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CALCULATION OF THE AILERON AND ELEVATOR STICK FORCES AND RUDDER PEDAL FORCES FOR THE BELL XP-83 AIRPLANE (PROJECT MX-511) IN SPINS

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

MEMORANDUM REPORT

for the

Air Technical Service Command, Army Air Forces

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SUMMARY

Aileron and elevator stick forces and rudder pedal forces for the Bell XP-83 (project MX-511) airplane in spins have been calculated. The hinge-moment characteristics of 0.14-scale models of the control surfaces of the XP-83 airplane in attitudes simulating spins, as determined in the Langley 4- by 6-foot tunnel and steady-spin data obtained on a 1/24-scale model of the subject airplane in the 20-foot free-spinning tunnel, have been used in the calculations.

The results indicate that the aileron and elevator stick forces may be excessive unless some suitable booster or more highly balanced control surfaces are used. The pilot will be able to move the surfaces only slightly from their normal floating locations. The ailerons will tend to float slightly with the spin (stick right in a right spin) and the elevator will float full up. The rudder pedal forces will be within the capabilities of the pilot.

INTRODUCTION

At the request of the Air Technical Service Command, Army Air Forces, an investigation has been made to determine the control forces that would be expected in spins of the Bell XP-83 airplane. Some indication of the elevator and rudder forces were obtained during the course of the spin tests of a 1/24-scale model in the

Langley 20-foot free-spinning tunnel (unpublished data). These tests have been supplemented by a more extensive series of hinge-moment measurements (reference 1) in the Langley 4- by 6-foot tunnel on 0.14-scale models of all three control surfaces in attitudes simulating those obtained in spins. In the present report the results of these hinge-moment measurements (reference 1) have been converted to actual full-scale control forces expected in spins at an altitude of 20,000 feet by considering the rates of descent, attitudes, and rates of rotation determined in the spin tests of a 1/24-scale model in the Langley 20-foot free-spinning tunnel. The results are given for the complete range of attitudes and rates of descent expected in spins of the XP-83 airplane for different control settings and loading conditions.

SYMBOLS

α_{ai} angle of attack of wing at midspan of aileron (the angle between the chord line and the line of the relative wind projected into a plane containing the chord line and parallel to the plane of symmetry) on inner wing (right wing in a right spin), degrees $\left(\alpha_{c.g.} - \frac{\Omega y}{V}\right)$

α_{ao} angle of attack of wing at midspan of aileron (the angle between the chord line and the line of the relative wind projected into a plane containing the chord line and parallel to the plane of symmetry) on outer wing (left wing in a right spin), degrees $\left(\alpha_{c.g.} - \frac{\Omega y}{V}\right)$

ψ angle of yaw at the tail (the acute angle between the direction of the relative wind at the tail and the plane of symmetry), positive when relative wind is striking left side of vertical tail surface, degrees $\tan^{-1}\left[\frac{-\Omega(l \sin \alpha_{c.g.} + R)}{V}\right] - \phi$

R radius of spin (distance from center of gravity of airplane to spin axis), feet $\left(\frac{32.2 \cot \alpha_{c.g.}}{\Omega^2}\right)$

F_a aileron stick force, pounds $\left(\frac{\left(C_{h_{a_i}} - C_{h_{a_o}}\right) q b_a \bar{c}_a^2}{\frac{180}{\pi} \frac{X_a}{\delta_{a_T}}}\right)$

F_e elevator stick force (positive when force is a pull force), pounds $\left(\frac{C_{h_e} q b_e \bar{c}_e^2}{\frac{180}{\pi} \frac{X_e}{\delta_{e_T}}}\right)$

F_r rudder pedal force (positive when push force is on right rudder pedal), pounds $\left(\frac{C_{h_r} q b_r \bar{c}_r^2}{\frac{180}{\pi} \frac{X_r}{\delta_{r_T}}}\right)$

$\alpha_{c.g.}$ angle of attack at plane of symmetry, degrees

Ω full-scale angular velocity about spin axis, positive in a right spin, radians per second

y projected distance from plane of symmetry of airplane to midspan of aileron (21 ft)

V full-scale rate of vertical descent, feet per second

l full-scale distance from normal center-of-gravity location to rudder hinge line (24.98 ft)

ϕ angle between span axis and horizontal, positive when right wing is down, degrees

a subscript denoting the aileron

i subscript denoting inner wing

o subscript denoting outer wing

e subscript denoting the elevator

r subscript denoting the rudder

T subscript denoting total angular movement

C_h hinge-moment coefficient $(H/qb\bar{c}^2)$

H hinge moment, foot-pounds

q dynamic pressure $\left(\frac{1}{2}\rho V^2\right)$

b span of the aileron, elevator, or rudder along corresponding hinge axis, feet

$\bar{c}$ root mean square chord of the control surface rearward of the hinge axis, feet

X total movement of the control stick or rudder pedal (values estimated from specifications listed in reference 2)

Control stick	laterally	1.5 feet
	longitudinally	1.5 feet
Rudder pedal		0.54 foot

δ angular movement of the control surfaces relative to the chord line of the surface to which it is attached, degrees

Total angular movement of:

Aileron	50° ($\pm 25^\circ$) positive when trailing edge is down
Elevator	40° (-25° to 15°) positive when trailing edge is down
Rudder	50° ($\pm 25^\circ$) or 40° ($\pm 20^\circ$) positive when trailing edge is to left. (The rudder pedal forces were calculated for both $\pm 25^\circ$ and $\pm 20^\circ$ total deflection inasmuch as it is not definite at present which deflections are to be used on the airplane).

ρ air density, slug per cubic foot

I_X, I_Y, I_Z moments of inertia about X-, Y-, and Z-body axes, respectively, slug-feet^2

APPARATUS AND METHODS

Models

Drawings showing the 0.14-scale models of the left wing panel and the dummy fuselage and tail surfaces used for the hinge-moment tests in the 4- by 6-foot tunnel (see reference 1) are presented on figures 1 and 2, respectively. A photograph of the tail surfaces mounted in the 4- by 6-foot tunnel is given in figure 3. A three-view drawing of the 1/24-scale spin-tunnel model used for the spin tests in the Langley 20-foot free-spinning tunnel is shown on figure 4. The dimensional characteristics of the plane are given in table I.

Method of Calculation

The hinge-moment characteristics of the 0.14-scale models of the control surfaces of the XP-83 airplane used in the calculation of the stick and rudder pedal forces are presented in reference 1. The steady-spin data obtained from spins of the 1/24-scale model of the XP-83 airplane used in the calculation of the stick forces are presented on tables II and III.

