EXPERIMENTS ON BALANCED CONTROL SURFACES FOR RIGID AIRSHIPS.

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SUMMARY.—(a) *Introductory.* (*Reasons for inquiry.*)—The experiments were conducted at the request of the Airship Design Department of the Admiralty in order to obtain data to assist in designing balanced control surfaces for airships of the R.38 class.

(b) *Range of investigation.*—(i) Pitching moments (about C.G.) were measured on a model of R.33 (see R. & M. 361) with stabilising surfaces of the same overall dimensions. The balancing area did not, however, extend along the whole length of the control surfaces, but was confined to the outer end of the elevators, loss of length being partially balanced by increased width. Two different balancing areas were used. The effect of cutting off a piece of the fin immediately in front of the balancing area was investigated.

(ii) Forces on a control surface and moments about the hinge were measured on larger models with corresponding balancing areas. A model of the hull of R.31 was used (see R. & M. 302), the angles of yaw of the ship being 0°, 2° and 5°, and the inclination of control surface to the axis of the ship varying between $-30°$ and $+30°$. Speed effect was also considered.

(c) *Conclusions.*—The moments about C.G. of the ship due to control surfaces on the complete model showed that even though the absolute moment increases with area of control surface it does not increase per unit area. This is probably due to the shielding of the balancing area by the fin, for on removing the corner of the fin the moment increases when both hull and elevators are turned in the same sense. The control surfaces appear to be much more efficient than those of the original R.33.

The moments about the hinge indicate that the largest balancing area used in the second set of experiments is more than sufficient. In the great majority of the observations the (lateral force) /V^2 increases with speed. The lateral force per unit area at first decreases with increasing area and then increases. Removing the corner of the fin in front of the balancing area causes the lateral force to increase or decrease when the ship and fin are turned in the same or opposite directions respectively, and moment to decrease throughout.

(d) *Application and further developments.*—It is probable that the cause of the inefficiency of the R.33 control surfaces compared with the present ones is the gap that exists between the control surfaces and the fin in the former case. Further experiments are necessary. Pressure plotting the fins and control surfaces should give valuable information to assist in the design of efficient stabilising surfaces.

The investigation was undertaken in response to a request from the Airship Design Department of the Admiralty for information concerning a suitable balancing area for rigid airship rudders in connection with the design of stabilising and controlling surfaces for R.38 class airships.

The experiments carried out were :—

I. A determination of the moments about an axis through the centre of gravity of the forces on a model of a complete airship (*i.e.*, hull and stabilising surface) with controlling surfaces set at different angles to the axis of the ship and with the axis of the ship inclined at different angles to the wind.

II. A determination of moments about the hinge and forces on the rudder only when detached from the remainder of the model.

I. The experiments were all carried out in a 7-ft. channel.

For the first set of experiments a model of the rigid airship R.33 (see R. & M. 361) was used ; new fins were fitted on to meet the requirements of the experiments. For symmetry the variations were made in the elevators (not the rudders) as both elevators are of the same size. The same vertical stabilising areas were used throughout. Thus the pitching moments about an axis through the C.G. (*i.e.*, an axis $28\frac{3}{16}$ inches from the nose of the model) were found at different angles of pitch and with different elevator settings. In addition the vertical force and longitudinal force have been determined with the elevators set amidships and at angles $\pm 20°$. The wind speed throughout was 40 ft/sec.

A drawing of the fins and elevators used is given in Fig. 1. The hinge about which the elevators turn is in the same position as in R. & M. 361, but whereas in that report they have a balancing area extending along the whole length of the elevators in front of the hinge, in the present cases the balancing area extends only for 11 mms. and 16 mms. in two cases, and in the third case there is no balancing area at all. Further, in one case the corners of the fins immediately in front of the balancing areas have been cut off at an angle of 30° with the outside edge of the fin as shown in the figure. The balancing area will be designated A and the corner of the fin B.

Following the method of R. & M. 361, the moments about the C.G. with the elevators set amidships have been subtracted from the corresponding moment with the elevators set at different angles and the "moment due to the elevators" obtained. In representing these quantities graphically a mean has been taken of the values at positive and negative angles of pitch and elevators.

The results are tabulated and plotted as follows :—

	Table.	Fig.
Shape of elevators and fins	—	1
Moments when balancing area A = 0	1	2
,, ,, ,, ,, A = 11 × 19 mm.^{2}	2	3
,, ,, ,, ,, A = 16 × 19 mm.^{2}	3	4
,, ,, triangular piece cut off fin	4	5
,, due to elevators	—	6
Longitudinal force and normal force	5	7
Sketch of flow past fins	—	8

Discussion of results.—I. In the first place it is necessary to explain the presence of two columns of figures (marked * and † in the tables) for certain elevator settings. The columns marked * are the actual moments measured, but on plotting the results against angle of elevator it was found that the values obtained did not lie on the curve as well as could be expected. This gave rise to the opinion that the accuracy of the observations was doubtful, particularly as it had been found difficult to set such small elevators accurately at any desired angle, and moreover, as the "hinge" on which the elevators were turned consisted of copper wire, it is possible that during some of the experiments the wire was not stiff enough to withstand the action of the wind on the elevators, even though the wire had been frequently renewed. Accordingly, the second column marked † has been added, the values given having been interpolated by cross plotting against angle of elevator setting.

