NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

REPORT No. 324

FLIGHT TESTS ON U. S. S. "LOS ANGELES"

PART I—FULL SCALE PRESSURE DISTRIBUTION INVESTIGATION

By S. J. DE FRANCE

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AERONAUTICAL SYMBOLS

1. FUNDAMENTAL AND DERIVED UNITS

	Symbol	Metric		English	
		Unit	Symbol	Unit	Symbol
Length	l	meter	m	foot (or mile)	ft. (or mi.)
Time	t	second	sec	second (or hour)	sec. (or hr.)
Force	F	weight of one kilogram	kg	weight of one pound	lb.
Power	P	kg/m/sec		horsepower	HP.
Speed		{km/hr		mi./hr	M. P. H.
		{m/sec		ft./sec	f. p. s.

2. GENERAL SYMBOLS, ETC.

W, Weight, $=mg$

g, Standard acceleration of gravity $=9.80665$ m/sec.$^2=32.1740$ ft./sec.^{2}

m, Mass, $=\frac{W}{g}$

ρ, Density (mass per unit volume).

Standard density of dry air, 0.12497 (kg-m^{-4} sec.^{2}) at 15° C and 760 mm $=0.002378$ (lb.-ft.$^{-4}$ sec.^{2}).

Specific weight of "standard" air, 1.2255 kg/m$^3=0.07651$ lb./ft.^{3}

mk^2, Moment of inertia (indicate axis of the radius of gyration, k, by proper subscript).

S, Area.

S_w, Wing area, etc.

G, Gap.

b, Span.

c, Chord length.

b/c, Aspect ratio.

f, Distance from $c.\ g.$ to elevator hinge.

μ, Coefficient of viscosity.

3. AERODYNAMICAL SYMBOLS

V, True air speed.

q, Dynamic (or impact) pressure $=\frac{1}{2}\rho V^2$

L, Lift, absolute coefficient $C_L=\frac{L}{qS}$

D, Drag, absolute coefficient $C_D=\frac{D}{qS}$

C, Cross-wind force, absolute coefficient $C_C=\frac{C}{qS}$

R, Resultant force. (Note that these coefficients are twice as large as the old coefficients L_C, D_C.)

i_w Angle of setting of wings (relative to thrust line).

i_t, Angle of stabilizer setting with reference to thrust line.

γ, Dihedral angle.

$\rho\frac{Vl}{\mu}$, Reynolds Number, where l is a linear dimension.

e. g., for a model airfoil 3 in. chord, 100 mi./hr. normal pressure, 0° C: 255,000 and at 15° C., 230,000;

or for a model of 10 cm chord 40 m/sec, corresponding numbers are 299,000 and 270,000.

C_p, Center of pressure coefficient (ratio of distance of $C.\ P.$ from leading edge to chord length).

β, Angle of stabilizer setting with reference to lower wing, $=(i_t-i_w)$.

α, Angle of attack.

ϵ, Angle of downwash.

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

NAVY BUILDING, WASHINGTON, D. C.

(An independent Government establishment, created by act of Congress approved March 3, 1915, for the supervision and direction of the scientific study of the problems of flight. It consists of 15 members who are appointed by the President, all of whom serve as such without compensation.)

EXECUTIVE COMMITTEE

REPORT No. 324

FLIGHT TESTS ON U. S. S. "LOS ANGELES"

PART I—FULL SCALE PRESSURE DISTRIBUTION INVESTIGATION

By S. J. De France

SUMMARY

The investigation reported herein was conducted by the National Advisory Committee for Aeronautics at the request of and in conjunction with the Bureau of Aeronautics, Navy Department. The purpose was primarily to obtain simultaneous data on the loads and stresses experienced in flight by the U. S. S. "Los Angeles," which could be used in rigid airship structure design. A secondary object of the investigation was to determine the turning and drag characteristics of the airship. The stress investigation was conducted by the Navy Department.

The aerodynamic loading was obtained by measuring the pressure at 95 locations on the tail surfaces, 54 on the hull, and 5 on the passenger car. These measurements were made during a series of maneuvers consisting of turns and reversals in smooth air and during a cruise in rough air which was just short of squall proportions.

The results of the pressure measurements on the hull indicate that the forces on the forebody of an airship are relatively small. The tail surface measurements show conclusively that the forces caused by gusts are much greater than those caused by horizontal maneuvers. In this investigation the tail surface loadings caused by gusts closely approached the designed loads of the tail structure.

The turning and drag characteristics will be reported in separate papers.

INTRODUCTION

Since the design data for rigid airships is still largely empirical, it is obvious that as much additional information as is possible should be obtained from each new design. One of the greatest deficiencies in design data is that concerning the forces imposed upon an airship by various maneuvers and by gusts, especially the latter. With this in mind, the Bureau of Aeronautics, Navy Department, instituted an elaborate series of tests on the U. S. S. *Los Angeles* for the purpose of determining the aerodynamic loads, their distribution, and the resulting stresses in certain structural members of the airship. As a secondary object of this investigation, data were to be obtained from which the turning characteristics of the ship could be determined.

The work was divided into two parts. The Bureau of Aeronautics, Navy Department, conducted the stress investigation and the National Advisory Committee for Aeronautics obtained the aerodynamic load distribution and turning data. All of the data obtained by both agencies were taken simultaneously and the records were synchronized. It is the purpose of this report to present the results of that part of the investigation which was conducted by the National Advisory Committee for Aeronautics.

Probably the best way of obtaining the aerodynamic forces acting on an airship is by the determination of full-scale pressure distribution. Such investigations on rigid airships to date have been limited to the British tests on the *R-32* (reference 1), *R-33* (reference 2), and the *R-38* (reference 3), and to an investigation made in Germany on the *LZ-126* (the present U. S. S. *Los Angeles*), the results of which have not been published. In this country previous airship pressure distribution investigations have been confined to the research on a nonrigid type, the *C-7* (reference 4).

With the exception of the tests on the *R-33* and *C-7*, all of these investigations have consisted of measuring the pressures at comparatively few points. In the investigation herein described the pressures were measured at 95 points on the tail surfaces, 54 on the forward portion of the hull, and 5 on the passenger car. The pressures at these locations were recorded during turning maneuvers and while the ship was encountering gusts.

APPARATUS AND INSTALLATION

In order to measure the pressures, orifices of the type illustrated in Figure 1 were secured to the outer cover, flush with the surface, at the location shown in Figure 2. On the hull, as

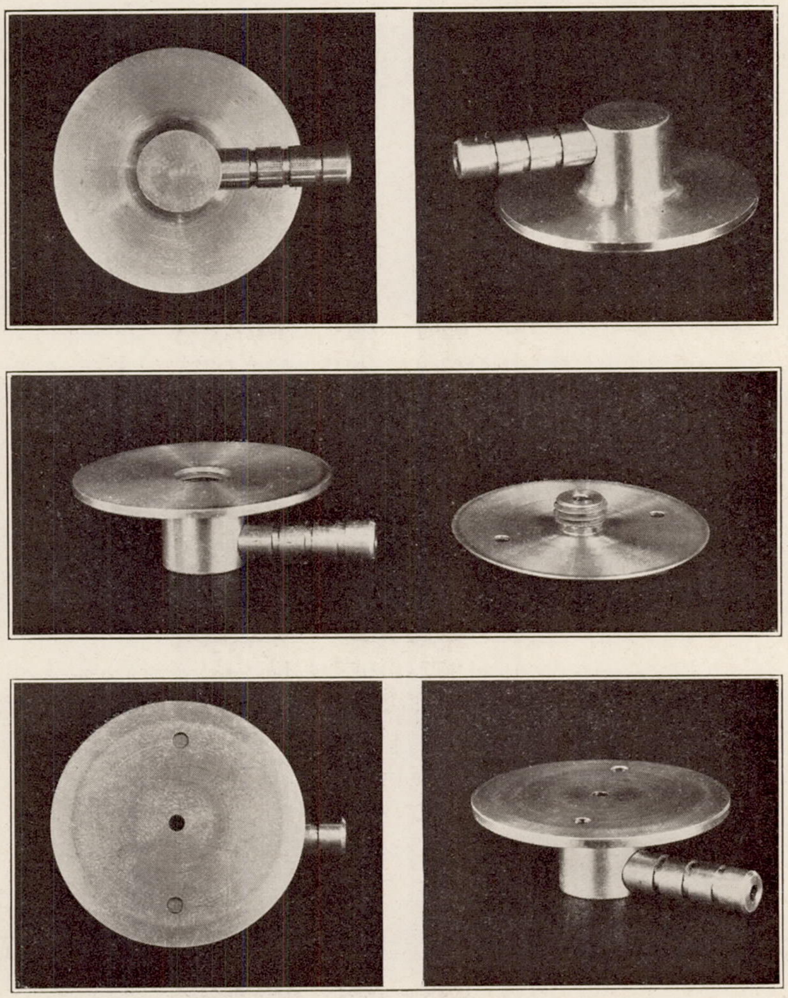

FIGURE 1.—Pressure orifice

shown in Figure 2, a row of orifices was installed along longitudinal 2 from the nose back to frame 145, and two circular rows girdled the hull at frames 175 and 145. In each of the circular rows, four orifices were located between longitudinals 2 and 2½ to determine the effect of the polygonal shape upon the pressure distribution. Orifices were also located inside of the hull, at the points indicated by arrows in Figure 2, for the purpose of determining the fabric loading.

The installation of orifices on the tail assembly (fig. 2) was concentrated on the lower fin and rudder, and on the starboard fin and elevator. The orifices were secured to the opposite sides of the lower fin and rudder at 41 stations and to the opposite sides of the starboard fin and elevator at 42 stations. In addition, orifices were fastened to both sides of the upper and port fins at six stations on each. These were used to obtain pressures for checking purposes.

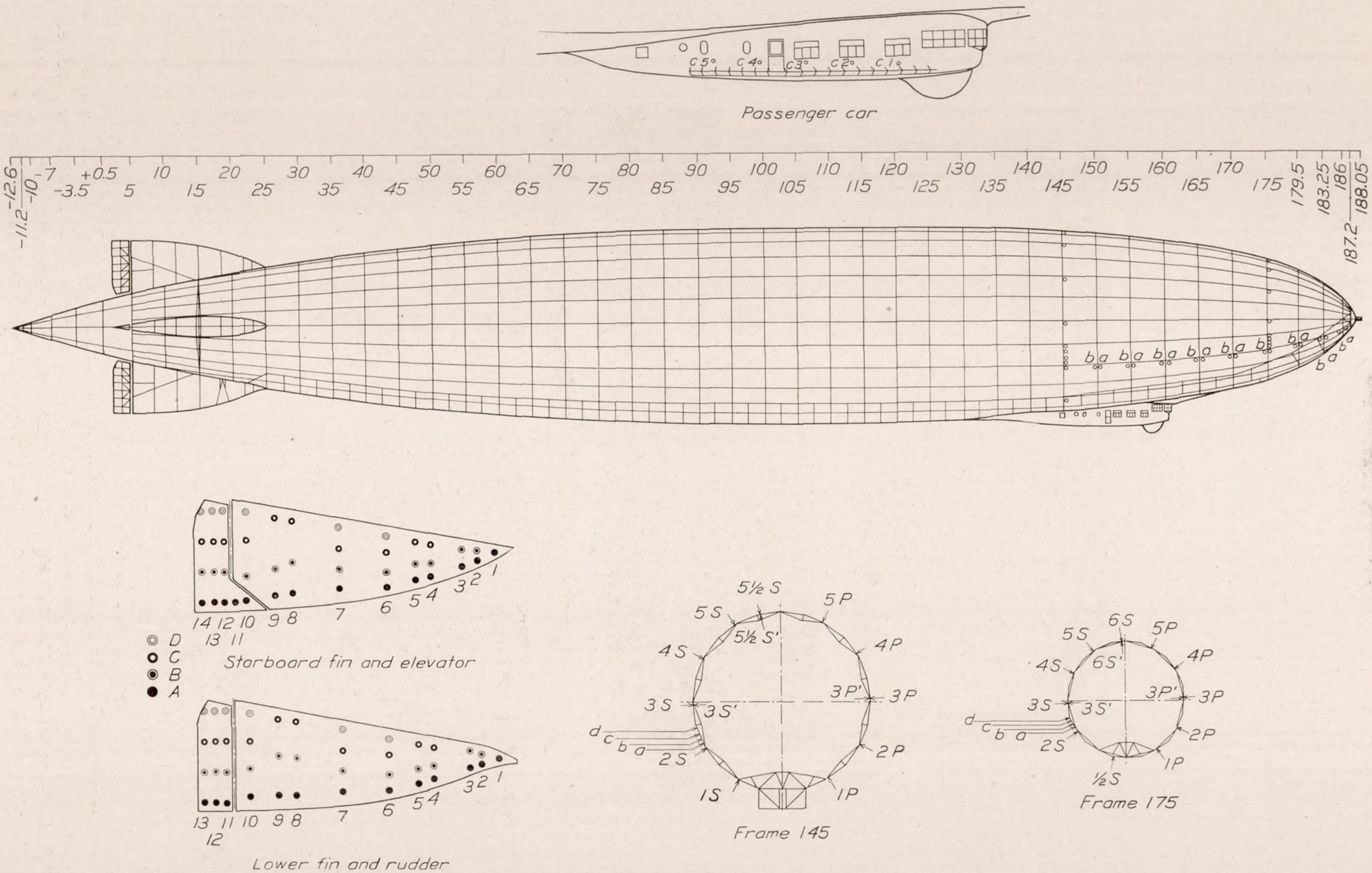

FIGURE 2.—Location of orifices on the U. S. S. *Los Angeles*

To determine the fin effect of the passenger car, five orifices were secured to each side of this body at the locations shown in Figure 2.

The pressures were transmitted from the orifices to multiple recording manometers by means of ¼-inch aluminum tubing. The manometers (fig. 3) were developed by the National Advisory Committee for Aeronautics for these tests. Each consists essentially of a light-tight aluminum box on which are mounted 60 pressure cells (reference 5), a light source, and a constant-speed electric motor which draws photographic film past the pressure cells at a speed which can be varied by a gear shift. Each manometer records 60 pressures simultaneously and continuous records can be obtained for periods of time varying from 1 to 4 minutes, depending upon the film speed used.

The system used for the hull pressure measurements is shown schematically in Figure 4. As shown, the external pressures normal to the surface were measured relative to that within the keel, which in turn was measured relative to the static pressure as obtained by a static head suspended 30 feet below the ship at frame 165. If the readings of static pressure had been satisfactory, the true aerodynamic pressures acting on the hull could have been determined by adding the two values algebraically. However, the suspended static head was in a disturbed area caused by the passenger car, and the static pressure readings therefore were erratic. Consequently, the pressures acting on the hull could be accurately measured only with respect to the keel pressure.

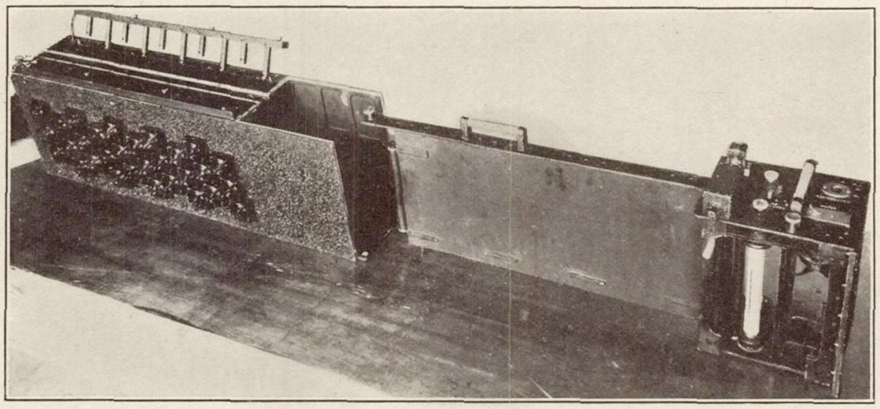

FIGURE 3.—Type 60 recording multiple manometer

A diagram of the pressure system used on the tail surfaces is given in Figure 5. Orifices on opposite sides of the tail surfaces at the same station are represented by X and Y. By connecting these to the opposite sides of the same pressure cell, the resultant normal pressure was recorded for that station. The internal fin pressure is denoted by Z. By connecting X and Z to another pressure cell, the fabric loading was obtained.

In addition to the multiple manometers employed for recording the pressures, the following instruments were used on board the ship:

(1) *N. A. C. A. Recording Altimeter and Air-Speed Meter.*—This instrument is a standard recording air-speed meter (reference 6) with a sensitive aneroid unit incorporated in it. The air-speed unit was connected by rubber tubing, through a flexible metal hose, to a Pitot-static head (fig. 6), which was suspended 35 feet below the ship at frame 110. Since the Pitot-static head was in a region where the disturbance caused by the ship was negligible, and since the flexible hose permitted the head to turn and assume the true flight path, the true dynamic pressure was recorded.

(2) *N. A. C. A. Recording Turnmeter* (*reference 7*).—This instrument was mounted so that it could be employed to give a continuous record of the angular velocity in either pitch or yaw.

(3) *N. A. C. A. Control Position Recorder* (*reference 8*).—This instrument was located in the lower fin so as to have the shortest possible connections to the control surfaces and thereby reduce the error in movement caused by the slackness of the control cables.

(4) *N. A. C. A. Recording Yawmeter.*—This instrument consists of a motion-picture camera, which is operated by a constant speed electric motor (fig. 7) and a streamlined "fish" which is stabilized by tail surfaces and attached to the end of a cable by a swivel. In operation the "fish" was suspended below the airship, where it was free to take up the true flight path. The camera was aligned with the axis of the ship at frame 80, so that the angle between the axis of the "fish" and the edge of the film gave the angle of yaw for this station on the ship's axis.

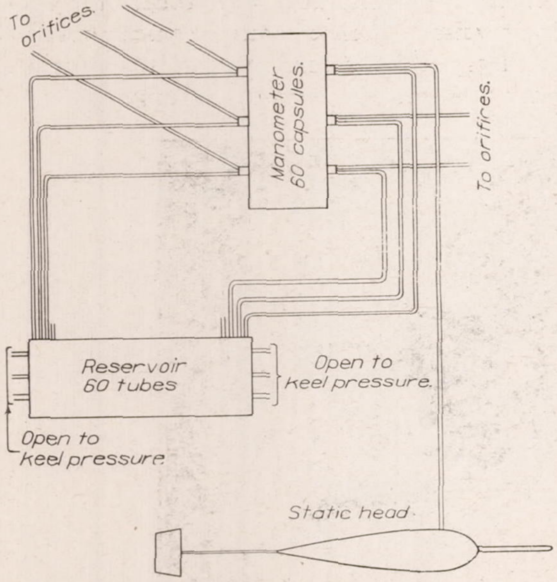

FIGURE 4.—Diagram of tube connections on hull

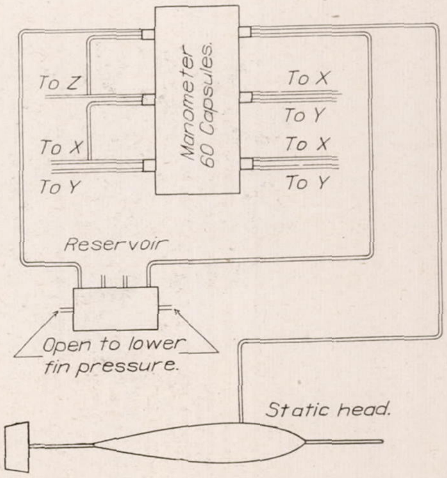

FIGURE 5.—Diagram of tube connections on tail surfaces

(5) *N. A. C. A. Recording Inclinometer.*—This instrument consists essentially of an oil-damped pendulum mounted in the standard photographic recording type of instrument used by the National Advisory Committee for Aeronautics. It was used to record the angle of the airship's axis to the horizontal. Knowing the rate of descent obtained from the sensitive altimeter record, and the air speed, the sine of the angle of the flight path was determined. The algebraic sum of this angle and the angle of inclination gave the angle of pitch.

