

After 90 degrees of turn, you will begin to roll out of the bank, though you will continue to increase your climb angle. The roll-out should be so timed that your wings will become



U.S. Navy precision aerobatic team, the BLUE ANGELS.

level just as your turn is completed and as the top of your climb is reached. At this point you will, of course, be very close to stall. Now hold it for a second—using rudder as necessary to correct for torque—then smoothly and slowly ease down the nose to normal flight position.

The prettiest and most graceful chandelles are the slowest ones. These require careful coordination to make everything come out right. Your air speed and rate of turn will dictate your maximum climb. If your rate of climb is fast, then your rate of turn must be fast so that you will complete your 180-degree turn before stall. And, your rate of turn will be determined by the steepness of your bank—which in turn depends upon the rate of roll-in. In other words, if you pull up fast, roll fast. But if you want to fly through this maneuver gracefully, pull up slowly and roll-in slowly.

This maneuver is handy for changing direction while gaining altitude at the end of the spectator area, and is sufficiently spectacular to hold crowd attention during your turn-around. Maneuvers of this type, at each end of the exhibition zone, help tie your performance together, leaving no waiting period for the crowd between your passes before them.



Roy Timm's modified Waco F is powered with 220 Continental engine.



Great Lakes 2T-1A owned by Bob Nance and flown by Lindsey Parsons in 1962 World's Aerobatic Championships in Hungary.

2. Lazy-8

The Lazy-8 is a valuable practice maneuver because its proper performance requires good coordination through a wide range of air speeds and flight attitudes. It consists of two 180-degree turns in opposite directions, the first 90 degrees of each is a climbing turn, and the second 90 degrees of each half of this maneuver is a diving turn, completing the 180. In other words, the flight path describes an S if viewed from above, (a horizontal S), and from the side it is an M standing upright with one leg your point of entry and the other leg your point of exit. (I've heard it called an 8 lying on its side; but I fail to see how you can have an 8 with no closed ends.)

Anyway, begin this maneuver with a shallow dive after picking a good reference point on the horizon at right angles to your heading. This reference point will be the center line which should run down the middle of your horizontal S like a dollar sign with a single line. With air speed about 20 per cent above normal cruise, pull up with wings level. As the nose meets the horizon, start a gradual climbing turn



The Soviet Yak-18P, powered with an Ivtchenko 260-hp radial engine, was the most impressive aerobatic plane at the 1964-1965 World Aerobatic Championships, in which the Russians took team honors.

This is a “lazy” maneuver, so make it lazy; you should pull almost no G’s. The steepest point of the climb will be at or slightly after 45 degrees of turn, and your bank angle should be about 45 degrees at the 45-degree point of the turn. From there, the bank angle will increase and will be steepest—between 60 and 90 degrees, depending upon air speed and rate of turn—just after the nose sweeps past the horizon on its way down after passing through 90 degrees of turn.

After crossing the horizon in the descent, slowly roll out of your bank, coordinating stick back-pressure and rate of roll so that this downward arc matches your upward one. Pulling the nose back to the horizon at the 180-degree point should exactly coincide with the leveling of your wings. Air speed should be back to that figure indicated when the entry was made. Precisely at this point a second climbing turn is begun in the opposite direction to complete the maneuver, this second half being performed just as the first half except that the turn is made to the opposite side.

3. Precision Spin

A precision spin is entered as a prolonged stall, with the nose of the aircraft held on point. Hold the stick back firmly

as the complete stall occurs. Apply full rudder in the direction of the spin. Normally, you should be fully in the spin in a one-quarter turn or less. Do not use ailerons. The spin recovery must be made at any predetermined number of turns or fractions-of-turns. Spins are described as one turn, two turns, two and one-half or three turns. On some aircraft the recovery must be led by one half-turn or more. This sometimes varies among airplanes of the same make.

At the predetermined point, opposite full rudder is applied, and the stick pushed forward and held until the spin stops. With the spin completely stopped, recovery to normal cruise is completed.

In order to avoid a progressive spin, the dive and pull-up following spin recovery must be smooth. An abrupt pull out can again stall the wings and cause the airplane to respin.

Reliable information regarding the spin characteristics of the airplane you are going to use should be obtained before doing precision spins.

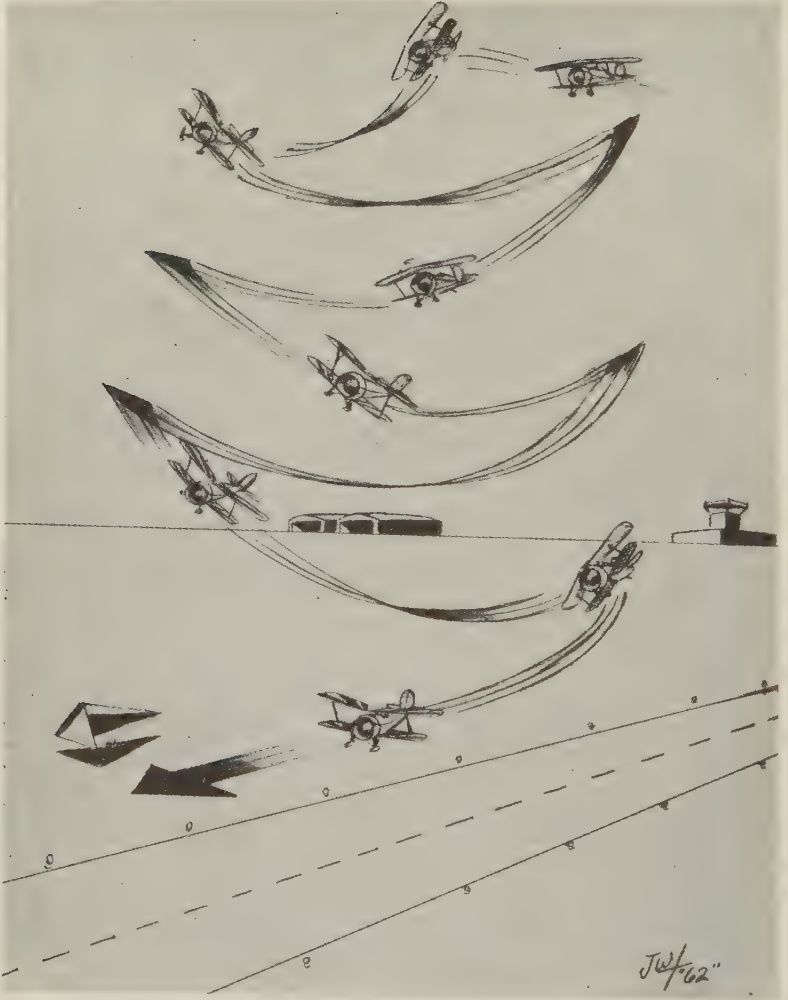
4. Falling Leaf

The falling leaf is a series of checked spins, in which the airplane is allowed to fall off first to the right and then to the left, or vice versa. This gives the appearance of a falling leaf and produces a very graceful maneuver when viewed from the ground. But to the person flying the airplane, it is a fairly fast-moving thing.

To begin, the airplane should be on a predetermined course and in level flight, throttle fully closed. The stick is pulled back just enough to keep the nose above the horizon. As you feel the airplane stall, apply a small amount of rudder to start one wing down. As soon as this wing drops (the stick is full back and the ailerons are neutral), apply full opposite rudder. The airplane will fall toward the side of the low wing until it regains some speed and the rudder and elevators will again control the plane. The airplane will return to the position of level flight and on its original course. However, with the stick still fully back, the plane will immediately again stall and, with the rudder still applied, will start fall-



Three-turn Precision Spin.



Falling Leaf.

ing off to the opposite side. Full opposite rudder is again applied and the same sequence results.

Thus, the same sequence is applied again and again. As long as plenty of altitude remains, the plane will continue to fall as a leaf. Recovery is affected by pushing or allowing the stick to return to neutral. The rudder, of course, also returns to neutral.

5. Loop

The normal inside loop is the easiest of all aerobatic maneuvers to perform, but still takes a high degree of skill to make it nearly round and graceful. For many pilots this loop is their first maneuver executed in a vertical plane. The airplane passes through a climb, inverted position, dive, and back to level flight. The controls used to execute the loop are the elevators and throttle. The rudder and ailerons are trimming controls only.

There are many types of loops, and we will start by describing the normal inside loop. It is executed in the vertical plane with the pilot riding on the inside of the circle. To perform the normal loop, select a road that is easy to identify since a cross wind will tend to make a lightplane drift. It will be best, when possible, to work into the wind on all inside loops, as this tends to make them appear more round when viewed from the ground. Place the airplane in a slight dive until about 20 per cent above normal cruise speed is reached. Ease back on the elevators until you feel well down in the seat; ease in full throttle to maintain speed as long as possible. As the nose passes through the horizon, glance at the wing tip (the wing tip will make a small loop on the horizon).

During the execution of the loop, use the rudder to keep the flight in the vertical plane and the ailerons to correct any tendency for a low or high wing in the normal manner. When the wing tip looks as if it is nearly inverted on the horizon, throw the head back to pick up the road you started the maneuver over. Control pressure is coordinated with the loss of air speed to keep you feeling in the seat. As the nose starts down past the horizon, ease the throttle off smoothly.



Inside Loop.

Keep the nose lined up with road and wings level in the normal manner. The recovery from the dive should be made as quickly and smoothly as possible to maintain the arc of the loop and to keep excess speed from building up.

As experience is gained and the characteristics of the airplane are learned, you can omit the matter of lining up on a road or object, it becomes second nature to watch the wing tips on the horizons and all controls blend in to make a directionally true loop even if not truly round one. You will feel the bump as the airplane passes through its own wake. If the airplane has a ball-bank indicator, a glance at it also helps in directional control.

Another variation is to enter from inverted flight and perform an inside loop; complete the loop in inverted flight.

6. Split-S Turns

The split-S turn is a maneuver in which the airplane is half rolled, either by the half snap or half slow or aileron roll into the inverted position. The elevators are then applied and the airplane completes the last half of a normal loop.

The maneuver is normally entered from level flight at cruise speed. The nose is brought well above the horizon and slow-rolled into the inverted position, the nose still well above the horizon. This is done to slow the airplane to the speed you would normally have at the top of a loop. The elevators are then applied and recovery is made exactly in the same manner as in a normal inside loop.

If the maneuver is entered using a half snap-roll, the nose is brought slightly up to slow the airplane to below cruise speed. The stick is then suddenly and very sharply snapped back and full rudder simultaneously applied in the direction you wish to roll. The approach of the inverted position is then anticipated by reversal of the controls at the correct time to assure the airplane stopping exactly inverted. The stick will be well forward and the nose of the airplane above the horizon at the approximate speed you would normally have at the top of a loop. The recovery is the same as the second part of a normal inside loop.



If the airplane is rolled at normal cruise speed to the inverted position and back elevator applied to complete the last half of a normal loop, excess speed can be easily built up to a point well beyond the red line of the airplane.

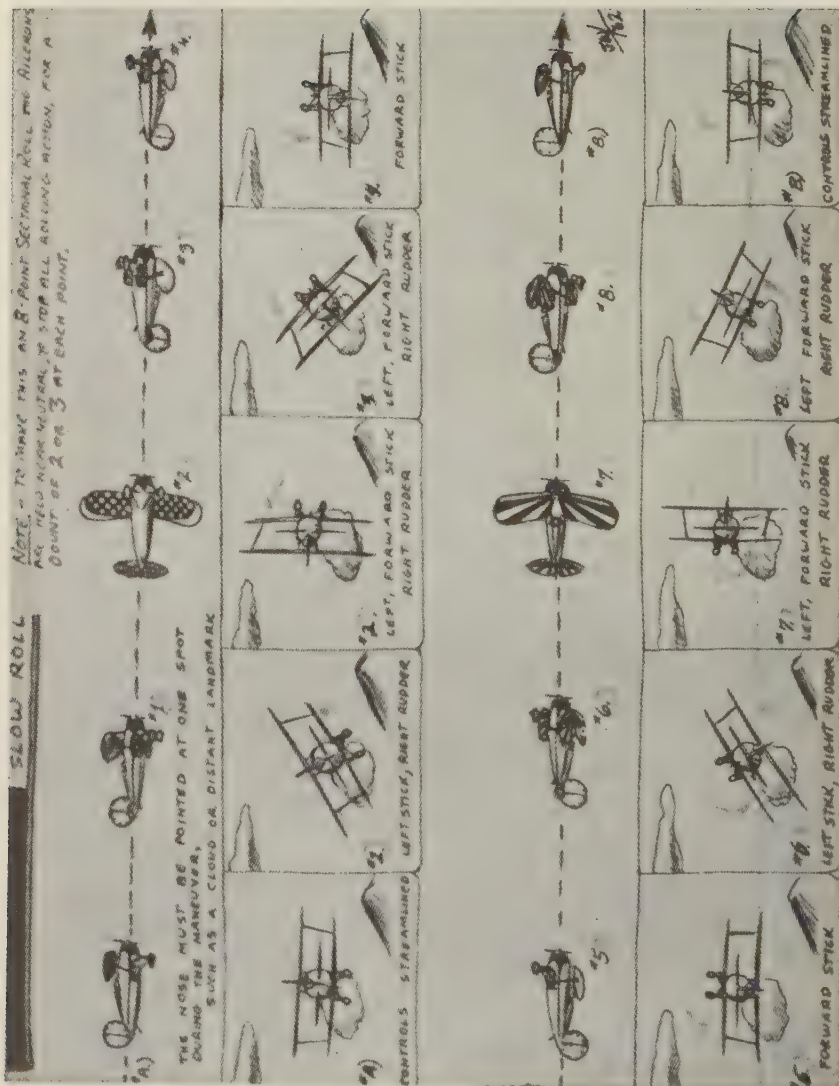
A half slow roll is one of the most difficult maneuvers to perform and one of the most valuable for developing competence in handling the controls, in orientation and coordination, particularly when the half slow roll is performed during climbs and dives. Complete coverage of the half slow roll is given under slow rolls.

