RESEARCH MEMORANDUM

TIME-HISTORY DATA OF MANEUVERS PERFORMED BY A MCDONNELL F2H-2 AIRPLANE DURING SQUADRON OPERATIONAL TRAINING

By Carl R. Huss, William H. Andrews, and Harold A. Hamer

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SUMMARY

Preliminary results of one phase of a control-motion study program are presented in time-history form and are summarized as plots of load factors and angular accelerations against indicated airspeed. The results were obtained from 276 maneuvers performed by a McDonnell F2H-2 jet fighter airplane during normal squadron operational training. Most of the tactical maneuvers that the F2H-2 airplane is capable of performing are included in the data. The maneuvers were performed at pressure altitudes of 0 to 40,000 feet and at indicated airspeeds of 75 to 500 knots.

INTRODUCTION

The present methods of determining tail-surface design loads require, among other things, a knowledge of the control-surface motion. In the usual methods, control-surface motions or load-factor variations with time are specified so as to obtain maximum design loads; however, the actual control motions and load-factor variations obtained in regular operational flying may differ appreciably from the specified variations.

In order to obtain information on the actual control motions used in flight the National Advisory Committee for Aeronautics in cooperation with the Bureau of Aeronautics, Department of the Navy, and the U. S. Air Force is conducting a control-motion study program. This program is directed toward obtaining sample measurements on several fighter-type airplanes of rates, amounts, and combinations of control motions used by service pilots in carrying out regular operational training missions. From the results obtained from this program it may be possible to specify a more practical design criterion for tail-surface loads based on the actual critical control-surface motions. In addition, information may be obtained which could be useful in the design of airplane control boost systems. Reference 1 was the first report of data obtained from this program.
This paper includes data in time-history form of maneuvers obtained by an F2H-2 airplane while performing regularly scheduled operational training missions. In order to make the data included in the time histories immediately available, only a minor analysis of the data is included in this paper.

TEST AIRPLANE

A standard United States Marine Corps McDonnell F2H-2 airplane, BuAer serial number 123256, was used for these tests. The F2H-2 airplane is a single-place, straight-wing, two-engine carrier- or land-based, jet-propelled fighter. It is powered by two Westinghouse J-34-WE-34 turbojet axial-flow engines mounted, one on either side of the fuselage, in the wing center section. It has speed brakes located in the upper and lower wing surfaces inboard of the aileron and just ahead of the partial-span flaps. These speed brakes consist of perforated rectangular plates which are extended vertically from the wing surfaces and are either in the "out" or "in" position. A hydraulic boost system was incorporated in the aileron control system.

The external appearance of the test airplane was unaltered by the NACA instrumentation except for the installation of a boom mounted in the nose of the airplane, used for measuring the sideslip angle, and a small electrical control-position transmitter mounted externally on the right-wing lower surface. A three-view drawing of the F2H-2 airplane is presented in figure 1 and its pertinent physical characteristics are given in table I.

INSTRUMENTS

Standard NACA photographically recording instruments were used to measure (1) the quantities defining the flight conditions; that is, airspeed, altitude, and speed-brake position, (2) the control-surface motions, and (3) the response of the airplane in terms of angular velocities, load factors, and sideslip angle. The recorders were synchronized at 1-second intervals by means of a common timing circuit.

In order to relieve the pilot of any recording-instrument switching procedure and thus assist in obtaining normal operations, a pressure switch was used to automatically turn on the recording instruments at an indicated airspeed of approximately 80 knots. All recorders were mounted in the nose section with the exception of the angular-velocity recorders which were located in the aft radio compartment.
A standard two-cell pressure recorder connected to the airplane service system was used to measure the altitude and airspeed. The service system employs a total-pressure tube located on the leading edge of the vertical tail and flush static-pressure orifices on both sides of the fuselage below the windshield. (See fig. 1.)

A microswitch was used on the right speed brake to indicate the "in" or "out" position of this surface. The control-surface angles were measured by a control-position recorder having remote recording electrical transmitters installed at the control surface. The elevator and rudder transmitters were installed inside the tail fairing to take measurements in the vicinity of the inner hinge. Aileron deflections were obtained with a transmitter located externally at approximately the aileron midspan.