Aileron stick forces.- In the calculation of the aileron stick forces, it is necessary to consider the variation of angle of attack at the aileron due to rolling. Reference 3 gives a method of obtaining, for the normal flight range, the location along the aileron span at which the angle of attack should be calculated for use in determining the hinge-moment coefficient for a given aileron deflection. This method is based on spanwise pressure distributions in unstalled flight. Because of the difference in pressure distribution between stalled and unstalled flight, it was felt that this method was not applicable to the present problem and therefore the angle of attack used was arbitrarily that of the midspan of the aileron.

Elevator stick forces.- In the calculation of the elevator stick forces the hinge-moment coefficient for a given elevator deflection was taken from the curve of elevator hinge-moment coefficient versus angle of attack for 0° yaw with the rudder neutral (fig. 6).

The use of these hinge-moment data is justifiable because the effects of yaw and rudder deflection on the elevator hinge-moment characteristics are generally small according to reference 1. The angle of attack at the plane of symmetry of the model was used in the computations. It is appreciated that as a result of rotation of the spinning airplane (or model) there is a variation in angle of attack along the tail span which may amount to a difference of approximately 5° between the angle of attack at the plane of symmetry and the angle of attack at the tip of the horizontal tail. This variation in angle of attack is, for all practical purposes, linear and, hence, the average angle of attack of the horizontal tail is approximately equal to the angle of attack at the plane of symmetry of the airplane. Inasmuch as the airplane will normally be spun with the elevator full up ($\delta_e = -25^\circ$), the stick force necessary to move the elevator from the up stop to neutral or full down was calculated using the steady-spin data for elevator-up spins with different aileron deflections, model loadings, and model configurations in order to cover the complete range of rate of descent expected for the airplane. The highest rate of descent and the lowest angle of attack recorded for a steady spin during the model spin tests was for an elevator-down spin. Data from this spin were used for several elevator-up spins that had rates of descent greater than that readily obtainable in the spin tunnel but were otherwise similar to this elevator-down spin. The elevator hinge-moment data (presented in reference I) were obtained with the stabilizer at -2.66° incidence, whereas the steady-spin data (tables II and III) were obtained with the stabilizer neutral. No correction was made for this difference in angle of attack of the horizontal tail.

Rudder pedal forces.- The rudder hinge-moment data (reference 1) are for the extended vertical tail surfaces whereas the majority of the steady-spin data used in these calculations were obtained with the original vertical tail. It is felt that this is justifiable because steady-spin data of brief tests with the extended tail did not vary appreciably when compared with that with the original tail. In the calculation of the forces required to move the rudder to its full deflection against the spin for the ±20° maximum rudder deflection, the steady-spin data for ±25° maximum rudder deflection were assumed to apply, as sufficient steady-spin data with the reduced deflections were not available. Brief spin tests (unpublished) with the revised rudder deflection indicate that the steady-spin data for spins with either of the rudder deflections are similar.

Rudder hinge-moment data (reference 1) were obtained only for angles of attack of 20° and 50° as these angles represented typical attitudes at the extremes of the range of angles of attack possible on the airplane. The rudder pedal forces were calculated for spins that had angles within a few degrees of these values. The forces necessary to fully reverse the rudder to 25° and 20° against the spin were calculated.

In the calculation of the stick and pedal forces it was assumed that the control movements were accomplished rapidly and that the attitude and rate of descent of the airplane did not change appreciably during the control movement. Because of the lack of data on control-system mass unbalanced and friction, control-system mass and friction forces were not considered in the calculations.

RESULTS AND DISCUSSION

The results of the aileron and elevator stick and rudder pedal force calculations are presented on figure 5, figure 6 and table II, and figure 7 and table III. The steady-spin and control-force data are presented in terms of full-scale values for the airplane at a test altitude of 20,000 feet.

Aileron Stick Forces

The results of the aileron stick-force calculations are presented on figure 5 as a plot of rate of descent versus aileron stick force for various aileron deflections. The results show that the ailerons will tend to float slightly with the spin (zero stick force). The results also show that the force required to move the stick laterally far from the floating location will be greater than the pilot can exert. From model spin tests it was indicated that aileron-with settings may seriously retard recovery for some loadings.

Elevator Stick Forces

The results of the elevator stick-force calculations are presented on figure 6 and table II. Figure 6 is a plot of the maximum elevator stick force for each of three elevator movements versus rate of descent. Table II is a list of the angles of attack, rates of descent, and the stick forces for the three elevator movements for each of the conditions calculated.

The curves represent the maximum elevator stick forces expected at the various rates of descent. For rates of descent below 330 feet per second, lower stick forces were also obtained for some conditions but for purposes of clarity on the figure these stick forces were not plotted. It is shown on the figure that the highest elevator stick force will be encountered while attempting to fully reverse the elevator in steep spins and will be of the order of 250 pounds push force. In reference 2 it is shown that the maximum push force that a pilot can exert with one hand is 120 pounds. It appears, therefore, that the stick force necessary to fully reverse the elevator may be greater than the pilot can exert.

Rudder Pedal Forces

The calculated rudder pedal forces, as well as the steady-spin data used in the calculation of the forces, are presented on figure 7 and table III. A study of this figure and table shows that the rudder pedal forces are within the capabilities of the pilot. Reference 2 states that the maximum push force that the pilot can exert on a rudder pedal is approximately 400 pounds. The maximum pedal force to move the rudder 25° against the spin was calculated as 265 pounds and the minimum force was 73 pounds. The maximum pedal force to move the rudder 20° against the spin was 119 pounds and the minimum force was 52 pounds.

Control Forces in Recovery

The recommended recovery technique for the XP-83 airplane is to hold the stick neutral laterally and full back; rapidly reverse the rudder and follow in 1/2 turn by movement of the stick forward of neutral. The control positions must be held until recovery is effected. Figures 5 and 6 indicate that the forces required to hold the stick neutral laterally and to move it forward of neutral will probably be in excess of the pilot's capabilities, the force required to hold the stick neutral laterally being of the order of 100 pounds and the force required to move the stick forward of neutral being in excess of 120 pounds.