I have described the maneuver in stages but it cannot be flown in a series of steps. All controls must be perfectly blended if you are to achieve a smooth maneuver.

7. Slow Roll

The slow roll is one of the most spectacular maneuvers to watch. The airplane is rolled approximately about its longitudinal axis by the use mainly of the ailerons. The elevators and rudders are used to maintain the direction in which the nose is pointed. In general the slow roll is the first time that a pilot is against the belt for any length of time, and in an open cockpit airplane, this may be a little terrifying at first. A very tight belt that will hold you firmly in the seat is a must.

The slow roll may be performed to the right or left, straight and level, in any type of climb or dive, while making a turn to the right or left. To execute a slow roll from straight and level flight, advance the throttle to near full power and start into a shallow dive to obtain another 10 to 15 miles an hour above normal cruise flight. Apply back pressure on the stick to start the airplane into a shallow climb. Since engine torque has an effect on the rate of roll of any single-engine airplane, you will find that the airplane rolls with more ease to the left. Apply ailerons and rudder as if you were starting a steep turn. After the rate of roll has been established, begin applying top rudder to stop all turning effect. As the airplane responds and the bank approaches the 45-degree position, continue the same rate of roll and apply more top rudder to



Slow Roll.

maintain the desired position of the nose in relation to the selected point on the horizon. As the wings of the airplane approach the 90-degree position, apply some forward stick pressure, and more rudder to maintain the nose on the point. As you approach the inverted position, the rudder will still be "on" and the stick well forward to keep the nose up. Here the normal tendency for the beginning pilot is to relax on the ailerons, but remember the ailerons are the controls that are rolling the airplane. Keep them on with extra effort.

As the airplane rolls past the inverted position, ease the rudder in the opposite direction to again be top rudder. The elevator control will still be well forward and you have nearly full aileron in. At the approximate three-quarter position the rudder will be near full on to keep the nose up. The aileron will be well on with the rudder. The last quarter of the roll is the same as recovering from a steep turn except you should keep in enough top rudder to prevent the airplane from turning. The nose must be kept straight ahead.

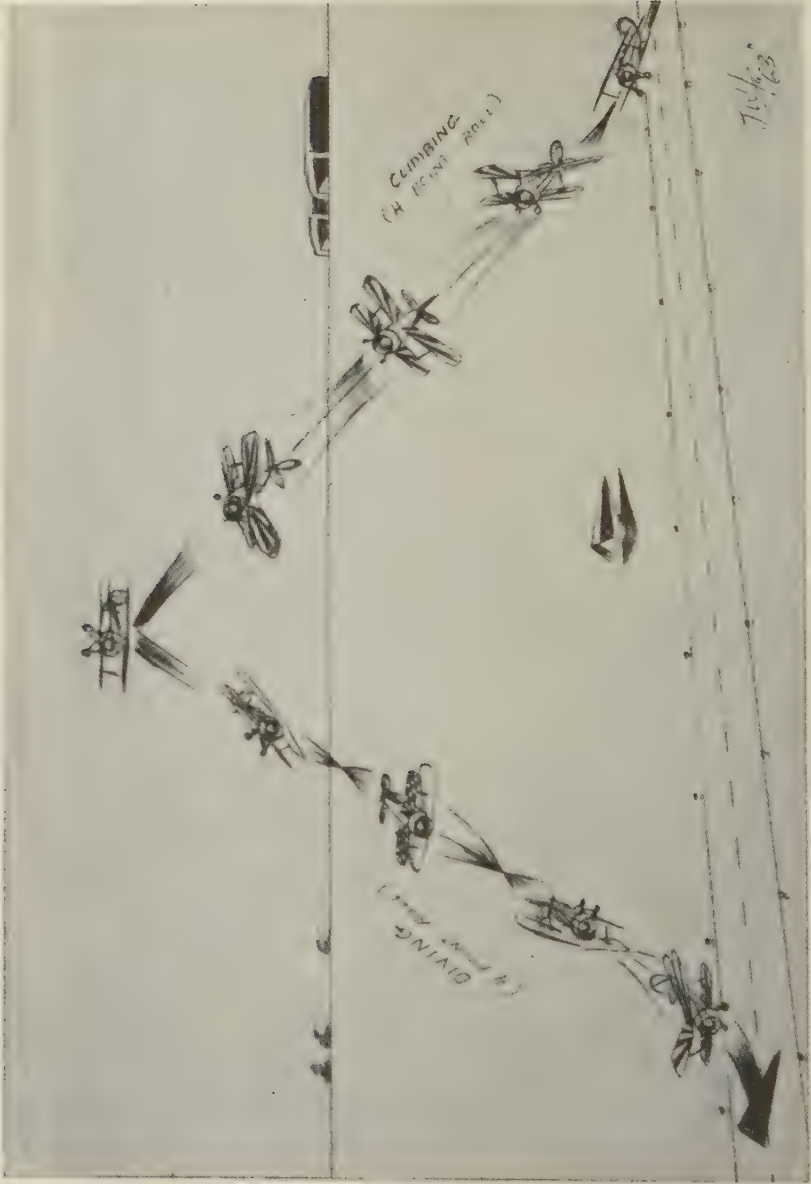
It is suggested rolls to be practiced both left and right, as will all other maneuvers. Also, the quicker or faster the airplane is rolled, the less trouble a beginning pilot will have with it. Later, as coordination and orientation improve, the roll can be slowed and more graceful accomplished.

8. Half Roll

This is the most simple variation of the slow roll. As in the slow roll, the airplane is rolled about its longitudinal axis until it is in the inverted position. Keep the stick well forward and just momentarily hold it in the inverted position with neutral ailerons and rudder. Then roll the airplane back to normal flight in the opposite direction. Other variations of this maneuver include: (1) one-half slow roll—one half inside or outside snap roll recovery; (2) one-half slow roll—diving out as in the last half of a loop. This, of course, is the split-S.

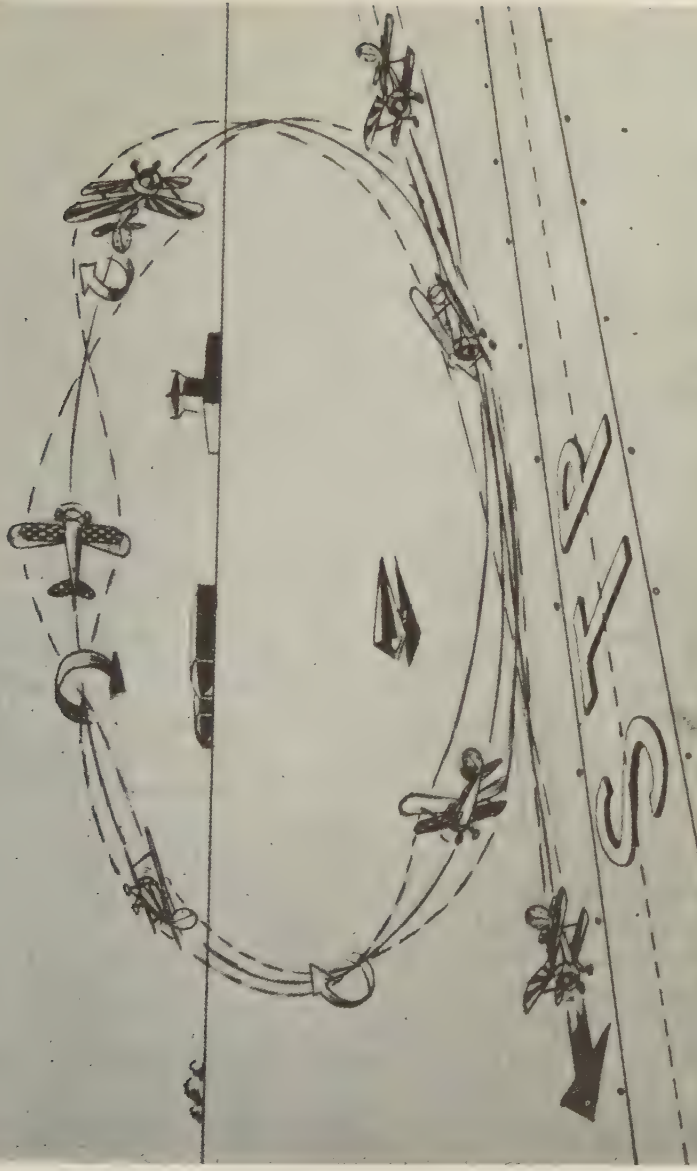
9. 4-Point Hesitation Slow Roll

This is another variation of the slow roll and can be mastered only after the slow roll has been perfected. In this



Climbing and Diving 8-Point Roll.

July 1922



360-degree Slow Roll.

maneuver the airplane is stopped each 90 degrees and held for a count of three or four. To stop the roll sharply, the ailerons are quickly brought to near neutral and held. The trimming controls, which are elevator and rudder, hold the airplane in the selected position. To roll to the next 90-degree position quickly, again apply full aileron. When done properly with no loss or gain of altitude throughout the maneuver, it is very spectacular. When you have mastered this variation of the slow roll, you are ready for further variations.

10. 8-Point Hesitation Slow Roll

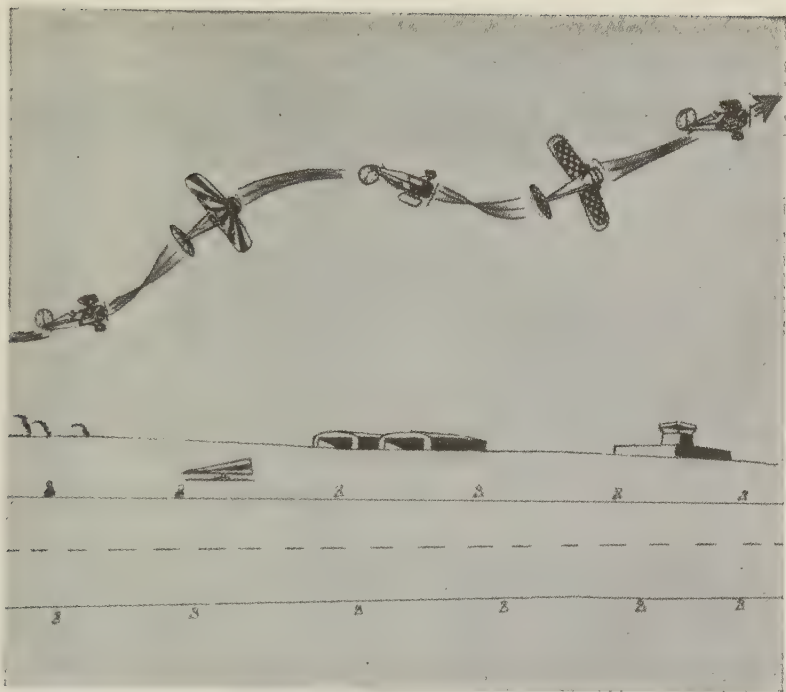
This again is basically a slow roll, but the rotation of the roll is stopped for a count of two or three each 45 degrees. When done properly, the airplane looks as if it is being turned about its longitudinal axis with a giant wrench, stopping each 45 degrees.

11. Series of Slow Rolls in a 360-Degree Turn

In this maneuver the airplane is allowed to slow-roll while tracking a 360-degree circle over the ground. Usually six or seven rolls, and sometimes more, are required to complete the circle. There are several ways of accomplishing this maneuver and all carry the same point value.

1. Rolls are in the same direction as the turns.
2. Rolls are in the opposite direction of the turns.
3. A very slow, slow roll—more than 10 seconds.
4. One slow roll while making a 360-degree turn.
5. Roll in same direction as the turn.
6. Roll in opposite direction of turn.
7. Two slow rolls while making a 360-degree turn with variations 5 and 6 above.
8. 8-point slow roll while making a 360-degree turn with variations 5 and 6 above.

There are many more combinations, but this will serve to give you an idea of some of the possibilities.



"Snap Roll"

12. Snap Roll

The snap roll is actually a spin in a horizontal direction in which the airplane is stalled at a speed considerably above its normal stalling speed. There are many speed-power combinations that can be used with different airplanes, so secure reliable information regarding the snap-roll characteristics of the airplane you are going to use. Some will snap better above cruise, others will not stand the G-forces built up at anything but a speed well below cruise.

When the correct speed has been assumed, pull the stick abruptly back. Aileron may or may not be used. Simultaneously apply abrupt full rudder in the direction of the snap roll and full throttle. Hold the controls in this position for approximately three-quarters of the roll, when you should start recovery in order to stop the snap roll exactly in level flight.

To stop the snap roll, apply full rudder in the opposite direction simultaneously with forward stick. Ailerons may also be used. Sometimes the throttle is retarded after the snap roll has started. If so, use full throttle to aid in the recovery.

There are various ways to do a good snap roll, and the procedure above is a general description.

13. Double Snap Roll

A double snap roll is one in which the recovery is made so the airplane stops in level flight after going through two turns. It will take about 20 per cent more speed to complete this maneuver, so be sure your airplane is stressed to take it. Since the nose will tend to drop more in two turns than one, start the nose more above the horizon than in the single snap. After a great deal of practice you will find that relaxing and working the stick at the proper time will greatly aid in getting in more turns of a snap roll for a given air speed.

Snap rolls are counted as one-half snap, single, one and one-half snap, two, and so on in fractions thereof. A snap can be started in any position and stopped in any position. There are airplanes that are capable of up to four snap rolls without



U.S. Air Force precision aerobatic team, the Thunderbirds.

the nose of the airplane dropping in excess. Normally any good aerobatic airplane is capable of executing at least a double and fractions thereof, also starting and stopping in any position.

14. One and One-Half Snap Rolls

A snap and one-half is one and a half-turn snap roll with the airplane stopping and flying in the inverted position. The snap and a half is beyond the performance and structural capabilities of many airplanes. It will need a 20 per cent increase in speed over the single snap to go out flying after its recovery in the inverted position. The recovery is the same as for any snap roll except that the stick will have to be held well forward to keep the nose of the airplane above the horizon.