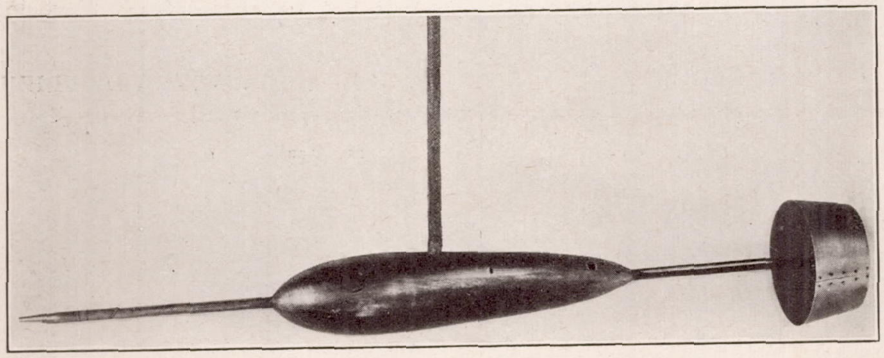

FIGURE 6.—Suspended Pitot static head

(6) *N. A. C. A Chronometric Timer (reference 9).*—All of the above instrument records were synchronized by means of this instrument.

In addition to the instruments mounted on board the airship, a camera obscura (reference 10) was located on top of the hangar to determine the turning characteristics independently of the data taken on the ship.

FLIGHT TESTS

The test program was divided into two parts—(*a*) maneuvers in smooth air and (*b*) flights in rough air to determine the effect of gusts. Because of the condition of the gas cells at the time of the tests and the necessity of conserving helium, it was considered undesirable to make vertical maneuvers. Consequently, all of the smooth-air maneuvers were confined to the horizontal plane. When the air in the vicinity of Lakehurst was smooth enough, these maneuvers were carried out over the camera obscura; but when the local conditions were rough, the tests were conducted well out to sea, where smooth air prevailed. Consequently, camera obscura measurements were not obtained during all of the tests. The second part of the program consisted of taking a series of continuous records while the ship was cruising in rough air.

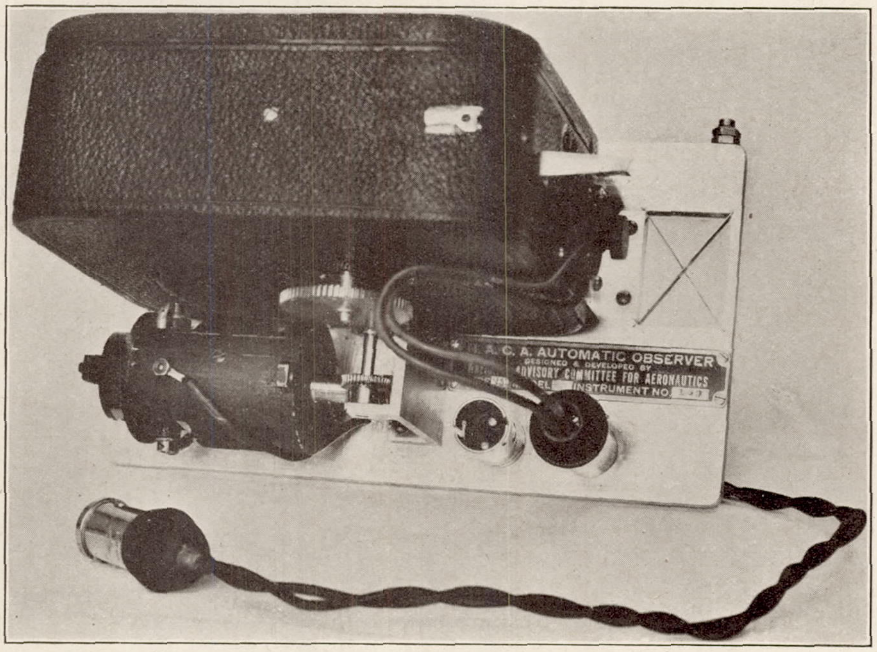

FIGURE 7.—Automatic angle of yaw recorder

A list of the maneuvers performed during the tests is given in the following table:

TABLE I

FLIGHT TEST PROGRAM—U. S. S. "LOS ANGELES" PRESSURE DISTRIBUTION

Maneuver	Requested rudder angle	Requested engine R. P. M.
Steady turn	8° R.	1,050
Do	8° R.	1,230
Do	8° L.	1,050
Do	12° R.	1,050
Do	12° R.	1,230
Reversal	8° R. to 8° L.	1,050
Do	8° R. to 8° L.	1,230
Do	12° R. to 12° L.	1,050
Do	12° R. to 12° L.	1,230
Deceleration	0	0
Do	0	Idling.
Cruising in rough air		

Of the above maneuvers the steady turns need no additional comment. The reversals, deceleration runs, and rough-air tests, however, might be further described. In the reversals, the airship was put into a right turn and when the turn had reached a steady condition, the rudders were rapidly reversed to the corresponding position for left turn. Records were obtained on all instruments from an instant before the rudders were reversed until the airship had reached a condition of steady left turn.

The deceleration tests, which were made to determine the drag characteristics of the airship, were carried out in two ways—(*a*) with the propellers stopped and (*b*) with the propellers disengaged and idling. The procedure in these tests was to stop all of the engines simultaneously while the ship was in steady horizontal flight and then to take a record of the air speed against time while the ship was decelerating.

The rough-air measurements were made while the airship was cruising in gusty air. There was, of course, no way of determining when the airship was about to encounter a gust. However, the air was particularly rough, with frequent gusts, while the data were being obtained, so that by taking a series of continuous records, each of four minutes' duration, the effects of several gusts of varying intensity were recorded.

During all of the tests an observer was placed at each instrument station in the ship to see that the instruments were working properly and to load them as it became necessary. Communication was established between the stations by means of a buzzer system and between the master station and the control car by word of mouth. As each maneuver was about to be performed, the master observer signaled a warning to the instrument stations. Then, at the proper moment, he indicated the start of the test and threw the control switch, thus starting all of the instruments at the same time. A similar procedure was carried out at the end of each maneuver. Consequently, the observers knew when the instruments were supposed to be operating. At the start of each flight over the camera obscura, a radio signal was sent to the operator, who started a stop watch and synchronized his records with those on the ship. All runs, with the exception of the decelerations, were of four minutes' duration.

COMPUTATION OF RESULTS

The pressures obtained on the tail surfaces were plotted upon drawings of the surfaces (figs. 8 to 27), and the resulting curves drawn through the points were integrated to determine the load per running foot of surface. These loads in turn were plotted against the length of the surfaces and the curves drawn through the points were integrated to obtain the total loads. The total loads were converted into coefficient form by the following equation

$$C_{NF}=\frac{2F}{S\rho v^2}$$

where
C_{NF} = normal force coefficient.
F = total load.
ρ = air density at time of tests.
S = area of the surface.
v = true velocity.

The pressures on the hull could not be expressed in coefficient form because of the erratic readings of static pressure previously mentioned, which prevented the determination of the true aerodynamic pressures. Therefore, the values which are given in Table V and plotted in Figures 28 to 36, are with reference to the keel pressure.

The transverse forces acting at frames 145 and 175, Table VI, were determined by plotting the values of pressure, obtained around the ship at these frames, upon base lines representing the horizontal and vertical diameters and integrating the resulting curves.

The resultant transverse pressures on the passenger car were determined in the same manner as the resultant pressures acting upon the tail surfaces. These results are given in Table VII.

PRECISION

The possible sources of error in the pressure measurements are:

(*a*) Irregularity in the airship's surface in the vicinity of the orifice location.
(*b*) Tube stopped or leaking.
(*c*) Change of calibration of pressure cell.
(*d*) Effect of acceleration of air in tubes.
(*e*) Time lag due to length of tube.

The error due to (*a*) was negligible, since all of the orifices were located within 18 inches from a girder where the true shape of the ship was maintained and the fabric was taut. The possibility of error due to (*b*) was removed, since the tubing was inspected after each flight and the data which were obtained from defective tubes were deleted. A clamping device was attached to each manometer which permitted the clamping off of all of the tubes leading to the orifices and the opening of tubes leading from a reservoir to the pressure cells. With the aid of a U-tube manometer which was connected to the reservoir, calibrations were made of all of the multiple recording manometers after each flight. There was a slight change (*c*) in the calibration of the pressure cells during the tests, and this could account for a maximum error of ±2 per cent in the pressures.

The effect of acceleration of the air in the tubes (*d*) was eliminated in the tail surface pressures, since only resultant pressures were measured and the tubes from the orifices on each side of the surface ran parallel to each other from the surface to the manometer. In the hull pressure installation, where the normal hull pressures were measured with respect to the keel pressures, there is a possibility of some error being introduced in the longer tubes. However, the manometer was centrally located so that the average length of tube was about 50 feet and the only appreciable error would be in the measurements from the nose orifices where the tube length reached 100 feet. The probable error in the measurements from these long tubes is ±1 per cent. The error due to time lag in tubing (*e*) is negligible, since it has been proven by tests (reference 11) that lag in ¼-inch tubing for 100-foot lengths is too small to measure, and in no part of the installation did the length of an individual tube exceed this value. Consequently, it is safe to say that the tail surface pressure measurements are not in error by more than ±2 per cent and the hull pressures by not more than ±3 per cent.

The greatest error in the results is due to the fairing of the curves through the points of plotted pressures. The fairing of these curves could cause a maximum error in the total loads of ±5 per cent.

DISCUSSION OF RESULTS

TAIL SURFACE RESULTS

The results are presented in tabular and curve form. The maximum pressures recorded for the vertical tail surfaces during turning maneuvers are given in Table II and are presented graphically in Figures 8 to 23. It will be observed that during all of the maneuvers there was a concentration of pressure in a vortex area along the leading edge of the fin. In several cases these local resultant pressures, which were the average of the vortex fluctuations, exceeded 100 per cent q at points 4A and 5A on the lower fin, and in one case, run Number 13D, a value of 1.42 q was reached. These pressures were large but localized, so that the total loads on each surface were never excessive.

The maximum fin load encountered during the turning maneuvers in smooth air was 2,139 pounds. In Table IV this load is reported as having been encountered by the surface during a reversal. Actually, it occurred while the airship was in a right turn, since the rudders had not been reversed at the time that the record was obtained. Unfortunately, the normal force coefficient could not be positively determined for this load, because the air-speed recorder failed and only an approximate value of the dynamic head could be obtained. The approximate head was 1.53 inches of water and the corresponding normal force coefficient was 0.253. This value was exceeded in two of the steady turns at slower speed. The maximum normal force coefficient for a fin alone during the smooth-air maneuvers was 0.320. This occurrred during a steady turn at a speed of 64.4 feet per second with rudder 8.3° to starboard and resulted from a load of only 1,482 pounds.

The maximum normal force coefficient for the rudder alone and also the maximum over-all normal force coefficient for the fin and rudder combined, resulting from the turning maneuvers, occurred during a reversal of the helm. In this maneuver, run Number 3C, the rudders were reversed from 12.35° right to 11.55° left in 9 seconds, while the airship was making a speed of 71 feet per second. The resulting coefficients were 0.323 for the rudder and 0.268 for the rudder and fin together.

While flying through gusts, the local pressures and the total loads encountered by the tail surfaces greatly exceeded the values obtained during horizontal maneuvers in smooth air. The pressures caused by two gusts are given in Table III and graphically represented in Figures 24 to 27. Only the results of two gusts are given, but these represent the largest loads encountered during 10 runs of approximately four minutes each, which were made during an elapsed time of four hours. Considering that all of these runs were made in rough air which was just short of squall proportions, the results of these two runs indicate the dangerous loadings that might be expected in a storm.

Considering the total loads and normal force coefficients in Table IV, it can be seen that the greatest effect of the gusts was in a vertical direction. The *Los Angeles* was designed to withstand a force equivalent to a normal force coefficient of 0.34 simultaneously on each set of tail surfaces. In run Number 4A, the normal force coefficient for the horizontal surfaces was 0.349, but that for the vertical surfaces at the same instant was only 0.126. Consequently, the design loading was approached but not exceeded even though the vertical loading was large. In run Number 5A, the design limit for the tail surface loading was more closely approached. Unfortunately the air-speed recorder failed during this run, so that only an approximate value of the dynamic head could be determined. Consequently the normal force coefficients may be in error, but by not more than 10 per cent. Allowing for this possible error, the normal force coefficient for the starboard fin and elevator is still large, and combining this with the normal force coefficient for the vertical surfaces, the resultant closely approaches the design value.

HULL AND PASSENGER CAR RESULTS

The investigation of the hull pressures was not as successful as that of the tail surfaces. The trailing head, from which the static pressure reference for all of the hull pressures was obtained, was not suspended far enough from the keel at frame 165 to be outside of the disturbance caused by the passenger car. Consequently the pressures given in Table V and represented graphically in Figures 28 to 36 are given with respect to the keel pressure. It might be mentioned, though, that by checking the nose pressure, obtained in this manner, against the air speed head it was found that there was never a discrepancy of more than 8 per cent, and therefore it is probable that the values of pressure given with respect to the keel pressure are within 8 per cent of the true aerodynamic pressure.

The error in the true aerodynamic pressure data did not affect the determination of the transverse forces at frames 145 and 175, since these forces were obtained by integrating the resultant pressure curves and, consequently, the effect of the static pressure was eliminated. The transverse forces for these two rings are recorded in Table VI. As can be seen, there was only one smooth-air maneuver that caused a sizable force. This was a steady turn, run Number 5C, and even in this case the force at frame 175 was small. The force at frame 145 might have been caused by a localized lateral gust. The forces obtained during the rough-air flights were somewhat larger, but indications are that for no condition were the forces on the forward portion of the hull excessive.

From the investigation of the pressures on the passenger car, it was found that the fin effect of that body was practically negligible. The resultant pressures are given in Table VII. The maximum pressure obtained was 0.78 lb. per sq. ft. and the majority of the values were practically zero. Therefore the total transverse force, and consequently the fin effect, of the passenger car, were small.

The orifices for measuring the fabric loads were located in the region of maximum pressure on the fin, close to the leading edge, and at three points each on transverse frames 145 and 175. At each location, one orifice was mounted on each side of the cover. The resultant pressures from these orifices are presented in Table VIII. The fabric loading of the hull cover never reached a value as large as 1 lb. per sq. ft., and on the fin cover, a maximum value of only 6.60 lb. per sq. ft. was obtained. Consequently, no excessive stresses were set up in the fabric.

TURNING AND DRAG CHARACTERISTICS

The turning characteristics could not be determined from the records taken on board the airship because of the inconsistent readings from the turnmeter. This instrument was of the airplane type and did not maintain the sensitive adjustment necessary for airship use. However, this information has been obtained from the camera obscura data. The results from these data will be given in a subsequent report.

The deceleration tests were not entirely satisfactory. During these tests the air speed fluctuated so much that consistent data could not be obtained. Consequently, the shape coefficients which were determined were only an indication of the drag characteristics. Another series of deceleration tests has been made on the U. S. S. *Los Angeles* at a more recent date and the data were very consistent. The results of this investigation will be given in a separate report.

CONCLUSION

The results of this investigation show that no excessive aerodynamic loads are imposed upon an airship by normal horizontal maneuvering in smooth air, but that gusts encountered while cruising in rough air can cause forces which closely approach the design limits of the structure.

As a recommendation for future investigation, apparatus should be developed to carefully study the structure of the air with especial reference to gusts.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., *August 14, 1928.*