Comparison of Spin-Model Control-Force Results with Results of Hinge-Moment Tests

A comparison of the control-force results obtained from the 1/24-scale spin-model tests in unpublished data for spins at moderate attitudes and rates of descent indicates good agreement with the results obtained herein from hinge-moment data for a corresponding condition. The elevator stick force measured in free-spinning tests at a rate of descent of 310 feet per second (full-scale values) was approximately 140 pounds. This compares favorably with a force of 160 pounds for the same rate of descent as taken from figure 6. The rudder pedal force obtained in free-spinning tests at a rate of descent of 272 feet per second (full-scale values) was approximately 140 pounds (full-scale values). It is shown on table III that forces calculated for spins with rates of descent of 273 foot per second vary from 135 to 142 pounds.

CONCLUSIONS

Based on the results of calculations of the aileron and elevator stick and rudder pedal forces for the XP-83 airplane in spins at a test altitude of 20,000 feet, the following conclusions are made for the airplane with the extended vertical tail surfaces:

1. The aileron and elevator stick forces will probably exceed the pilot's capabilities and may, therefore, prevent use of the recommended technique for recovery.

2. The rudder pedal force necessary to move the rudder to full against the spin will be within the capabilities of the pilot for both the $\pm 25^\circ$ and $\pm 20^\circ$ deflection.

Langley Memorial Aeronautical Laboratory
National Advisory Committee for Aeronautics
Langley Field, Va, September 7, 1945.

REFERENCES

1. Hoggard, H. Page, Jr., and Hagerman, John R.: Tests of 0.14-Scale Models of the Control Surfaces of Army Project MX-511 in Attitudes Simulating Spins. NACA MR No. L5D12a, 1945.

2. Gough, M. N., and Beard, A. P.: Limitations of the Pilot in Applying Forces to Airplane Controls. NACA TN No. 550, 1936.

3. Swanson, Robert S., and Toll, Thomas A.: Estimation of Stick Forces from Wind-Tunnel Aileron Data. NACA ARR No. 3J29, 1943.

TABLE I

DIMENSIONAL CHARACTERISTICS OF THE BELL XP-83 AIRPLANE

Wing span, ft	53
Length over all, ft	44.8
Normal weight, lb	18,300
Normal center-of-gravity location, percent M.A.C.	23.5
Wing:	
Area, sq ft	430
Aspect ratio	6.51
Sweepback of leading edge of wing, deg	8.1
Dihedral at 45-percent chord line, deg	2
Mean aerodynamic chord, in.	105
Leading edge of M.A.C. aft of leading edge of wing root	11.32
Flaps:	
Type	Fowler
Chord in percent of wing chord, percent:	
Inboard end	24.9
Outboard end	31.6
Ailerons:	
Chord, percent of wing chord	25
Area, from hinge line aft, percent wing area	7.30
Span, percent semispan	40.1
Horizontal tail surfaces:	
Total area, sq ft	75.9
Span, ft	18.66
Elevator area, including balance, sq ft	29.80
Distance from normal center of gravity to elevator hinge line, ft	24.10
Dihedral, deg	10
Original vertical tail surface:	
Total area, sq ft	42.86
Span, along hinge axis, ft	8.84
Rudder area, including balance, sq ft	18.33
Distance from normal center of gravity to rudder hinge line, ft	24.98

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TABLE I - Concluded

DIMENSIONAL CHARACTERISTICS - Concluded

Extended vertical tail surface:	
Total area, sq ft	47.6
Span, along hinge axis, ft	10.34
Rudder area, including balance, sq ft	20.06

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TABLE II

ELEVATOR STICK FORCES AND STEADY-SPIN PARAMETERS FOR DIFFERENT CONFIGURATIONS OF THE XP-83 AIRPLANE

[Configurations and steady-spin parameters taken from free-spinning test data (unpublished); stick forces calculated from data in reference 1 and from free-spinning test data]

Configuration	Control setting		Airspeed V (ft/sec)	Angle of attack α (deg)	Stick force for δ_e = -25° (lb)	Stick force for δ_e = 0° (lb)	Stick force for δ_e = 15° (lb)
	Ailerons	Elevator					
Normal loading, clean condition	Against	Up	277	46.5	50	85	137
Do	do	Up	274	45.7	47	80	131
Do	1/2 against	Up	288	40.5	52	73	134
Do	do	Up	234	54.9	42	81	117
Flaps 22° down	Against	Up	244	48.3	40	71	111
Flaps 5° down	do	Up	248	41.3	39	56	101
Flaps 5° down	do	Up	226	55.0	39	76	110
Landing condition	do	Up	241	46.6	38	65	104
Landing gear alone	do	Up	273	46.5	49	83	133
I_X and I_Z increased 20 percent I_X, clean condition	do	Up	274	43.5	47	75	127
I_Y and I_Z decreased 20 percent I_Y, clean condition	do	Up	284	47.5	54	94	148
Do	do	Up	249	57.0	49	98	139
c.g 11 percent forward, clean condition	do	Up	263	44.9	44	72	120
Do	do	Up	230	57.7	42	84	120
c.g. 15.7 percent rearward, clean condition	do	Up	277	48.2	52	90	143
Alternate loading III	With	Up	337	35.5	67	86	172
c.g. 10 percent rearward, clean condition	Against	Up	234	58.4	45	91	126
Do	do	Up	280	39.8	49	68	124
Do	do	Up	305	44.2	59	94	160
c.g. 11 percent forward, clean condition	1/3 against	Up	333	33.8	66	82	167
Alternate loading III	1/3 with	Up	372	32.7	81	103	206
Do	1/5 with	Up	387	33.7	90	111	225
I_Y and I_Z increased 20 percent I_Y, clean condition	1/3 against	Up	330	34.2	65	82	163
Do	do	Up	255	49.6	44	81	124
Alternate loading II	With	Up	266	51.3	49	93	140
Do	Neutral	Up	259	58.2	55	110	153
Alternate loading III	With	Up	308	42.5	60	91	158
Alternate loading II	1/5 with	Up	280	54.2	58	113	164
Stabilizer leading edge 7° down	Against	Up	226	65.6	49	102	137
Do	do	Up	250	53.2	45	87	129
Stabilizer leading edge 3° up	do	Up	263	47.2	45	79	126
Revised normal loading, clean condition	do	Up	263	51.6	50	91	138
Revised vertical tail, normal loading	do	Up	284	41.0	50	73	131
Do	do	Up	244	65.0	56	120	157
Do	2/3 against	Up	255	50.4	45	83	126
Do	do	Up	226	52.3	36	69	102
Do	1/3 against	Up	245	49.2	41	73	114
Stabilizer leading edge 7° down	Neutral	Down	443	18.8	20	78	254