15. Outside Snap Rolls

In an outside snap roll the pilot is against the belt, riding on the outside of the roll. The outside snap roll is executed in the same manner as the inside snap roll, the difference being that the stick is abruptly pushed full forward and to stop the outside snap the stick is pulled backward. If aileron is used in an outside snap, it would be as follows: right aileron with left rudder, or vice versa. The outside snap is beyond the capabilities of many airplanes. But for airplanes capable of doing them, they may be started and stopped in any positions in one turn, two turns, two and one-half, or any fractions thereof.

Variations of Snap Rolls

Vertical reverse.

Vertical snap roll.

Outside vertical snap roll.

One and one-half snap rolls in a turn.

Double vertical snap.

Outside double vertical snap roll.

One-half inside snap roll.

One-half outside snap roll.

INVERTED TURNS

LEFT STICK,
RIGHT RUDDER.



INVERTED LATERAL BALANCE

LEFT STICK,
RIGHT RUDDER.



TO MAKE WINGS LEVEL

RIGHT STICK,
LEFT RUDDER.



July 62

Snap roll on top of a loop.

Double snap on top of a loop.

Snap roll at the bottom of a loop.

Double snap at the bottom of a loop.

There are many more possible combinations, but this will serve to give an idea of some of them.

16. Inverted Flight

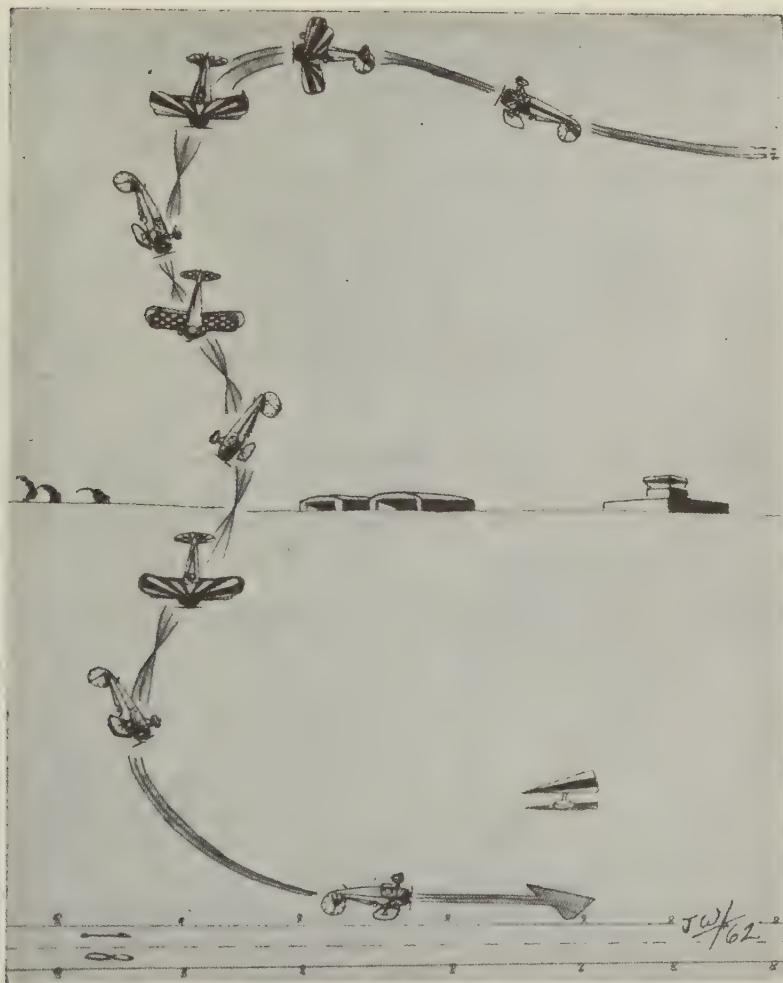
Inverted flight may be entered from a half slow roll, half barrel roll, half snap roll or half of a normal inside loop, and recovery may be made by completing any of the above maneuvers. The use of the controls in inverted flight will take time to become accustomed to. You push the stick forward to climb and pull it back to dive. If you see a wing drop below the horizon, move the stick toward the wing to pick it up. If you wish to do a turn to your right, apply right rudder and left aileron. And if you wish to turn to your left, apply left rudder and right aileron.

Due to the angle of incidence of the wings of the airplane, the nose will be carried higher during inverted flight to maintain a constant altitude. The use of the trim control during inverted flight is recommended. Apply forward trim, this marked nose down, which to you during inverted flight will be nose up. Several of the maneuvers used are the 180- and 360-degree inverted turns. Of course, inverted flight is the starting point and finishing point of many maneuvers, and is used at some point in nearly all aerobatic maneuvers. It must be mastered so that it is performed as well as normal flight.

17. Inverted Outside Spin

During an inverted spin, the airplane spins in the same fashion as it does in a normal spin, except that it is upside down. The pilot is on the outside of the turn instead of on the inside as in a normal spin.

Usually the entry is from inverted flight and a prolonged inverted stall. Apply full forward stick and rudder. If you wish to spin to your left, apply left rudder. Recovery is ac-



Inverted Spin with Inverted Recovery.

complished by pulling the stick back and applying opposite rudder. After the spin has stopped, ease the stick forward for recovery in the inverted position, or pull the stick back as in the split-S.

18. Horizontal-8—with Descending Rolls

The horizontal-8 replaces the former Cuban-8 to conform with the present F.A.I. Maneuver List.

The horizontal-8 is approximately three quarters of a normal loop followed by half a slow roll, timed to be completed at the right position and air speed to again complete another three quarters of a normal loop. This is followed by another half slow roll with recovery to cruise flight.

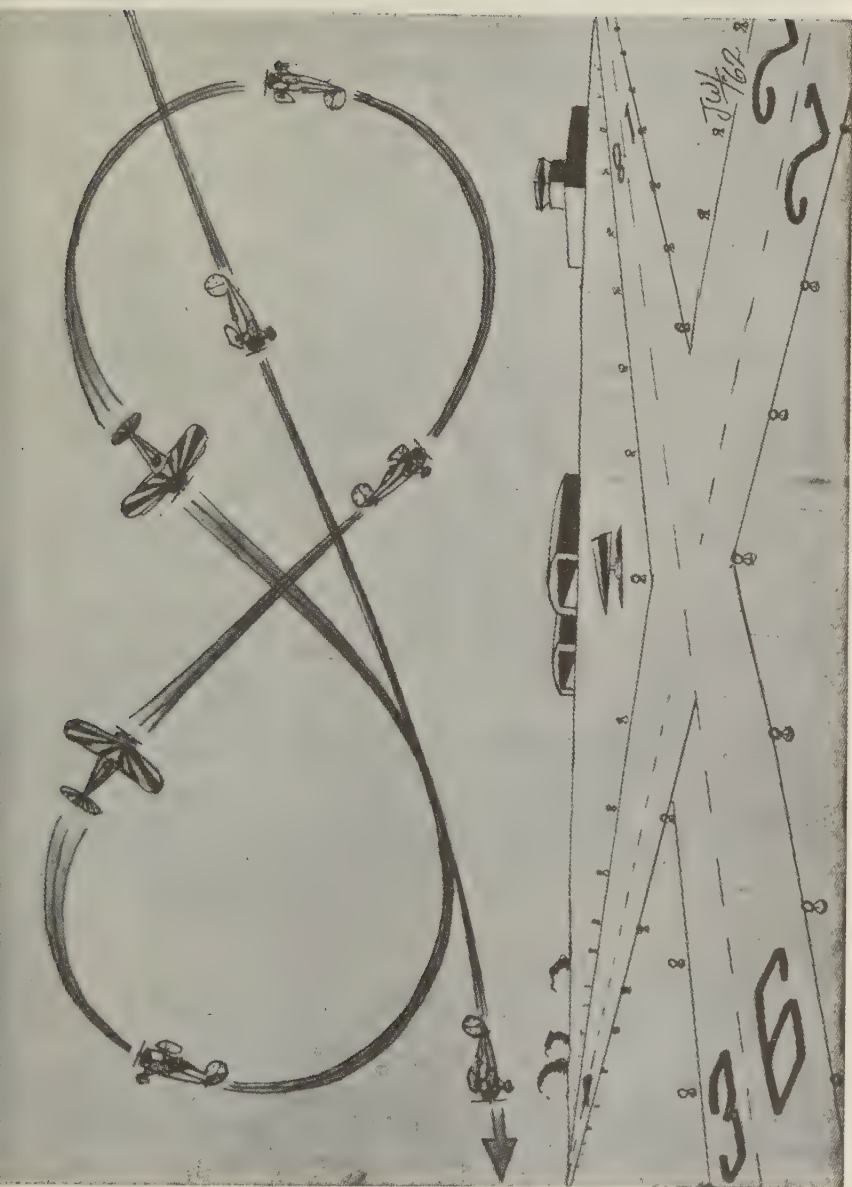
One half of the horizontal-8 may be used as a training maneuver for the Immelmann turn by each time starting the half roll earlier until the true Immelmann is developed.

As with the normal loop, select a road and start to perform the loop, but do not ease off the throttle at the top as in the loop. When the 45-degree downward position is reached, ease the stick forward and complete the last half of a slow roll in the 45-degree position. Roll the nose on the point to prevent turning of the airplane. If the roll has been properly timed, the position and air speed will be correct to again start another normal loop. This then is terminated at the three-quarter position, followed by another one half of a slow roll in the 45-degree position, with recovery to cruise flight over the road selected to start the maneuver.

The one-half slow roll used in the 45-degree plane may be to the left or right. It is suggested as with other maneuvers that it be performed both ways. Some variations are to use one and one-half slow rolls in the 45-degree plane, also to execute the last half of an 8-point roll in the 45-degree dive.

19. Horizontal-8—with Ascending Roll

In the horizontal-8 with ascending roll the air speed is increased from 10 to 15 miles above normal cruise speed and the airplane is pulled up smoothly to the 45-degree position and half slow-rolled into the inverted flight position. The



Horizontal-8 (formerly Cuban-8).

one-half slow roll is timed to have enough air speed to round out the last three quarters of a normal loop with the power on and have the proper air speed to again roll to the inverted position in the 45-degree climb position. Then again complete the last three quarters of a normal loop.

The half slow roll may be to the right or left. It is suggested, as with other maneuvers, it be performed both ways. Another variation sometimes used in shows is for the slow roll to be performed as the first half of the 8-point slow roll.

20. Outside Horizontal-8—with Descending Rolls

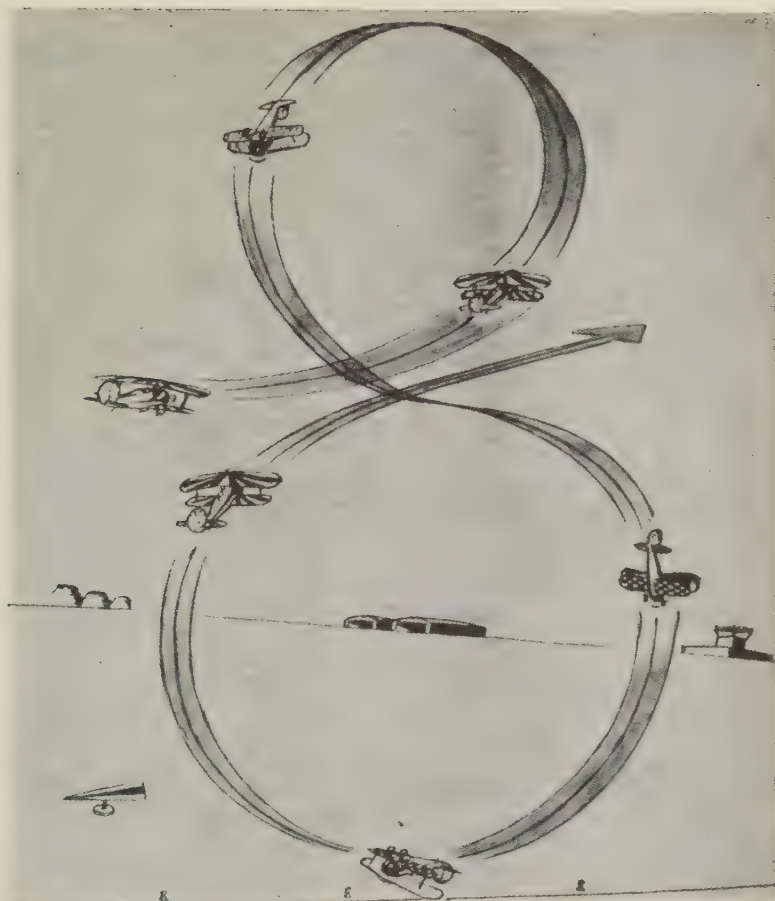
Entered from normal flight at normal air speed, the nose is dropped and the airplane is slow-rolled to the inverted flight position in the approximate 45-degree plane. The airplane is then flown through the last three quarters of an outside loop to normal flight at the top. It is again slow-rolled in the approximate 45-degree dive position to inverted flight, and again flown through the last three-quarters of an outside loop entered from the inverted flight position.

21. Outside Horizontal-8—with Ascending Rolls

From normal flight at a below cruise air speed and stick is pushed forward until the first three-quarters of a normal outside loop is completed. The airplane is slow-rolled in the approximate 45-degree climb position to normal flight at an air speed below cruise to again complete three-quarters of an outside loop, and slow-rolled in the approximate 45-degree climb position to recover at the entry air speed and altitude.

22. Inside-Outside Horizontal-8 Outside-Inside Horizontal-8

The inside-outside 8 is performed by completing the first three-quarters of a normal inside loop at the 45-degree down position. When position is reached, the stick is eased forward, and when the proper air speed is reached, approximately three-quarters of an outside loop from inverted position is completed.



Vertical-8 (Inside/Outside-8).

In the outside-inside 8 the airplane is eased into a slight climb and when the air speed is below normal cruise speed, apply forward stick to complete three-quarters of a normal outside loop, then ease the stick back. When the air speed has decreased, round out the last three-quarters of a normal inside loop.

Two Other Variations Are

Inside-outside horizontal-8 from inverted flight position.

Outside-inside horizontal-8 from inverted flight position.

