

# AEROBATICS FIGURES

## Table of Contents

|                            |           |
|----------------------------|-----------|
| <i>Table of Contents</i>   | <i>1</i>  |
| <i>General Comment</i>     | <i>2</i>  |
| <i>Rolls</i>               | <i>3</i>  |
| Aileron Rolls              | 3         |
| Slow Rolls                 | 3         |
| Snap Rolls                 | 4         |
| <i>Loops</i>               | <i>4</i>  |
| Basic Loop                 | 4         |
| Loop Avalanche             | 5         |
| Square Loop                | 5         |
| Eight Sided Loop           | 5         |
| <i>Half Loops</i>          | <i>6</i>  |
| Immelman                   | 6         |
| Split-S                    | 6         |
| English Bunt               | 7         |
| <i>Cuban Eight Figures</i> | <i>7</i>  |
| Half Cuban Eight           | 7         |
| Cuban Eight                | 7         |
| Reverse Half Cuban Eight   | 8         |
| Reverse Cuban Eight        | 8         |
| Inside-Outside Eight       | 8         |
| <i>Hammerhead</i>          | <i>9</i>  |
| <i>Humpty-Bump</i>         | <i>10</i> |
| <i>Competition Turn</i>    | <i>10</i> |
| <i>Rolling Turn</i>        | <i>11</i> |
| <i>Tailslides</i>          | <i>11</i> |
| <i>Spin</i>                | <i>11</i> |
| <i>Chandelle</i>           | <i>12</i> |
| <i>Wing Over</i>           | <i>12</i> |
| <i>Lazy Eight</i>          | <i>13</i> |
| <i>Barrel Roll</i>         | <i>13</i> |

## General Comment

I didn't think it was necessary, but in these days of frivolous litigations I guess I should include the following:

No pilot should attempt to fly any of these figures in aircraft not certified for aerobatic flight. Further, no pilot should attempt these figures without training from a competent aerobatic instructor. Descriptions contained in these pages are NOT intended as instruction. They are incomplete as instructional material and will get you into trouble if you believe that they are.

This is a list of areobatic figures that have common names. Some of these were invented during aerial combat in WW I. I have included a short verbal description and the IAC symbol for each basic figure.

The symbols for the figures follow the rules of the FAI for depicting aerobatic figures. The figure starts at the small solid circle and ends at the vertical bar. All aerobatics figures start and end from horizontal lines in either upright or inverted flight. In aerobatics competition, most figures can be entered and/or exited from either upright or inverted flight. This affects the difficulty numbers for the figures. In general, the altitude at which the figure is entered does not have to be the same as the exit altitude. Exceptions are for instance the Cuban Eight, all full loops (regular loop, square loop, etc). In cases where the entry and exit lines have to be the same altitude, they are drawn slightly separated to better show them.

The elements used in these figures are horizontal, vertical and 45 degree lines. These describe straight flight in these directions. Solid lines describe upright flight, dashed lines describe inverted flight. Parts of loops connect these line segments (see e.g. the Humpry-Bump). Rolls in 1/4, 1/2, 3/4, etc increments up to 2 rolls can be added to the lines.

The looping portions in almost all figures have to have the same radius in all parts of a figure. For instance the quarter loops going into and coming out of a hammerhead have to have the same radius. There are some figures where this does not apply completely.

Rolls on vertical lines and on 45 degree lines have to be centered on this line to score well. Any deviation from the center results in a downgrading during a competition.

There are other figures that are not in the IAC list of aerobatics figures. These include for instance the Aileron roll and the Barrel roll. I will try to include some descriptions of these too as I go along adding figures.

The K-values included with the competition figures give an indication of the difficulty of each of these maneuvers. Higher K-values mean more difficult maneuvers.

This list is incomplete. If you would like to see a figure included, please let me know about it and I will put it in. Any comments and additions are welcome, especially help with writing the verbal descriptions.

## Rolls

Rolls can be added to most other figures to increase the difficulty factor of the figure. There are two basic types of rolls: slow rolls and snap rolls (flick rolls in european parlance).