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TABLE III

RUDDER PEDAL FORCES AND STEADY-SPIN PARAMETERS FOR DIFFERENT CONFIGURATIONS

OF THE XP-83 AIRPLANE

[Configurations and steady-spin parameters taken from free-spinning test data (unpublished); rudder pedal forces calculated from data in reference 1 and from free-spinning test data]

Configuration	Control setting		Steady-spin parameters						Rudder pedal force (lb)	
	Ailerons	Elevator	V (ft/sec)	α (deg)	Ω (rad/sec)	∅ (deg)	R (ft)	ψ (deg)	$\delta_r = 25^\circ$	$\delta_r = 20^\circ$
Normal loading, clean condition	Against	Down	259	46.3	2.61	8.2	4.48	21.0	106	76
Do	----do----	Up	277	46.5	2.01	12.9	7.62	23.5	150	117
Do	----do----	Down	259	45.9	2.59	6.6	4.65	19.3	121	86
Do	----do----	Up	273	45.7	2.04	8.4	7.55	19.1	135	99
Do	Neutral	Down	344	26.0	3.28	0.6	5.96	9.9	182	79
Do	1/2 against	Up	234	54.9	2.26	1.7	4.41	15.2	108	77
Flaps 22° down	Against	Down	226	49.7	2.59	6.8	4.07	21.6	77	55
Do	----do----	Up	244	48.3	2.16	6.7	6.12	19.1	108	80
Flaps 5° down	----do----	Down	219	52.9	2.58	6.1	3.54	21.6	73	52
Do	----do----	Up	226	55.0	2.22	6.3	4.60	20.1	94	71
Do	With	Down	358	25.6	3.37	2.0	5.94	11.0	175	85
Landing condition	Against	Down	226	51.0	2.38	7.0	4.60	21.2	84	57
Do	----do----	Up	241	46.6	1.99	9.2	7.70	21.3	108	85
Landing gear alone	----do----	Down	259	46.0	2.34	7.2	5.65	19.3	121	86
Do	----do----	Up	273	46.5	1.75	6.5	10.02	16.7	142	101
I_Y and I_Z increased 20 percent I_Y, clean condition	----do----	Down	241	52.8	2.26	6.3	4.79	19.3	105	75
Do	----do----	Down	251	47.7	2.20	7.2	6.05	19.3	113	81
Do	----do----	Up	284	47.5	2.08	9.0	6.79	19.5	147	110
c.g. 11 percent forward, clean condition	----do----	Down	255	48.9	2.36	9.2	5.06	21.7	97	70
Do	Neutral	Down	380	23.7	2.47	1.1	12.00	9.3	195	92
c.g. 15.7 percent rearward, clean condition	Against	Down	255	45.0	2.17	5.9	6.84	17.7	131	97
Do	----do----	Up	277	48.2	1.63	10.8	10.85	20.6	147	110
c.g. 10 percent rearward, clean condition	----do----	Down	234	50.9	2.22	3.9	5.31	17.1	113	84
I_Y and I_Z increased 20 percent I_Y, clean condition	1/3 against	Up	255	49.6	1.88	0.8	7.71	12.0	156	94
Alternate loading II	With	Up	266	51.3	2.36	-2.6	4.63	9.5	148	99
Do	1/5 with	Up	280	54.2	2.00	-2.9	5.79	7.7	161	106
Stabilizer leading edge 7° down	Against	Up	250	53.2	2.10	6.0	5.46	18.1	115	83
Do	----do----	Down	223	53.7	2.49	4.6	3.82	19.6	87	62
Stabilizer leading edge 3° up	Neutral	Down	443	18.8	3.73	-1.9	6.80	5.2	265	119
Revised normal loading, clean condition	Against	Up	263	47.2	2.14	10.3	6.50	21.7	123	85
Revised vertical tail, normal loading	----do----	Up	263	51.6	1.79	7.3	7.97	17.9	134	99
Do	1/3 against	Up	245	49.2	2.14	1.0	6.07	13.3	142	114
Do	Against	Down	244	48.4	2.29	6.9	5.45	19.6	105	81
Do	2/3 against	Up	226	52.3	2.14	4.9	5.45	18.3	97	71
Do	----do----	Up	255	50.4	2.10	3.5	6.05	15.3	129	111

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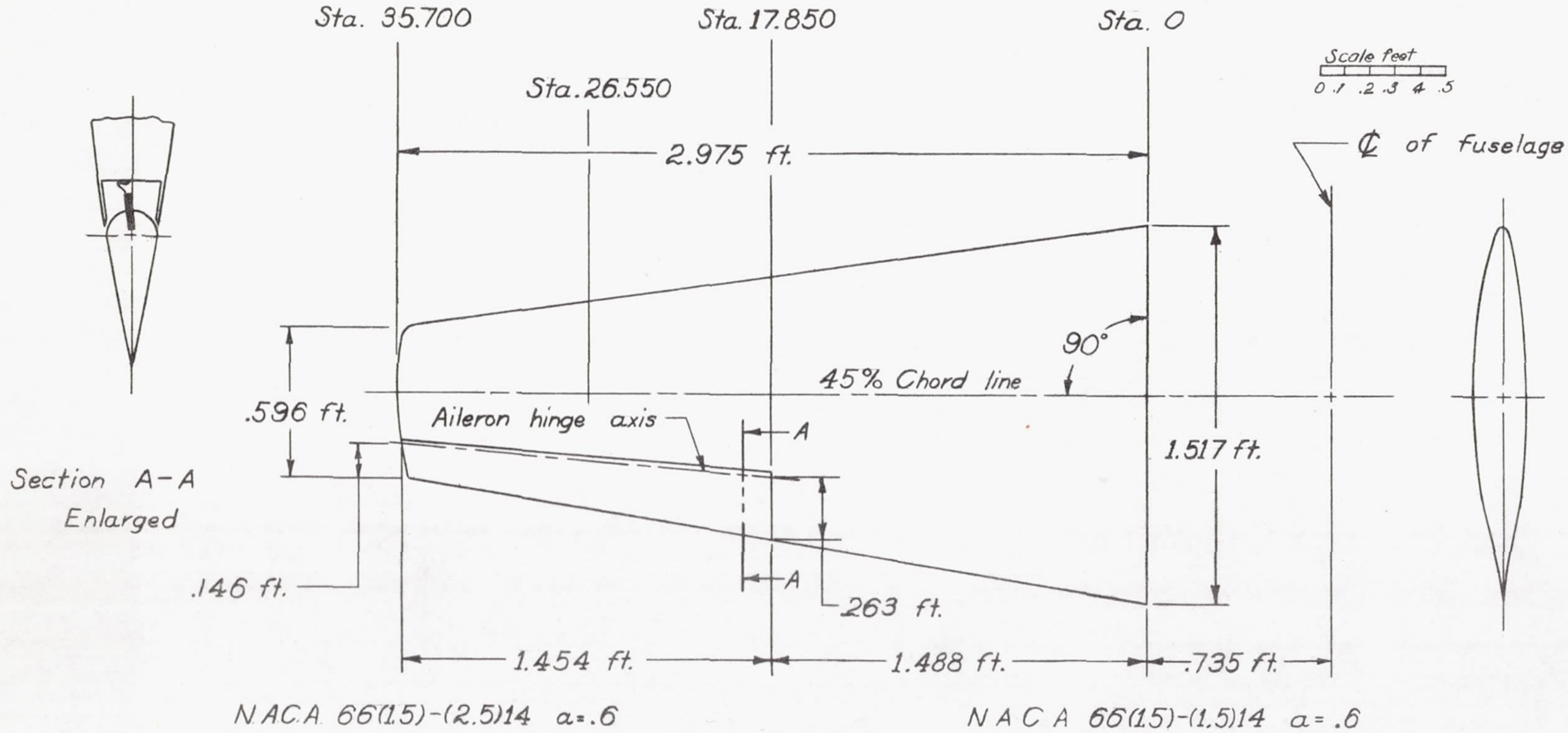