Vertical figure 8 starting at the center—the normal vertical figure 8 is flown as the first three-quarters of a normal inside loop that is stopped at the three-quarter position and a normal outside loop is started. After you complete the last quarter of the normal outside loop, you will again be in level flight at a reduced air speed.

Vertical figure 8 starting from inverted flight, followed by an outside loop, then the inside loop which ends in inverted flight.

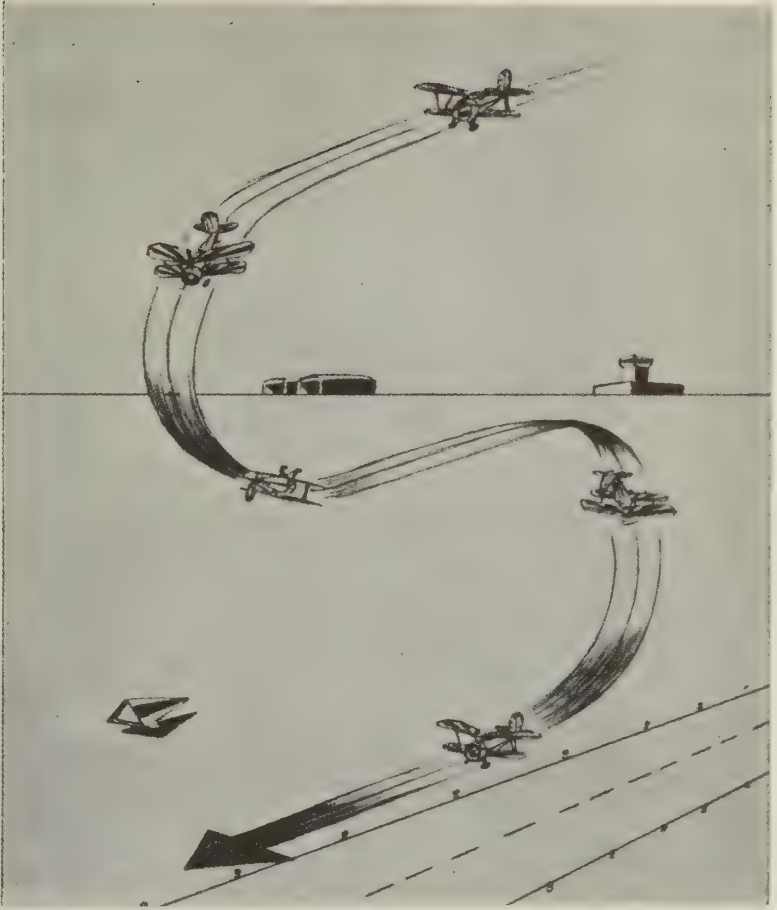
Vertical figure 8 starting at the top—descending, making a vertical S then ascending to complete the vertical figure 8 at the top.

Vertical figure 8 starting at the bottom—ascending, making a vertical S, then descending to complete the vertical figure 8 at the bottom.

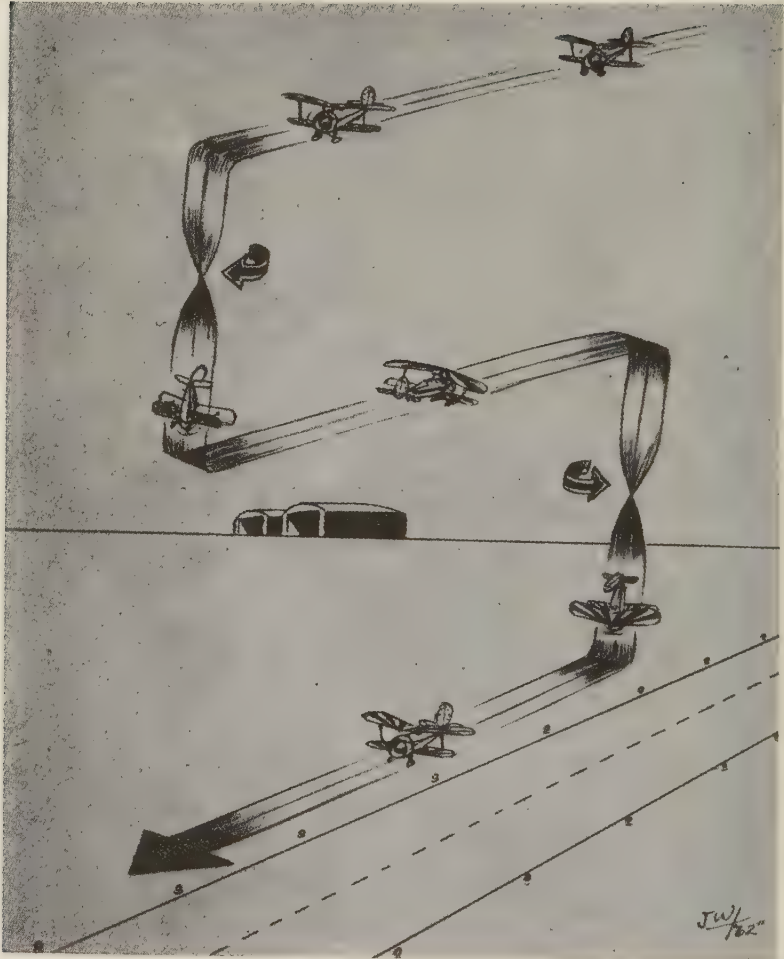
Vertical figure 8 starting at the bottom—ascending as in a normal loop, half rolling at top. Then complete a normal inside loop, half rolling at the bottom, descending as in the last half of a normal loop.

Vertical figure 8 starting at the bottom from inverted flight—completing half of an outside loop. Half roll and complete an outside loop from the inverted flight position. Half roll and complete the last half of an outside loop, ending in inverted flight.

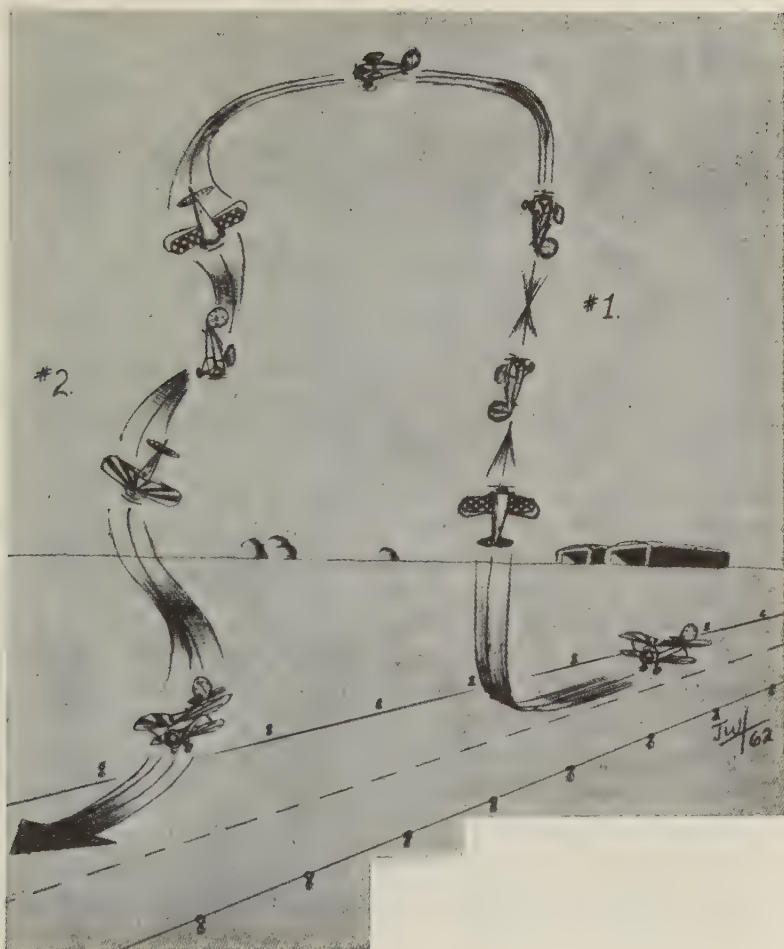
There are many more possible combinations that can be used and are high point maneuvers.



Outside/Inside Vertical-S.



Outside/Inside Square-S with Vertical Rolls.



Cobra Roll

23. Immelmann Turn

The Immelmann turn is a maneuver consisting of the first half of the inside loop and the last half of the slow roll. The aircraft reverses direction 180 degrees.

Place the airplane in a dive to pick up speed approximately 25 miles per hour over cruising. (Some airplanes are capable of doing it from cruise, but these are few.) Trainers of the World War II type need as much as 40 or 50 miles over cruise flight.

Use the throttle the same as in a loop. Begin the maneuver the same as the inside loop. As you approach the top of the loop with the nose still well above the horizon, ease the stick forward and start your roll. The roll may be to the left or right, whichever you planned before you start the maneuver. Apply aileron and rudder action as the last half of the slow roll. You have now changed direction 180 degrees and picked yourself up a good amount of altitude. Variations use the one-half snap roll at the top. It can either be half inside or half outside, snap-rolled to level flight.

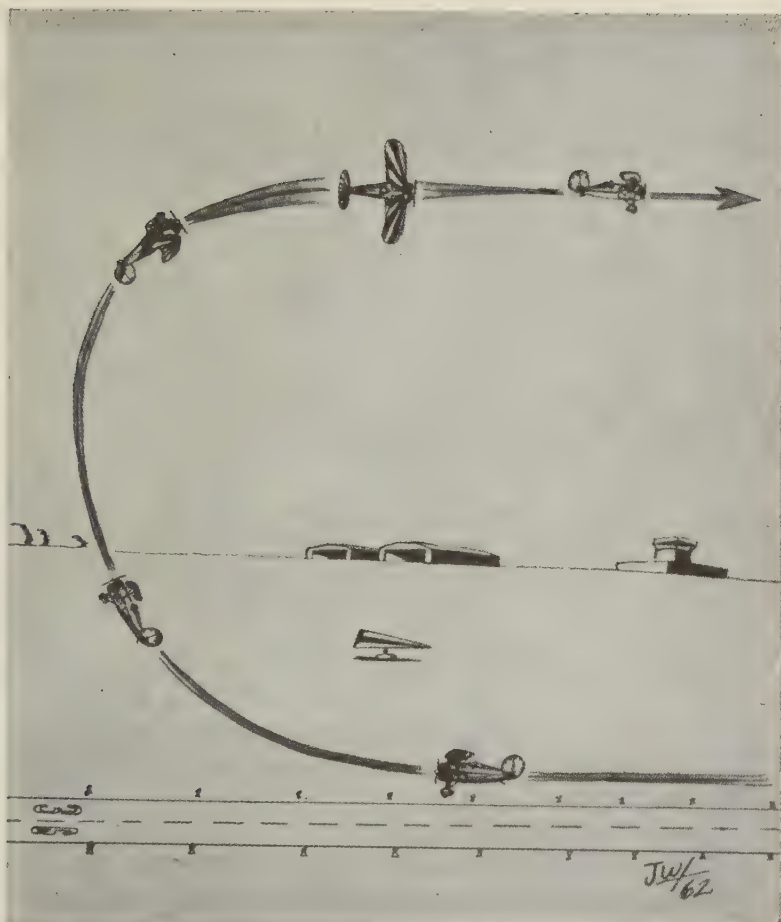
The Immelmann turn is used by some exhibition pilots on take-off in aircraft with ample horsepower or light wing loading.

24. Outside Immelmann Turn

The outside Immelmann turn is a maneuver consisting of the first half of the slow roll and the first half of an outside loop from the inverted flight position. The aircraft reverses directions 180 degrees with an increase in altitude.

25. Hammerhead Turns

The hammerhead turns or hammerhead stall turns as they are sometimes called is a vertical maneuver in which the aircraft changes direction 180 degrees in a very small area usually the width of a runway or the width of a normal smoke trail pattern. The aircraft on a well-executed hammerhead will end at the same altitude as the maneuver was started.



Immelman Turn.

At an air speed above cruise pull the airplane up smoothly into the vertical position, throttle full on. Just before the airplane stalls, apply full rudder in the direction you wish the airplane to turn. It will then pivot on the wing tip and cut a straight line through the horizon. It is well to perform the maneuver over a road so you can watch the down wing back up through the road. The nose will then be pointed straight down at the road. In the maneuver the rudder is used to turn the airplane, and the elevators are used to keep the airplane in the vertical position. As you start the vertical dive to the ground, ease off the throttle and apply back pressure on the stick as smoothly as possible so as not to induce a high-speed stall. By proper timing you will be able to come out on the same altitude you started the hammerhead turn on.

The maneuver may be performed to the right or left. Due to engine torque, most airplanes will do the maneuver with more ease to the left.

Variations:

Hammerhead turn from normal flight to inverted flight recovery, with no change of direction. Hammerhead from inverted flight to normal flight, with no change of direction. When the hammerhead is used in this manner, it is called the roller coaster.

Inverted hammerhead turns:

The inverted hammerhead turns are entered from the inverted flight position. As soon as the vertical position is reached, the maneuver is accomplished the same as the normal hammerhead. Recovery is in the inverted position and a 180-degree direction change is accomplished.

Hammerhead turns are also performed using one-half vertical slow rolls going up, then the hammerhead turn followed by a half slow roll descending, thereby completing a 180-degree change of direction. In this maneuver sometimes the one-quarter slow roll is used. The complete slow up and down may be used. Entry may be from normal flight or inverted flight.