The effect of setting the elevators over is best seen in Fig. 6, in which the moment due to elevators has been plotted. As was to be expected this moment increases with the area of elevator, though not to the extent anticipated, for the moment per unit area of elevator does not increase in general, even though the additional surface A added to the elevators was added to that part of the control surface generally considered most efficient, *i.e.*, that part away from the hull. It is possible that the fins shield the balancing areas when the elevators are inclined and thus decrease the efficiency of the added part. An argument in favour of this supposition appears to be afforded in the results obtained on the moment due to elevators, when triangular pieces of the fins were cut off immediately in front of the balancing areas and when hull and elevators are turned in the same sense. Fig. 6 shows that at negative angles of yaw and negative angles of elevators (or positive in both cases) the moment due to elevator increases when the triangular pieces are removed, the reverse being the case when the hull and elevators are turned in opposite senses, though to a less marked extent. The sketches appended in Fig. 8 show what presumably takes place. This indicates that the restoring moment acting in order to bring an airship back to a straight course after a turn would be greater if a portion of the fin immediately in front of the rudder were to be cut off, since the most efficient part of the rudder would then be more exposed to the wind. On the other hand the "upsetting" moment is less when the rudders are being used to make the ship, when turning, turn in a smaller circle.

It is, however, possible that, should the gap between the control surfaces and fins be too large or not so arranged as to bring the most efficient part of the rudder into more direct action, its existence would not be an advantage. If it were not so, it would be difficult to explain the small moment due to the control surfaces obtained with the original R.33 fins. These have been reproduced from R. & M. 361 and plotted in Fig. 6. A glance shows that the moment is less than that due to the smallest elevators in the present series, even though the area of the R.33 elevators was much larger than that of the largest of the three sets of elevators described. It must, however, be borne in mind that in the R.33 elevators the balancing areas extended all along the control surfaces, but they were only 10 mm. wide on the model, whereas in the present case the leading edge of balancing area was 19 mm. in front of the hinge.

Attention may be drawn to Fig. 7 showing the longitudinal and normal force on the model with elevators amidships and over at $\pm 20°$. At zero angle of yaw, turning the elevators over increases the drag by nearly 20 per cent., and gives rise to a normal force which is equal to that on the ship at an angle of pitch of 4 or 5 degrees with elevators amidships.

II. In the second set of experiments, in view of the fact that the size of the elevators used on the R.33 model were so small and that consequently the forces and moments on them would be small, it was decided to make use of the large model of R.31 described in R. & M. 302 and to make models of fins and elevators in proportion. One model elevator was deemed sufficient and the size was such that it could be fixed on to a spindle which could be mounted in the chuck of the balance and the forces and moments would be measured in the ordinary way. Each of the remaining stabilising surfaces was made of one piece and of the same overall dimensions as the fin and the elevator on which the forces were measured. The area of the unbalanced rudder was 14·15 sq. ins. and the model was so arranged that a balancing area 2, 3 or 4 sq. ins. could be added to the rudder and a corresponding piece of the fin removed. In each case the *length* of the balancing area added was 2 ins., the width thus being 1, 1·5 or 2 ins. Further, it was possible to remove the corner of the fin immediately in front of the balancing area as in the previous set of experiments.

The forces and moments were measured with the angle between the control surface and the fin varying between $-30°$ and $+30°$ and with the axis of the airship hull inclined to the wind at 0°, 2° and 5°. The length of the model hull was so large that angles larger than 5° could not be considered.

The wind speeds at which the experiments were conducted were :—

Angle of Yaw of Ship.	Balancing Area (sq. ins.).	Speed (ft./sec.).			
0° and 5°	0, 2 × 1 and 2 × 2 ...	Forces	40	50	60
		Moments	—	—	60
0° and 5°	2 × 1·5 with triangular piece in place and 2 × 1 and 2 × 2 with triangular piece cut off.	Forces	—	50	—
		Moments	—	—	60
2°	0, 2 × 1, 2 × 1·5 and 2 × 2.	Forces	—	50	—
		Moments	—	—	60

In presenting the results, the drag and cross wind force in lbs. (*i.e.*, the forces along and perpendicular to the direction of the relative wind) have been divided by the square of the wind speed in ft./sec., and similarly for the moments about the hinge in lbs./ft. In addition the lateral force on the control surface itself has been calculated (*i.e.*, the force perpendicular to the surface, *not* to the axis of the ship).