Angular velocities were recorded about three mutually perpendicular axes in which the X-axis is parallel to the fuselage reference line. (See fig. 1.) Load factors along these three axes were recorded by an air-damped three-component accelerometer located in the fuselage 76.5 inches forward, 14 inches to the right, and 10 inches above the average flight center-of-gravity location (26.5 percent of the wing mean aerodynamic chord).

The sideslip angle was measured by a flow directional recorder using a vane mounted on a boom 6 feet ahead of the fuselage nose. The boom was mounted in the left cannon port nearest the airplane center line. (See fig. 1.)

The estimated accuracies based on the instrument accuracy and a reading accuracy of 0.01 inch are as follows:

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indicated airspeed, $V_i$, knots</td>
<td>±5</td>
</tr>
<tr>
<td>Pressure altitude, $H_p$, ft</td>
<td>±50</td>
</tr>
<tr>
<td>Control position, deg</td>
<td>±0.5</td>
</tr>
<tr>
<td>Normal load factor</td>
<td>±0.05</td>
</tr>
<tr>
<td>Longitudinal and transverse load factor</td>
<td>±0.02</td>
</tr>
<tr>
<td>Rolling angular velocity, radians per second</td>
<td>±0.10</td>
</tr>
<tr>
<td>Pitching and yawing angular velocity, radians per second</td>
<td>±0.02</td>
</tr>
<tr>
<td>Sideslip angle, deg</td>
<td>±0.3</td>
</tr>
</tbody>
</table>

All the recording instruments were damped to about 0.65 of critical damping at sea level. The natural frequency of the elements in the three-component accelerometer was selected to give the best compromise value which would minimize the magnitudes of extraneous vibratory accelerations and still give correct response to the maneuver accelerations.

In order to expedite the presentation of time-history results all the instruments were adjusted to specified sensitivities and the film drums were selected so that they ran at the same constant speed. Thus in many
cases it was possible to trace the record lines directly on special grid paper with the exception of the airspeed and altitude which had to be plotted. Those records on which either the film speed had deviated from the selected standard or in which it was desired to change the sensitivity for better presentation of the data were processed on a newly developed enlarger. The enlarger effectively enabled the time scale or longitudinal dimension of the film and the scale or vertical dimension of the film to be either increased or decreased independently of each other so that the film record could be adjusted to fit accurately the scale of the grid paper. It is believed that this method has permitted a detailed, accurate, and rapid reproduction of the film records in time-history form.

TESTS

The tests consisted of 18 normal squadron operational training missions carried out during the months of February to April 1951. Included in these 18 flights were acrobatic, gunnery, bombing, and pilot familiarization missions. The maneuvers obtained from these missions were performed at altitudes from 0 to 40,000 feet and at airspeeds from 75 to 500 knots and included such maneuvers as turns, dives and pull-outs, pull-ups, slow rolls, barrel rolls, loops, Immelmans, lazy eights, Cuban eights, wing-overs, and stalls.

The test airplane normally is equipped with wing-tip tanks; however, all the maneuvers reported were performed with the wing-tip tanks empty.

Enough film was carried during each flight to allow 30 minutes of flight time to be recorded. This was usually sufficient time to record the complete flight. In this program 17.5 hours of flight time were recorded of which 2.5 hours are presented in this paper as maneuvers in time-history form.

Twelve pilots flew the test airplane during the course of this program. No pilot accounted for more than 10 percent of the total flight time. In an effort to obtain records which would contain representative samples of normal piloting technique in the performance of the maneuvers, the pilots were assured that the instrumentation would not restrict them as to type of maneuver, manner of control manipulation, or severity of maneuvering. It is also of interest to note that during these tests all of the pilots wore antigravity suits.
METHODS AND RESULTS

The results of this flight program are presented in figures 2 to 282. All the maneuvers performed during the 18 flights plus 3 landings are presented in figures 2 to 277 as time histories of the measured quantities. The three landings include a short portion of the landing approach prior to and including main-gear touch-down and were made by three different pilots. The time histories are arranged in this paper according to maneuver classification as given in table II. Included in the legends of these figures is the classification of the type of maneuver, estimated airplane weight, and estimated flight center-of-gravity location. The classification of the maneuvers was, of necessity, done in a general sense as it was sometimes difficult to determine from the flight records exactly the type of maneuver performed. However, it was comparatively simple to determine when the airplane was maneuvering, since in normal steady flight the record traces were fairly straight lines on or near the trim or zero position for the particular trace and during a maneuver the traces would, of course, vary from their trim or zero position. Some of the standard maneuvers are interpreted in references 2 and 3. The in-flight airplane weight and center-of-gravity location were estimated on the basis of the total amount of fuel used and the time of the flight including warm-up and taxiing.