26. Whip Stalls

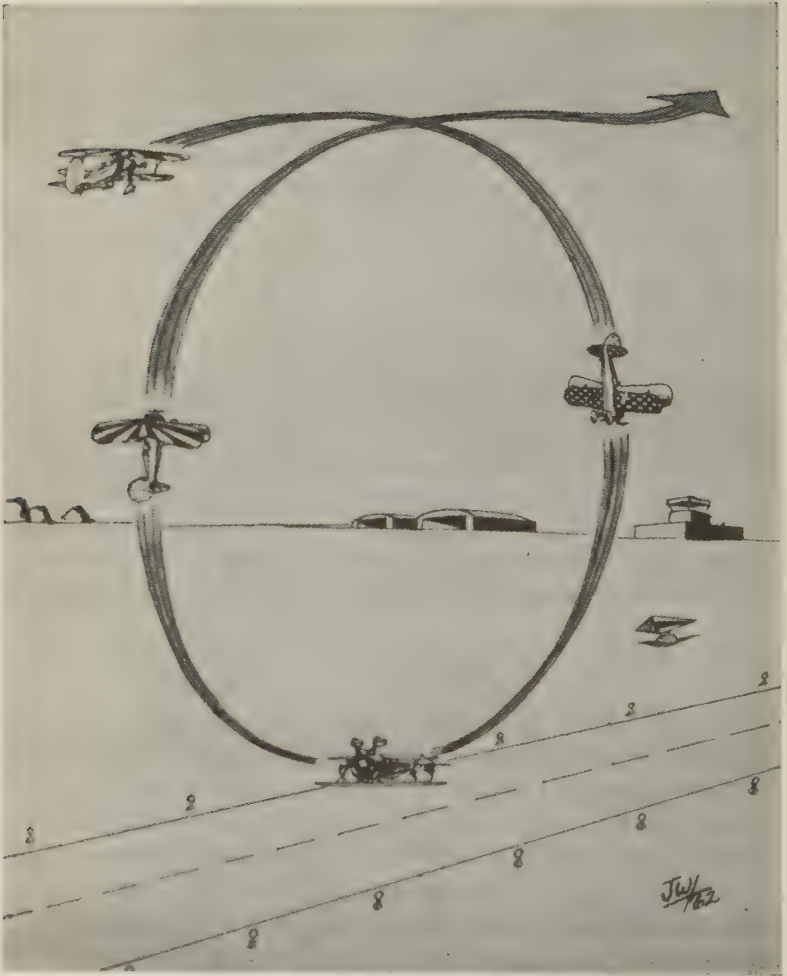
For a whip stall the airplane is pulled into the vertical position as in the hammerhead, but no effort is made to cause it to fall left or right. It is held in the vertical plane until it stalls completely and slides backward. Recovery can be either to normal flight or inverted flight. Entry can be from either normal flight or inverted flight. Plan your direction of recovery to either inverted or normal flight before entry. Keep a firm grip on all controls.

27. Square Inside Loop

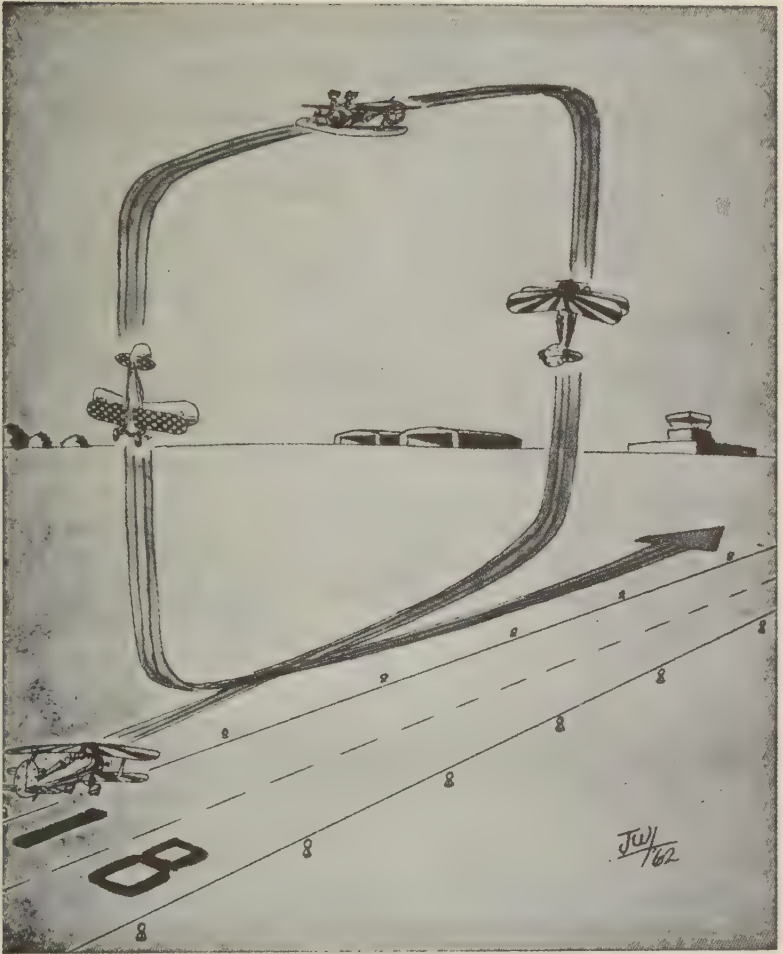
The name covers the maneuver very well in that it is square instead of round. Use more speed for this than for the normal inside loop because the airplane will have to fly at the top in the inverted position. It is pulled as sharply as possible into the vertical plane without inducing a high-speed stall. It is held in the vertical plane until maximum altitude is obtained with enough speed to fly the airplane above stall speed in the inverted flight position. It is again pulled as sharply as possible without inducing a high-speed stall.

An estimate of the distance covered in the vertical position must be made and the same distance covered in inverted flight. Then again sharply apply back pressure to fly the airplane straight down in the vertical position. Again estimate the distance and make the last corner as sharp as possible without inducing a high-speed stall.

In this maneuver you must know your airplane and work at it steady. Someone on the ground is a big help to tell you if you are getting all sides equal and squaring off the corners. If your airplane has smoke, use it. You can be your own judge of how well you are doing. Normally you close the throttle on the down leg of the square loop. If you do this with smoke, be sure to turn off the smoke system before retarding the throttle. This will save you a smoke oil fire since sample oil will burn with the throttle retarded or if the engine has lost power from fuel starvation or other cause.



Outside Loop.



Square Loop.

Variations of the inside loop:

The square inside loop from inverted flight position is another variation of this maneuver and carries the same point value.

8-point loop—Instead of having four sides as does the square of 4-point loop, the 8-point loop has eight sides. More air speed is used and more timing on the part of the pilot. It is stopped each 45 degrees instead of each 90 degrees in the square loop.

28. Snap Roll on the Top of the Inside Loop

A snap roll on the top of a loop is a combination of two aerobatic maneuvers. It is a normal loop performed with enough air speed to be snap-rolled at near the inverted position. The loop is then completed in the normal manner. On most airplanes the snap roll is started when the nose is about 20 degrees above the horizon before the inverted flight position is reached. Here full rudder is applied in the direction of rotation and the stick is snapped all the way back. Ailerons may or may not be used. If ailerons are used, they are applied in direction of roll. When the inside snap roll is near three-quarters completed, apply full opposite rudder and relax stick pressure. The wings are stopped level. The nose will be below the horizon approximately 20 degrees. From this position a normal loop is completed. Some of the difficulty encountered in this maneuver is the loss of orientation by the pilot, which results in the loss of heading with a recovery in a different direction than that used during entry.

Variations:

Inside loop with double snap roll on top and bottom of the loop.

Inside loop with slow roll on top.

Inside loop with slow roll on top and bottom.

Perhaps the one most often being used is the snap roll on top of the loop.



Snap Roll at top of Loop.

29. Outside Loop

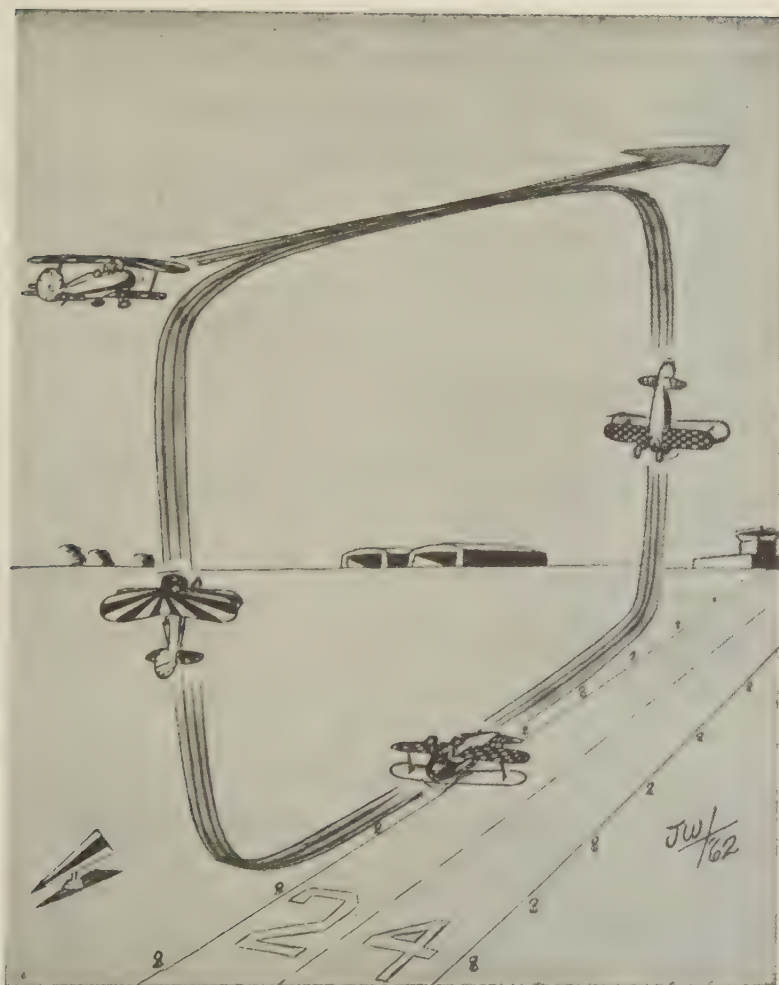
From level flight with the air speed reduced to 20 miles below normal cruise speed, the stick is eased forward in a dive past the vertical position to the full inverted position. Here your air speed should be near 30 miles an hour more than normal cruise speed. The stick is still forward and the airplane returns to the vertical climb position and on past to normal flight. The air speed will be well reduced, but a good margin above stall will still be maintained. The entry speed to some degree will determine if you are to complete the maneuver at the same altitude you started it. Too much stick pressure will cause the airplane to snap-roll out of this maneuver. Trim should be full forward. The throttle will be retarded during the first two-thirds of the maneuver and full throttle applied as you start up the back side.

Variations:

The airplane is placed in a dive in the inverted position to near 30 miles above normal cruise speed, the trim rolled forward, and the stick pushed forward and held until near normal flight at the top is reached. The stick pressure is relaxed to round out the top of the outside loop. The air speed is well above a stall, but greatly reduced from normal cruise speed. As you go over the top, more forward stick is used on down past the vertical. The throttle is now retarded to keep the air speed slowed down as the airplane reaches the inverted position. Relax on stick pressure and fly out in normal inverted flight.

30. Square Outside Loop

Start the square outside loop from a speed well below cruise. The throttle should be well retarded in the vertical dive for the first side of the square. The bottom side is the inverted flight part of the maneuver and the air speed on this leg will be about 40 miles an hour over cruise speed. The back side of the square being the vertical climb part of the maneuver is held as long as practical and the maneuver is complete in normal flight at a speed of around 10 miles



Square Outside Loop.

an hour above stall speed of the airplane. Full throttle is used doing the vertical climb part of the maneuver.

31. Square Outside Loop from Inverted Flight

From normal inverted flight dive the airplane to a speed of near 40 miles an hour above cruise. The trim is rolled full forward to help on the stick load. The first part of the maneuver is the vertical climb part. The second part of the square is in normal flight position. The third section is a vertical dive, throttle retarded. The fourth section is in inverted flight.

32. Rolling Loop Series

The airplane is looped and rolled as one nearly continuous maneuver. The rolling loop series has many variations. Here are some.

1. Rolling loop with one slow roll. Starting from normal flight—up.
2. Rolling loop with one slow roll. Starting from inverted flight—up.
3. Rolling loop with two slow rolls. Starting from normal flight—up.
4. Rolling loop with two slow rolls. Starting from inverted flight—up.

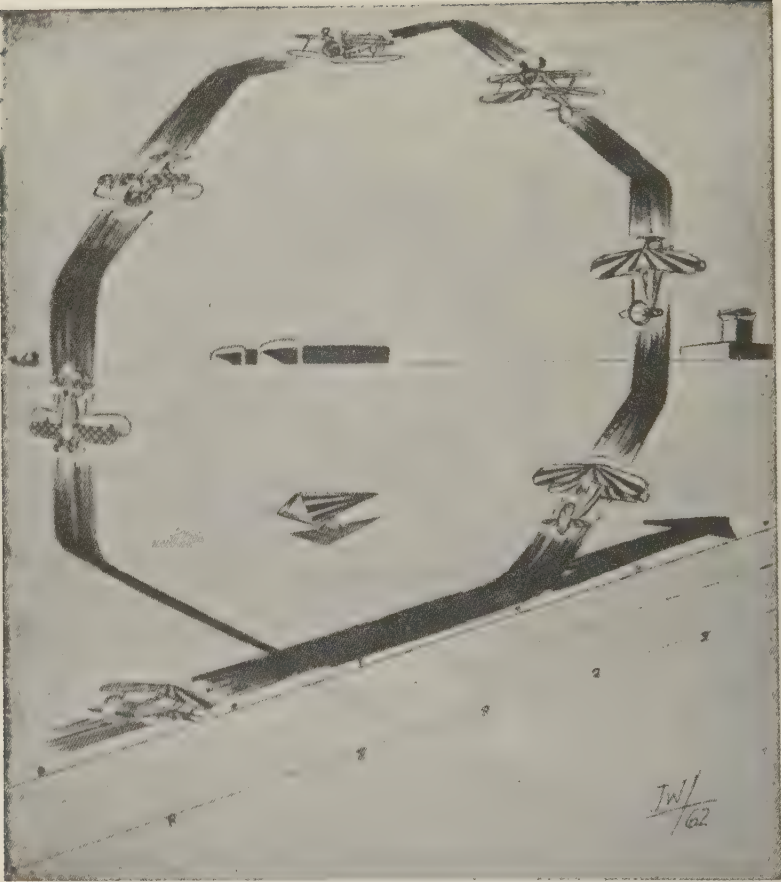
Four more variations of the above maneuvers would be to work them in a down plane from the starting position.