The presence of such a large model in the wind channel has, of course, an appreciable effect on the wind speed in the channel. In order to estimate this effect a few pitot readings were taken on both sides of the hull with the latter at zero and at 5° incidence. With the same difference of pressure between the hole in the side of the channel and the atmosphere as in the unobstructed channel at 40 and 60 ft./sec., the percentage increase (+) or decrease (−) in the speed squared was as follows :—

Position of Pitot. Distance up stream from Control Hinge (x).	Angle of Incidence 0°.		Angle of Incidence + 5°.	
	Lateral Distance of Pitot from Control Hinge (y) (ft.).			
	26″ Port.	26″ Starboard.	26″ Port.	26″ Starboard.
8′	− 1·0	− 1·5	− 8·0	− 3
4′	+ 1·5	+ 1·0	− 4·5	0
0	− 3·0	− 3·0	− 6·0	− 5

The value taken when dividing the forces and moments by the square of the speed was that obtained at a distance of 7·5 ft. up stream from the balance ; appropriate corrections based on the above observations were consequently applied.

In addition a few pitot readings were taken in the neighbourhood of the airship near the fin. The end of the pitot was in line with the control hinge at a distance below the axis of the model of 4·5 ins. The horizontal distance of the pitot from the fin was varied from 1 in. to 12 ins.

With the model at zero incidence the following table gives the ratio of the speed 7·5 ft. up-stream of the balance as determined above, to the speed in the neighbourhood of the fin :—

Distance from fins (ins.)	1	2	4	6	8	12
Ratio of speeds ...	1·25	$1{\cdot}19_5$	$1{\cdot}18_4$	$1{\cdot}03_4$	1·02	1·00

The values obtained for the forces and moments have been tabulated and plotted as follows :—

	Table.	Fig.
Diagram showing tail of model and fin	—	9
Forces and moments, angle of incidence 0° ...	6	10
" " " " " " 2° ...	7	11
" " " " " " 5° ...	8	12
Lateral force per unit area	9	—

Discussion of results. (II).—An examination of the moment curves given in Figs. 10–12 will show that the moments about the hinge on the rudder with 4 sq. ins. balancing area A is negligible for small angles of rudder, and even at 25° is only about one-fourth of that when A = 0 (0° angle of incidence of ship). At 5° angle of incidence of ship and + 20° angle of rudder it is but little larger than one-fourth of the moment on the unbalanced rudder. Accordingly on an airship a balancing area proportional to the 4 sq. ins. used would probably be more than sufficient, as it would be desirable to have the rudders under, rather than over, balanced.

The speed effect on the forces is such that the lateral force increases at a higher rate than the square of the speed. On examining the tables it will be found that this is generally true except at the larger angles of inclination and at small values of the lateral force. The latter deviation is probably due to errors of observation, since the cross wind force to be observed was extremely small. The moment readings at 40 ft/sec. were so small that it was considered inadvisable to make use of them in endeavouring to find a speed effect on the moments. A few readings were taken at 50 ft/sec. at the larger angles of yaw, and the evidence derived from these observations showed that the moment coefficient increased with the speed.

Attention may be drawn to the manner in which the lateral force on the rudder varied with the area. Figures are given in Table 9 showing the general effect. In this table the value of Y/V^2 at ± 5° and ± 15° angles of control obtained from Tables 6, 7 and 8 have been divided by the appropriate area of rudder. The statement made in the first part of this report that the moment due to elevators per unit area does not increase is supported by the figures given in the table. It will be seen that the lateral force at ± 15° angle of control decreases in every case upon the addition of 2 sq. ins. balancing area. This is more or less true at ± 5°, but since the forces at 5° are small, only about one-third of those at 15°, small errors of observation would give rise to appreciable differences. On adding a further 2 sq. ins. the lateral force per unit area at 15° increases, particularly so when the triangular part is removed from the fin and the angle of control setting is positive. At 5° this is hardly the case except perhaps on the positive side at 5° angle of yaw. The difference arising out of the removal of the triangular part is seen in Figs. 10 and 12, in which the force and moment, with and without the triangular part in place, are plotted together (the dotted curves apply to the case where the triangle is removed). At zero incidence of the ship the lateral force is slightly increased numerically over the whole range on removing the corner of the fin, whereas at $\pm$ 5°, it increases numerically for positive control settings and decreases for negative settings, a result agreeing with the conclusions arrived at from the measurements of moments about the C.G. described earlier. Moreover, the moment about the hinge is reduced numerically throughout, showing that a balancing area of this type is more efficient for *balancing purposes* when a part of the fin immediately in front of the balancing area is removed. These deductions support the suggestions made regarding the shielding effects of the fin when the rudder hinge is not placed at the leading edge of the fin.

Control surfaces similar to those described in the present report are to be fitted to R.38 and full-scale trials on this ship when completed should provide valuable information on the efficiency of control surfaces. Model experiments have already been carried out, and the results show that control surfaces of the type dealt with above are more efficient than those used on earlier ships.