In these time histories the airspeed is indicated airspeed, defined as the reading of a differential-pressure airspeed indicator, calibrated in accordance with the accepted standard adiabatic formula to indicate true airspeed for standard sea-level conditions only (uncorrected for instrument and installation errors), and the altitude is the NACA standard pressure altitude. The control-position curves shown were measured with respect to their neutral position. Only the right aileron position was measured. It will be noted in figures 275 to 277 that the rudder trace has been dotted to avoid confusion with other traces. The position of the speed brakes is indicated on the time histories by the dash line and the words "brakes out."

In these figures load factors associated with forces acting up, forward, and to the left are positive. Nose up, nose right, and right wing down are positive for the pitching, yawing, and rolling angular velocities which are given in radians per second. No angular-velocity or angular-acceleration corrections to the recorded load factors, due to the displacement of the accelerometer from the center of gravity, have been made in these time histories.

The sideslip angle indicates the lateral angle between the airplane longitudinal axis and the relative wind.
A comparison between the maximum normal load factors obtained in these tests and the operational V-n diagram is presented in figure 278. The V-n envelopes shown in this figure as solid and dashed lines are the operational limitations for the test airplane at a gross weight of 16,400 pounds as specified by the Bureau of Aeronautics. The maximum normal load factors in figure 278 were taken directly from the time histories and are plotted without any angular-velocity or angular-acceleration corrections because such corrections were found to be small. Since the average flight weight of the airplane during this program was approximately 16,100 pounds, the values have been plotted without being corrected for weight. Only selected values of maximum normal load factor have been plotted to demonstrate to what extent the operational limit envelopes for altitude, airspeed, and normal load factor were obtained.

The maximum transverse load factors and corresponding indicated airspeeds are presented in figure 279. Because of the large number of transverse load factors available from the time histories, only the values above the arbitrary lower limit of 0.05 are shown. All the points given in this figure have been corrected for rolling and yawing angular velocity and angular acceleration.

The maximum pitching-, rolling-, and yawing-angular-acceleration variations with indicated airspeed are shown in figures 280, 281, and 282, respectively. The values of acceleration were obtained from the maximum slope of the appropriate angular-velocity curve in the time histories. As in the case of transverse load factor, only the values above some arbitrary limit are presented. These limits were 0.1 radian per second per second for pitch and yaw and 0.5 radian per second per second for roll.

DISCUSSION

The results of this investigation, as shown in figure 278, indicate that the present sampling of maneuvers includes, for the positive-load-factor region, the operational capabilities of the F2H-2 airplane. Although this investigation was limited to a few hours of actual flying time, the data obtained represent a cross section of the maneuvers performed during operational training and include most of the tactical maneuvers used by the test airplane.

Examination of the time histories indicates that usually the higher positive normal load factors were associated with pull-up or pitching types of maneuvers. In this program the highest positive value of normal load factor, 6.2, was obtained during an abrupt left turn. (See fig. 53.) The other high values between 5 and 5.5 occurred in
pull-outs and pull-ups during dives, loops, Immelmans, and Cuban eights. (See figs. 140, 151, 230, 245, 253, 258, and 272.) The largest negative normal load factors, -0.5, were associated with rolling maneuvers, usually a slow roll. (See figs. 151 and 166.)

It is evident from the maximum values of normal load factor obtained that the maximum operational value of normal load factor, 6.4, was not exceeded during these tests; furthermore, figure 278 indicates that at no time during these tests were the operational limits for combinations of load factor, airspeed, and altitude exceeded.

The maximum values of transverse load factor shown on the time histories are -0.26 (fig. 51) and -0.22 (fig. 53). However, when the angular-velocity and angular-acceleration corrections are added to these values, the maximum transverse load factors become -0.34 and -0.29. Both of these maximum values occurred during abrupt left turns. Examination of figure 279 indicates that the value of maximum transverse load factor was usually between ±0.1.

Longitudinal load factors were usually small. The largest deflection of the longitudinal-load-factor trace was a deceleration caused by the extension of the speed brakes. This speed-brake effect amounted to about -0.4 at 400 knots and 12,000 feet altitude. (See fig. 274.)