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TABLE II

RESULTANT PRESSURES ON TAIL SURFACES—TURNING

Run number	4B		4C		5C		2B		13D		6C		5D	
Timing interval	2		7		9		5		13		5th from end		1	
Rudder position	9.70° L.		8.30° R.		7.85° R.		12.75° R.		12.95° R.		13.25° R.		9.05° R.	
Velocity, ft./sec	74.2		64.4		75.0		64.0		61.1		74.5		73.4	
Angular velocity, rad./sec	0.0043 count. clock.		0.0189 clock.		0.0217 clock.		0.0149 clock.		0.0191 clock.		------------		0.0153 clock.	
Yaw at frame 80	7.1° L.		7.6° R.		6.8° R.		7.4° R.		7.4° R.		------------		2.7° R.	
q in lb./sq. ft	6.19		4.37		5.93		4.47		3.95		5.98		5.82	
Pressure	% q	#/sq.ft.	% q	#/sq.ft.	% q	#/sq.ft.	% q	#/sq.ft.	% q	#/sq.ft.	% q	#/sq.ft.	% q	#/sq.ft.
LOWER FIN AND RUDDER														
Orifice No.—														
1A	36.1	1.88	−6.7	−0.26	−8.8	−0.52	0.0	0.00	10.5	0.42	−10.0	−0.60	−6.2	−0.36
1A′	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00
2A	−67.2	−3.50	108.2	4.74	95.4	5.72	76.8	3.43	98.8	3.90	104.4	6.24	53.3	3.12
2A′	−16.8	−0.87	56.0	2.44	52.6	3.12	47.7	2.13	59.2	2.34	53.0	3.17	43.8	2.55
2B	−42.0	−2.18	40.5	1.77	39.4	2.34	52.3	1.87	59.2	2.34	34.8	2.08	35.7	2.08
3A	−57.1	−2.97	50.0	2.18	52.6	3.12	39.5	1.77	43.4	1.72	55.6	3.32	29.5	1.72
3A′	−33.6	−1.75	41.6	1.82	35.1	2.08	23.2	1.04	46.1	1.82	42.5	2.54	10.7	0.62
3B	−33.6	−1.75	40.5	1.77	35.1	2.08	32.5	1.46	52.6	2.08	45.2	2.70	17.8	1.04
4A	−46.2	−2.40	89.3	3.90	70.1	4.16	113.9	5.10	131.6	5.20	108.6	6.50	38.5	2.24
4A′	−21.0	−1.09	34.5	1.51	35.1	2.08	33.7	1.51	26.3	1.04	34.8	2.08	25.9	1.51
4B	−39.5	−2.05	29.8	1.30	26.6	1.56	30.2	1.35	32.9	1.30	34.8	2.08	17.8	1.04
4C	−29.4	−1.53	23.8	1.04	17.6	1.04	23.2	1.04	22.4	0.88	25.2	1.51	13.5	0.73
5A	−69.7	−3.67	130.0	5.67	78.9	4.68	133.7	5.97	142.0	5.62	130.4	8.01	59.0	3.43
5A′	−60.5	−3.14	26.2	1.14	21.9	1.30	17.4	0.78	19.8	0.78	26.1	1.56	14.0	0.83
5B	−16.8	−0.87	61.8	2.71	52.6	3.12	44.2	1.95	52.7	2.08	53.0	3.17	35.7	2.08
5C	−19.3	−1.00	30.9	1.35	26.6	1.56	25.6	1.15	30.3	1.20	29.6	1.77	17.8	1.04
6A	−65.5	−3.40	138.3	6.03	100.9	5.98	107.0	4.78	131.5	5.20	140.0	8.37	62.6	3.64
6A′	−75.6	−3.93	23.8	1.04	17.5	1.04	9.3	0.42	0.0	0.00	11.3	0.68	13.0	0.73
6B	−35.3	−1.83	48.9	2.14	35.1	2.08	24.4	1.09	32.9	1.30	35.6	2.13	25.1	1.46
6C	−28.6	−1.49	45.3	1.95	19.4	1.15	22.1	0.99	17.1	0.68	26.9	1.61	8.9	0.52
6D	−10.1	−0.53	51.2	2.24	17.5	1.04	24.4	1.09	17.1	0.68	21.7	1.30	7.2	0.42
7A	−68.9	−3.58	87.1	3.80	78.9	4.68	65.2	2.91	79.0	3.12	76.5	4.57	29.5	1.72
7B	−14.3	−0.74	32.2	1.40	30.7	1.82	23.2	1.04	22.4	0.88	28.7	1.72	15.1	0.88
7C	−10.1	−0.53	19.1	0.83	21.9	1.30	17.4	0.78	15.8	0.62	26.9	1.61	8.9	0.52
7D	−5.9	−0.31	7.1	0.31	8.7	0.52	4.6	0.28	9.2	0.36	37.4	2.24	2.7	0.16
8A	−52.1	−2.71	90.6	3.95	65.8	3.90	73.2	3.28	73.7	2.91	73.9	4.42	32.1	1.87
8B	−7.6	−0.40	14.3	0.62	8.7	0.52	−2.3	−0.10	7.9	0.31	12.2	0.73	1.7	0.10
8C	−3.4	−0.18	−11.9	−0.52	−8.7	−0.52	−8.1	−0.36	−13.2	−0.52	−11.3	−0.68	−8.9	−0.52
9A	−54.6	−2.84	93.0	4.06	68.4	4.06	58.1	2.60	72.4	2.86	65.2	3.90	40.2	2.34
9B	−8.4	−0.44	−6.0	−0.26	0.0	0.00	−5.8	−0.26	−7.9	−0.31	−4.3	−0.26	−8.9	−0.52
9C	2.5	0.13	0.0	0.00	−4.3	−0.26	−5.8	−0.26	−7.9	−0.31	−5.2	−0.31	−9.8	−0.57
10A	−21.0	−1.09	52.4	2.29	35.1	2.08	8.6	0.38	23.7	0.94	38.2	2.28	16.8	0.99
10B	0.0	0.00	−11.9	−0.52	−8.7	−0.52	−17.4	−0.78	−19.8	−0.78	−8.7	−0.52	−17.8	−1.04
10C	0.0	0.00	0.0	0.00	0.0	0.00	−34.9	−1.56	−20.4	−0.83	13.0	0.78	−14.0	−0.83
10D	16.8	0.87	19.1	0.83	8.7	0.52	0.0	0.00	0.0	0.00	0.0	0.00	4.7	0.26
11A	−10.9	−0.57	−15.5	0.68	0.0	0.00	−34.9	−1.56	−19.8	−0.78	−34.8	−2.08	−11.0	−0.62
11B′	−26.0	−1.35	−29.8	−1.30	−21.9	−1.30	−8.6	−0.52	−19.8	−0.78	−21.7	−1.30	−15.0	−0.88
11B	30.5	1.58	−70.3	−3.07	−61.2	−3.64	−69.8	−3.12	−85.6	−3.38	−69.6	−4.16	−47.4	−2.76
11C	26.0	1.35	−57.0	−2.50	−53.4	−3.17	−55.8	−2.50	−53.0	−2.08	−60.0	−3.59	−46.4	−2.70
11D	8.4	0.44	−26.2	−1.14	−35.1	−2.08	−37.2	−1.63	−39.5	−1.56	−34.8	−2.08	−35.7	−2.08
12A	−24.4	−1.27	9.5	0.42	17.5	1.04	2.3	0.10	−6.6	−0.26	0.0	0.00	8.8	0.47
12B	5.0	0.26	−33.3	−1.46	−26.6	−1.56	−34.9	−1.56	−46.1	−1.82	−29.6	−1.77	−20.6	−1.20
12C	10.1	0.53	−17.9	−0.78	−17.5	−1.04	−25.6	−1.15	0.0	0.00	−18.3	−1.09	−14.0	−0.83
12D	10.9	0.57	−9.5	−0.42	−4.4	−0.26	0.0	0.00	−9.2	−0.36	−13.0	−0.78	−6.1	−0.36
13A	−8.4	0.44	9.5	0.42	26.6	1.56	8.6	0.52	17.1	0.68	12.2	−0.73	17.8	1.04
13B	4.2	0.22	4.8	0.21	0.0	0.00	−8.6	−0.52	0.0	0.00	0.0	0.00	4.4	0.26
13C	0.0	0.00	−7.1	−0.31	−8.8	−0.52	−5.8	−0.26	−13.2	−0.52	−11.3	−0.68	−8.9	−0.52
UPPER FIN														
1A	−62.2	−3.84	89.4	3.90	57.0	3.38	87.2	3.90	56.6	2.23	78.3	4.68	25.9	1.50
2A	−5.9	−0.36	65.5	2.86	61.4	3.64	55.8	2.45	72.4	2.86	67.8	4.05	43.7	2.55
2B	−37.0	−2.28	33.4	1.43	35.1	2.08	34.9	1.56	32.9	1.30	39.1	2.34	19.7	1.14
3A	−82.4	−5.10	85.8	3.74	96.5	5.71	17.5	0.78	105.1	4.16	110.5	6.51	24.1	1.40
4A	−65.6	−4.05	60.8	2.65	70.2	4.16	58.1	2.60	65.8	2.60	63.5	3.80	26.8	1.56
4B	−4.2	−0.26	11.9	0.52	8.8	0.52	0.0	0.00	6.6	0.26	4.4	0.26	4.5	0.26

* Approximate.

NOTE.—Positive pressures act from port to starboard.

TABLE II

MANEUVERS U. S. S. "LOS ANGELES"

5D		5D		3C		3C		3C		17D		17D		17D		17D	
2¼		6		2		3¼		6		4		6		7		8	
4.50° L.		7.70° L.		12.35° R.		6.50° L.		11.55° L.		12.50° R.		11.65° L.		12.15° L.		12.15° L.	
72.0		71.7		71.0		70.6		66.4		* 86.8		* 78.4		* 77.2		* 80.3	
0.0180 clock.		0.0096 count. clock.		0.0190 clock.		0.0205 clock.		0.0180 count. clock.		0.0226 clock.		0.0167 clock.		0.0035 clock.		0.0025 count. clock.	
5.1° R.		5.1° L.		6.6° R.		5.2° R.		5.8° L.		8.5° R.		3.6° R.		2.0° L.		5.2° L.	
5.62		5.56		5.41		5.36		4.73		* 7.96		* 6.50		* 6.30		* 6.81	
% q	#/sq. ft.	% q	#/sq. ft.	% q	#/sq. ft.	% q	#/sq. ft.	% q	#/sq. ft.	% q	#/sq. ft	% q	#/sq. ft.	% q	#/sq. ft.	% q	#/sq. ft.
LOWER FIN AND RUDDER																	
0.0	0.00	52.2	2.91	−11.5	−0.62	0.0	0.00	−47.2	−2.24	-------	−0.62	-------	0.85	-------	2.24	-------	2.91
0.0	0.00	2.6	0.16	1.9	0.10	1.9	0.10	−2.2	−0.10	-------	0.00	-------	0.10	-------	−0.16	-------	−0.21
55.6	3.12	−59.9	−3.33	94.3	5.09	58.2	3.12	−55.0	−2.60	-------	5.82	-------	0.85	-------	−2.60	-------	−4.58
44.5	2.50	−17.8	−0.99	52.0	2.81	34.0	1.82	−20.9	−0.99	-------	3.43	-------	1.04	-------	−1.04	-------	−1.66
30.7	1.72	−54.1	−3.02	38.5	2.08	26.2	1.40	−14.3	−0.68	-------	4.16	-------	0.16	-------	−3.59	-------	−3.85
30.7	1.72	−42.1	−2.34	48.1	2.60	33.0	1.77	−73.7	−3.48	-------	2.96	-------	0.52	-------	−2.24	-------	−3.95
31.5	1.77	−29.8	−1.66	40.4	2.18	26.2	1.40	−34.1	−1.61	-------	2.96	-------	1.04	-------	−1.30	-------	−2.50
26.0	1.46	−35.6	−1.98	39.4	2.13	27.2	1.46	−40.7	−1.92	-------	3.12	-------	0.10	-------	−1.92	-------	−3.07
36.4	2.03	−46.8	−2.60	66.4	3.59	32.0	1.72	−52.8	−2.50	-------	8.37	-------	0.73	-------	−2.24	-------	−4.32
18.6	1.04	−7.2	−0.42	32.7	1.77	20.2	1.09	−13.2	−0.62	-------	2.44	-------	0.78	-------	−1.30	-------	−1.66
18.6	1.04	−39.3	−2.18	28.9	1.56	15.5	0.83	−46.2	−2.18	-------	2.44	-------	−0.21	-------	−2.18	-------	−3.02
7.5	0.42	−36.5	−2.03	18.3	0.99	4.8	0.26	−46.2	−2.18	-------	1.56	-------	−0.52	-------	−2.86	-------	−1.70
55.3	3.12	−45.0	−2.50	104.0	5.62	49.5	2.68	−67.0	−3.18	-------	9.41	-------	1.14	-------	−1.35	-------	−6.24
16.0	0.88	−46.8	−2.60	15.4	0.83	7.8	0.42	−63.7	−3.02	-------	1.56	-------	0.00	-------	−2.29	-------	−5.36
39.9	2.24	−16.9	−0.94	46.2	2.50	42.7	2.28	−23.1	−1.09	-------	3.38	-------	1.56	-------	−0.88	-------	−1.82
15.7	0.88	−14.0	−0.78	29.8	1.61	19.4	1.04	−18.7	−0.88	-------	2.03	-------	0.26	-------	−0.94	-------	−1.40
71.3	4.06	−65.5	−3.64	134.5	7.28	60.1	3.22	−68.2	−3.22	-------	9.88	-------	0.42	-------	−2.86	-------	−6.60
7.5	0.42	−77.8	−4.32	14.4	0.78	12.6	0.68	−92.3	−4.37	-------	0.78	-------	0.00	-------	−2.13	-------	−6.55
25.3	1.41	−29.9	−1.66	39.4	2.13	25.2	1.35	−30.8	−1.46	-------	2.44	-------	0.36	-------	−1.72	-------	−2.50
4.6	0.26	−31.8	−1.77	18.3	0.99	9.7	0.52	−37.4	−1.77	-------	1.72	-------	−0.26	-------	−1.77	-------	−2.08
7.5	0.42	−14.0	−0.78	21.1	1.14	10.7	0.57	−22.0	−1.04	-------	1.61	-------	0.00	-------	−1.04	-------	−1.04
68.6	3.85	−59.0	−3.28	75.0	4.06	32.0	1.72	−74.8	−3.54	-------	5.20	-------	0.26	-------	−3.12	-------	−5.93
21.4	1.20	−15.8	−0.88	28.9	1.56	25.2	1.35	−18.7	−0.88	-------	2.18	-------	0.52	-------	−0.26	-------	−1.25
11.0	0.62	−14.0	−0.78	15.4	0.83	8.7	0.47	−16.5	−0.78	-------	1.25	-------	0.26	-------	−0.78	-------	−2.50
5.5	0.31	−6.4	−0.36	6.7	0.36	6.8	0.31	−9.9	−0.47	-------	0.52	-------	0.00	-------	−0.26	-------	−0.99
55.6	3.12	−56.6	−3.17	68.2	3.69	51.4	2.76	−61.5	−2.91	-------	5.20	-------	0.31	-------	−2.91	-------	−3.95
13.0	0.73	−5.5	−0.31	5.8	0.31	17.5	0.94	−6.6	−0.31	-------	1.72	-------	0.52	-------	0.52	-------	−0.62
1.8	0.10	2.8	0.16	−11.5	−0.62	−4.0	−0.21	−7.7	−0.36	-------	−0.36	-------	0.16	-------	0.26	-------	−0.05
67.8	3.80	−57.9	−3.22	61.5	3.33	79.5	4.26	−68.2	−3.22	-------	5.20	-------	0.94	-------	−4.11	-------	−4.94
4.6	0.26	−4.6	−0.26	−11.5	−0.62	12.6	0.68	−4.4	−0.21	-------	−0.36	-------	0.21	-------	0.10	-------	−0.10
8.4	0.47	4.6	0.26	−4.8	−0.26	16.5	0.88	9.9	0.47	-------	−0.42	-------	0.62	-------	0.88	-------	0.42
64.8	3.64	−24.3	−1.35	32.7	1.77	83.5	4.47	−9.9	−0.47	-------	2.08	-------	1.77	-------	−1.66	-------	−1.61
25.1	1.41	9.4	0.52	−13.5	−0.73	34.9	1.87	12.1	0.57	-------	−0.52	-------	1.61	-------	1.87	-------	1.09
21.4	1.20	13.1	0.73	−5.8	−0.31	42.7	2.28	26.4	1.25	-------	−0.83	-------	1.82	-------	2.08	-------	1.82
20.3	1.14	18.7	1.04	2.9	0.16	33.0	1.77	29.7	1.41	-------	−0.16	-------	2.03	-------	1.77	-------	1.56
82.6	4.63	−12.2	−0.68	−28.9	−1.56	116.5	6.24	−6.6	−0.31	-------	−1.56	-------	5.36	-------	0.99	-------	0.52
12.1	0.68	−22.5	−1.25	−24.0	−1.30	21.4	1.14	−9.9	−0.47	-------	−1.66	-------	−1.56	-------	−0.83	-------	0.52
42.6	2.39	44.1	2.45	−76.0	−4.11	57.2	3.07	69.3	3.28	-------	−4.68	-------	3.85	-------	5.10	-------	−4.57
36.2	2.03	36.5	2.03	−66.0	−3.59	38.0	2.03	43.0	2.03	-------	−2.81	-------	2.03	-------	3.54	-------	3.54
9.3	0.52	23.4	1.30	−38.5	−2.08	16.5	0.88	27.5	1.30	-------	−2.08	-------	0.85	-------	1.66	-------	2.18
46.4	2.60	−19.6	−1.09	8.7	0.47	59.2	3.17	−17.6	−0.83	-------	0.16	-------	2.24	-------	−0.16	-------	−1.04
5.5	0.31	9.4	0.52	−32.7	−1.77	17.5	0.94	24.2	1.14	-------	−1.92	-------	0.94	-------	0.88	-------	1.20
11.0	0.62	18.7	1.04	−20.2	−1.09	27.0	1.46	13.2	0.62	-------	0.26	-------	1.66	-------	1.66	-------	2.08
0.0	0.00	11.1	0.62	−12.5	−0.68	5.8	0.31	6.6	0.31	-------	−0.78	-------	0.62	-------	0.94	-------	0.62
37.1	2.08	−12.2	−0.68	23.1	1.25	38.8	2.08	−8.8	−0.42	-------	1.04	-------	2.45	-------	−0.26	-------	−0.52
1.8	0.10	9.4	0.52	−3.8	−0.21	16.5	0.88	18.7	0.88	-------	−0.52	-------	0.47	-------	0.47	-------	0.88
−1.8	−0.10	0.0	0.00	−17.3	−0.94	1.9	0.10	0.0	0.00	-------	3.22	-------	0.10	-------	0.10	-------	0.10
UPPER FIN																	
35.2	1.97	−61.6	3.43	42.3	2.29	19.4	1.04	−90.2	−4.26	-------	4.99	-------	−0.21	-------	−2.60	-------	−5.68
50.9	2.86	−10.7	−0.52	67.3	3.64	27.2	1.45	−5.5	−0.25	-------	3.22	-------	1.30	-------	−1.04	-------	−3.65
23.1	1.30	−32.7	−1.82	32.7	1.77	16.5	0.88	−44.0	−2.08	-------	2.65	-------	0.10	-------	−1.66	-------	−2.92
51.9	2.91	−88.8	−4.94	82.7	4.47	33.0	1.77	−132.0	−6.24	-------	7.49	-------	0.16	-------	−6.14	-------	−9.39
47.2	2.65	−56.1	−3.12	49.0	2.65	43.6	2.39	−79.2	−3.74	-------	4.32	-------	0.21	-------	−1.14	-------	−5.52
12.0	0.67	10.7	0.52	4.8	0.26	19.4	1.04	14.3	0.67	-------	0.00	-------	0.73	-------	0.52	-------	0.26

TABLE III

RESULTANT PRESSURES ON TAIL SURFACES U. S. S. "LOS ANGELES" DUE TO GUSTS

[Pressures in lb./sq. ft.]

Orifice No.	Run No. 4A	Run No. 5A	Orifice No.	Run No. 4A	Run No. 5A	Orifice No.	Run No. 4A	Run No. 5A
STARBOARD FIN AND ELEVATOR								
1A	7.29	6.25	6A	13.02	8.95	10C	0.26	2.86
1A′	3.13	3.12	6B	3.13	1.82	11D	−1.30	1.04
2A	7.29	6.25	6C	3.39	2.08	11A	10.93	12.20
2A′	2.86	2.60	6D	1.82	0.94	11A′	−0.78	2.60
2B	4.69	3.12	7A	8.07	6.25	12A	8.85	11.45
3A	5.22	4.15	7B	1.30	0.78	12B	−1.04	9.35
3A′	2.08	1.82	7C	1.30	0.67	12C	−3.65	4.42
3B	2.87	1.56	7D	0.62	0.36	12D	−1.30	2.86
4A	10.68	7.80	8A	7.81	6.25	13A	1.82	8.58
4A′	1.30	1.04	8B	1.56	1.56	13B	0.52	3.12
4B	4.17	2.60	8C	0.52	0.83	13C	0.52	2.08
4C	2.61	0.94	9A	7.81	7.30	13D	−0.78	0.52
5A	10.68	7.80	9B	1.82	2.08	14A	−0.78	0.00
5A′	1.56	1.56	9C	0.00	0.00	14B	−0.26	1.56
5B	3.13	2.08	10A	13.02	16.10	14C	−0.78	0.52
5C	2.19	1.04	10B	0.52	2.60	14D	0.00	0.00
LOWER FIN AND RUDDER								
1A	2.08	2.18	6A	−3.12	−3.12	10B	−1.00	−2.08
1A′	----------	----------	6A′	----------	----------	10C	−1.30	−2.08
2A	−2.08	−3.02	6B	−2.08	−2.65	10D	0.00	−0.10
2A′	−0.00	0.00	6C	−1.30	−1.82	11A	−4.69	−7.28
2B	−1.56	−2.18	6D	−0.78	−1.04	11B	−2.35	−3.90
3A	−2.35	−3.12	7A	−1.82	−1.56	11B′	−3.38	−5.72
3A′	−1.30	−1.30	7B	−0.78	−1.09	11C	−1.04	−2.08
3B	−1.30	−1.56	7C	−0.52	−0.78	11D	0.00	−0.68
4A	−2.08	−2.08	7D	−0.52	−1.14	12A	−4.17	−6.24
4A′	0.00	−1.04	8A	−1.30	−2.86	12B	−1.30	−1.56
4B	−2.08	−2.08	8B	0.63	−1.04	12C	−0.78	−1.04
4C	−1.30	−1.82	8C	−0.63	−1.19	12D	0.00	−0.26
5A	−0.78	−1.46	9A	−1.30	−5.10	13A	−2.08	−4.58
5A′	0.00	−1.56	9B	−0.52	−0.42	13B	----------	−0.26
5B	−0.52	−0.94	9C	−0.26	−1.04	13C	----------	−5.30
5C	−0.62	−1.30	10A	−2.08	−2.50	13D	----------	----------

NOTE.—Run 4A, q=8.01 lb./sq. ft. Run 5A, q=7.02 lb./sq. ft. (approximate).
Positive pressures act from port to starboard and bottom to top.