Table 1.

PITCHING MOMENTS (LBS/FT.) ABOUT C.G. ON A MODEL OF R.33 FITTED WITH NEW ELEVATORS.

Balancing Area = 0.

Angle of Pitch (degs.).	Angle of Elevators (degrees).									
	− 20	− 15	− 10	− 5	0 *	0 †	5	10	15	20
− 20	0·204	0·135	+ 0·047$_5$	− 0·035	− 0·128$_5$	− 0·116	− 0·198	− 0·275	− 0·341	− 0·405
− 15	0·121	0·052$_5$	− 0·037	− 0·116	− 0·205	− 0·195	− 0·272	− 0·342	− 0·411	− 0·471
− 10	0·081	0·011$_5$	− 0·069$_5$	− 0·150$_5$	− 0·236	− 0·228	− 0·294	− 0·352	− 0·418	− 0·473
− 8	0·079	0·011$_5$	− 0·072$_5$	− 0·145$_5$	− 0·226	− 0·216	− 0·281	− 0·337	− 0·397	− 0·448
− 6	0·094$_5$	0·025$_5$	− 0·052$_5$	− 0·126$_5$	− 0·203	− 0·194	− 0·257	− 0·310	− 0·375	− 0·422
− 4	0·121	0·055	− 0·020	− 0·089$_5$	− 0·163	− 0·150	− 0·204	− 0·261	− 0·323	− 0·377
− 3	—	—	—	—	− 0·126$_5$	− 0·115	− 0·169	− 0·226	− 0·288	− 0·339
− 2	0·156	0·101	+ 0·032$_5$	− 0·025$_5$	− 0·090$_5$	− 0·077	− 0·132	− 0·188	− 0·249	− 0·301
− 1	—	—	—	—	− 0·044	− 0·034	− 0·084	− 0·141	− 0·205	− 0·260
0	0·222	0·166	0·102	+ 0·053$_5$	− 0·001	+ 0·006	− 0·043	− 0·099	− 0·167	− 0·224
+ 1	0·248	0·207	0·150	0·098	+ 0·044	0·050	—	—	—	—
2	0·293	0·248	0·189	0·135	0·081	0·085	+ 0·030$_5$	− 0·032$_5$	− 0·100	− 0·178
3	0·322	0·283	0·224	0·167	0·114	0·118	—	—	—	—
4	0·352	0·310	0·250	0·194	0·135	0·139	+ 0·080	+ 0·006$_5$	− 0·075	− 0·149
6	0·382	0·342	0·281	0·226	0·164	0·165	0·104	0·025$_5$	− 0·056	− 0·130
8	0·412	0·362	0·301	0·240	0·173	0·176	0·110	0·030$_5$	− 0·058	− 0·135
10	0·431	0·369	0·308	0·246	0·174	0·175	0·106	+ 0·019	− 0·066$_5$	− 0·142
15	0·420	0·348	0·278	0·214	0·133	0·137	+ 0·060	− 0·035	− 0·118	− 0·193
20	0·341	0·271	0·196	0·129	0·041	0·048	− 0·032$_5$	− 0·124	− 0·211	− 0·281

* Actual observed moments, probable value of angle of elevators 0°·5.

† Probable value of moments with elevators at 0, obtained by interpolation off a smooth curve.

	A = 0	A = 11 × 19 mm.²	A = 16 × 19 mm.²
Area of 1 elevator, sq. ft.	0·0153	0·0175	0·0185

Distance of C.G. from nose, 28 $\frac{1}{16}$ ins. Scale of model 1/120 full size.

Table 2.

PITCHING MOMENTS (LBS/FT.) ABOUT C.G. ON A MODEL OF R.33 FITTED WITH NEW ELEVATORS.