1. Square loop with a half slow roll each quarter. Normal starting from the top.
2. Square loop with a half slow roll each quarter. Normal starting from the bottom.
3. & 4. Two more variations would be starting from the inverted position.

From the list of rolling loop maneuvers, I selected to use the square rolling loop with a half slow roll each quarter starting from the bottom for my normal aerobatic exhibitions and at contests due to its high point coefficient. The airplane is placed in a dive to obtain a speed of 40 miles an hour above cruise and sharply pulled into the vertical flight position.



Bottleneck Loop.



8-Point Loop.

It is then slow-rolled vertically by watching the lower wing panel and keeping it in such a position that it appears to be one foot above the horizon. At the 180-degree position, the roll is stopped and held for an instant. Then forward stick is applied to bring the airplane to level flight for the second section of the maneuver.

Another half slow roll is made to bring the airplane to inverted flight again. Then back-stick to put the plane in a vertical dive, power off. At this point (while slow-rolling in the vertical downward attitude), the trim is changed to full forward to aid in squaring the last corner, which is on the outside and will produce a high negative load factor. The last section is entered in inverted flight, with an air speed of 40 miles an hour above cruise, then half slow-rolled to normal flight.



Czechoslovakian-manufactured Z-226A AKROBAT. Powered by Walter Minor 6-III 160 h.p. engine. Flown with great success by many aerobatic pilots in Europe.



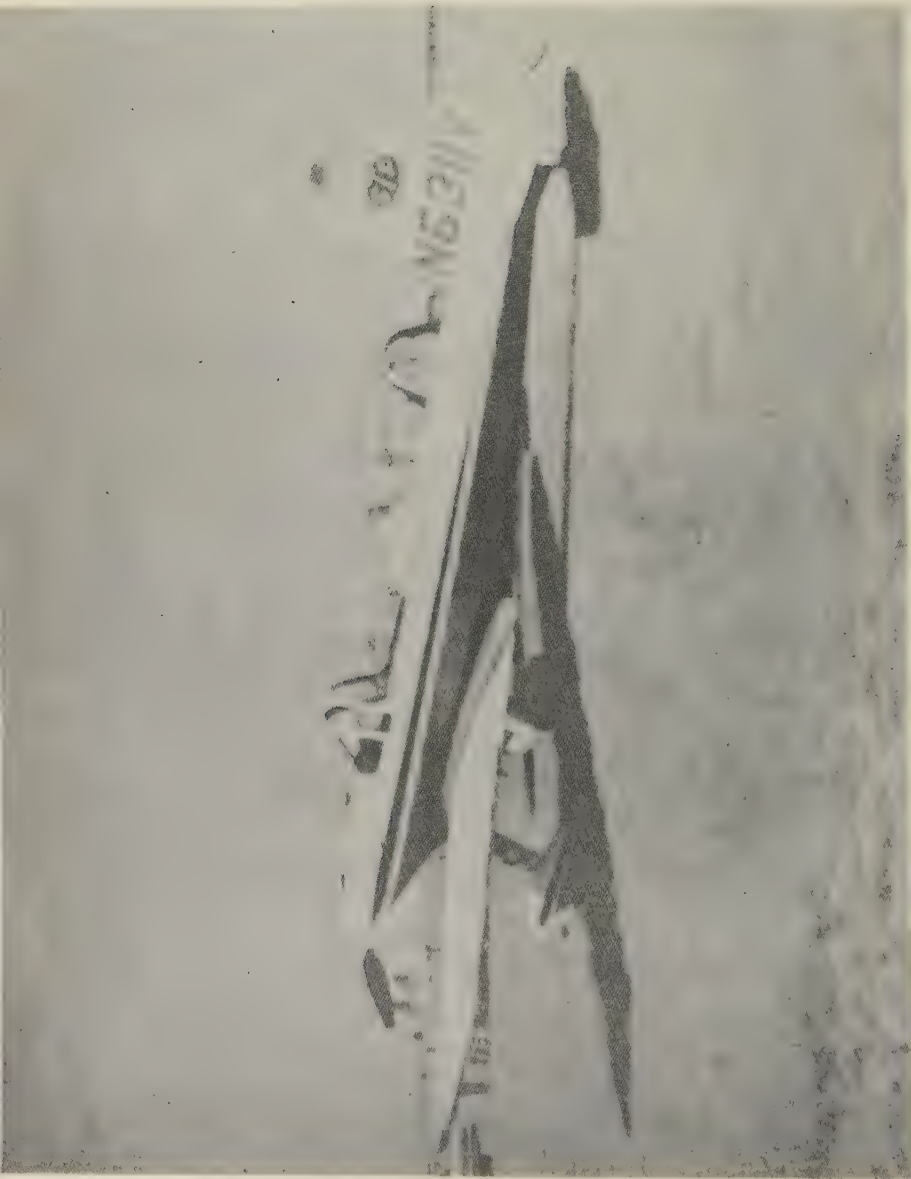
The lomcevak (opposite) is one of the few really new maneuvers developed in recent years. It is extremely spectacular because you actually tumble tail-over-prop, a thing generally regarded as impossible until a couple of years ago.

Lomcevak entry speeds will vary with different aircraft, and some aerobatic planes won't do it at all. It's a critical maneuver; everything must be just right. In other words, you do it perfectly or not at all. Here's how I do it in the KrierKraft:

At 120 mph and at a climb angle of 20 degrees, set up as if I were going to fly a parabolic curve, I $\frac{1}{4}$ -roll to knife-edge flight and reduce power. As airspeed drops to 100-105 mph, I do a fast, outside snap-roll to the left. After one and a-quarter revolutions, I'm upright for just an instant near the top of the parabolic curve and with most of my forward momentum drained away. Hard down-elevator at this critical point transfers the strong gyroscopic-force built up from the outside snap roll down the length of the airplane while forward speed is insufficient to counteract it. This produces the tumble. She'll tumble "head over heels" through one and a-half rotations, and the maneuver is completed as the airplane is pointed directly down at the runway. If the controls are held longer (hard, down-elevator, left aileron and full, right rudder), the plane goes into an outside spin. For the best viewing by an air show crowd, I execute the lomcevak with the spectators on my right.

It may surprise some to learn that my G-meter only registers about $3\frac{1}{2}$ G's for this wild-appearing maneuver. But the tumble does produce sort of a weird sensation for the pilot.

Caution: the author has recently discontinued this maneuver after several propeller-hub failures. I do not recommend that you try it, and present it here only for its interest-value.



3. The Aresti Aerocryptographic System

The Aresti Aerocryptographic System, or the "Aresti Key," as it is often called, is the written, universal language of the aerobatic pilot. It has been adopted by the *Federation Aeronautique Internationale*, the keeper and arbiter of all aviation records, as standard throughout the world, and all official aerobatic contests employ it.

Use of the Aresti Key makes it possible to diagram any aerobatic sequence, and allows a positive frame of reference within which any precision performance may be accurately judged. It was devised by Count Jose L. Aresti, a colonel in the Spanish Air Force and a famous akro-pilot himself.

It has been called a form of "shorthand," because it employs simple symbols to represent all basic maneuvers such as loops, rolls, turns, etc. Combinations of these are put together to diagram more complex maneuvers.

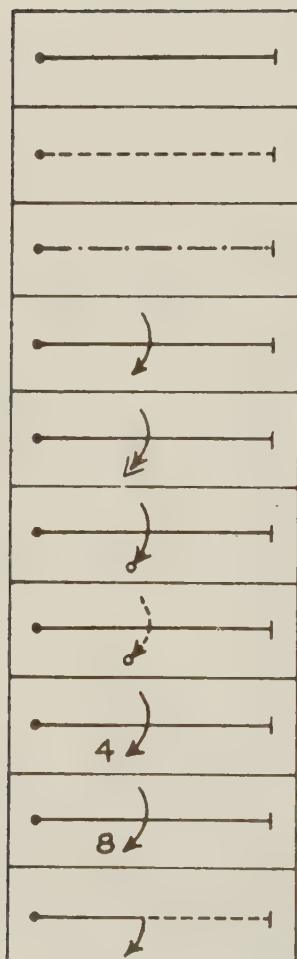
Aresti divided all maneuvers into nine "families:"

1. Lines and lines plus angles.
2. Horizontal turns.
3. Vertical turns.
4. Spins.
5. Wing slides.
6. Tail slides.
7. Loops.
8. Rolls.
9. $\frac{1}{2}$ loops and $\frac{1}{2}$ rolls; and $\frac{1}{2}$ rolls plus $\frac{1}{2}$ loops (the split-S is an example of a maneuver in this family).

Each Aresti figure is numbered for instant identification. For example, an inside loop is figure 7.1.1. In addition, each figure has been given a carefully calculated "coefficient of difficulty" (K). The inside loop, figure 7.1.1., has a K-value of 12 in competition.

In scoring a performance, judges award a grade of 1 to 10

BASIC KEYS



Normal Flight

Inverted Flight

Knife Edge Flight

Slow Roll

Super Slow Roll (More than 15 sec.)

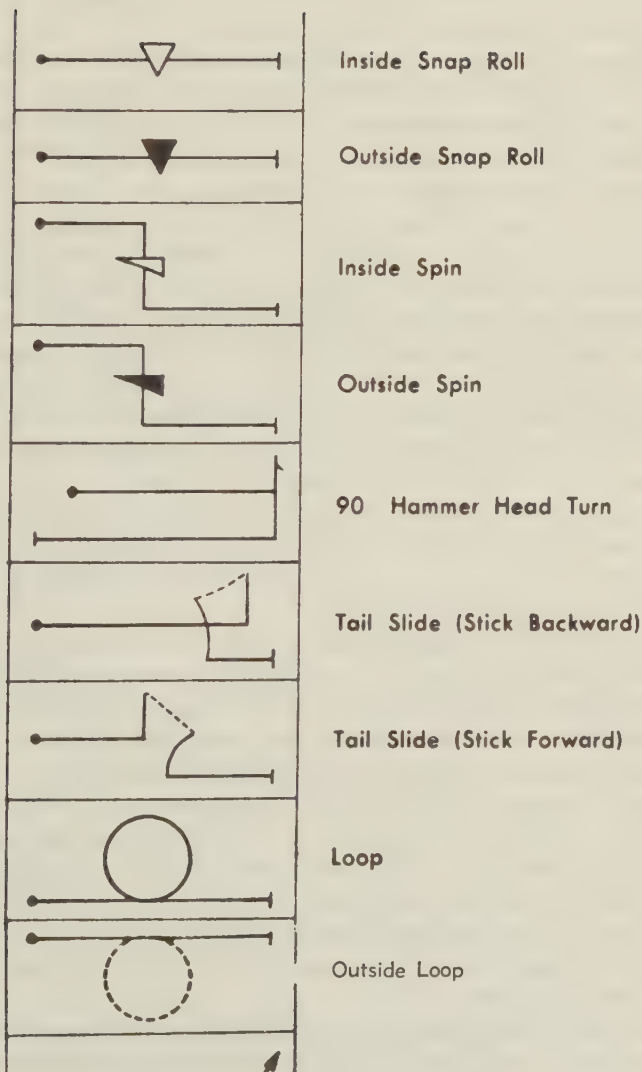
Inside Barrel Roll

Outside Barrel Roll

4 Point Roll

8 Point Roll

$\frac{1}{2}$ Slow Roll



for each maneuver, then this grade is multiplied by the maneuver's coefficient of difficulty. Therefore, if a contestant is awarded a grade of, say, 9 for his loop, his score from that particular judge will be 9×12 or 108.

However, one good loop doesn't necessarily call for another one, because each time a maneuver from the same line of Aresti figures is repeated, it's K-value decreases and soon reaches zero. For instance, say a contestant has performed an inverted loop, figure 7.1.1.1., which has a K-value of 28. Next, he makes a downward, outside loop, figure 7.1.1.2., which has a K-value of 24. Then he does still another loop, figure 7.1.1.3., having a K-value of 16. Well, the judges will figure his first loop at its assigned K-value of 12. But the second loop will lose half its K-value and therefore its coefficient of difficulty will be 14 instead of 28. The third loop will suffer a $\frac{3}{4}$ reduction in K-value, from 16 down to 4. And had he made still another loop from this same line of Aresti figures, the contestant would get nothing for it.

Also, the Aresti System assigns K-values to such things as harmony, rhythm and diversity of an aerobatic program, its framing within an ideal zone; and provides penalties for violation of time limits.

Good framing is important because this carries a K-value of 80. Good framing is accomplished by evenly balancing your maneuvers on each side of a marked center line and equidistant from each end of your zone. At the 1966 world championships in Moscow, an arrow, about 2,400 feet in length, bisected at the half-way point, with panels reaching 450 feet to either side, served as a reference on the ground for proper framing. The actual size of the aerobatic zone, however, depends upon the speed for your airplane. Eight hundred by twelve hundred feet would be enough for a Cub; the Soviet Yak 18P requires about two thousand by five thousand feet.

The aerobatic zone does have definite altitude limits. The upper limit varies between 2,225, 2,600 and 3,250 feet (approximately. The actual figures are 700, 800 and 1,000 meters) according to which of the three aerobatic programs—two obligatory and one free-style—the contestants are flying.