### ***Aileron Rolls***

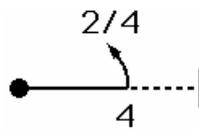
Aileron rolls are flown with the rudder and elevator in the neutral position during the roll. The aileron is fully deflected in the direction of the roll. This is the easiest of the rolls to fly. The aileron roll is started by pulling the nose up to 20 - 30 degrees above the horizon. The elevator is then neutralized and the aileron fully deflected in the direction of the roll. The controls are maintained in that position till the roll is completed. After the roll is completed the nose is usually 20 - 30 degrees below the horizon.

The aileron roll is not a competition maneuver.

### ***Slow Rolls***



1.) (K=10)



2.) (K=7)

Slow rolls have to be flown normally on a straight line (exception is the avalanche). The roll rate has to be constant and the longitudinal axis of the plane has to go straight. This requires constantly changing rudder and elevator control inputs throughout the roll. Hesitation or point rolls include stops at certain roll angles. The number on the base of the roll symbol describes the number of points the roll would have if it were a 360 degree roll. Allowed are 2 point, 4 point and 8 point rolls. The fraction on the arrow of the roll symbol describes what fraction of a full roll is to be executed. If no points are specified, rolling is done without hesitations. If no fraction is specified, a roll symbol that starts at the line specifies a half roll (see description of the Immelman). A roll symbol that crosses the line specifies a full roll (first figure). The second figure shows the symbol for 2 points of a 4 point roll (adding up to half a roll) from upright to inverted flight.

## Snap Rolls



3.) (K=13)



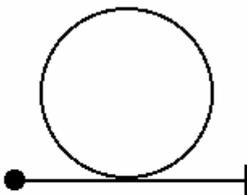
4.) (K=17)

Snap or flick rolls also have to be flown normally on a straight line. A snap roll is similar to a horizontal spin. It is an autorotation with one wing stalled. Figure 3 shows the symbol for a regular snap roll, figure 4 for an outside snap. In the regular snap, the plane has to be stalled by applying positive g forces. In an outside snap, the plane is stalled by applying negative g. In both cases rudder is then used to start autorotation just like in a spin.

## Loops

There are several forms of loops: the basic loop, the loop avalanche, the square loop, and the eight sided loop.

### Basic Loop

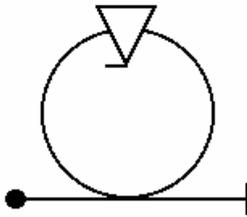


(K=10)

This is one of the most basic maneuvers, but not easy to fly well. It has to be perfectly round, entry and exit have to be at the same altitude. The difficulty in flying this maneuver well is in correcting for effects of wind drift. In competition, it helps if you don't have to fly first, so you can watch what your competitors are doing and judge the wind drift that you have to take into account.

The maneuver starts with a pullup of about 3 - 4 g. Once past the vertical, the back pressure on the elevator is slowly relaxed to float over to top of the loop to keep it round. Past the top, the back pressure is slowly increased again throughout the back part till horizontal flight. The plane has to stay in one plane with the wings orthogonal to the flight path. Rudder is used to maintain the plane of the figure and ailerons are used to maintain the orientation of the wings.

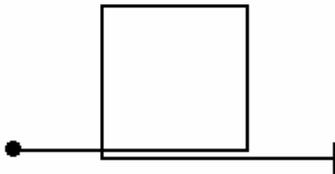
### ***Loop Avalanche***



(K=21)

This is the basic loop with a roll (usually a snap roll) at the top of the loop. The roll has to be centered at the top of the loop.

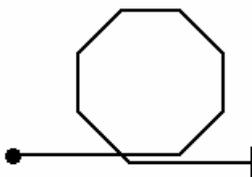
### ***Square Loop***



(K=14)

This is a variation of the basic loop. The two vertical lines and the horizontal line on top have to be of the same length. The exit line at the bottom has to be at least as long as the other three sides. The quarter loops that connect the four sides have to have the same radius at each corner.

### ***Eight Sided Loop***



(K=19)

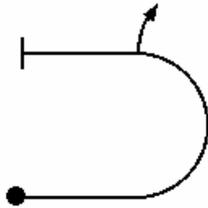
This is another variation of the basic loop. The two vertical lines, the 45 degree lines and the horizontal line on top all have to be of the same length. The exit line at the bottom has to be at least as long as the other seven sides.