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Figure 1.- Details and dimensions of 0.14-scale model of the XP-83 airplane left wing panel as tested in the Langley 4-by 6-foot wind tunnel.

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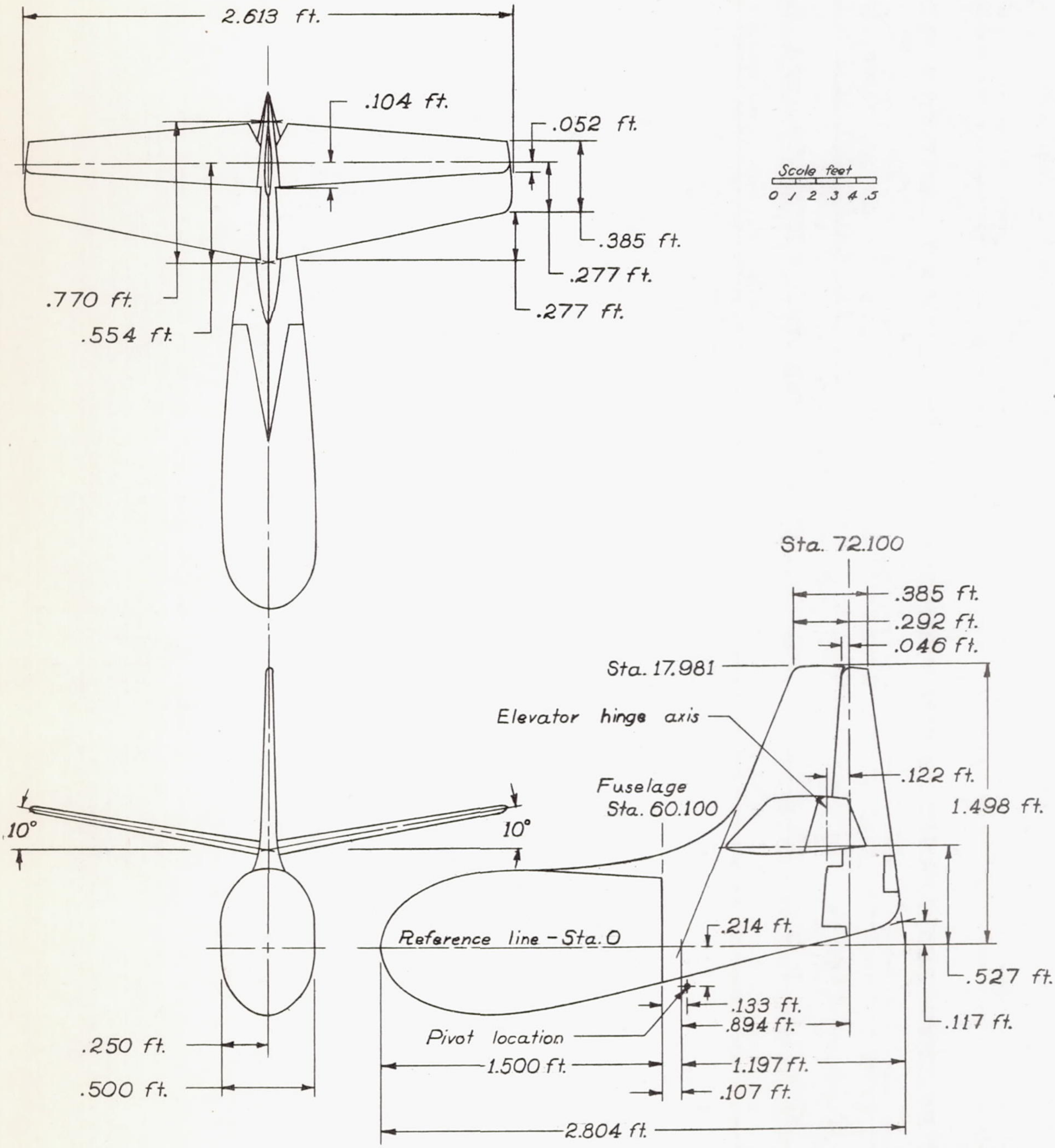

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Figure 2.- Details and dimensions of 0.14-scale model of the XP-83 airplane tail unit tested in the Langley 4-by 6-foot wind tunnel.