Balancing area 11 × 19 mm.²

Angle of Pitch (degs.).	Angle of Elevators (degrees).								
	− 20	− 15	− 10	− 5	0	5	10	15	20
− 20	+ 0·199	0·153	+ 0·054$_5$	− 0·021	− 0·112	− 0·198	− 0·259	− 0·336	− 0·409
− 15	0·113	0·060	− 0·038	− 0·107	− 0·197	− 0·273	− 0·340	− 0·406	− 0·465
− 10	0·068	0·009$_5$	− 0·078	− 0·149	− 0·229	− 0·295	− 0·347	− 0·411	− 0·456
− 8	0·064	0·005	− 0·078	− 0·146	− 0·224	− 0·284	− 0·341	− 0·397	− 0·456
− 6	0·092	0·026	− 0·060	− 0·125	− 0·202	− 0·259	− 0·311	− 0·368	− 0·433
− 4	0·112	0·058	− 0·023$_5$	− 0·089	− 0·158	− 0·208	− 0·263	− 0·324	− 0·412
− 3	—	—	—	—	− 0·129	− 0·177	− 0·232	− 0·290	− 0·368
− 2	0·143	0·096$_5$	+ 0·023$_5$	− 0·032$_5$	− 0·096	− 0·139$_5$	− 0·197	− 0·257	− 0·338
− 1	—	—	—	—	− 0·053	− 0·098$_5$	− 0·152	− 0·214	− 0·311
0	0·201	0·164	0·096	+ 0·046	− 0·006	− 0·056$_5$	− 0·107	− 0·182	− 0·261
+ 1	0·242	0·208	0·146	0·091	+ 0·039	—	—	—	—
2	0·283	0·251	0·181	0·138	0·077$_5$	+ 0·018	− 0·040	− 0·123	− 0·177
3	0·320	0·283	0·219	0·167	0·107	—	—	—	—
4	0·342	0·309	0·244	0·194	0·135	+ 0·069	+ 0·003	− 0·074$_5$	− 0·148
6	0·372	0·343	0·283	0·226	0·165	0·093$_5$	+ 0·023	− 0·061	− 0·136
8	0·407	0·370	0·301	0·244	0·176	0·099$_5$	+ 0·026	− 0·058	− 0·136
10	0·429	0·381	0·311	0·252	0·179	0·098$_5$	+ 0·021	− 0·065	− 0·141
15	0·431	0·368	0·293	0·222	0·143	+ 0·053	− 0·023	− 0·111	− 0·187
20	0·373	0·298	0·208	0·145	0·062	− 0·034	− 0·105	− 0·189	− 0·264

TABLE 3.

PITCHING MOMENTS (LBS/FT.) ABOUT C.G. ON A MODEL OF R.33 FITTED WITH NEW ELEVATORS.

Balancing Area 16 × 19 mm.²

Angle of Pitch (degs.).	Angle of Elevators (degrees).										
	− 20	− 15	− 10	− 5		0		5	10	15	20
				*	†	*	†				
− 20	+ 0·197	$0{\cdot}138_5$	$+ 0{\cdot}057_5$	$- 0{\cdot}025_5$	− 0·044	− 0·143	− 0·131	− 0·230	− 0·289	− 0·379	− 0·440
− 15	0·126	$0{\cdot}056_5$	− 0·027	$- 0{\cdot}108_5$	− 0·119	− 0·192	− 0·205	− 0·298	− 0·368	− 0·435	− 0·494
− 10	0·097	0·016	− 0·067	− 0·144	− 0·156	− 0·247	− 0·240	− 0·312	− 0·378	− 0·431	− 0·482
− 8	0·097	0·015	− 0·064	− 0·144	− 0·151	− 0·237	− 0·233	− 0·298	− 0·357	− 0·414	− 0·454
− 6	0·109	0·033	− 0·044	− 0·118	− 0·128	− 0·211	− 0·206	− 0·266	− 0·326	− 0·379	− 0·426
− 4	0·122	0·055	$- 0{\cdot}013_5$	$- 0{\cdot}080_5$	− 0·093	− 0·167	− 0·160	− 0·215	− 0·273	− 0·332	− 0·376
− 3	—	—	—	—	—	− 0·131	− 0·125	− 0·183	− 0·236	− 0·292	− 0·343
− 2	0·156	0·101	+ 0·039	− 0·019	− 0·029	$- 0{\cdot}092_5$	− 0·083	$- 0{\cdot}137_5$	− 0·199	− 0·251	− 0·302
− 1	—	—	—	—	—	− 0·048	− 0·037	$- 0{\cdot}094_5$	− 0·154	− 0·210	− 0·261
0	0·216	0·167	0·122	$+ 0{\cdot}060_5$	+ 0·055	+ 0·002	+ 0·005	$- 0{\cdot}050_5$	− 0·110	− 0·172	− 0·221
+ 1	0·259	0·215	0·164	0·107	0·096	0·037	0·043	—	—	—	—
2	0·301	0·253	0·207	0·147	0·135	$0{\cdot}074_5$	0·076	+ 0·021	$- 0{\cdot}050_5$	− 0·116	− 0·178
3	0·330	0·288	0·239	0·179	0·166	0·105	0·106	—	—	—	—
4	0·366	0·314	0·264	0·205	0·191	0·126	0·131	0·064	$- 0{\cdot}010_5$	− 0·084	− 0·155
6	0·393	0·349	0·295	0·239	0·223	0·155	0·162	0·086	$+ 0{\cdot}011_5$	$- 0{\cdot}067_5$	− 0·143
8	0·422	0·371	0·312	0·253	0·238	0·163	0·171	0·089	$+ 0{\cdot}010_5$	$- 0{\cdot}071_5$	− 0·147
10	0·441	0·387	0·321	0·258	0·238	$0{\cdot}159_5$	0·167	0·084	+ 0·001	− 0·081	− 0·160
15	0·440	0·367	0·297	0·227	0·205	0·105	0·115	$+ 0{\cdot}035_5$	− 0·045	$- 0{\cdot}131_5$	− 0·200
20	0·371	0·290	0·209	$0{\cdot}138_5$	0·116	$0{\cdot}027_5$	0·030	− 0·062	$- 0{\cdot}139_5$	− 0·220	− 0·273

* Actual observed moments. Probable values of angle of elevators − 6° and + 0·5°.