The eight loops that connect the eight sides have to have the same radius at each corner.

## Half Loops

Half loops can be combined with half rolls. The loop can either start with pull up or with push down. Furthermore it is possible to start the figure in inverted flight.

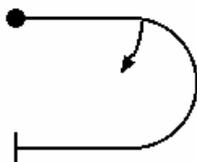
### *Immelman*



(K=10)

The figure starts with a half loop to inverted flight. A half roll then results in horizontal upright flight. This is one of the maneuvers that have been used in WW I to reverse direction. This maneuver does not preserve speed and altitude. It trades speed for altitude.

### *Split-S*

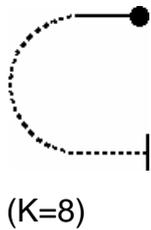


(K=10)

The figure starts with a half roll to inverted followed by the second half of a loop downward.

This is another maneuver to reverse direction. This one, like the immelman, does not preserve speed and altitude. In this case it trades altitude for speed.

### **English Bunt**

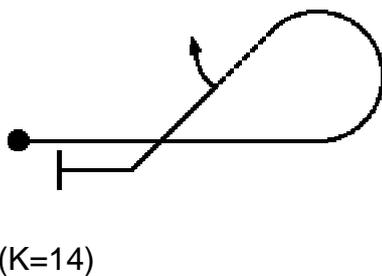


This figure also is the second half of a loop downward, this time an outside loop. You push forward and fly the second half of an outside loop till you are in horizontal inverted flight. Make sure you are not too fast going into the maneuver, otherwise you may exceed redline speed.

### **Cuban Eight Figures**

There are a lot of possibilities to show the figure 8 in the air. If the figure is visible from the top, it is called Lazy Eight. If the figure is visible from the side and horizontally, it is called Cuban Eight.

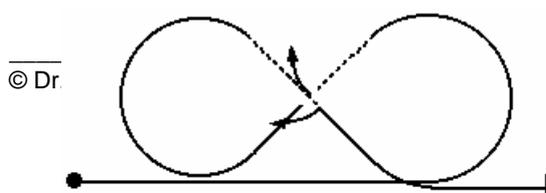
### **Half Cuban Eight**



Five-eighths of a loop to a down-line at a 45 degree angle. The plane is inverted at this point. Centered on this downline is a half roll from inverted to upright. A pullout to horizontal completes the figure.

This is another one of the maneuvers that reverse direction. The downline can be used to adjust the altitude and speed at the end of the figure.

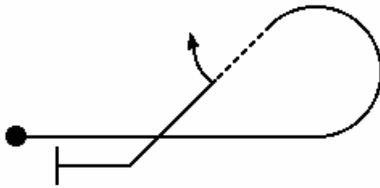
### **Cuban Eight**



(K=29)

Two Half Cuban Eights can be combined to form a Cuban Eight or Lay-down Eight. In this figure in competition the two looping parts have to be flown at the same altitude with the same radius. The exit has to be at the same altitude as the entrance to the figure.

### ***Reverse Half Cuban Eight***

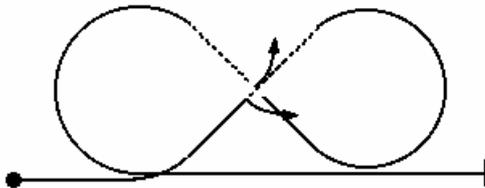


(K=16)

This figure starts with a pull to a 45 degree up-line. Centered on this line is a half roll from upright to inverted. Five-eighths of a loop complete the figure to horizontal flight.

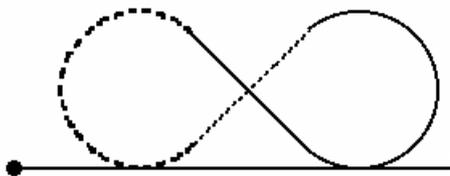
This again is one of the maneuvers that have been used to reverse direction while preserving altitude and airspeed.