TABLE IV

FORCES AND NORMAL FORCE COEFFICIENTS TAIL SURFACES U. S. S. "LOS ANGELES"

Maneuvers	Run No.	Timing interval	Rudder position	q lb./ft.^{2}	Fin load, lbs.	Rudder load, lbs.	Total load, lbs.	C_{NF} Fin	C_{NF} Rudder	C_{NF} Total
LOWER FIN AND RUDDER										
Turn	4B	2	9.70° L.	6.19	−1,255	87	−1,168	−0.191	0.068	−0.149
Do	4C	7	8.30° R.	4.37	1,482	−182	1,300	.320	−.201	.235
Do	5C	9	7.85° R.	5.93	1,533	−229	1,304	.244	−.187	.173
Do	2B	5	12.75° R.	4.47	968	−212	756	.204	−.229	.133
Do	13D	13	12.95° R.	3.95	1,184	−200	984	.282	−.244	.196
Do	6C	5 F. E.[1]	13.25° R.	5.98	1,936	−297	1,639	.305	−.240	.216
Reversal	5D	1	9.05° R.	5.82	728	−182	546	.118	−.151	.074
Do	5D	2¼	4.50° L.	5.62	1,460	219	1,679	.245	.188	.236
Do	5D	6	7.70° L.	5.56	−1,045	120	−925	−.177	.104	−.131
Do	3C	2	12.35° R.	5.41	1,466	−278	1,188	.256	−.248	.173
Do	3C	3¼	6.50° L.	5.36	1,459	358	1,817	.257	.323	.268
Do	3C	6	11.55° L.	4.73	−1,141	168	−973	−.227	.172	−.162
Do	17D	4	12.50° R.	*7.96	2,139	−217	1,922	*.253	*−.132	*.190
Do	17D	6	11.65° L.	*6.50	589	329	918	*.085	*.245	*.111
Do	17D	7	12.15° L.	*6.30	−205	315	110	*.031	*.242	*.014
Do	17D	8	12.15° L.	*6.81	−1,612	281	−1,331	*.223	*.199	*.154
Rough Air	4A	8¼	3.05° R.	8.01	−1,031	−246	−1,277	−.121	−.149	−.126
Do	5A	9 9/16	6.90° R.	*7.02	−1,689	−323	−2,012	*−.227	*−.222	*−.226
STARBOARD FIN AND ELEVATOR										
Rough air	4A	8¼	15.60° D.	8.01	3,227	274	3,501	0.396	0.146	0.349
Do	5A	9 9/16	18.40° D.	[1]7.02	2,533	986	3,519	[1].355	[1].598	[1].400

* Approximate.

NOTE.—Positive pressures act from port to starboard and from bottom to top.

Lower fin area=1,061 sq. ft.
Lower rudder area=207 sq. ft.
Starboard fin area=1,018 sq. ft.
Starboard elevator area=235 sq. ft.

TABLE V

PRESSURES ON HULL OF U. S. S. "LOS ANGELES"

Run No.	4A	5A	4B	4C	5C	6C	3C	3C	3C
Timing interval	8¼	9⁹⁄₁₆	2	7	9	5th F. E.	2	3¼	6
Rudder position	3° R.	7° R.	9.70° L.	8.30° R.	7.85° R.	13.25° R.	12.35° R.	6.50° L.	11.55° L.
Velocity ft./sec.	83.2	* 79.2	74.2	64.4	75.0	74.5	71.0	70.6	66.4
Angular velocity rad./sec.	---	---	0.0043 Count. clock.	0.0189 Clock.	0.0217 Clock.	---	0.0190 Clock.	0.0205 Clock.	0.0180 Count. clock.
Yaw at frame 80	---	---	7.1° L.	7.6° R.	6.8° R.	---	6.6° R.	5.2° R.	5.8° L.
q in lb./ft.^{2}	8.01	* 7.02	6.19	4.37	5.93	5.98	5.41	5.36	4.73
PRESSURES IN POUNDS PER SQUARE FOOT									
Orifice No.	**Longitudinal row**								
Nose	6.19	7.49	5.73	4.16	5.98	6.14	5.46	5.04	4.73
186A	4.94	4.58	3.44	2.71	4.01	4.03	3.28	2.76	3.12
186B	---	1.98	2.16	2.13	2.86	2.86	2.34	2.08	2.34
183-¼A	1.87	1.20	0.99	1.46	1.66	1.74	1.46	1.71	1.46
183-¼B	1.46	1.61	0.83	0.93	1.46	1.09	0.99	0.68	0.83
179-½A	---	---	−0.21	---	---	---	---	---	---
179-½B	1.20	0.21	---	0.21	0.26	0.36	0.21	0.00	0.21
175B	0.00	−0.42	---	0.47	0.52	0.62	0.36	0.26	0.42
170A	---	−0.26	---	0.00	0.00	0.15	−0.15	---	0.00
170B	−0.10	−0.42	−0.05	−0.21	0.00	0.00	−0.36	−0.31	−0.36
165A	−0.62	−0.47	−0.31	−0.21	−0.26	−0.21	−0.36	−0.21	−0.26
165B	---	---	---	---	---	---	---	---	---
160A	---	---	−0.26	−0.05	0.00	0.00	0.00	0.00	−0.05
160B	0.00	+0.10	0.15	0.31	0.26	−0.26	0.10	0.05	0.10
155A	---	---	---	---	---	---	---	---	---
155B	−0.42	−0.31	0.00	−0.10	0.00	0.00	0.10	−0.05	−0.10
150A	−0.50	−0.68	−0.10	0.42	0.21	0.21	0.00	−0.10	0.21
150B	−0.31	−0.52	−0.15	0.15	0.31	0.15	0.15	−0.26	0.15
175-2S	−0.68	−0.78	−0.52	−0.26	−0.36	0.15	−0.42	−0.10	−0.36
145-2S	---	−0.26	0.00	0.10	0.00	0.31	0.00	−0.05	0.00
	Frame 175								
½S	0.42	0.00	0.10	0.42	0.26	0.42	0.10	0.10	0.36
2S	−0.68	−0.78	−0.52	−0.26	−0.36	−0.15	−0.42	−0.10	−0.36
2Sa	−0.16	−0.36	−0.21	0.15	0.00	0.10	0.00	0.00	0.15
2Sb	−0.13	−0.42	0.15	0.31	0.36	0.42	0.15	0.15	0.31
2Sc	−0.13	−0.42	0.00	0.15	0.26	0.21	0.05	0.00	0.05
2Sd	---	---	---	---	---	---	---	---	---
3S	−0.31	−0.42	−0.10	−0.10	−0.26	0.00	0.31	−0.21	−0.10
3S′	−0.16	−0.31	−0.15	0.00	0.00	0.00	0.00	0.00	0.00
4S	−0.62	−0.78	−0.10	−0.26	0.00	0.00	−0.36	−0.36	−0.26
5S	−0.10	−0.10	−0.36	0.36	0.52	0.68	0.31	0.31	0.36
6S	−0.10	−0.21	−0.15	0.00	0.00	0.15	0.00	−0.05	0.00
6S′	0.00	−0.05	0.00	0.00	0.00	0.15	0.00	−0.15	0.00
5P	---	−0.78	−0.31	−0.31	−0.52	−0.52	−0.31	−0.31	−0.05
4P	−0.68	−0.68	−0.31	0.00	0.00	0.00	−0.31	0.05	−0.10
3P	---	−0.26	0.10	0.00	0.00	0.26	−0.21	0.10	−0.10
3P′	−0.39	+0.26	−0.10	0.21	0.21	0.21	0.31	−0.36	0.26
2P	−0.42	+0.36	−0.15	0.42	0.36	0.36	0.10	0.36	0.10
1P	0.26	0.21	0.21	0.00	0.00	0.15	---	−0.05	−0.10
	Frame 145								
1S	−0.68	−0.31	−0.31	−0.31	0.00	0.00	0.00	−0.31	0.00
2S	---	−0.26	0.00	0.10	0.00	0.31	0.00	−0.05	0.00
2Sa	−0.42	−0.26	0.00	0.05	0.00	0.00	0.10	0.10	0.10
2Sb	−0.42	−0.42	−0.15	0.00	0.00	0.00	0.00	0.00	0.00
2Sc	−0.10	−0.10	−0.10	−0.05	0.00	0.00	0.00	0.21	0.00
2Sd	−0.31	−0.36	0.00	0.00	0.00	0.00	−0.15	−0.05	−0.10
3S	−0.36	−0.52	−0.15	0.00	0.00	0.00	0.00	0.00	−0.36
3S′	−0.36	−0.16	−0.15	0.00	0.00	−0.10	0.00	0.00	0.00
4S	−0.21	−0.42	−0.21	−0.26	−0.36	−0.52	−0.21	−0.21	−0.21
5S	−0.26	−0.36	0.10	0.00	0.26	0.26	0.26	0.05	0.26
5½S	−0.68	−0.94	0.57	−0.36	−0.52	−0.52	−0.15	−0.36	−0.21
5½S′	−0.10	−0.47	0.62	0.00	0.00	−0.10	−0.10	0.00	−0.10
5P	−0.42	−0.31	−0.26	−0.10	0.00	0.00	0.00	−0.05	−0.26
4P	−0.36	−0.47	−0.15	−0.21	−1.04	0.00	−0.15	−0.36	−0.15
3P	−0.78	−0.94	−0.62	−0.15	0.00	−0.15	−0.15	0.00	−0.15
3P′	−0.26	−0.21	0.26	0.00	0.00	0.00	0.15	0.10	0.00
2P	−0.62	−0.42	−0.31	−0.10	0.00	−0.10	0.15	−0.10	0.15
1P	−0.57	−0.42	−0.15	0.00	0.00	0.00	0.00	−0.15	0.00

* Approximate.

TABLE VI

TRANSVERSE FORCES AT TWO FRAMES U. S. S. "LOS ANGELES" HULL

Run No.	Timing interval	Frame 145		Frame 175	
		Vertical lbs.	Horizontal lbs.	Vertical lbs.	Horizontal lbs.
4A	8¼	14.40	−12.2	6.70	22.00
5A	9 9/16	11.61	11.8	2.50	17.50
4B	2	19.87	−19.47	−4.60	12.87
4C	7	2.67	5.73	−4.40	9.33
5C	9	13.73	25.53	−1.00	5.60
6C	5th from end	0.13	13.93	3.33	8.20
3C	2	1.33	5.20	6.33	7.67
3C	3¼	1.80	10.00	−8.40	5.23
3C	6	−3.07	12.33	1.27	2.87

NOTE.—Positive forces act up and to starboard.

TABLE VII

TURNING MANEUVERS U. S. S. "LOS ANGELES"—RESULTANT PRESSURES ON PASSENGER CAR

Run No.		4B	4C	5C	6C	3C	3C	3C
Timing interval		2	7	9	(1)	2	3¼	6
q in lb./ft.²		6.19	4.37	5.93	5.98	5.41	5.36	4.73
Orifice No.	Dist. to nose of car, ft.	Resultant pressures in lb./sq. ft.						
C1	15.0	−.26	0	.78	0	.10	0	.31
C2	22.7	−.21	−.42	.26	−.42	−.21	−.21	−.21
C3	30.3	−.73	−.73	0	−.62	−.73	−.62	−.73
C4	38.0	0	−.31	.52	−.62	−.31	0	−.31
C5	45.6	−.10	0	.78	0	0	0	0

[1] Fifth from end of record.

TABLE VIII

RESULTANT PRESSURES ON FABRIC OF TAIL SURFACES AND HULL DURING MANEUVERS IN SMOOTH AIR

Run No.	4A	5A	4B	4C	5C	2B	13D	6C	5D	5D	5D	3C	3C	3C	17D	17D	17D	17D
Timing interval	8¼	9 9/16	2	7	9	5	13	(1)	1	2¼	6	2	3¼	6	4	6	7	8
Orifice No.	Lower fin and rudder pressure in lb./sq. ft.																	
1A–1A′	------	------	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.10	0.10	0.10	0.00	0.10	0.16	0.21
2A–2A′	0.00	0.00	1.04	2.44	3.12	2.13	2.34	3.17	2.55	2.50	.99	2.81	1.82	.52	3.43	1.04	1.04	1.66
3A–3A′	1.30	1.30	2.08	1.82	2.08	1.04	1.82	2.60	.62	1.77	1.67	2.18	1.40	1.61	2.96	1.04	1.30	2.50
4A–4A′	0.00	1.04	1.30	1.51	2.08	1.51	1.04	2.08	1.51	1.04	.42	1.77	1.09	.62	2.44	.78	1.30	1.66
5A–5A′	0.00	1.56	3.74	1.14	1.30	.78	.78	1.56	.83	.88	2.60	.83	.42	3.02	1.56	.00	2.29	5.36
6A–6A′	1.82	1.66	4.68	1.04	1.04	.42	.00	.68	.73	.42	4.31	.78	.68	4.36	.78	.00	2.13	6.60
11B–11B′	3.38	5.72	1.61	.88	1.30	.52	.78	1.30	.88	.68	1.25	1.30	1.14	.47	1.66	1.56	.83	.52
	Hull pressure in lb./sq. ft.																	
145–3S–3S′	.36	.16	.00	.00	.00	------	------	0.10	------	------	------	0.00	.00	.36	------	------	------	------
145–5½S–5½S′	.10	.47	.05	.36	.52	------	------	.42	------	------	------	.05	.36	.10	------	------	------	------
145–3P–3P′–3P′	.26	.21	.88	.16	.00	------	------	.16	------	------	------	.31	.10	.16	------	------	------	------
175–3S–3S′	.16	.31	.05	.10	.26	------	------	.00	------	------	------	.31	.21	.10	------	------	------	------
175–6S–6S′	.00	.47	.16	.00	.00	------	------	.00	------	------	------	.00	.10	.00	------	------	------	------
175–3P–3P′	.39	.42	.21	.21	.21	------	------	.05	------	------	------	.52	.47	.36	------	------	------	------

[1] Indicates fifth from end.

NOTE.—Manometer for recording hull pressures was not on board during all runs, causing the lack of hull data.

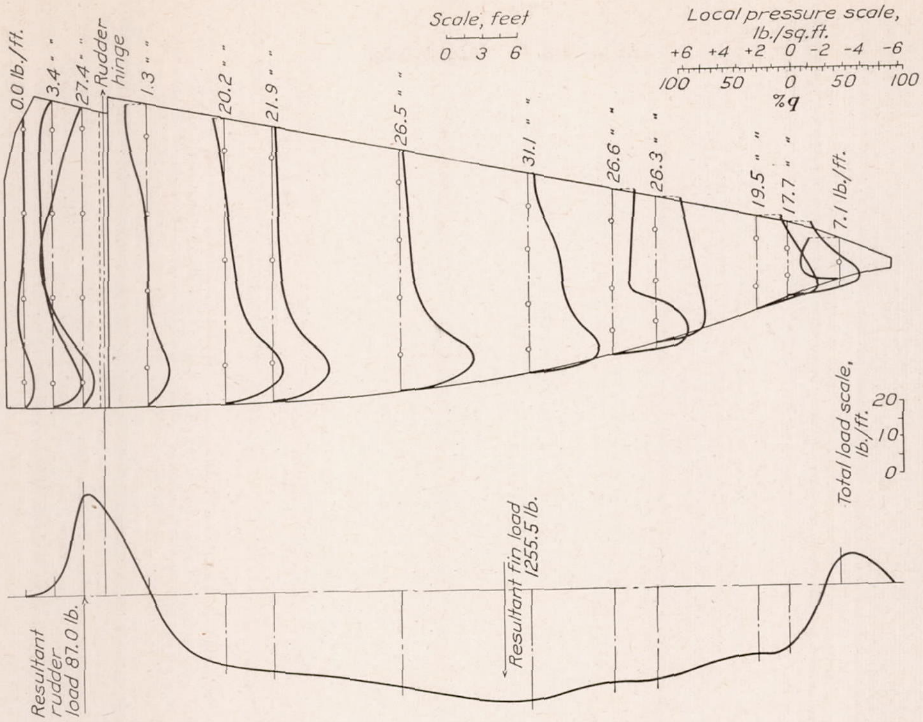


FIGURE 8.—Pressure distribution on lower fin and rudder. Steady turn. Run No. 4B—timing interval 2. Rudder position 9° 15′ port. Air speed 50.6 M. P. H.

NOTE.—*Positive pressures acting from port to starboard*

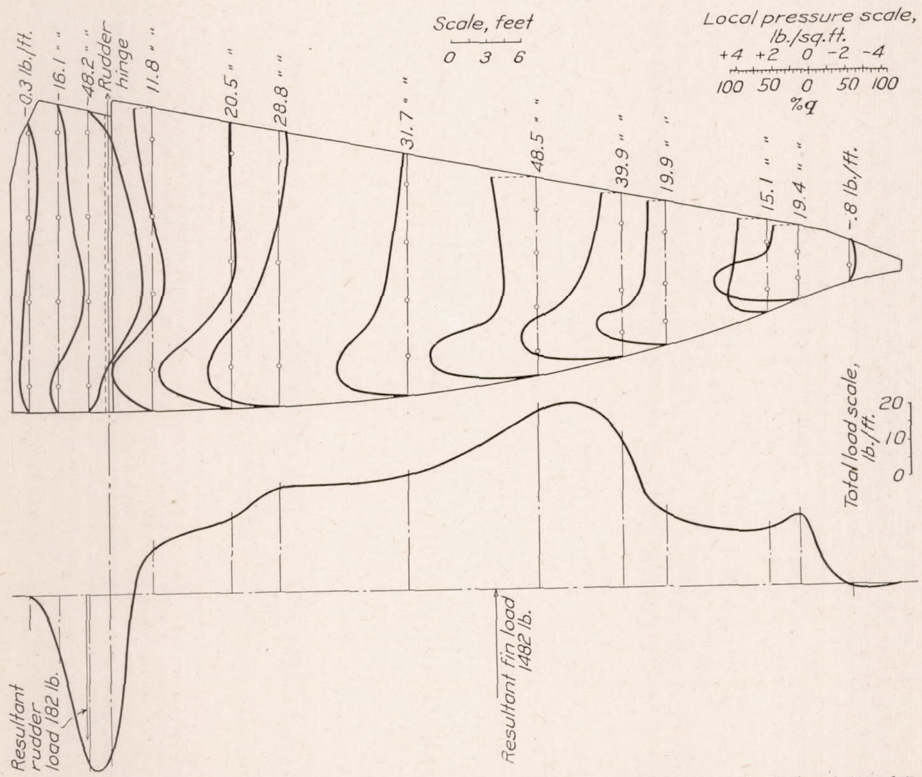


FIGURE 9.—Pressure distribution on lower fin and rudder. Steady turn. Run No. 4C—timing interval 7. Rudder position 8° 15′ starboard. Air speed 43.9 M. P. H.

NOTE.—Positive pressures acting from port to starboard

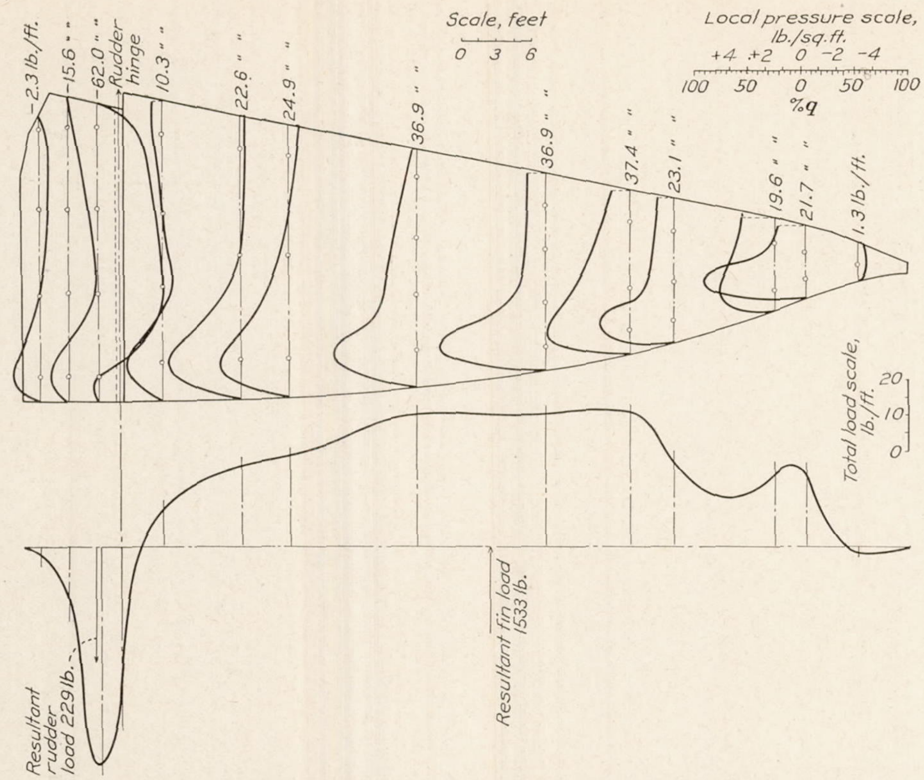


FIGURE 10.—Pressure distribution on lower fin and rudder. Steady turn. Run No. 5C—timing interval 9. Rudder position 7° 30′ starboard. Air speed 51.2 M. P. H.