As would be expected, the largest rates and amounts of elevator movement occur during landings and maneuvers that necessitated pull-ups, such as Immelman, loop, entry into a stall, and recovery from dives. The largest positive elevator movement occurred in pull-ups, Immelmans, pull-outs, stall, loops, and landings. (See figs. 68, 93, 152, 245, 248, 251, 253, 273, and 277.) The greatest negative elevator movement occurred in push-overs, stalls, and landings. (See figs. 106, 273, and 277.) Greater negative rates of elevator movement were obtained than positive rates. (See figs. 106 and 273.)

The largest pitching accelerations obtained in these tests occurred at about 300 knots (fig. 280) and decreased above and below this airspeed. The greatest negative pitching acceleration, -1.4 radians per second per second, occurred during a recovery from a pull-up (fig. 83) and was about twice as large as the greatest positive pitching acceleration which occurred during an abrupt left turn. (See fig. 49.) This maximum value is about half of the value obtained for an airplane weight of 16,000 pounds from the envelope of maximum pitching accelerations given in reference 4.

The largest aileron displacement and rates of movement occurred during rolling maneuvers. An estimate of the magnitude of aileron rates and movements can be obtained from the time histories, such as figures 52, 152, 155, 197, 200, 228, 242, 254, and 256.
The maximum rolling accelerations obtained in these tests occurred at about 325 knots (fig. 261) and decreased above and below this airspeed. The maximum values occurred during an abrupt left turn (fig. 52) and amounted to 4.72 and -5.8 radians per second per second.

The maximum rolling velocity recorded in these tests occurred during slow rolls (figs. 155 and 157) and amounted to 1.7 radians per second at an altitude of about 10,000 feet and an indicated airspeed of about 300 knots. This value is less than the maximum obtainable rolling velocity of 2.5 radians per second at an altitude of 10,000 feet and an indicated airspeed of 310 knots as given in unpublished data for a McDonnell F2H-1 airplane.

In general, little rudder movement was used in any of the maneuvers. The greatest amount of rudder movement occurred in landings, stalls, rolls, split-S, and Immelman maneuvers. (See figs. 276, 251, 273, 154, 202, 203, 217, 226, 242, 253, 255, and 254.) The time histories show that these maximum rudder movements are usually associated with high yawing velocities, large sideslip angles, and large aileron movements. This result is to be expected since the rudder and aileron movements are usually coordinated.

The maximum yawing accelerations in these tests, as shown in figure 282, occurred at about 325 knots and decreased above and below this airspeed. These maximum values occurred during abrupt left turns (see figs. 51 and 53) and amounted to about -0.6 and 0.5 radian per second per second.

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National Advisory Committee for Aeronautics
Langley Field, Va.
REFERENCES