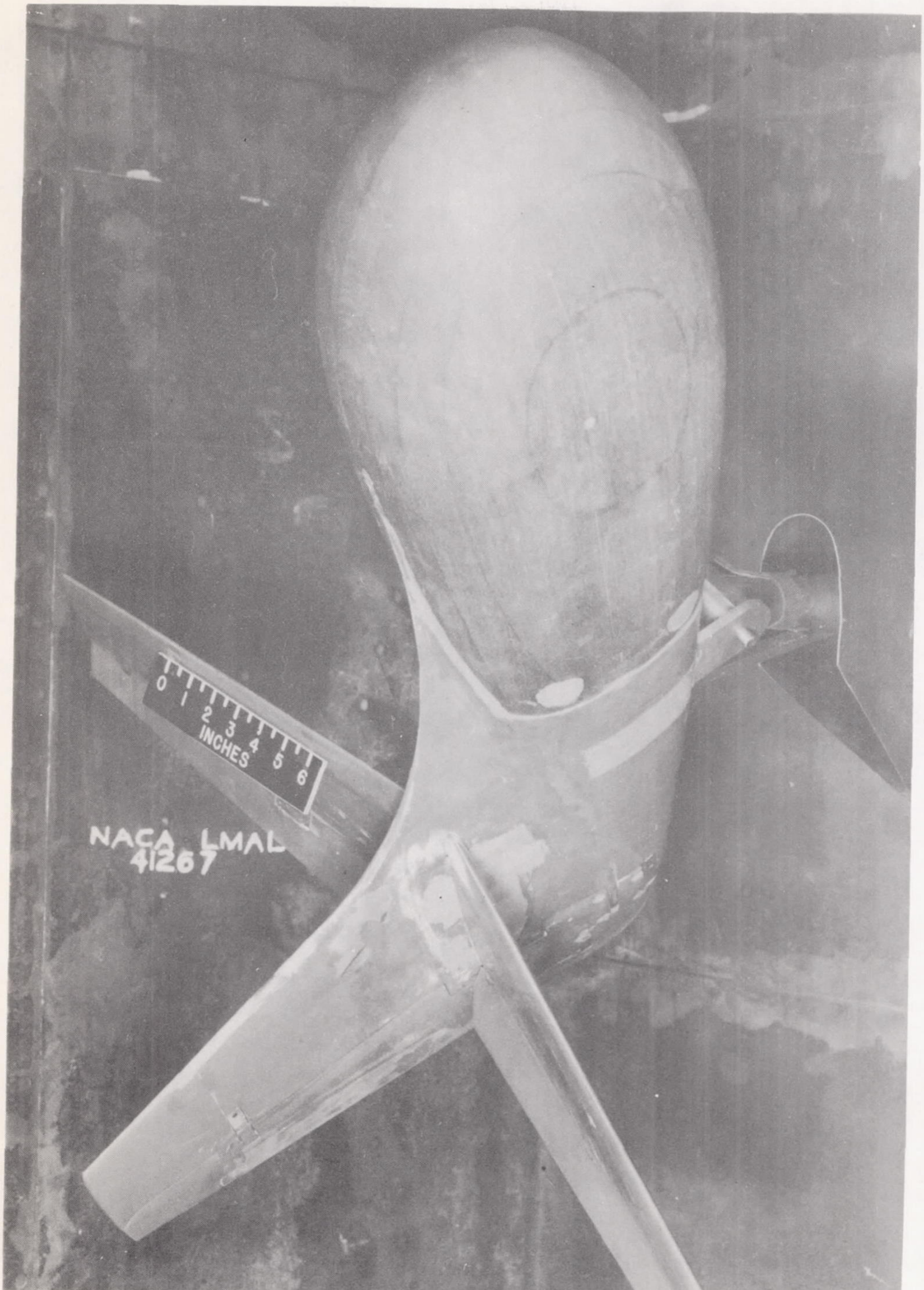

Figure 3.- Three-quarter top view of the XP-83 tail surfaces as tested in the Langley 4- by 6-foot tunnel. Wind direction vertically downward in plane of picture.

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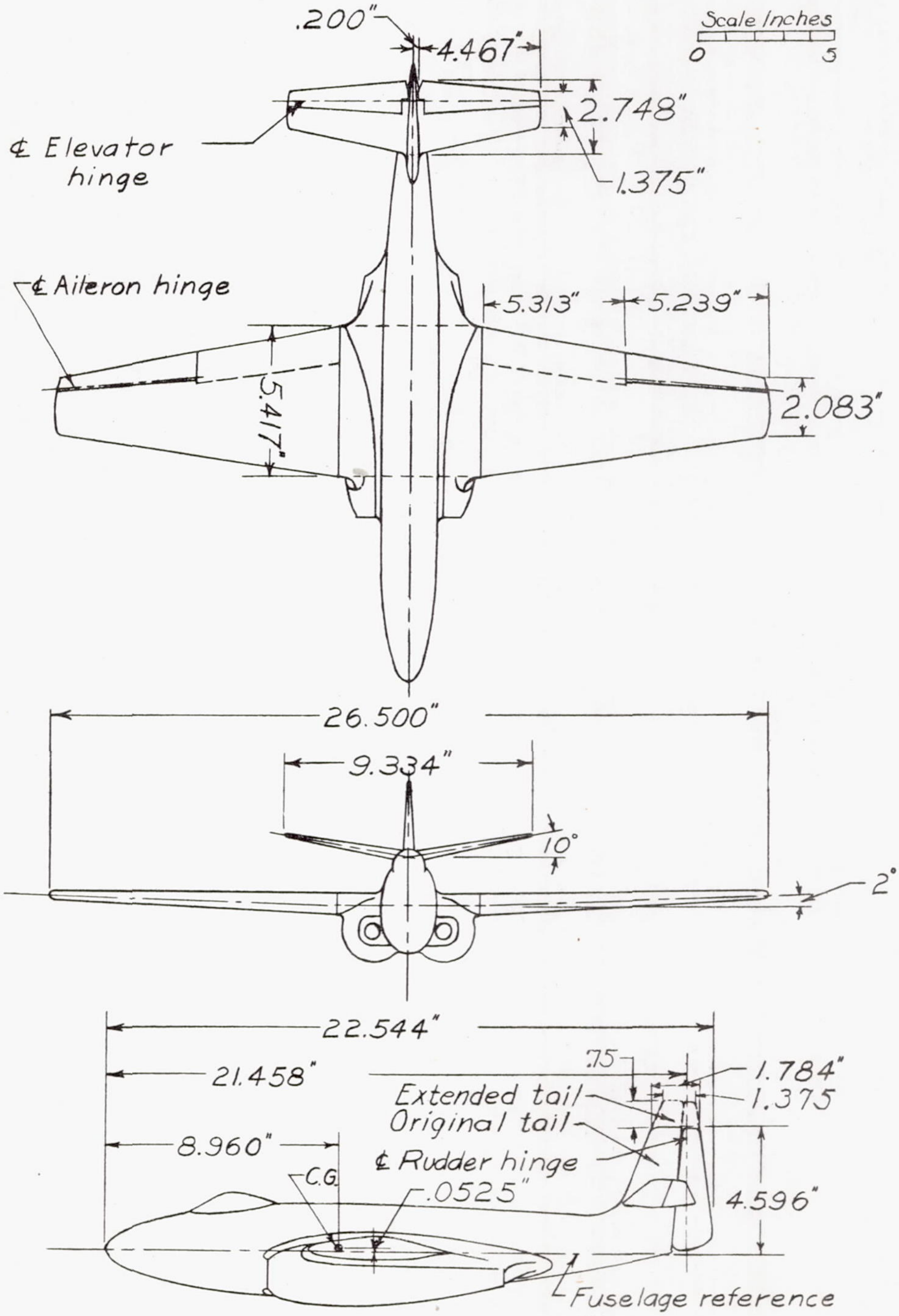

Figure 4.- Drawing of 1/24-scale model of the Bell XP-83 airplane as tested in the spin tunnel. Wing incidence 1° leading edge up. Stabilizer incidence 0°. Center-of-gravity position shown for normal loading.