NOTE.—Positive pressures acting from port to starboard

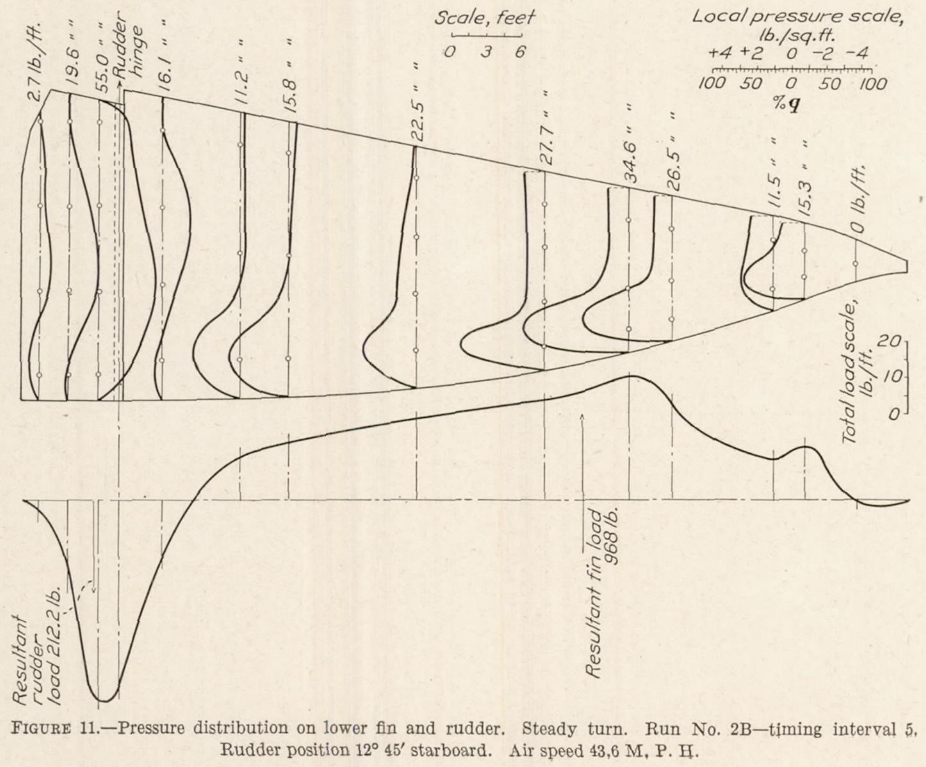


FIGURE 11.—Pressure distribution on lower fin and rudder. Steady turn. Run No. 2B—timing interval 5. Rudder position 12° 45′ starboard. Air speed 43.6 M. P. H.

NOTE.—Positive pressures acting from port to starboard

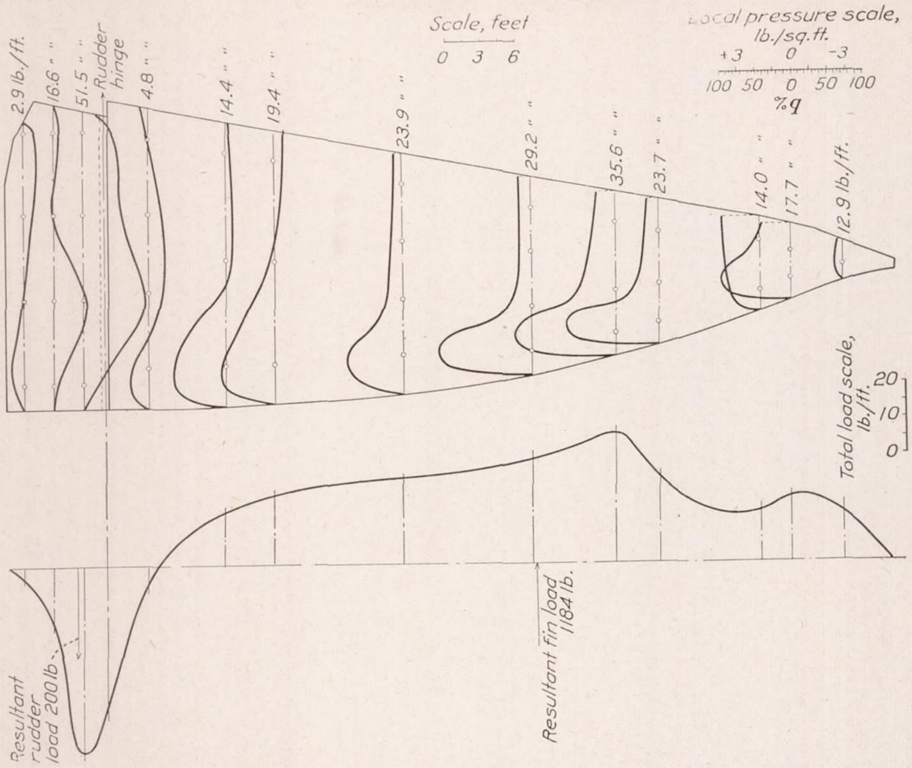


FIGURE 12.—Pressure distribution on lower fin and rudder. Steady turn. Run No. 13D—timing interval 13. Rudder position 12° 30′ starboard. Air speed 41.7 M. P. H.

NOTE.—Positive pressures acting from port to starboard

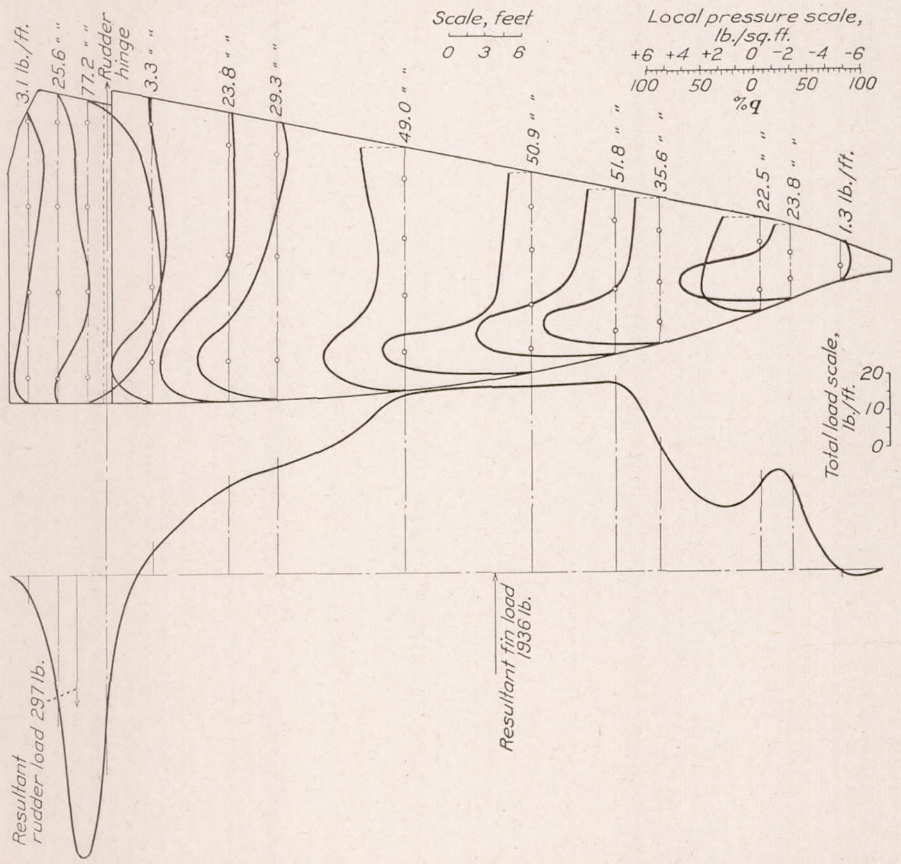


FIGURE 13.—Pressure distribution on lower fin and rudder. Steady turn. Run No. 6C—timing interval 5th from end. Rudder position 12° 45′ starboard. Air speed 50.8 M. P. H.

NOTE.—Positive pressures acting from port to starboard

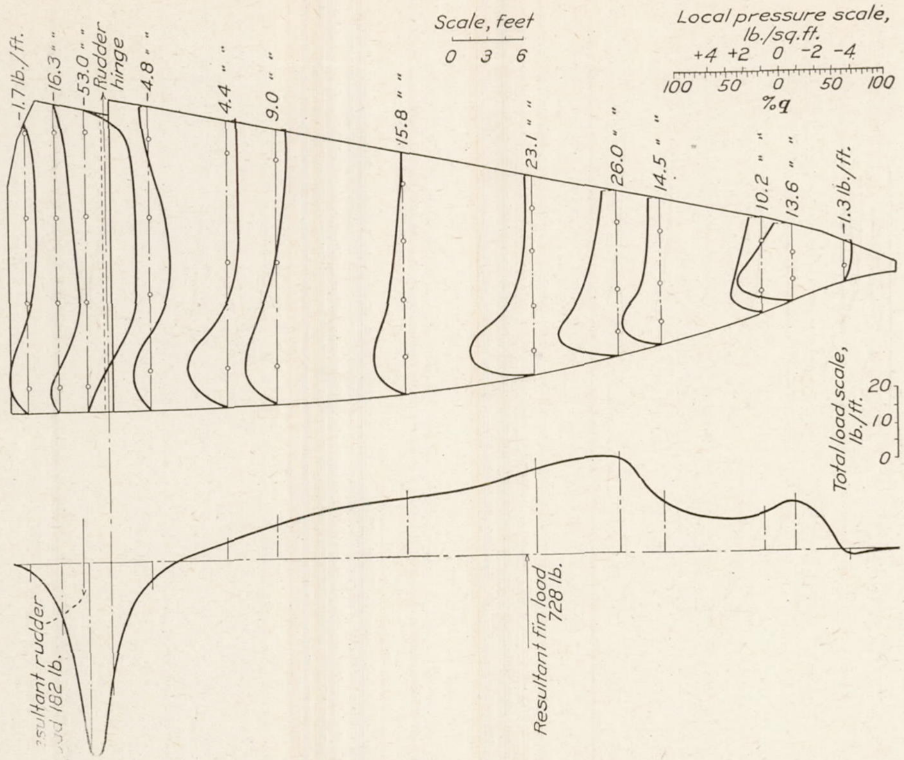


FIGURE 14.—Pressure distribution on lower fin and rudder. Steady turn. Run No. 5D—timing interval 1. Rudder position 9° starboard. Air speed 50.1 M. P. H.

NOTE.—Positive pressures acting from port to starboard

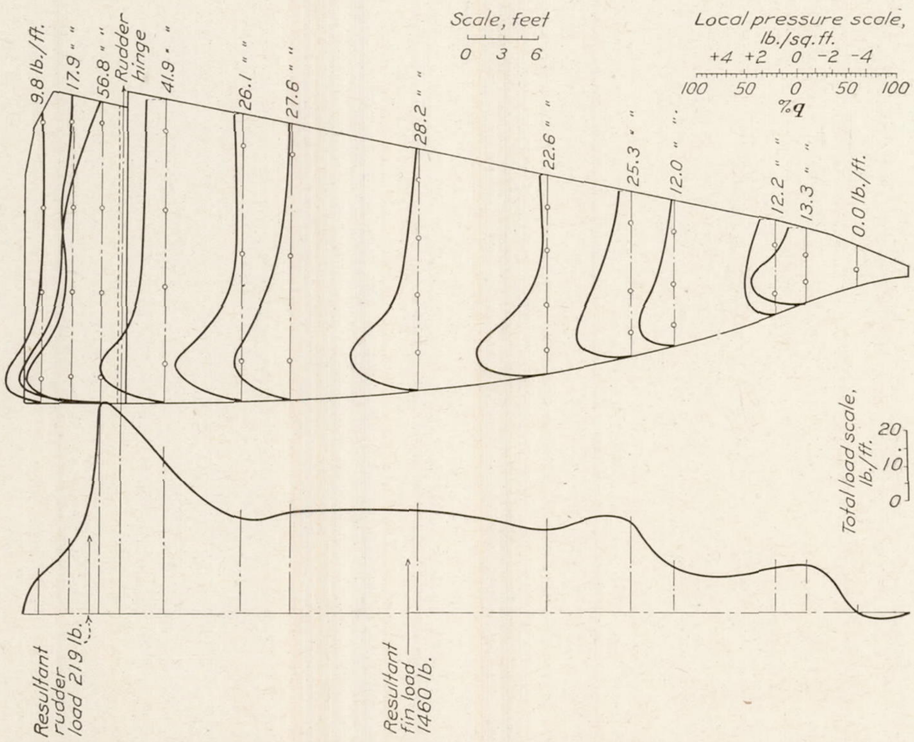


FIGURE 15.—Pressure distribution on lower fin and rudder. Steady turn. Run No. 5D—timing interval 2¼. Rudder position 6° 45′ port. Air speed 49.1 M. P. H.

NOTE.—Positive pressures acting from port to starboard

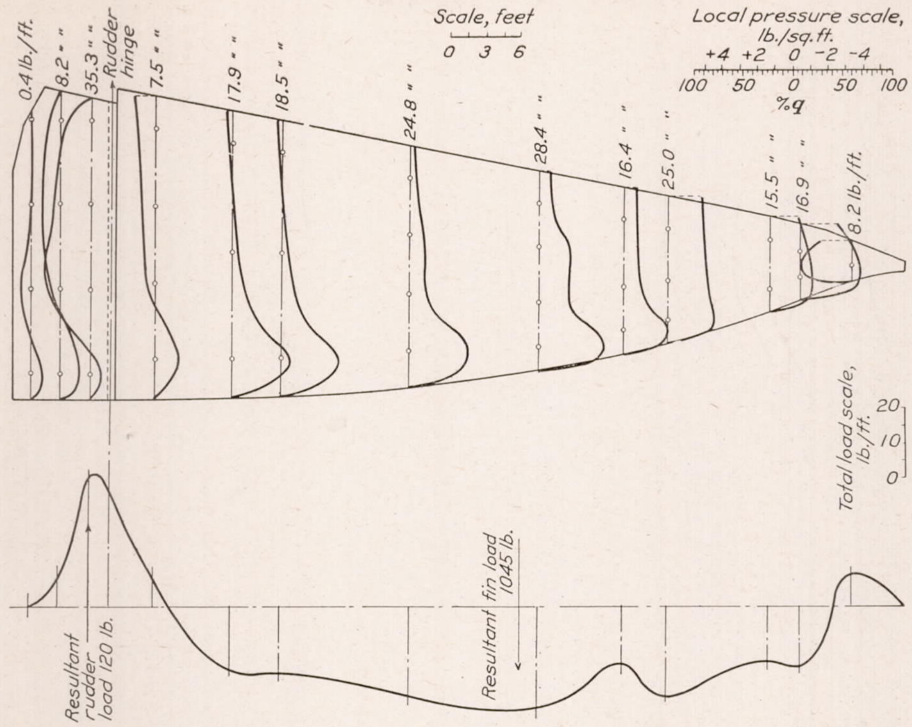


FIGURE 16.—Pressure distribution on lower fin and rudder. Steady turn. Run No. 5D—timing interval 6. Rudder position 7° 45′ port. Air speed 48.9 M. P. H.

NOTE.—Positive pressures acting from port to starboard

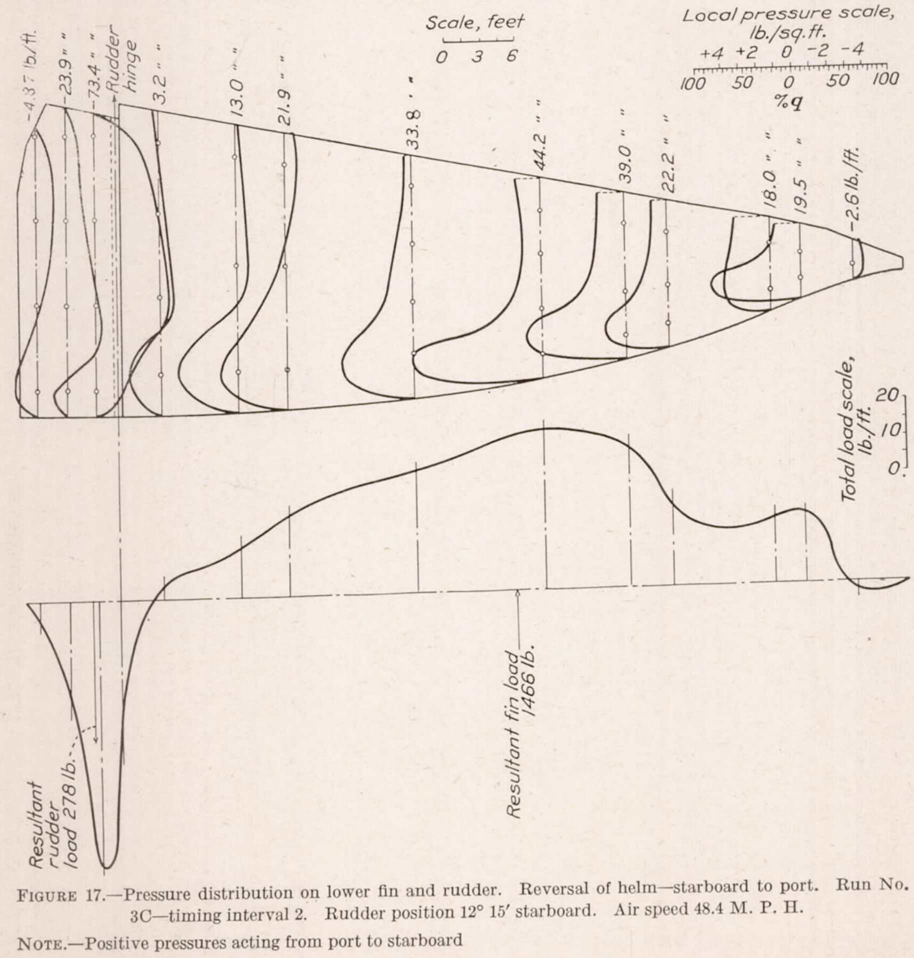


FIGURE 17.—Pressure distribution on lower fin and rudder. Reversal of helm—starboard to port. Run No. 3C—timing interval 2. Rudder position 12° 15′ starboard. Air speed 48.4 M. P. H.