**TABLE I**

**PHYSICAL CHARACTERISTICS OF TEST AIRPLANE**

<table>
<thead>
<tr>
<th>Wing:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Total area (including flaps, ailerons, and 33.3 sq ft covered by fuselage), sq ft</td>
<td>294.1</td>
</tr>
<tr>
<td>Span (horizontal with tip tanks), in.</td>
<td>539.9</td>
</tr>
<tr>
<td>Span (horizontal without tip tanks), in.</td>
<td>500.8</td>
</tr>
<tr>
<td>Aspect ratio</td>
<td>5.89</td>
</tr>
<tr>
<td>Taper ratio (c&lt;sub&gt;tip&lt;/sub&gt;/c&lt;sub&gt;root&lt;/sub&gt;)</td>
<td>0.52</td>
</tr>
<tr>
<td>Mean aerodynamic chord (at wing station 111.0 measured normal to airplane center line), in.</td>
<td>88.37</td>
</tr>
<tr>
<td>Sweepback (leading edge), deg</td>
<td>0</td>
</tr>
<tr>
<td>Sweepforward (0.25-chord line), deg</td>
<td>4.33</td>
</tr>
<tr>
<td>Root airfoil section</td>
<td>NACA 651-212</td>
</tr>
<tr>
<td>Tip airfoil section</td>
<td>NACA 63-209</td>
</tr>
<tr>
<td>Incidence of root section chord (measured from fuselage reference line), deg</td>
<td>-0.5</td>
</tr>
<tr>
<td>Incidence of tip section chord (measured from fuselage reference line), deg</td>
<td>-0.5</td>
</tr>
<tr>
<td>Dihedral (measured from wing reference plane), deg</td>
<td>3</td>
</tr>
<tr>
<td>Aileron area (one), sq ft</td>
<td>9.42</td>
</tr>
<tr>
<td>Aileron span, in.</td>
<td>88.4</td>
</tr>
<tr>
<td>Aileron root-mean-square chord, in.</td>
<td>15.42</td>
</tr>
<tr>
<td>Aileron static control limits, deg</td>
<td>±20</td>
</tr>
<tr>
<td>Dive brakes (total area including cut-outs), sq ft</td>
<td>11.6</td>
</tr>
<tr>
<td>Distance from nose to leading edge of mean aerodynamic chord, in.</td>
<td>1.197</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Horizontal tail:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Total area (including 17.66 sq ft of elevator), sq ft</td>
<td>69.8</td>
</tr>
<tr>
<td>Span, in.</td>
<td>224.7</td>
</tr>
<tr>
<td>Aspect ratio</td>
<td>4.65</td>
</tr>
<tr>
<td>Taper ratio</td>
<td>0.603</td>
</tr>
<tr>
<td>Mean aerodynamic chord (horizontal-tail station 49.63 measured normal to airplane center line), in.</td>
<td>47.4</td>
</tr>
<tr>
<td>Airfoil section</td>
<td>NACA 65(10)-011</td>
</tr>
<tr>
<td>Incidence (measured from fuselage reference line), deg</td>
<td>0.42</td>
</tr>
<tr>
<td>Dihedral, deg</td>
<td>0</td>
</tr>
<tr>
<td>Tail length (leading edge of wing mean aerodynamic chord to 25 percent of mean aerodynamic chord of horizontal tail), in.</td>
<td>225.2</td>
</tr>
<tr>
<td>Elevator area (including 0.523 sq ft of horn area, 0.758 sq ft of trim-tab area, and 1.426 sq ft of spring-tab area) (one), sq ft</td>
<td>9.375</td>
</tr>
</tbody>
</table>
TABLE I

PHYSICAL CHARACTERISTICS OF TEST AIRPLANE - Continued

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elevator span (one), in.</td>
<td>94.1</td>
</tr>
<tr>
<td>Elevator root-mean-square chord, in.</td>
<td>13.65</td>
</tr>
<tr>
<td>Elevator static control limits, deg</td>
<td>±15</td>
</tr>
<tr>
<td>Vertical tail:</td>
<td></td>
</tr>
<tr>
<td>Total area (including 1.63 sq ft of dorsal area) sq ft</td>
<td>40.5</td>
</tr>
<tr>
<td>Span, in.</td>
<td>86.0</td>
</tr>
<tr>
<td>Aspect ratio</td>
<td>1.34</td>
</tr>
<tr>
<td>Taper ratio</td>
<td>0.453</td>
</tr>
<tr>
<td>Mean aerodynamic chord (at water line 98.59 parallel to airplane reference line), in.</td>
<td>67.25</td>
</tr>
<tr>
<td>Airfoil section</td>
<td>NACA 65(10)-011</td>
</tr>
<tr>
<td>Tail length (leading edge of wing mean aerodynamic chord to 25 percent of mean aerodynamic chord of vertical tail), in.</td>
<td>227.46</td>
</tr>
<tr>
<td>Rudder area, sq ft</td>
<td>10.13</td>
</tr>
<tr>
<td>Rudder span, in.</td>
<td>86.0</td>
</tr>
<tr>
<td>Rudder root-mean-square chord, in.</td>
<td>17.2</td>
</tr>
<tr>
<td>Rudder static control limits, deg</td>
<td>±20</td>
</tr>
<tr>
<td>Fuselage:</td>
<td></td>
</tr>
<tr>
<td>Total length (not including nose boom), in.</td>
<td>481.8</td>
</tr>
<tr>
<td>Maximum width, in.</td>
<td>46.9</td>
</tr>
<tr>
<td>Height (vertical tail above static ground line), in.</td>
<td>173.5</td>
</tr>
<tr>
<td>Frontal area (including 2.535 sq ft of canopy frontal area above fuselage), sq ft</td>
<td>18.185</td>
</tr>
<tr>
<td>Side area (including 7.43 sq ft of canopy side area above fuselage), sq ft</td>
<td>158.93</td>
</tr>
<tr>
<td>Plan area, sq ft</td>
<td>116.8</td>
</tr>
<tr>
<td>Tip tanks:</td>
<td></td>
</tr>
<tr>
<td>Frontal area, sq ft</td>
<td>3.30</td>
</tr>
<tr>
<td>Fineness ratio</td>
<td>7.398</td>
</tr>
<tr>
<td>Capacity, gal</td>
<td>200</td>
</tr>
<tr>
<td>Power plant (two)</td>
<td>Westinghouse J-34-WE-34</td>
</tr>
<tr>
<td>Airplane weight (includes 2 cannons, no ammunition, instruments, 210 lb. pilot with parachute, fuel in all tanks except wing-tip tanks, and ballast), lb</td>
<td>17,944</td>
</tr>
<tr>
<td>Airplane center-of-gravity position corresponding to the airplane weight of 17,944 lb and with gear down, percent wing mean aerodynamic chord</td>
<td>26.59</td>
</tr>
</tbody>
</table>
TABLE I