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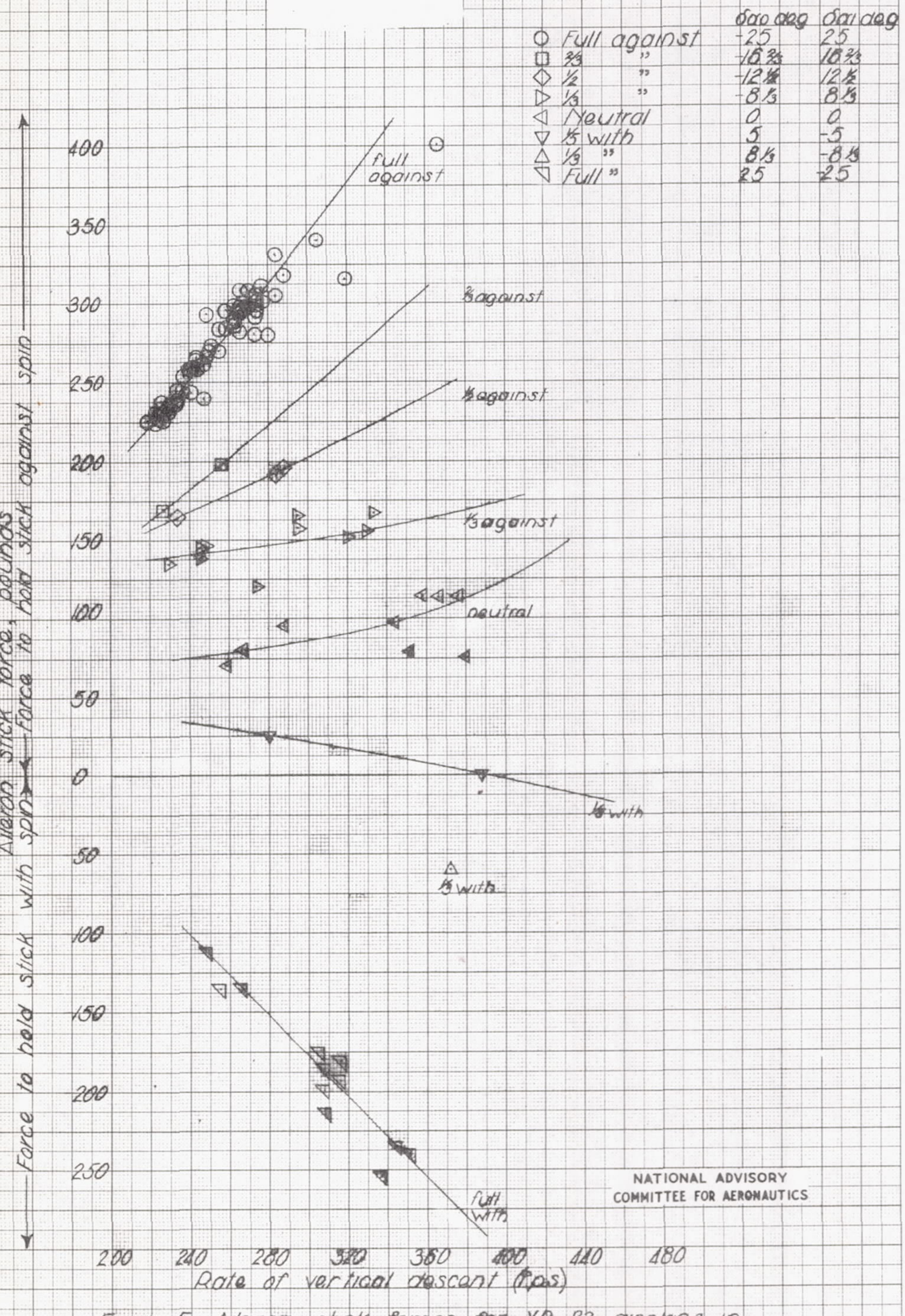

Figure 5.- Aileron stick forces for XP-83 airplane in spins. Values are for the airplane at an altitude of 20,000 feet, right erect spins.