NOTE.—Positive pressures acting from port to starboard

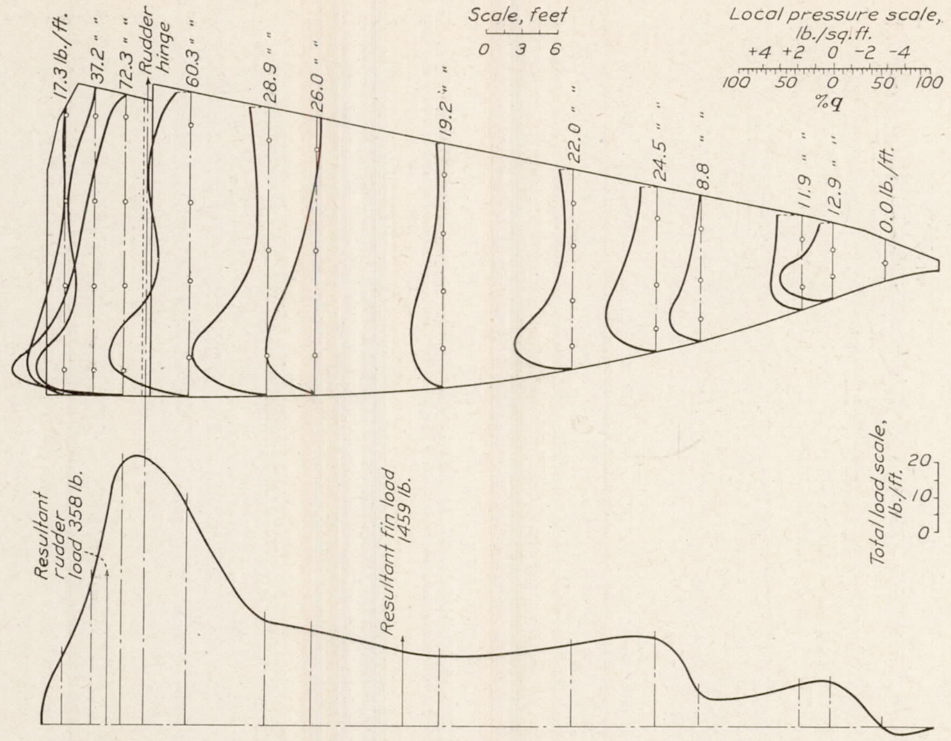


FIGURE 18.—Pressure distribution on lower fin and rudder. Reversal of helm—starboard to port. Run No. 3C—timing interval 3¼. Rudder position 3° port. Air speed 48.1 M. P. H.

NOTE.—Positive pressures acting from port to starboard

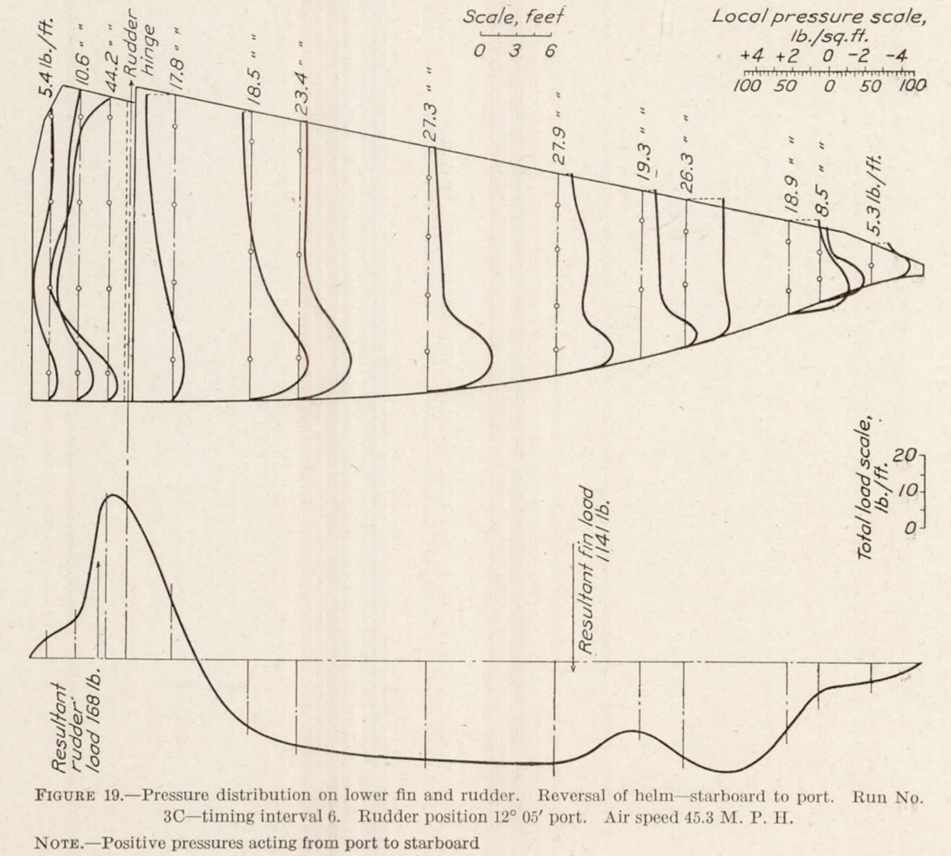


FIGURE 19.—Pressure distribution on lower fin and rudder. Reversal of helm—starboard to port. Run No. 3C—timing interval 6. Rudder position 12° 05′ port. Air speed 45.3 M. P. H.

NOTE.—Positive pressures acting from port to starboard

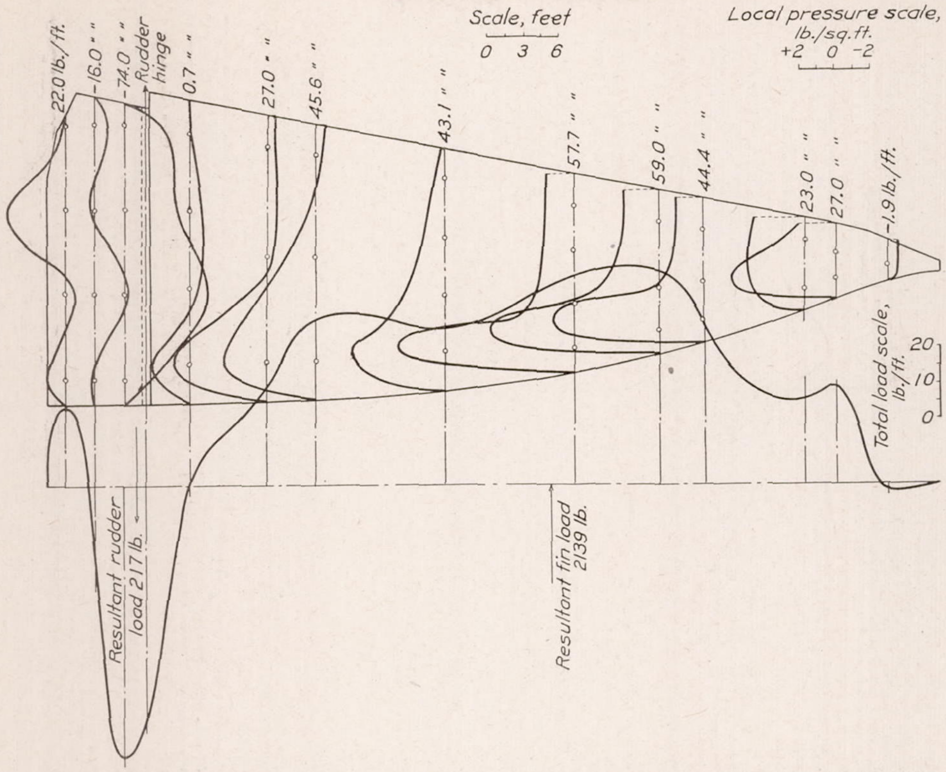


FIGURE 20.—Pressure distribution on lower fin and rudder. Reversal of helm—starboard to port. Run No. 17D—timing interval 4. Rudder position 12° 30′ starboard. Air speed 59.2 M. P. H. (approximate)

NOTE.—Positive pressures acting from port to starboard

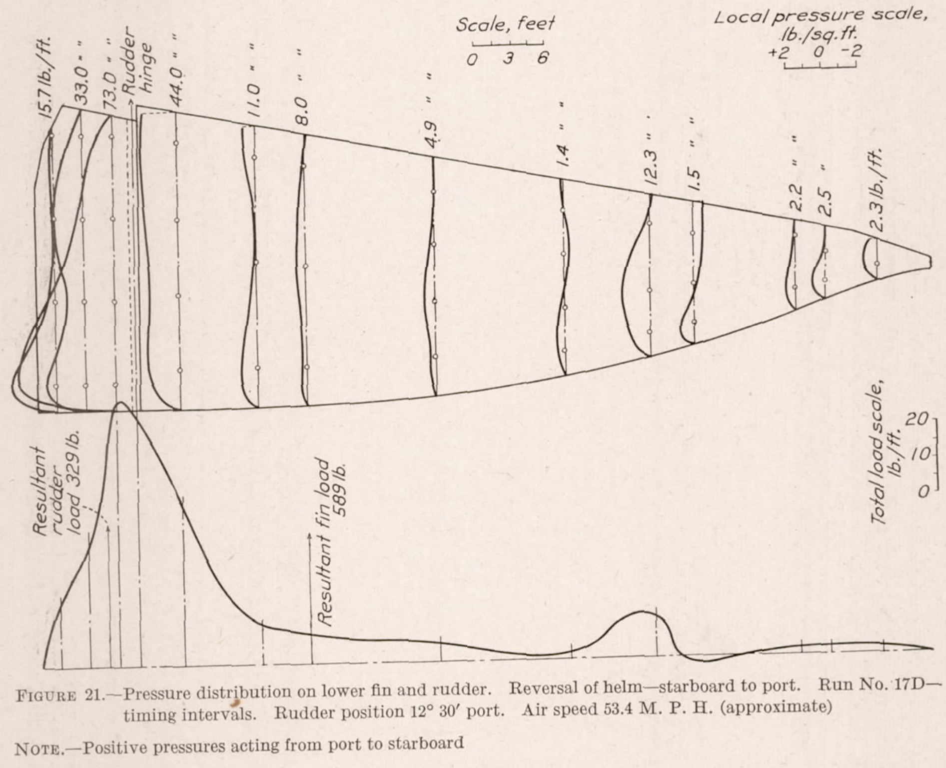


FIGURE 21.—Pressure distribution on lower fin and rudder. Reversal of helm—starboard to port. Run No. 17D—timing intervals. Rudder position 12° 30′ port. Air speed 53.4 M. P. H. (approximate)

NOTE.—Positive pressures acting from port to starboard

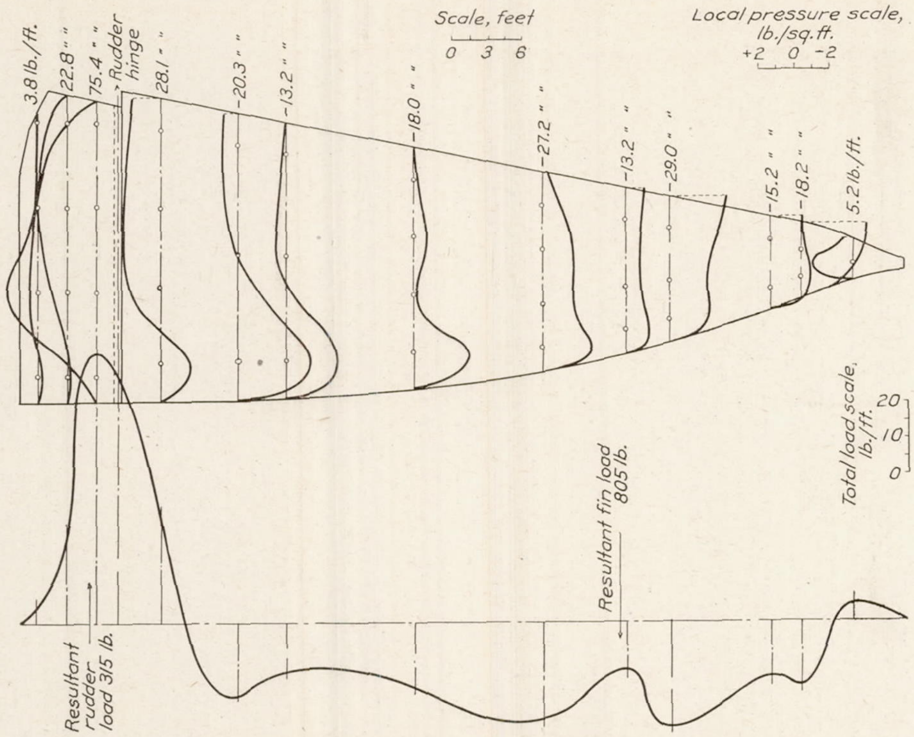


FIGURE 22.—Pressure distribution on lower fin and rudder. Reversal of helm—starboard to port. Run No. 17D—timing interval 7. Rudder position 12° 30′ port. Air speed 52.6 M. P. H. (approximate)

NOTE.—Positive pressures acting from port to starboard

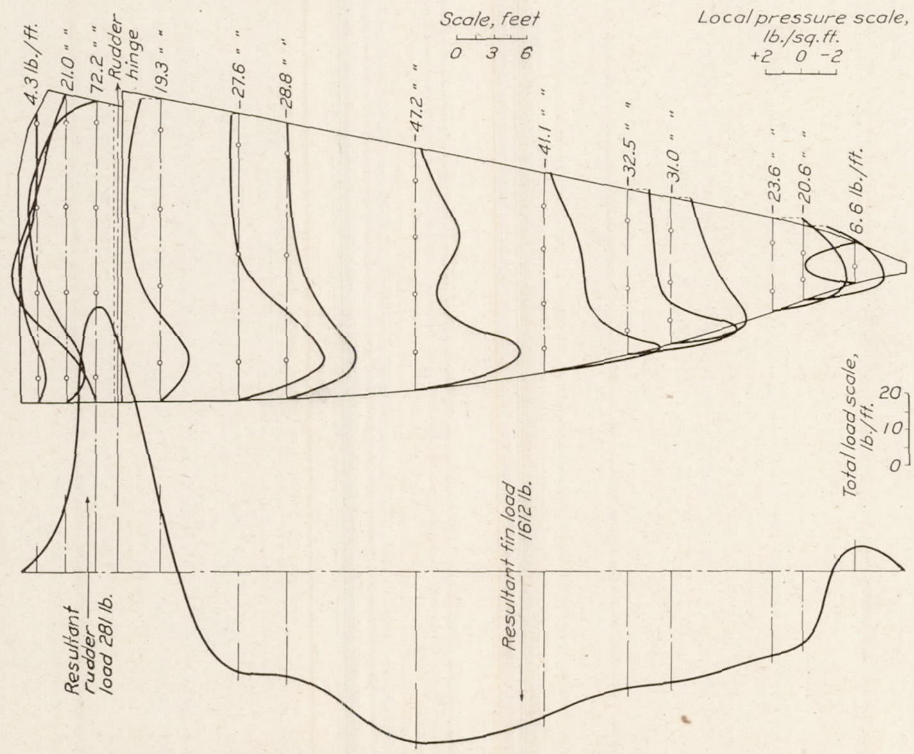


FIGURE 23.—Pressure distribution on lower fin and rudder. Reversal of helm—port to starboard to port. Run No. 17D—timing interval 8. Rudder position 12° 30′ port. Air speed 54.8 M. P. H. (approximate)

NOTE.—Positive pressures acting from port to starboard

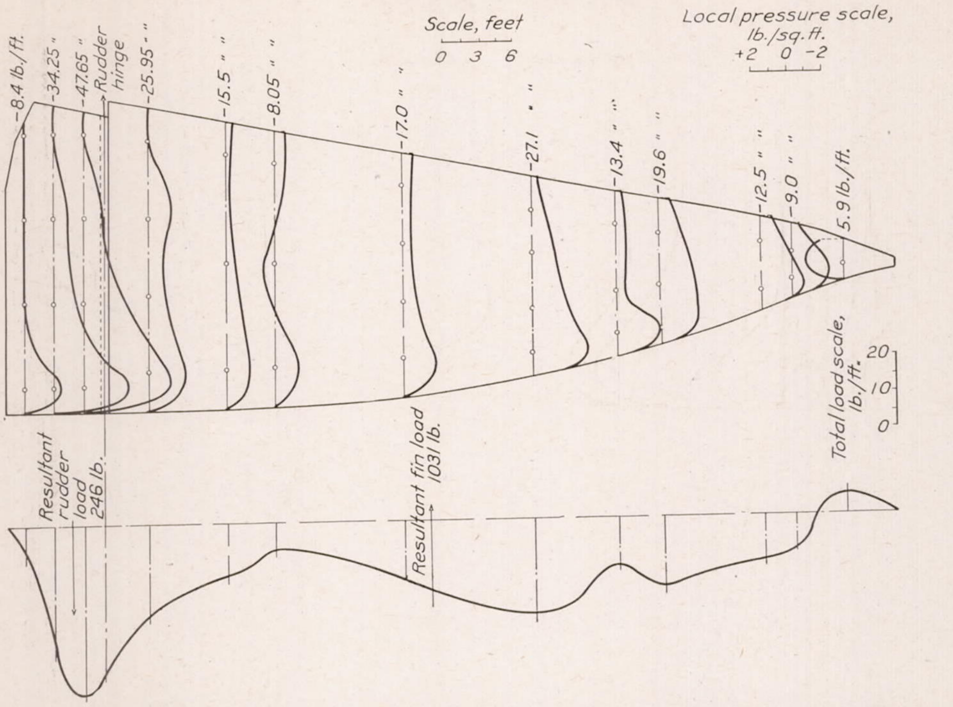


Figure 24.—Pressure distribution on lower fin and rudder. Flying through gusts. Run No. 4A—125 seconds from start. Rudder position 2° 36′ starboard. Air speed 56.7 M. P. H.

Note.—Positive pressures acting from port to starboard

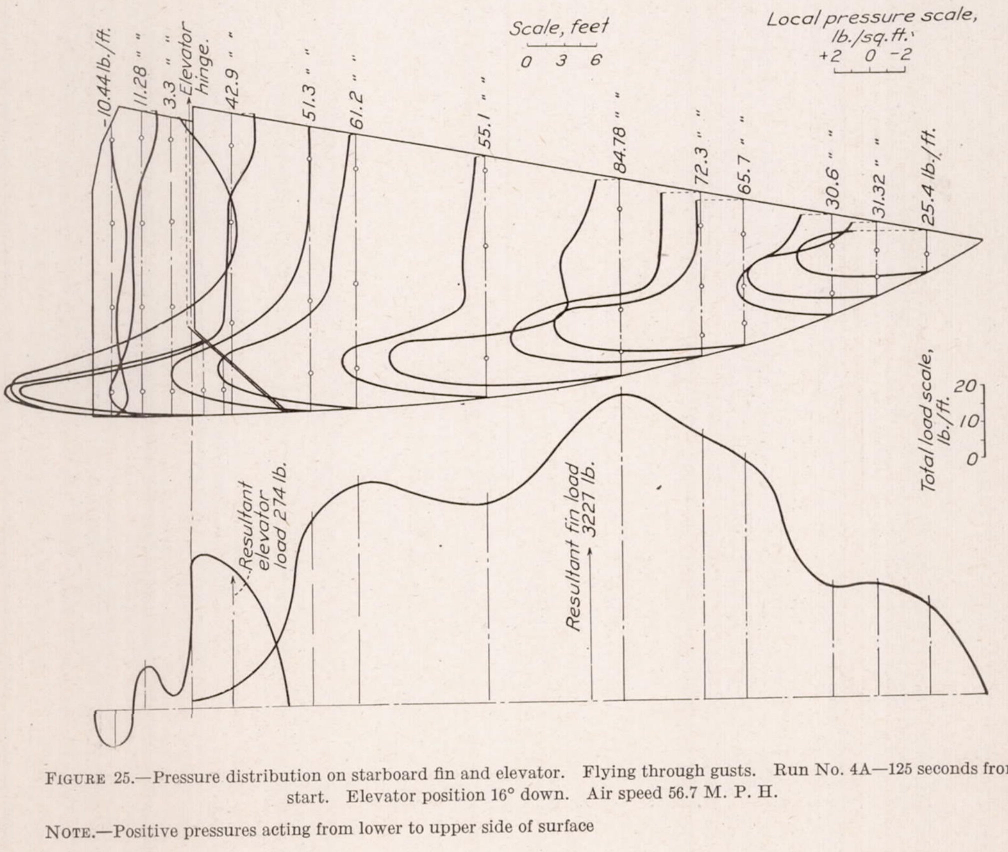


Figure 25.—Pressure distribution on starboard fin and elevator. Flying through gusts. Run No. 4A—125 seconds from start. Elevator position 16° down. Air speed 56.7 M. P. H.