† Probable value of moments with elevators at − 5° and 0°, obtained by interpolation off a smooth curve.

Table 4.

PITCHING MOMENTS (LBS/FT.) ON A MODEL OF R.33 FITTED WITH NEW ELEVATORS.

Balancing Area 16 × 19 mm². Triangular piece cut off fin.

Angle of Pitch (degs.).	Angle of Elevators (degrees).									
	− 20	− 15	− 10	− 5	0	5	10	15 *	15 †	20
− 20	0·178	0·133	+ 0·039	− 0·044	− 0·129	− 0·227	− 0·312	− 0·372	− 0·396	− 0·454
− 15	0·110	0·061	− 0·041	− 0·123	− 0·210	− 0·301	− 0·380	− 0·438	− 0·457	− 0·505
− 10	0·082	0·023	− $0·071_5$	− 0·152	− 0·232	− 0·310	− 0·379	− 0·437	− 0·450	− 0·488
− 8	0·100	$0·028_5$	− $0·066_5$	− 0·146	− 0·223	− 0·292	− 0·360	− 0·410	− 0·420	− 0·462
− 6	0·119	0·045	− $0·051_5$	− 0·126	− 0·198	− 0·262	− 0·332	− 0·380	− 0·392	− 0·430
− 4	0·125	$0·067_5$	− 0·015	− $0·086_5$	− 0·154	− 0·212	− 0·275	− 0·323	− 0·335	− 0·375
− 3	—	—	—	—	− 0·116	− 0·179	− 0·238	− 0·290	− 0·300	− 0·338
− 2	0·158	$0·109_5$	+ 0·038	− 0·022	− 0·077	− 0·139	− 0·196	− 0·249	− 0·259	− 0·302
− 1	—	—	—	—	− $0·032_5$	− $0·091_5$	− 0·155	− 0·201	− 0·216	− 0·256
0	0·217	0·175	0·115	+ 0·059	+ $0·009_5$	− $0·046_5$	− 0·112	− 0·163	− 0·176	− 0·216
+ 1	0·256	0·220	0·159	0·101	0·056	—	—	—	—	—
2	0·295	0·261	0·202	0·148	0·096	+ $0·027_5$	− $0·046_5$	− 0·105	− 0·122	− 0·173
3	0·332	0·296	0·238	0·180	0·129	—	—	—	—	—
4	0·361	0·326	0·268	0·214	0·156	0·076	− $0·009_5$	− $0·068_5$	− 0·085	− 0·149
6	0·395	0·368	0·308	0·250	0·190	0·104	+ 0·019	− $0·049_5$	− 0·065	− 0·133
8	0·429	0·393	0·330	0·268	0·204	0·115	+ $0·028_5$	− $0·046_5$	− 0·057	− 0·130
10	0·448	0·411	0·343	0·275	0·203	0·113	+ 0·023	− $0·050_5$	− 0·074	− 0·133
15	0·460	0·397	0·324	0·248	0·167	+ $0·071_5$	− 0·024	− 0·096	− 0·117	− 0·166
20	0·399	0·325	0·244	0·160	0·081	− 0·017	− $0·106_5$	− 0·178	− 0·195	− 0·236