### ***Reverse Cuban Eight***



Like the Cuban Eight, a Reverse Cuban Eight can be formed by flying two Reverse Half Cuban Eights back to back.

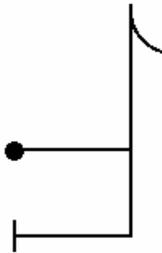
### ***Inside-Outside Eight***



(K=20)

This figure is similar to a Full Cuban Eight, but it does not contain any rolls. The second loop is an outside loop. Again, the two loops have to have the same radius and have to be flown at the same altitude. Entry and exit have to be at the same altitude.

## Hammerhead



(K=17)

It starts with a quarter loop into a vertical climb. When the plane stops climbing, it pivots around its vertical axis (which is now horizontal). The nose moves in a vertical circle from pointing up through the horizon to pointing down. After moving vertically down to pick up speed again, the maneuver is finished with the last quarter of a loop to horizontal flight. This figure can have optionally rolls on both the up-line and the down-line.

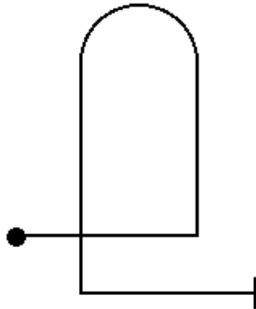
The quarter loop is flown just like the first part of a loop. When the plane is vertical, the elevator backpressure is released completely. During the vertical line up, some right aileron and right rudder is needed to maintain the vertical attitude because of the engine torque and p-factor. When the plane has slowed enough, full rudder initiates the turnaround. It is followed by right-forward stick (right aileron and forward elevator) to keep the plane from torquing off.

The pivot is stopped with opposite rudder when the nose points straight down. When the pivot is completed, the ailerons and rudder are neutralized. Elevator and rudder are used to keep the nose pointing straight down. The pivot must be completed within one wingspan. Rolls on the downline require only aileron input if the plane is trimmed correctly.

This maneuver is sometimes called a hammerhead stall. This is not an accurate name because the airplane never stalls. The airspeed may be very low, close to zero, but since there is no wingloading during the turn-around, there is no stall (at zero g wing loading, a wing does not stall). The plane is flying throughout the maneuver with all the control surfaces effective (although sometimes only marginally so).

This also is one of the maneuvers that have been used to reverse direction while adjusting altitude and airspeed by changing the length of the down-line.

## Humpty-Bump



(K=13)

The figure starts with a quarter loop to a vertical climb. A half loop then results in a vertical down-line. The figure completes with another quarter loop to horizontal flight. The looping part on the top of the figure does not have to be the same radius as the two other looping portions (the quarter loops going into and coming out of the humpty). Again the figure can have optionally rolls on both the up-line and the down-line.

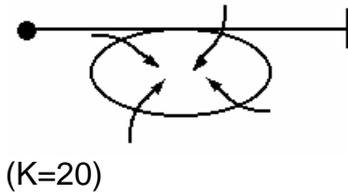
## Competition Turn



(K=5)

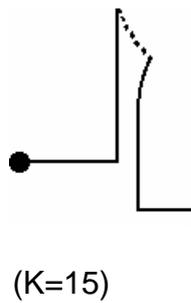
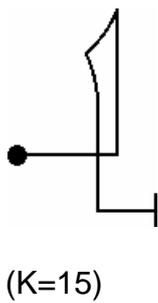
Competition turns are not the coordinated maneuvers that you use in normal flying. In a competition turn you first roll to the desired bank. It has to be at least 60 degrees. My experience shows that the steeper the bank, the better the scores. I try to get close to 90 degrees bank. Once the bank is established the turn is started. The plane has to maintain a constant bank and altitude throughout the turn. At the end of the turn the turn is stopped and then the wings leveled for horizontal flight. The example shows the symbol for a 270 degree turn.

## Rolling Turn



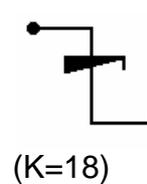
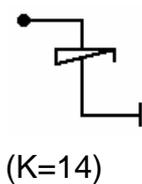
This maneuver combines a turn with rolls. The example shows a 360 degree turn with four rolls to the inside. The plane has to maintain a constant roll rate, constant turn rate and constant altitude throughout the rolling turn. This maneuver is quite difficult to fly. It requires constantly changing inputs from all three controls (rudder, aileron, elevator).