Note.—Positive pressures acting from lower to upper side of surface

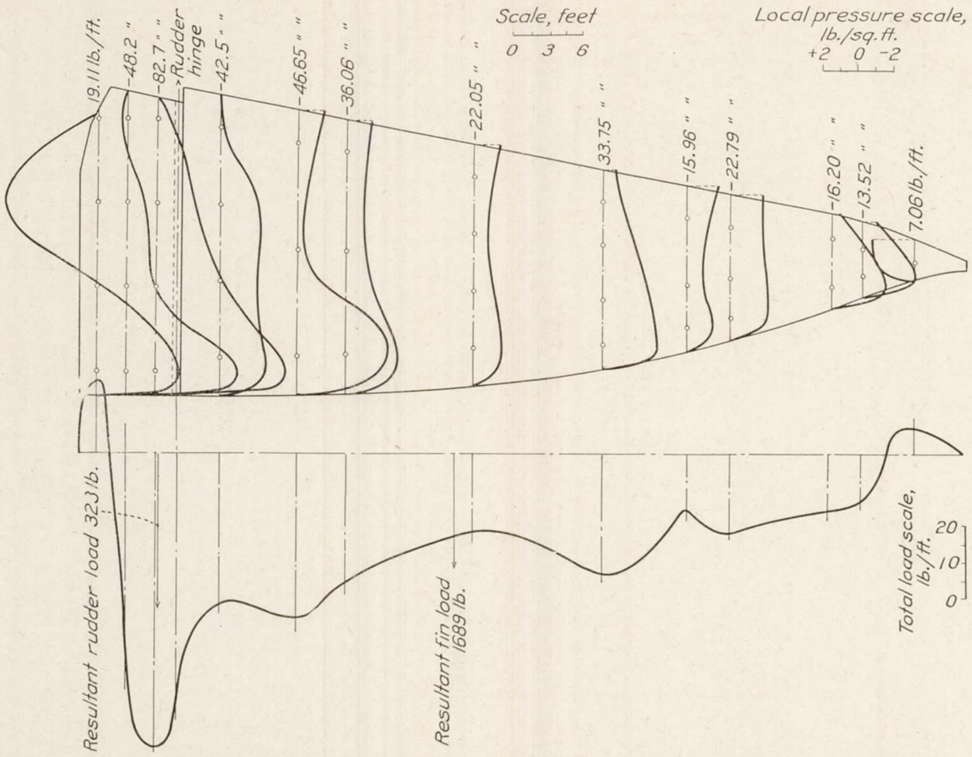


FIGURE 26.—Pressure distribution on lower fin and rudder. Flying through gusts. Run No. 5A—145 seconds from start. Rudder position 6° 0′′ starboard. Air speed 54 M. P. H. (approximate)

NOTE.—Positive pressures acting from port to starboard

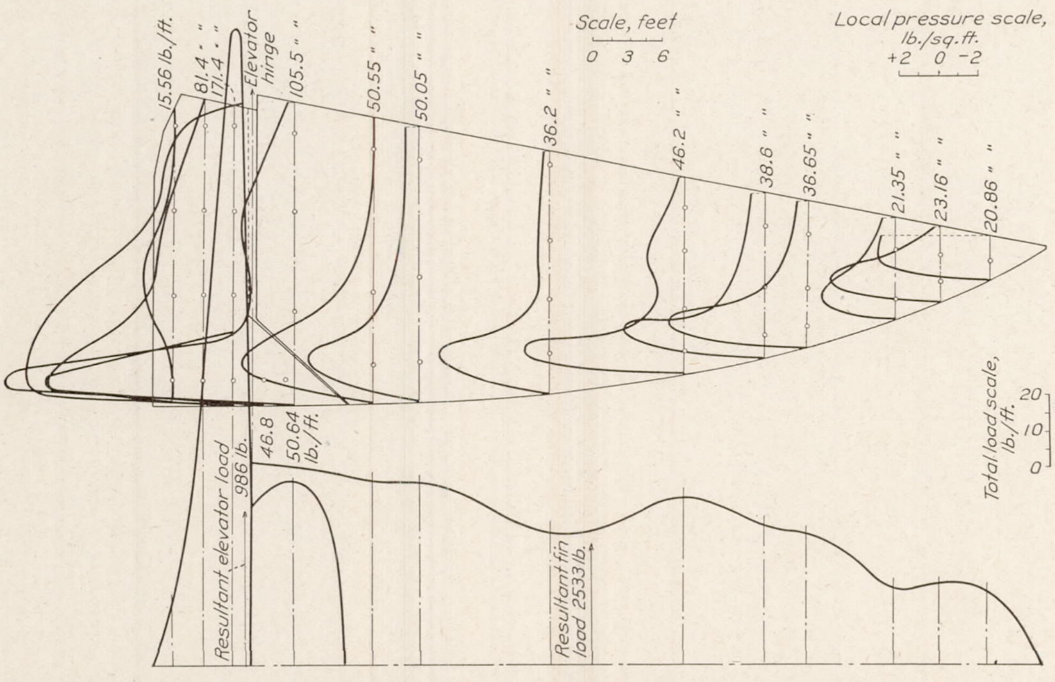


FIGURE 27.—Pressure distribution on starboard fin and elevator. Flying through gusts. Run No. 5A—145 seconds from start. Elevator position 19° 15′ down. Air speed 54 M. P. H. (approximate)

NOTE.—Positive pressures acting from lower to upper side of surface

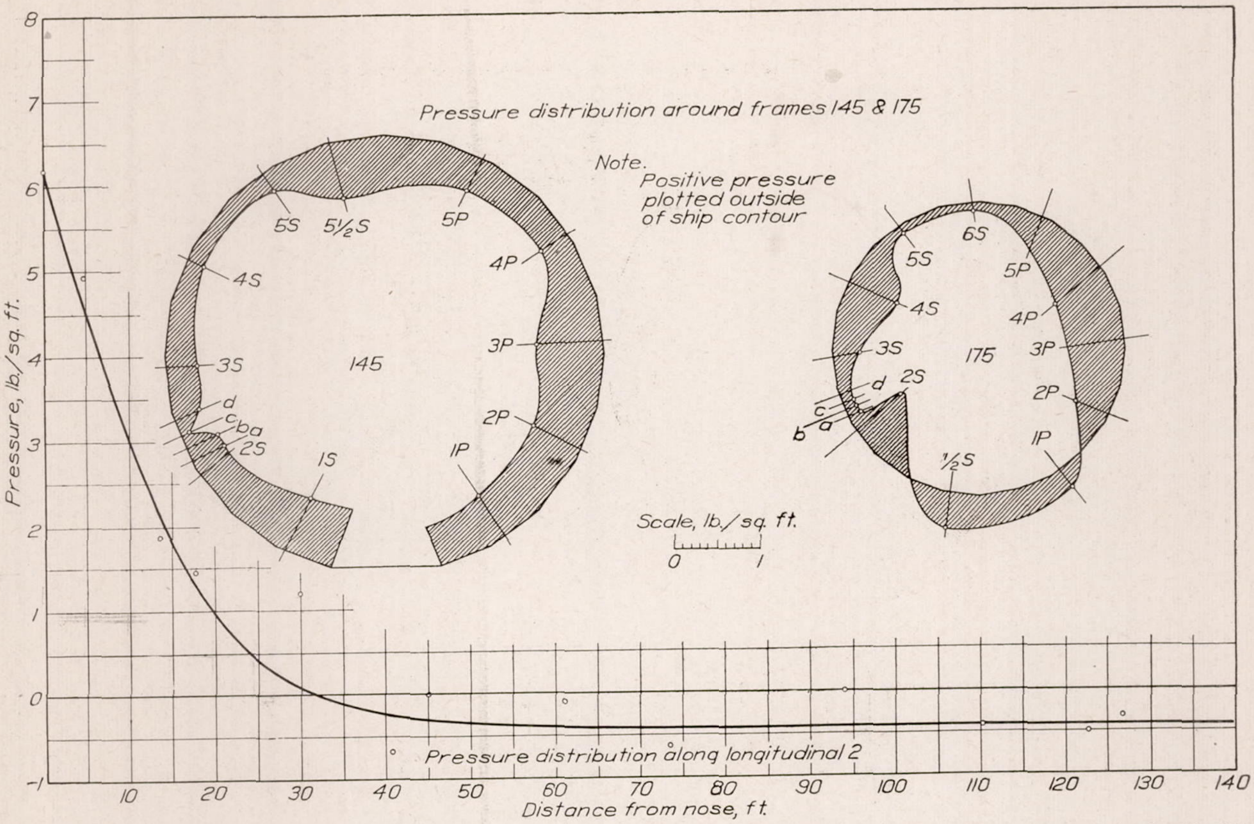


FIGURE 28.—Pressure distribution on hull. Flying through gusts. Rudder 3° 00′ starboard; elevator 15° 36′ down. Run No. 4A—timing line No. 8¼

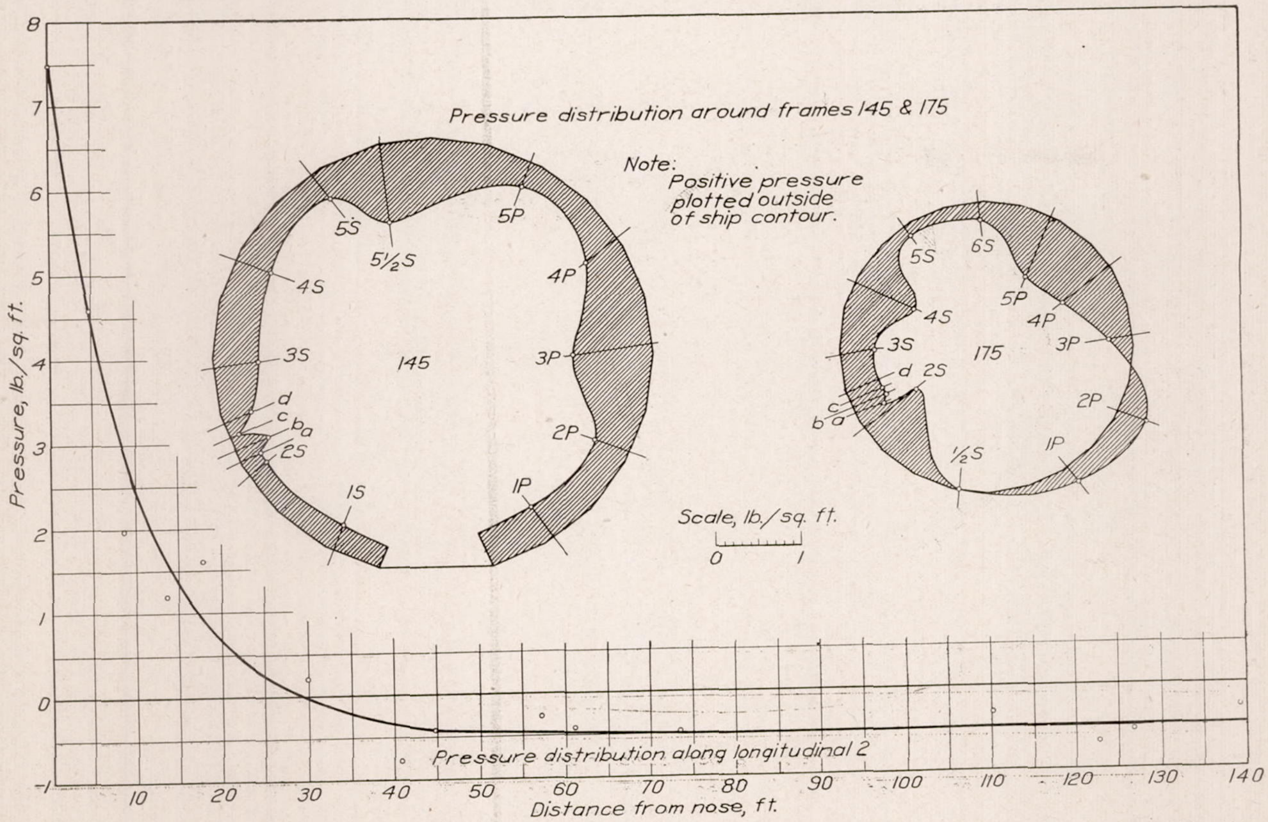


FIGURE 29.—Pressure distribution on hull. Flying through gusts. Rudder 7° 00′ starboard; elevator 18° 24′ down. Run No. 5A—timing line 9$\frac{9}{16}$

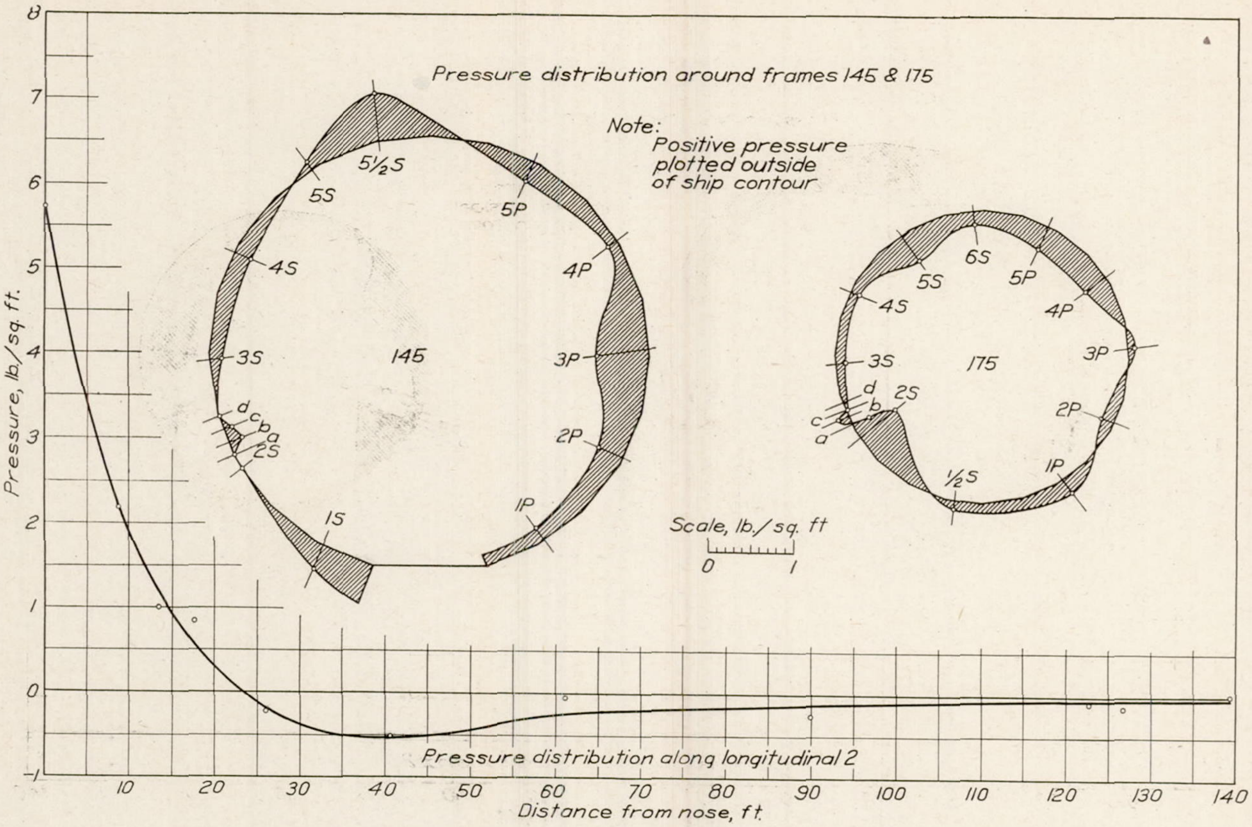


FIGURE 30.—Pressure distribution on hull. Steady turn—rudder 9° 42′ port. Run No. 4B—timing line 2

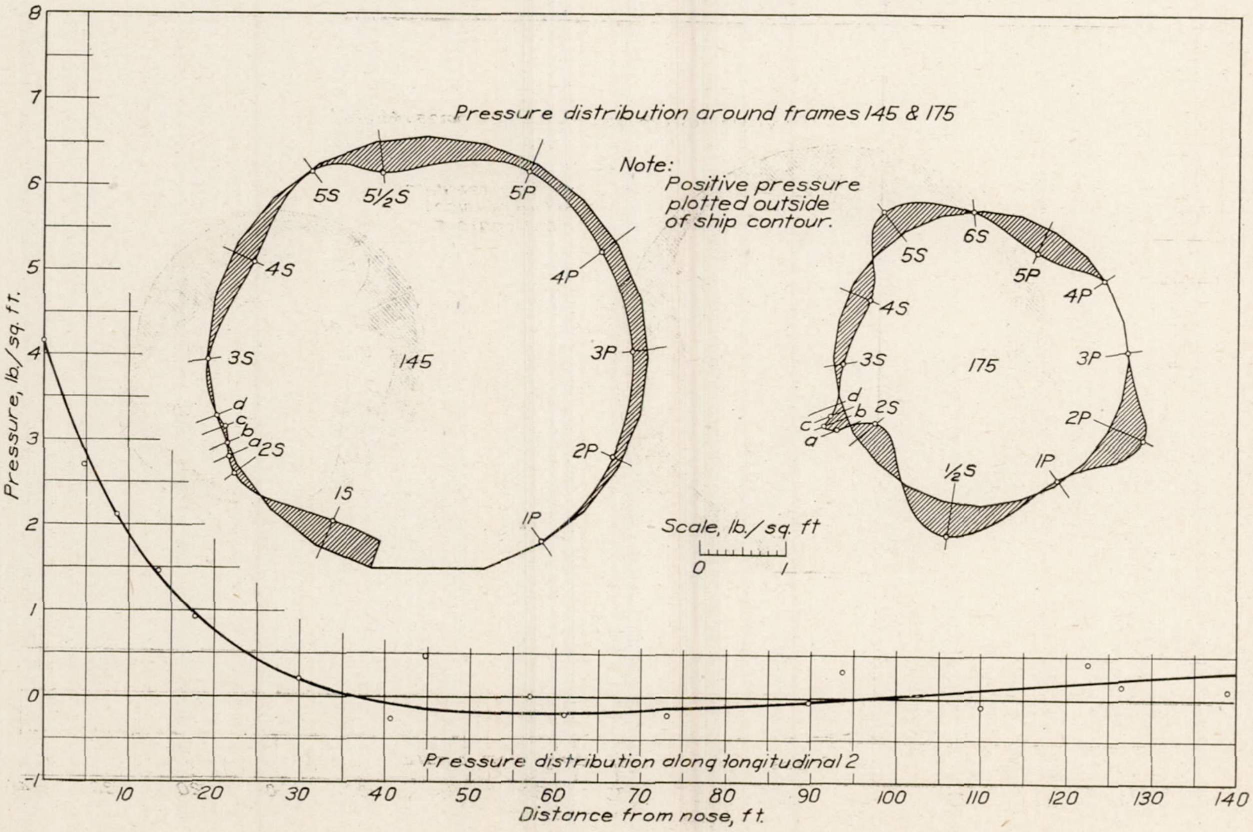


FIGURE 31.—Pressure distribution on hull. Steady turn—rudder 8° 18′ starboard. Run No. 4C—timing line 7