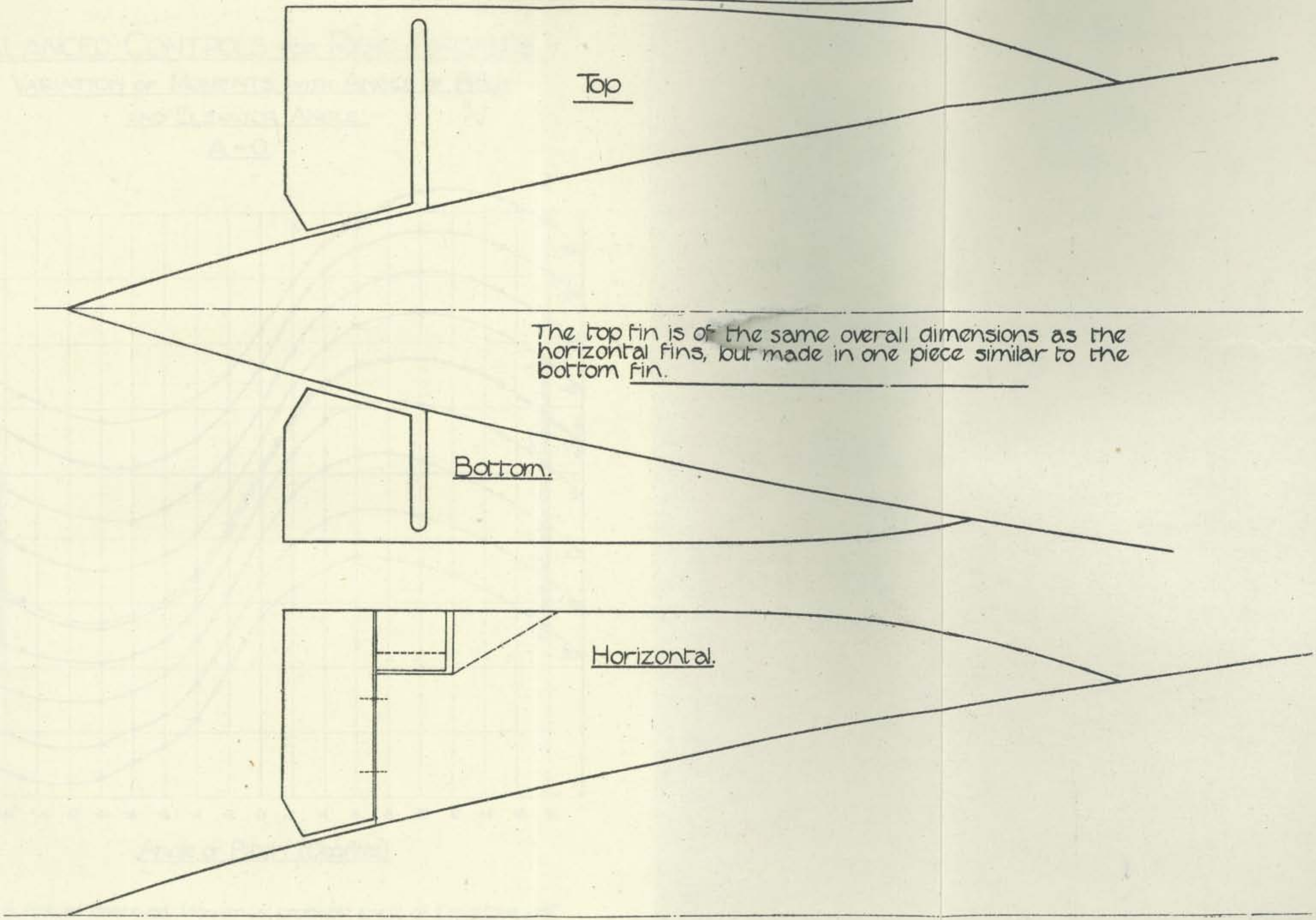
* Actual observed moments, probable value of angle of elevators 13·5°.

† Probable value of moments with elevators at 15°, obtained by interpolation off a smooth curve.

BALANCED CONTROLS FOR RIGID AIRSHIPS.

FIG. I.

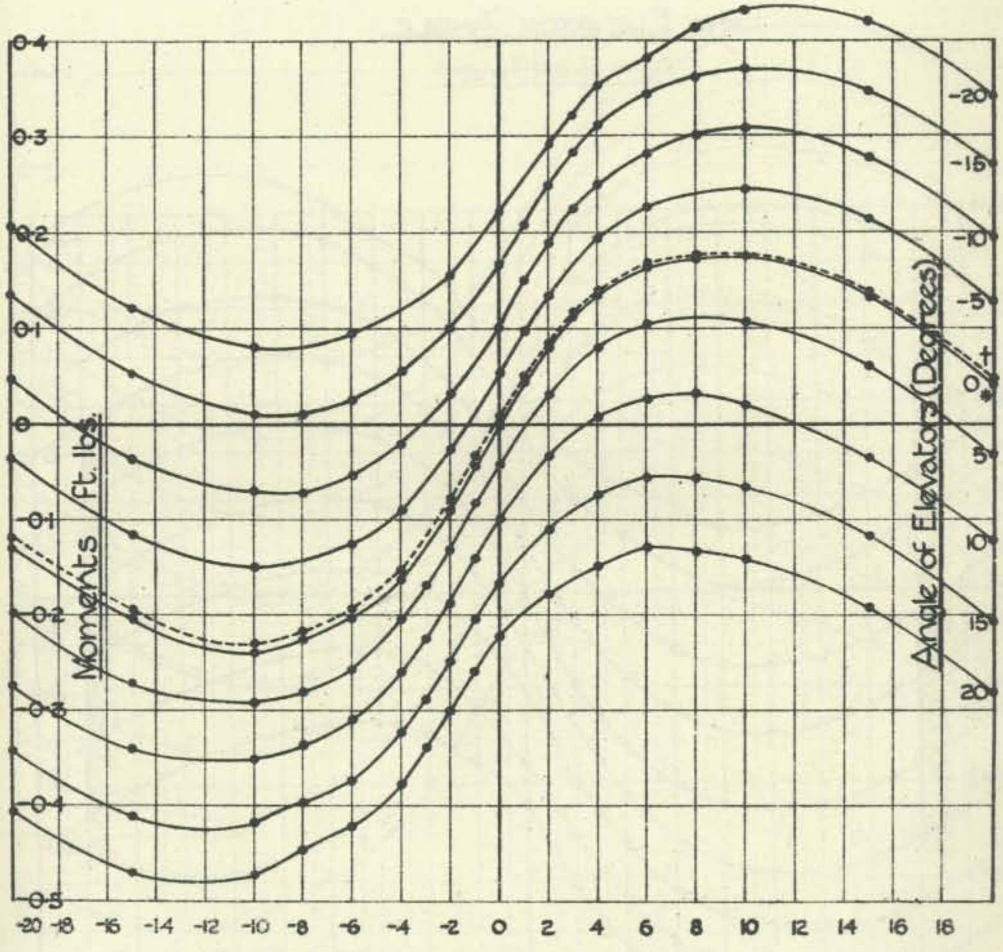
Diagram shewing Fins and Elevators.