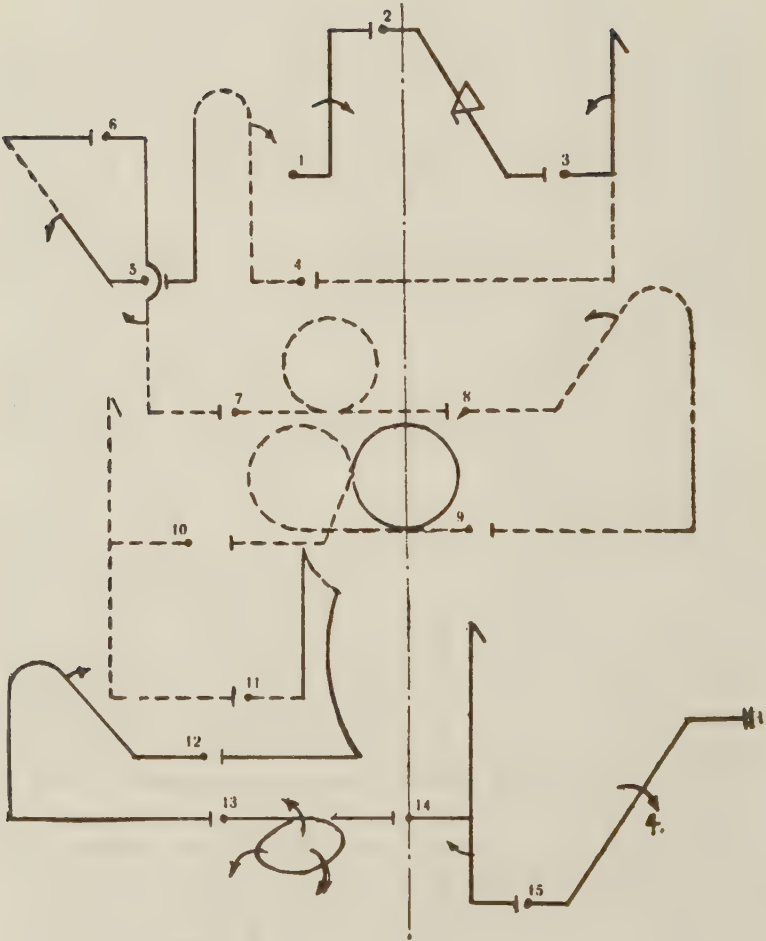
The lower limit is 325 feet (100 meters) above the surface. All planes are equipped with barographs to insure observance of these limits.

Another thing you must consider in planning your sequence is turn-around maneuvers at each end of the aerobatic zone. A simple turn adds almost nothing to your score and takes more time than an Immelmann or a tail-slide. So, you'll pick maneuvers that will turn you around—and position you for your next maneuver—that have K-values as high as possible. You will also use a different one each time, or suffer loss of points under the repeat formula.

Actually, there are exceptions to the repeat formula. In choosing your free-style program, you may take only one maneuver from each horizontal line of each family of Aresti figures EXCEPT:

1. Three different maneuvers may be taken from each line in sub-families 8.1., 8.2., 8.3.1. and 8.3.2. and performed with an angle or line in family 1.
2. Two maneuvers may be used from lines 8.4. and 8.5. without penalty.
3. Two may be used from 9.1.
4. Four maneuvers may be selected from 9.2.

It is obvious from what I've said so far that the more complicated maneuvers are made up from a combination of figures from two or more families—or combinations from the same family. Therefore, a pilot has to use his imagination, within the limits of his skill and his airplane's capabilities, to put together from basic Aresti figures the compound maneuvers that have high K-values. A complex maneuver will have a K-value equal to the sum of the K-values possessed by the basic figures it contains. As an example: an outside flick (snap) roll performed in a vertical climb and ending in level flight at the top, has a K-value of 32. The outside flick roll's K-value is 15; the vertical climb's K-value is 4; and the angle—from level to vertical to level ending at greater altitude—has a K-value of 13. So, $15 + 4 + 13 = 32$. Refer to the accompanying list of Aresti figures and see how this one was put together. The outside flick roll is figure 8.3.2.1.1. The vertical climb is figure 1.1.4.1. And the angle is 1.4.1.1.



Aresti diagram of an aerobatic sequence.

This is why, in championship aerobatics, pilots choose compound maneuvers and maneuvers that string together well (with no penalizing repeats). Allowed but ten minutes in a free-style competition, you must pick a routine composed of maneuvers that will total as near the 700-point maximum as you can. In my own case, I've found it impractical to go beyond 25-28 maneuvers in this period of time. It's better to employ difficult maneuvers and use fewer of them to get your 700 points of total K-value.

Another factor important in diagramming your sequence is selection of maneuvers that end with your airplane well positioned for the maneuver to follow. This allows you to make the most of the your allotted time and adds harmony points. If your second maneuver is one that must be entered from an inverted position, then your first maneuver should be one that leaves you inverted at its conclusion—and pointing in the right direction.

So, clearly, like 'most everything else in flying, good planning of an aerobatic program is half the battle. Besides, in competition, you must furnish to the judges, before take-off, an Aresti diagram of your sequence. And you may not deviate from it without penalty. I always attach a copy of this diagram to my instrument panel for quick reference during flight.

To give you a specific example of the Aresti System at work, let's look at the accompanying Aresti diagram and the aerobatic program it represents. This one happens to be the Group I Obligatory Program proposed by the Soviets for the 1966 world championships. A dot marks the beginning of each maneuver and a vertical dash ends it:

1. From normal flight, a slow roll in a 90-degree climb and finish in normal flight. K = 27.
2. Beginning in normal flight, do a flick roll in a 45-degree dive and end in normal flight. K = 16.
3. Starting in normal flight, perform a 90-degree wing slide and a slow $1\frac{1}{2}$ roll in a climbing line, ending inverted. K = 34.

4. Beginning inverted, do a $\frac{1}{2}$ slow roll in a 90-degree climb and $\frac{1}{2}$ inverted loop, ending in normal flight. K = 32.
5. From normal flight, do a $\frac{1}{2}$ slow roll in a 45-degree climb and end in normal flight. K = 18.
6. Begin in normal flight and do a $\frac{1}{2}$ slow roll in a 90-degree climb, ending in inverted flight. K = 27.
7. From inverted, do an outside climbing loop, ending inverted. K = 28.
8. Beginning inverted, perform a $\frac{1}{2}$ slow roll in a 45-degree climb and $\frac{1}{2}$ outside loop, ending inverted. K = 30.
9. From inverted flight, do a vertical-8-lying-down and finish inverted. K = 34.
10. Starting from inverted flight, perform a 90-degree wing-slide and end inverted. K = 32.
11. Again, start inverted and do a stick-back tail slide ending in normal flight. K = 21.
12. From normal flight, do a $\frac{1}{2}$ slow roll in a 45-degree climb and a $\frac{1}{2}$ loop, finishing in normal flight. K = 16.
13. Beginning in normal flight, do three rolls in a horizontal circle to the outside of the turn and end in normal flight. K = 36.
14. Start in normal flight and do a 90-degree wing slide and $\frac{1}{2}$ slow roll in a diving line. End in normal flight. K = 29.
15. Beginning in normal flight, perform a 4-point hesitation roll in a 45-degree climb and end in normal flight. K = 17.

Each contestant is allowed six minutes to perform the 15 maneuvers of Group I (plus 5 minutes for take-off and climb), and the total K-values of this program equal 397. Therefore, a perfect score for this sequence will result in 3,970 contest points per judge; plus up to 800 additional points for good framing within the aerobatic zone, and up to 400 points for good rhythm. The K-value for rhythm is 40; and the K-value for framing is 80. The Group I program is made known to all contestants at least six months in advance.

But the Group II program is called the "Unknown obligatory" group because the contestants are handed this one just 24 hours in advance—and are not allowed to practice it. This is the second flight made by each participant at a national or international contest. It is made up "on the spot" so to speak, by a meeting of the team captains and judges. Team captains take turns selecting maneuvers from a prepared list of Aresti figures until 15 have been picked. Then the judges toss in a couple of turn-around or link-up maneuvers for a total of 17. Eight minutes are allowed for the Group II performance.

Next, in Group III, each pilot chooses his own program. It may consist of as many maneuvers as he thinks he can do within the allotted 10 minutes (you suffer penalty points if you go over the time limit), but this free group may not exceed 700 points of K-value.

At the end of these three performances, the champion team is determined by picking the country possessing the most total points among its top three scorers. The female champion is also chosen at this time.

However, in order to pick the world's individual champion, the top 16 scorers of the first three groups re-fly the unknown obligatory maneuvers and their free groups in a run-off for the title.

Of course, local and regional contests may be simpler; but the Aresti System allows a lot of flexibility for different occasions. But no matter how the ground rules are altered or time limits changed, the Aresti System itself works just as well and is just as indispensable.

You'll understand that I don't have the space here to go deeply into this system. After all, there are 8,000 figures in Aresti's big book. But serious akro-pilots (and fans, too) may join the Aerobatic Club of America for only \$10 per year and get more detailed information. Also, these dues help send an American team to the world contests every two years. families follows. Each figure is shown with its Aresti number, and K-values are displayed in a circle beside each.

A representative list of Aresti figures from each of the nine

LISTA DE FIGURAS

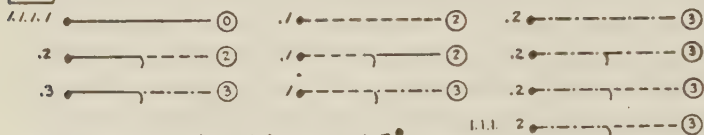
Family ①

①

①①

Horizontal Lines

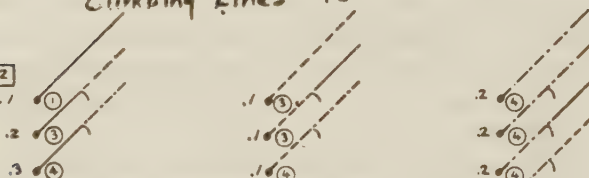
1.1.1



Climbing Lines - 45°

1.1.2

1.1.2.1



Diving Lines - 45°

1.1.3

1.1.3.1



1.1.2.4.2

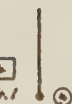


1.1.3.4.2

Vertical Lines

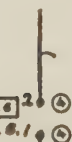
1.1.4

1.1.4.1



1.1.6

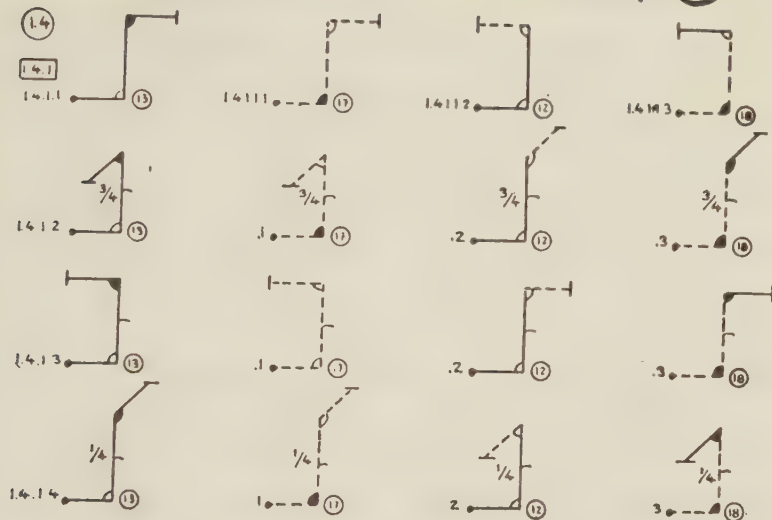
1.1.6.1



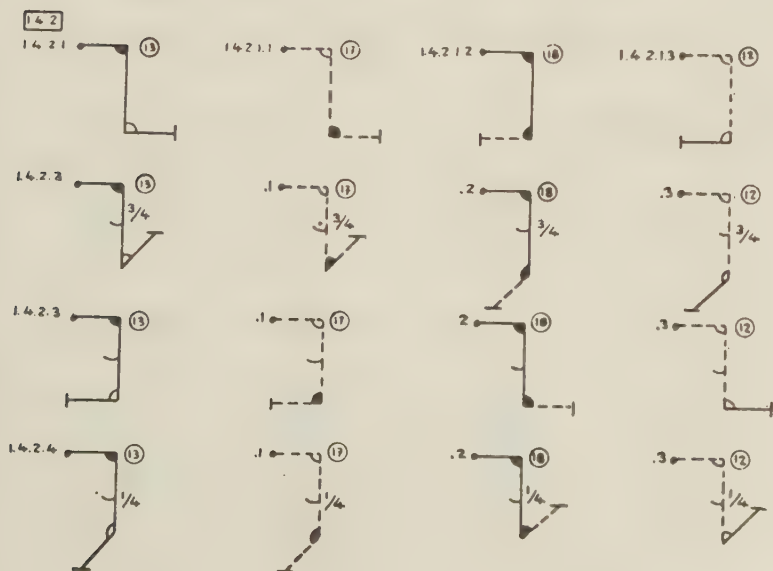
2

Lines plus Angles - 90°

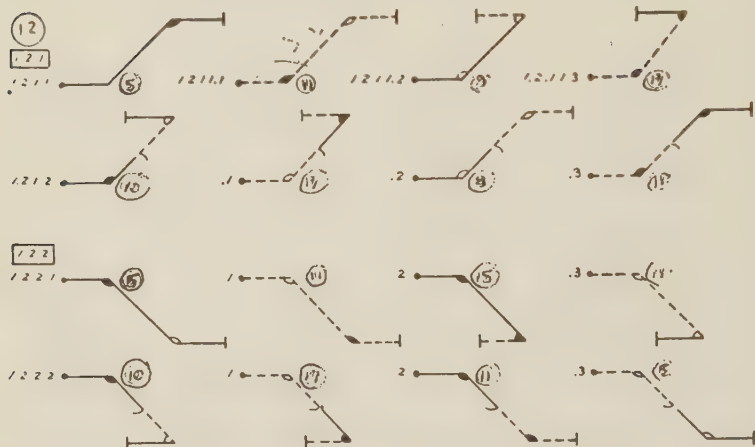
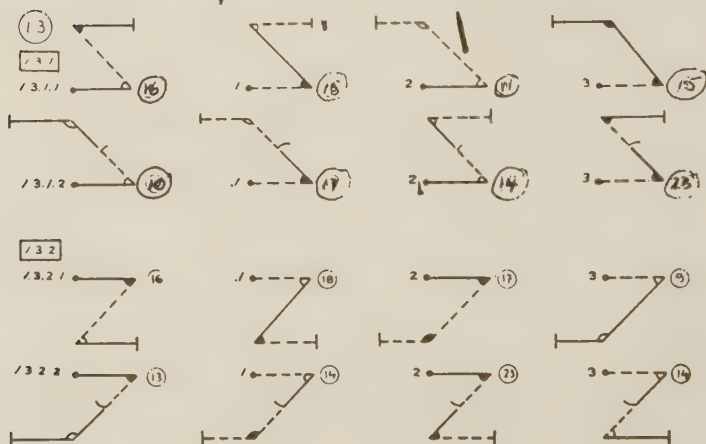
Family (1)