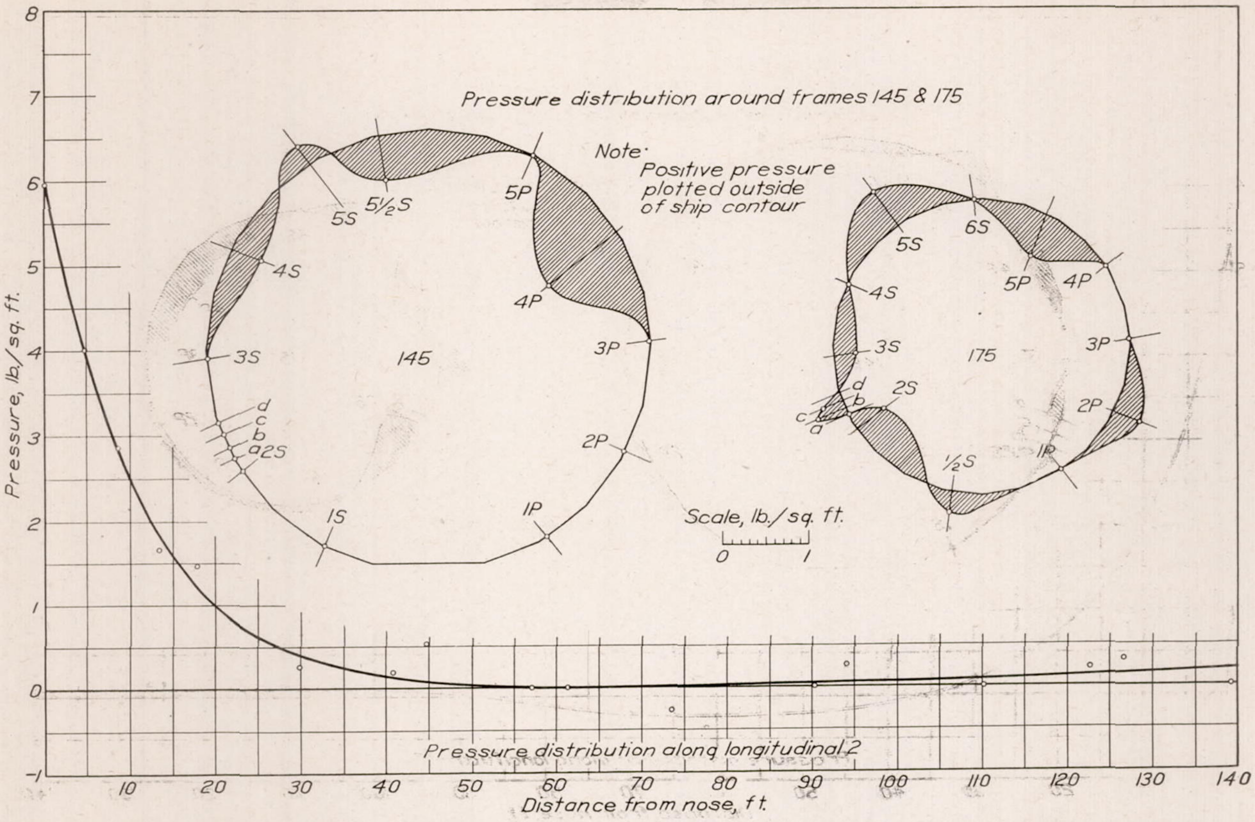


FIGURE 32.—Pressure distribution on hull. Steady turn—rudder 7° 51′ starboard. Run No. 5C—timing line 9

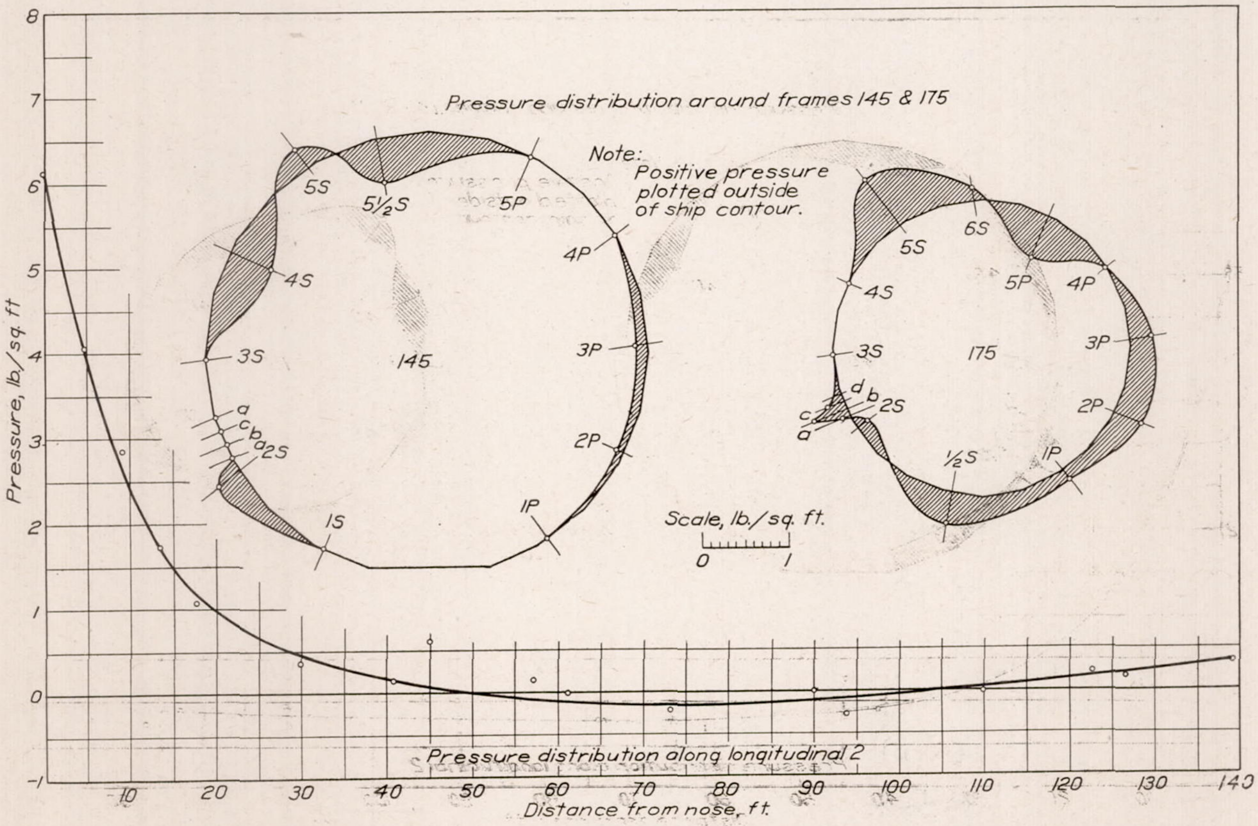


FIGURE 33.—Pressure distribution on hull. Steady turn—rudder 13° 15′ starboard. Run No. 6C—timing line 5th from end

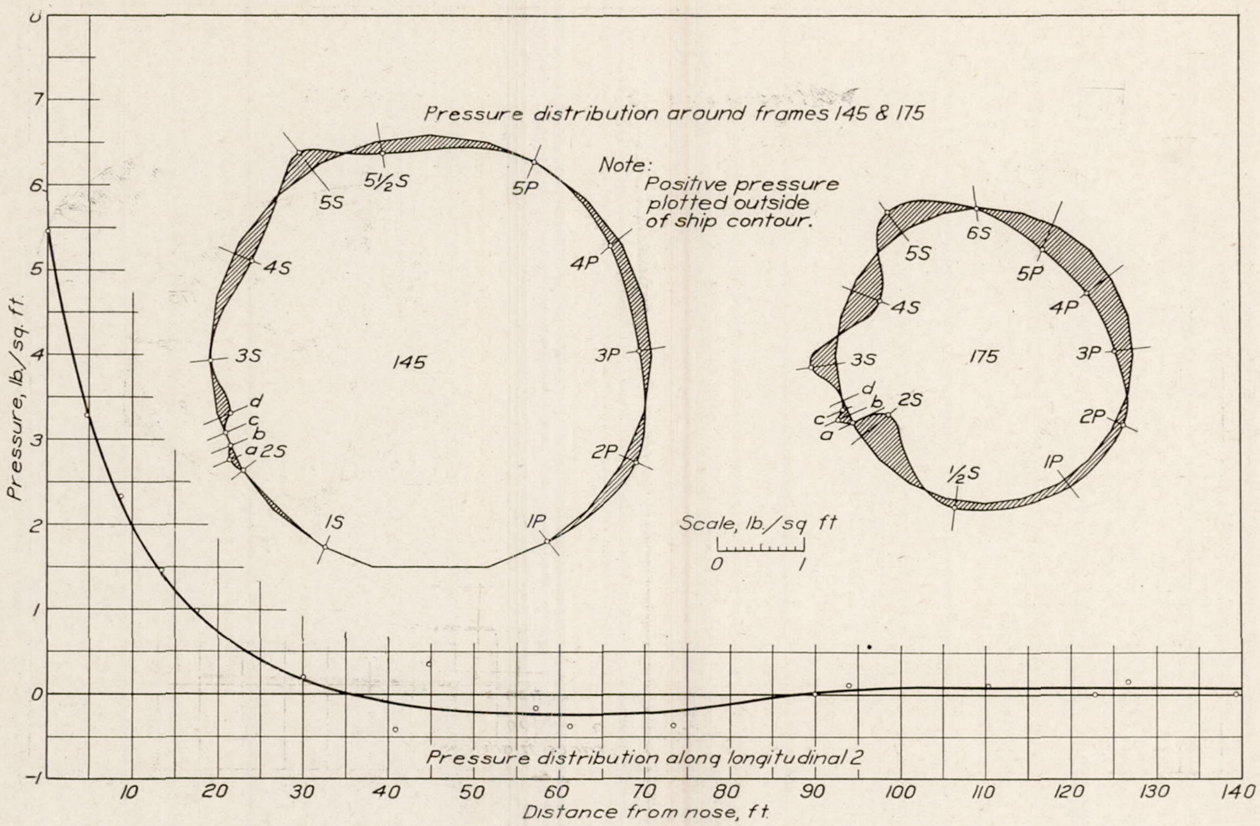


FIGURE 34.—Pressure distribution on hull. Reversal of helm—starboard to port. Rudder 12° 21′ starboard. Run No. 3C—timing line 2

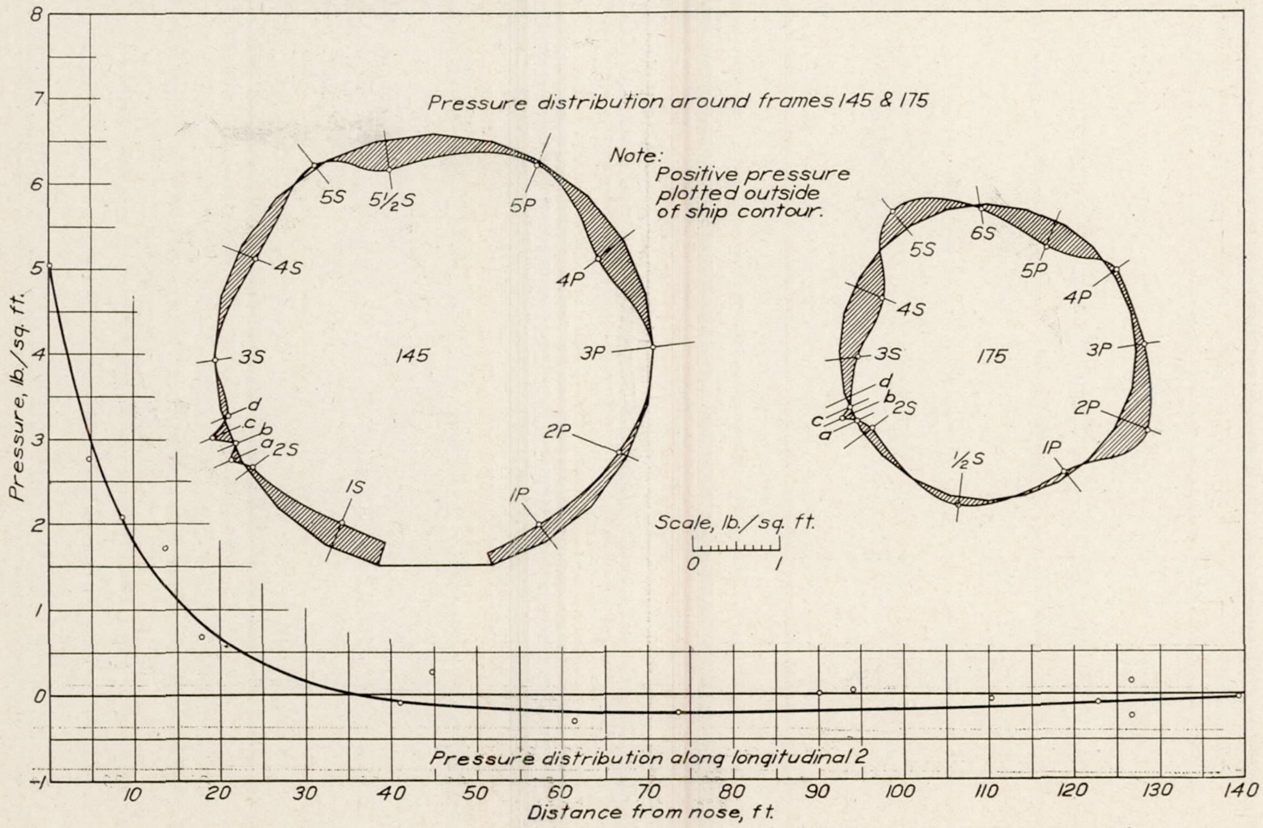


FIGURE 35.—Pressure distribution on hull. Reversal of helm—starboard to port. Rudder 6° 30′ port. Run No. 3C—timing line 3¼

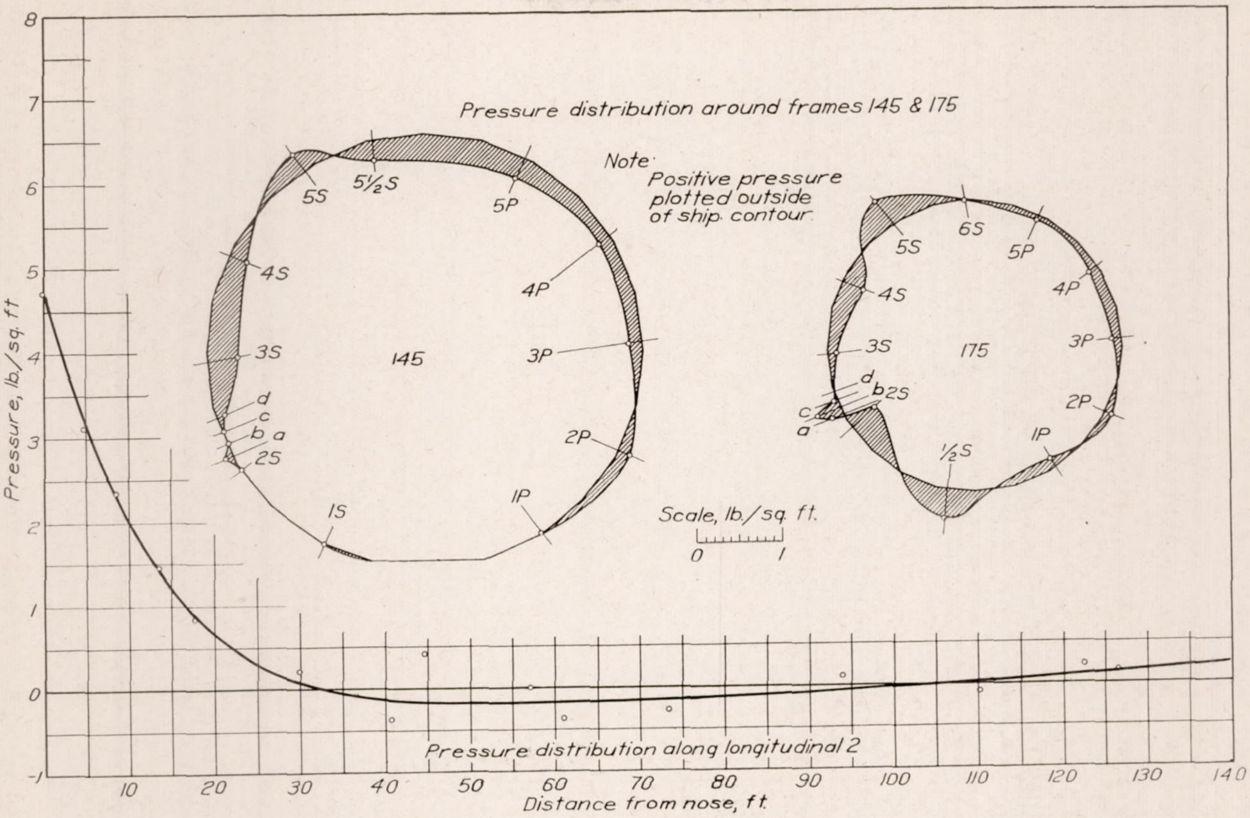
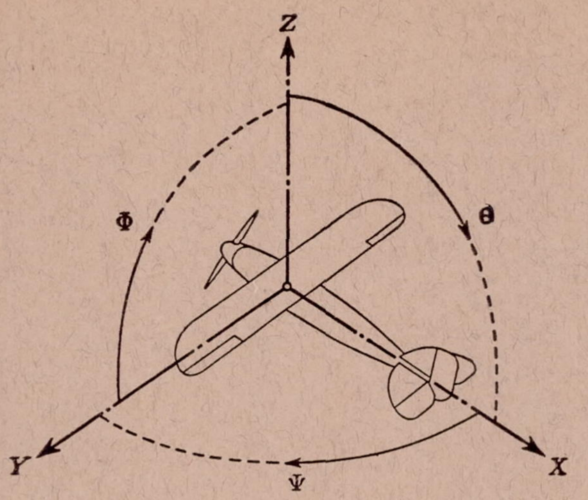


FIGURE 36.—Pressure distribution on hull. Reversal of helm—starboard to port. Rudder 11° 33′ port. Run No. 3C—timing line 6



Positive directions of axes and angles (forces and moments) are shown by arrows

Axis		Force (parallel to axis) symbol	Moment about axis			Angle		Velocities	
Designation	Symbol		Designation	Symbol	Positive direction	Designation	Symbol	Linear (component along axis)	Angular
Longitudinal	X	X	rolling	L	$Y \longrightarrow Z$	roll	Φ	u	p
Lateral	Y	Y	pitching	M	$Z \longrightarrow X$	pitch	Θ	v	q
Normal	Z	Z	yawing	N	$X \longrightarrow Y$	yaw	Ψ	w	r

Absolute coefficients of moment

$$C_L=\frac{L}{qbS}\; C_M=\frac{M}{qcS}\; C_N=\frac{N}{qfS}$$

Angle of set of control surface (relative to neutral position), δ. (Indicate surface by proper subscript.)

4. PROPELLER SYMBOLS

D, Diameter.
p_e, Effective pitch
p_g, Mean geometric pitch.
p_s, Standard pitch.
p_v, Zero thrust.
p_a, Zero torque.
p/D, Pitch ratio.
V', Inflow velocity.
V_s, Slip stream velocity.

T, Thrust.
Q, Torque.
P, Power.
(If "coefficients" are introduced all units used must be consistent.)
η, Efficiency $= T\,V/P$.
n, Revolutions per sec., r. p. s.
N, Revolutions per minute., R. P. M.
Φ, Effective helix angle $=\tan^{-1}\left(\frac{V}{2\pi rn}\right)$

5. NUMERICAL RELATIONS

1 HP = 76.04 kg/m/sec. = 550 lb./ft./sec.
1 kg/m/sec. = 0.01315 HP.
1 mi./hr. = 0.44704 m/sec.
1 m/sec. = 2.23693 mi./hr.

1 lb. = 0.4535924277 kg.
1 kg = 2.2046224 lb.
1 mi. = 1609.35 m = 5280 ft.
1 m = 3.2808333 ft.