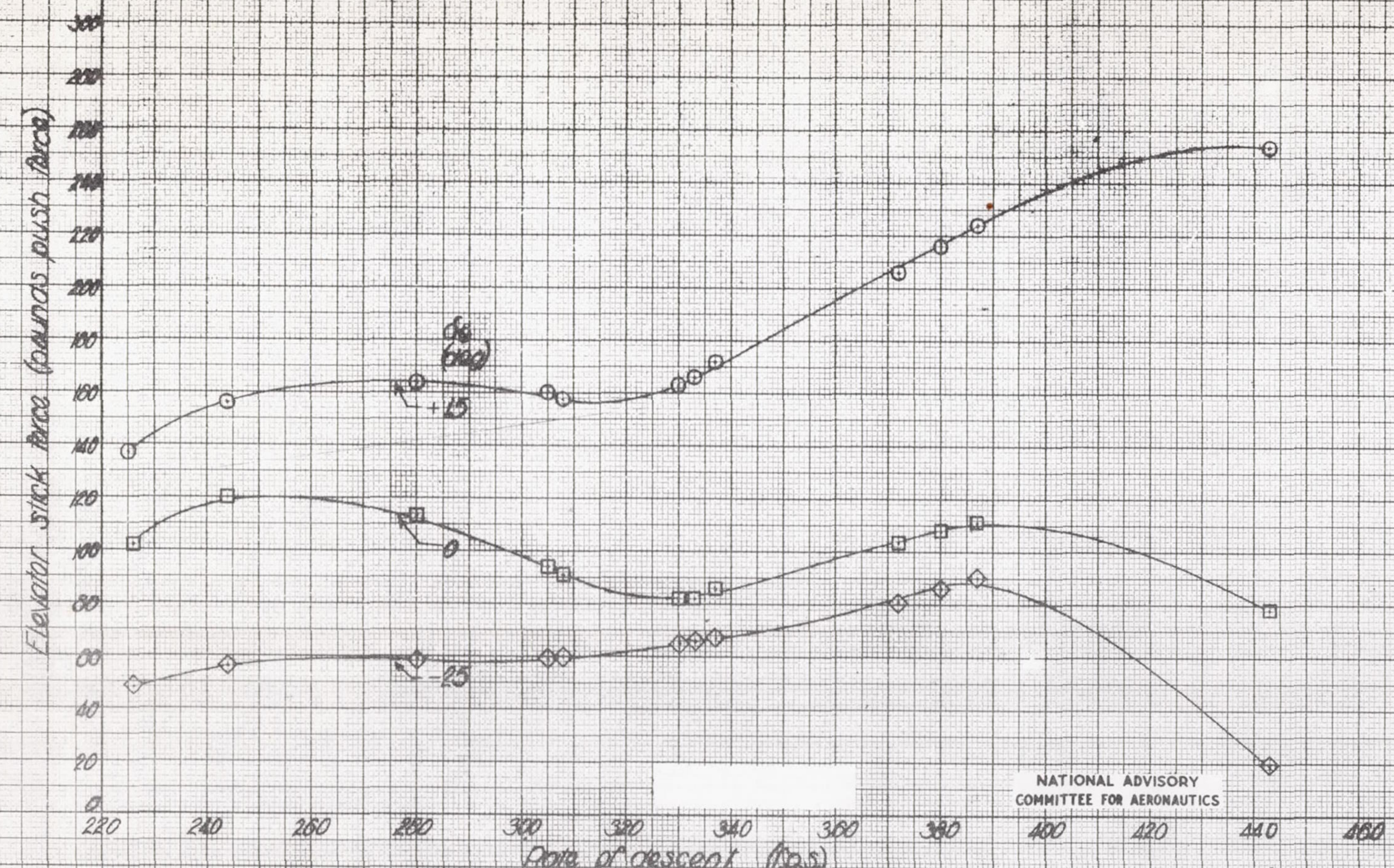

Figure 6.- Maximum elevator stick forces for XP-83 airplane in elevator-up spins. (Values for the airplane at an altitude of 20,000 feet)

L-575

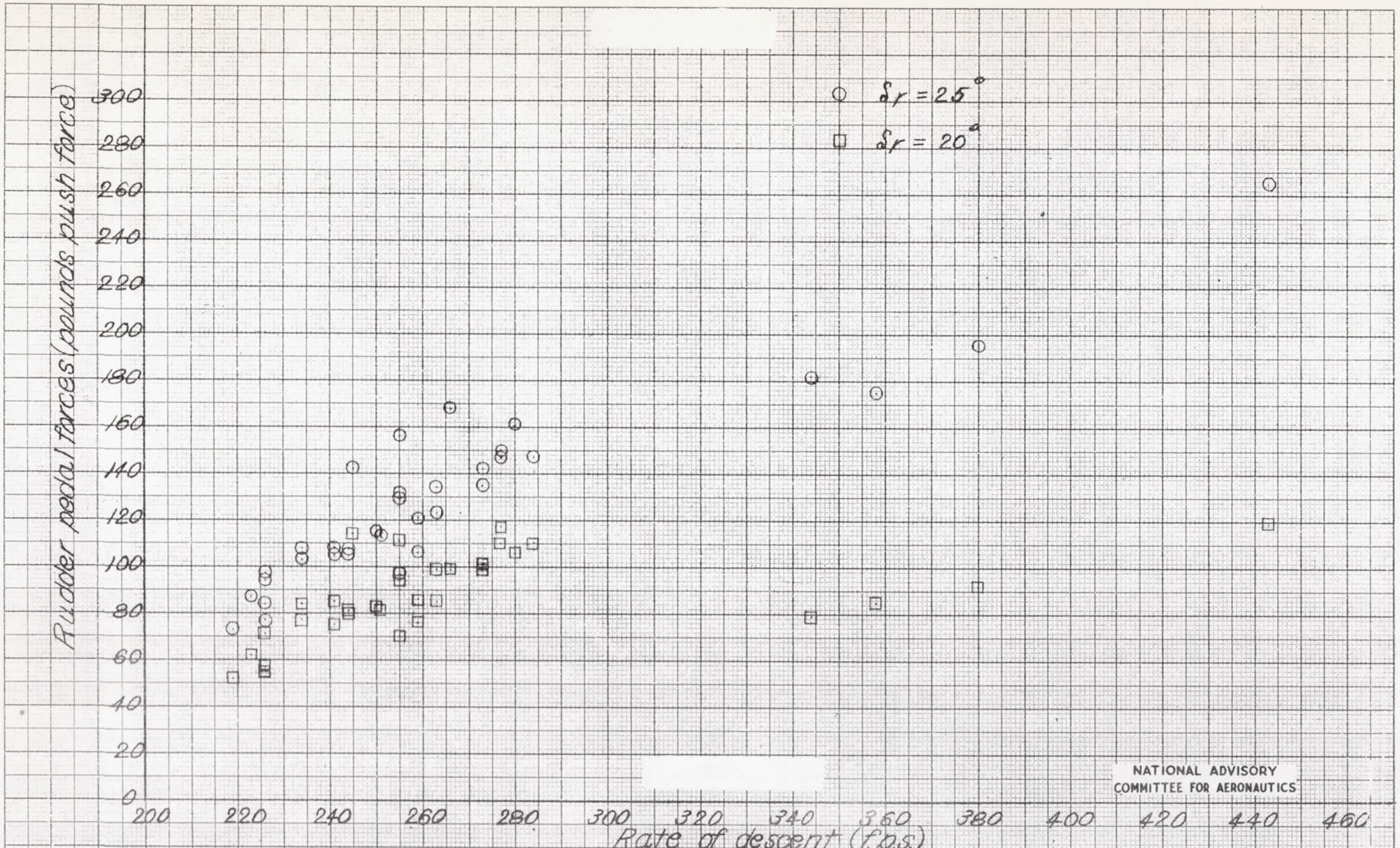

Figure 7.- Rudder pedal forces for XP-83 airplane in spins. (Values for the airplane at an altitude of 20,000 feet.)