Lines plus Angles - 90° Diving

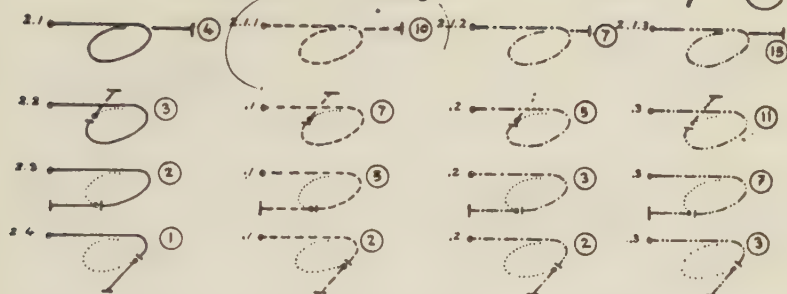


Family (1)

Lines plus Angles - 45° Lines plus Angles - 135° 

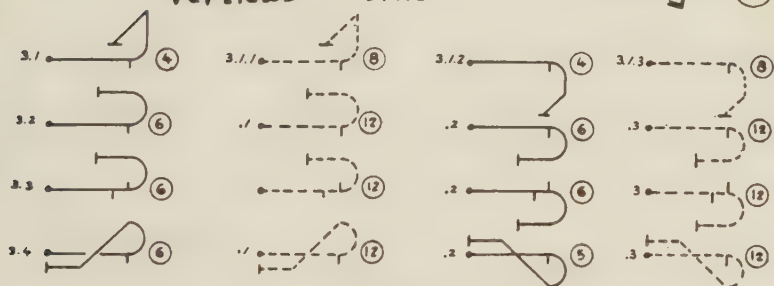
Horizontal Turns

Family (2)



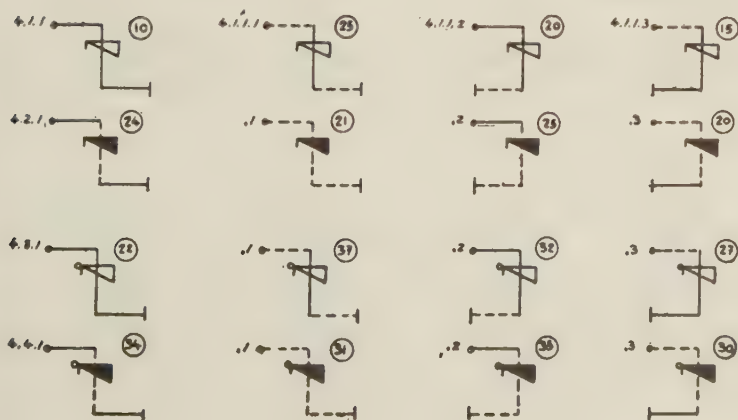
Vertical Turns

Family (3)



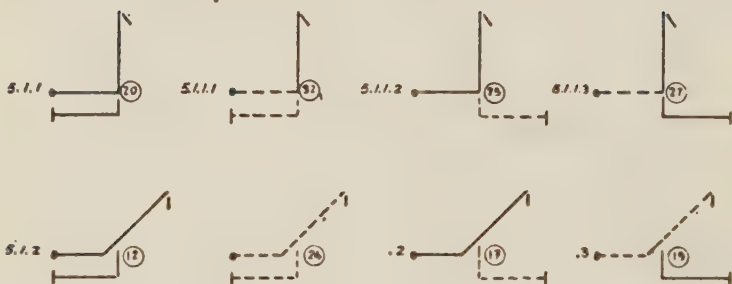
Spins

Family (4)



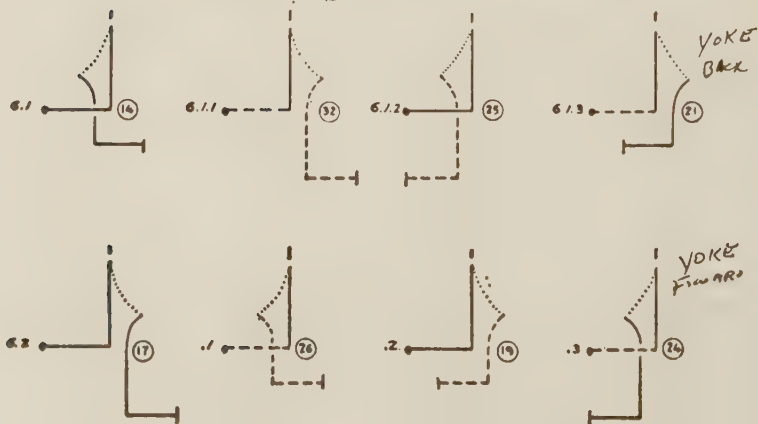
Family ⑤

Wing slides



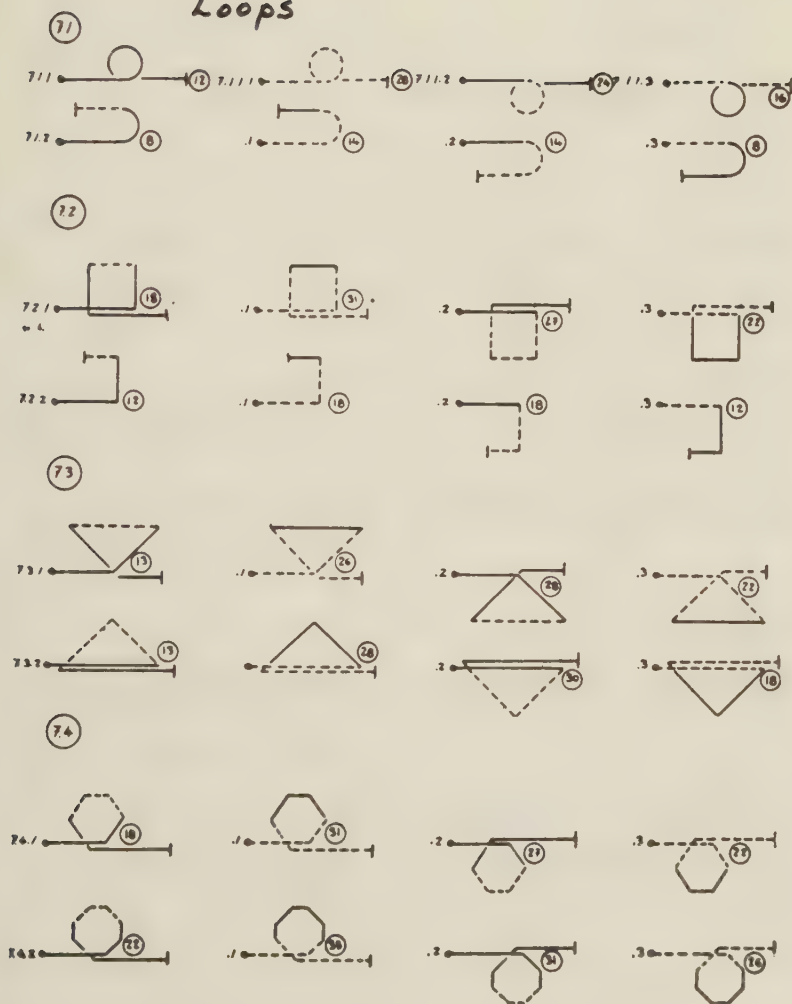
Family ⑥

Tail slides



Family ⑦

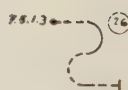
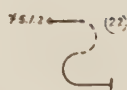
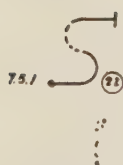
Loops



Family ⑦

Vertical - S

⑦5



⑦6

Vertical - 8



⑦7



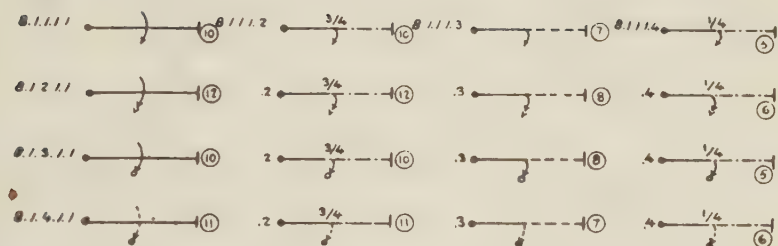
⑦8



slow rolls

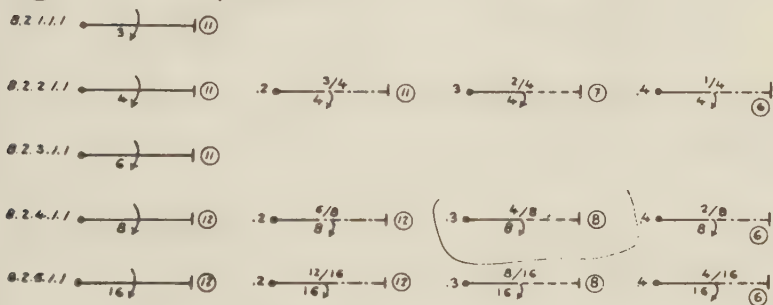
Family 8

(8.1)



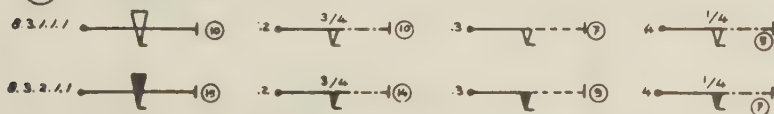
(8.2)

Hesitation rolls



(8.3)

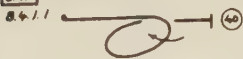
Flick Rolls



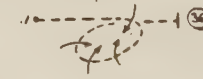
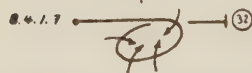
84
84.1

slow roll in horizontal circle Family

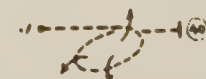
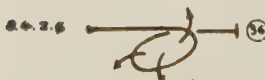
8



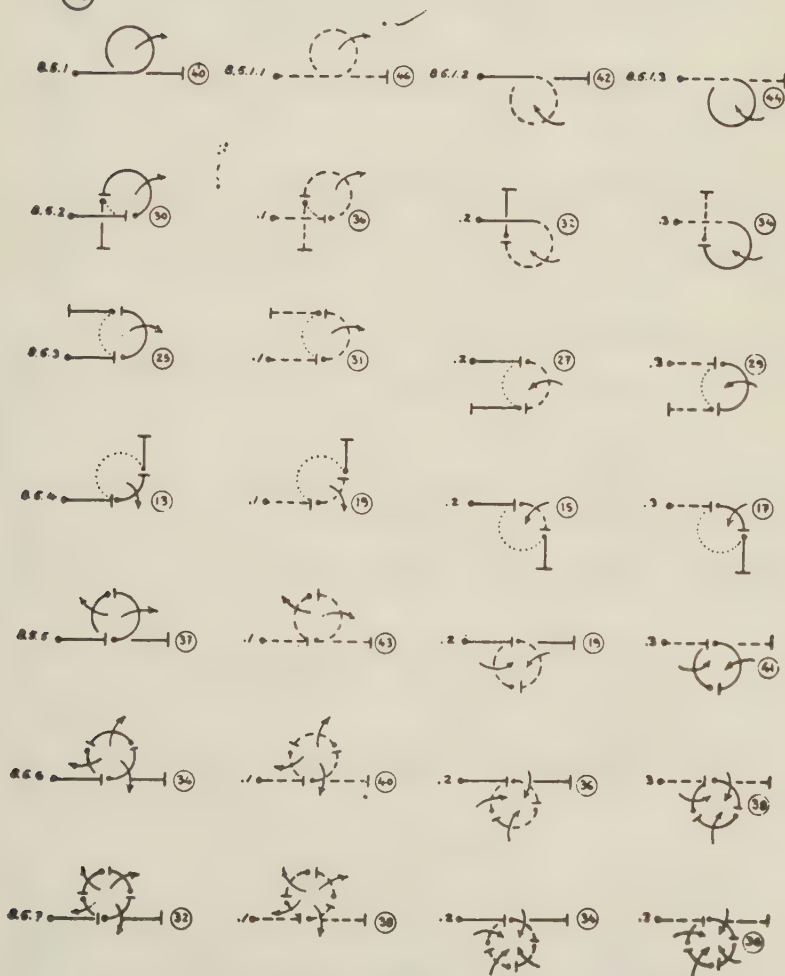
11



roll to outside of turn

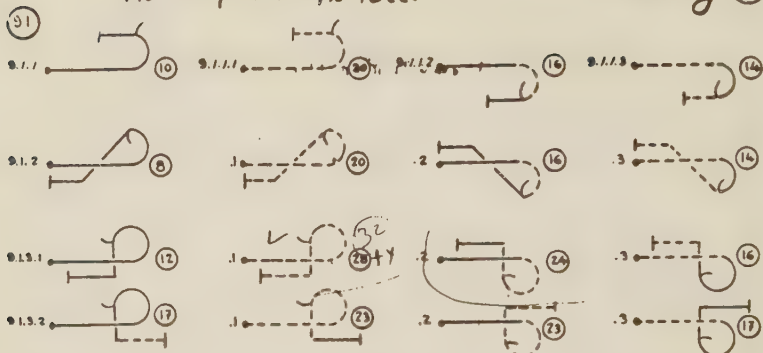


slow roll in vertical circle *Family 8*



$\frac{1}{2}$ loop and $\frac{1}{2}$ roll.

Family ⑨



⑨2

 $\frac{1}{2}$ roll and $\frac{1}{2}$ Loop