## Tailslides



These maneuvers involve bringing the airplane to a complete stop in a vertical attitude and then sliding back a visible amount. The airplane must then tip over and fall through a vertical down position. The left figure indicates a tailslide with the wheels down during the flip, the right figure is a tailslide with the wheels up (inverted) during the flip. Going into the figure and coming out, the same rules apply as for other figures (quarter loops of constant and equal radius, vertical lines).

## Spin



Spins also are aerobatics competition maneuvers. The two figures show a regular and an inverted crossover one turn spin. Spins come in  $3/4$ , one,  $1\ 1/4$  and  $1\ 1/2$  turns.

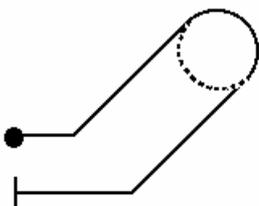
During spin entry, the plane has to show a stall break, followed by the auto-rotation. The rotation has to stop exactly after the specified number of turns. Once the rotation has stopped, a vertical downline has to be established.

In a crossover spin, the plane is first stalled upright. At the stall break, the nose is pushed forward to get into an inverted spin while maintaining the stall. The inverted spin is then completed as it would be for an inverted spin with entry from inverted flight.

## Chandelle

The Chandelle is not a figure for aerobatics competition. On the FAA power commercial pilots test a Chandelle is defined as a maximum performance climbing turn through 180 degrees while maintaining a constant turn rate. The idea is that this is a "plan ahead" maneuver. You first establish a medium bank depending on the performance of your aircraft. Then a smooth pullup is started. The angle of bank stays constant during the first 90 degrees of turn, while the pitch angle increases steadily. At the 90 degree point the plane has the maximum pitch angle which should be close to the critical angle of attack. During the second 90 degrees of turn, the pitch angle is held constant, while the bank angle is smoothly decreased to reach 0 degrees of bank at 180 degrees of turn with the airspeed close to the stall speed. The plane should not settle during the last part of the maneuver and the recovery. The decreasing bank angle during the second half of the Chandelle will maintain a constant turn rate together with the decreasing airspeed. The turn needs to be kept coordinated by applying the right amount of rudder. A Chandelle to the left is quite different than one to the right because of the ever increasing amount of p-factor in the second half of the maneuver.

## Wing Over



(K=6)

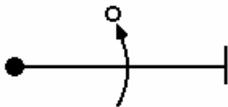
The Wing-Over is a competition maneuver in glider aerobatics. You pull up and at the same time bank the plane. When the bank increases past 45 degrees, the nose will

start to drop while the bank keeps increasing and the plane keeps turning. Halfway through the maneuver, the plane has turned 90 degrees, the fuselage is level with the horizon and the bank is 90 degrees. The plane is above the original flight path. The nose then keeps dropping below the horizon and the plane keeps turning, while the bank is shallowed. When the bank drops below 45 degrees, the nose is pulled up towards the horizon and the plane reaches horizontal flight with wings level after 180 degrees of turn. At the completion of the maneuver, the plane is at the same altitude as on entry and flying in the opposite direction.

## Lazy Eight

Like the Chandelle, the Lazy Eight is not a competition maneuver but is required for the power commercial pilot test. The aerobatics version of the Lazy Eight is two wingovers back to back. The FAA commercial pilot version is similar but the maximum bank is only 45 degrees instead of 90 degrees. The name Lazy Eight comes from the fact that the nose of the airplane is following a figure 8 on its side on the horizon.

## Barrel Roll



The Barrel Roll is a not competition maneuver. The barrel roll is a combination between a loop and a roll. You complete one loop while completing one roll at the same time. The flight path during a barrel roll has the shape of a horizontal cork screw. Imagine a big barrel, with the airplanes wheels rolling along the inside of the barrel in a cork screw path. During a barrel roll, the pilot experiences always positive G's. The maximum is about 2.5 to 3 G, the minimum about 0.5 G.