PHYSICAL CHARACTERISTICS OF TEST AIRPLANE - Concluded

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Airplane center-of-gravity position corresponding to the airplane weight of 17,944 lb and with gear up, percent wing mean aero-dynamic chord</td>
<td>26.80</td>
</tr>
<tr>
<td>Airplane weight (average flight weight), lb</td>
<td>16,145</td>
</tr>
<tr>
<td>Airplane center-of-gravity location corresponding to average airplane flight weight (clean condition), percent wing mean aero-dynamic chord</td>
<td>26.47</td>
</tr>
<tr>
<td>Estimated moments of inertia (wing-tip tanks on but empty), slug/ft²:</td>
<td></td>
</tr>
<tr>
<td>Iₓ</td>
<td>18,982</td>
</tr>
<tr>
<td>Iᵧ</td>
<td>26,288</td>
</tr>
<tr>
<td>Iₜ</td>
<td>42,679</td>
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</table>
TABLE II

MANEUVER CLASSIFICATION AND ARRANGEMENT

<table>
<thead>
<tr>
<th>Maneuver classification</th>
<th>Figures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right turns</td>
<td>2 to 18</td>
</tr>
<tr>
<td>Left turns</td>
<td>19 to 53</td>
</tr>
<tr>
<td>Series of turns</td>
<td>54 to 67</td>
</tr>
<tr>
<td>Pull-ups</td>
<td>68 to 103</td>
</tr>
<tr>
<td>Push-over</td>
<td>104 to 106</td>
</tr>
<tr>
<td>Pull-up push-over combination</td>
<td>107 to 108</td>
</tr>
<tr>
<td>Dives with various recoveries</td>
<td>109 to 153</td>
</tr>
<tr>
<td>Right slow rolls</td>
<td>154 to 167</td>
</tr>
<tr>
<td>Left slow rolls</td>
<td>168 to 201</td>
</tr>
<tr>
<td>Right barrel rolls</td>
<td>202 to 208</td>
</tr>
<tr>
<td>Left barrel rolls</td>
<td>209 to 223</td>
</tr>
<tr>
<td>Double rolls</td>
<td>224 to 237</td>
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<tr>
<td>Triple rolls</td>
<td>238 to 240</td>
</tr>
<tr>
<td>4-point rolls</td>
<td>241 to 244</td>
</tr>
<tr>
<td>Loop</td>
<td>245 to 251</td>
</tr>
<tr>
<td>Immelman</td>
<td>252 to 254</td>
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<tr>
<td>Split-S</td>
<td>255 to 256</td>
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<tr>
<td>Cuban eight</td>
<td>257 to 258</td>
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<tr>
<td>Lazy eight</td>
<td>259 to 260</td>
</tr>
<tr>
<td>Wing-over</td>
<td>261 to 263</td>
</tr>
<tr>
<td>Chandelle</td>
<td>264 to 268</td>
</tr>
<tr>
<td>Vertical reverse</td>
<td>269 to 271</td>
</tr>
<tr>
<td>Split-S into loop with slow rolls</td>
<td>272</td>
</tr>
<tr>
<td>Stall</td>
<td>273</td>
</tr>
<tr>
<td>Effect of speed brakes</td>
<td>274</td>
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Right Left Roll
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