BALANCED CONTROLS FOR RIGID AIRSHIPS.

VARIATION OF MOMENTS WITH ANGLE OF PITCH AND ELEVATOR ANGLE.

A = O.



* Actual observed Moments, probable angle of Elevators 0·5°
† Probable value of Moments with Elevators at 0°

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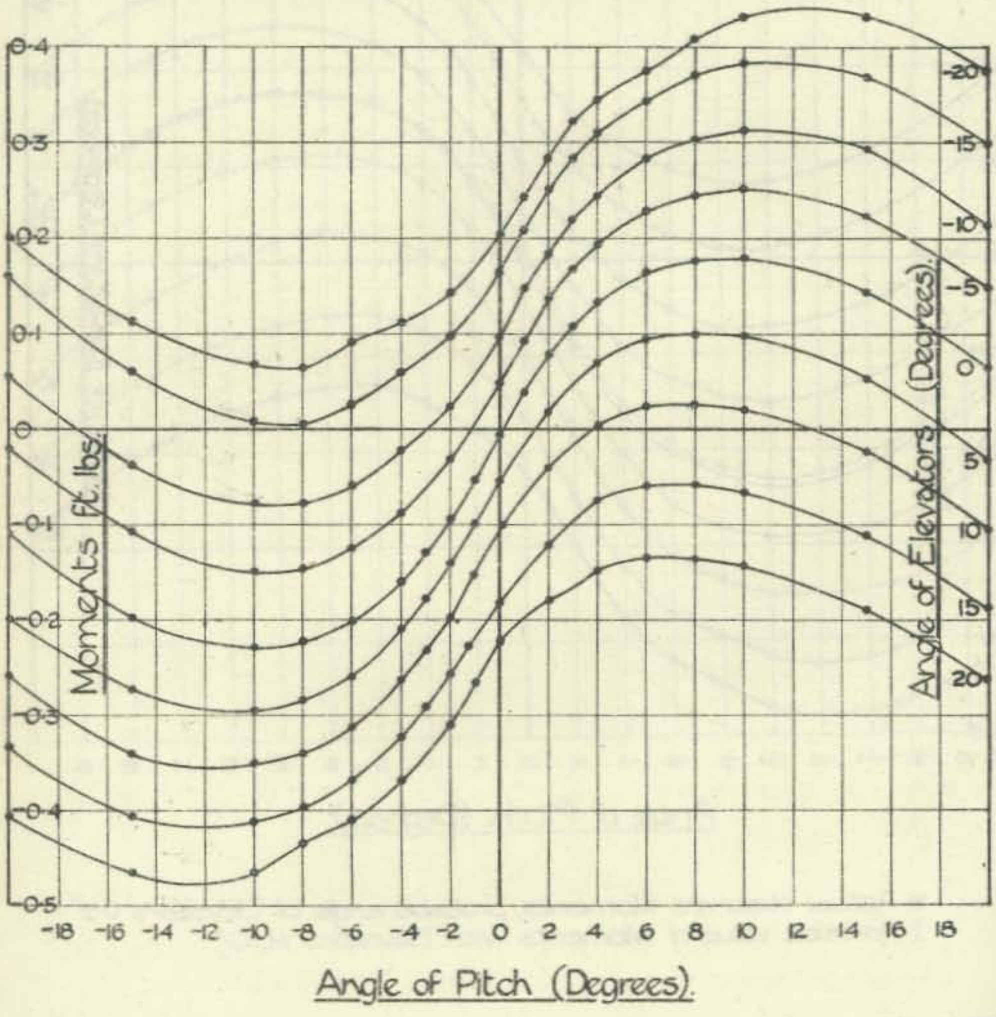
BALANCED CONTROLS FOR RIGID AIRSHIPS.

VARIATION OF MOMENTS WITH ANGLE OF PITCH AND ELEVATOR ANGLE.

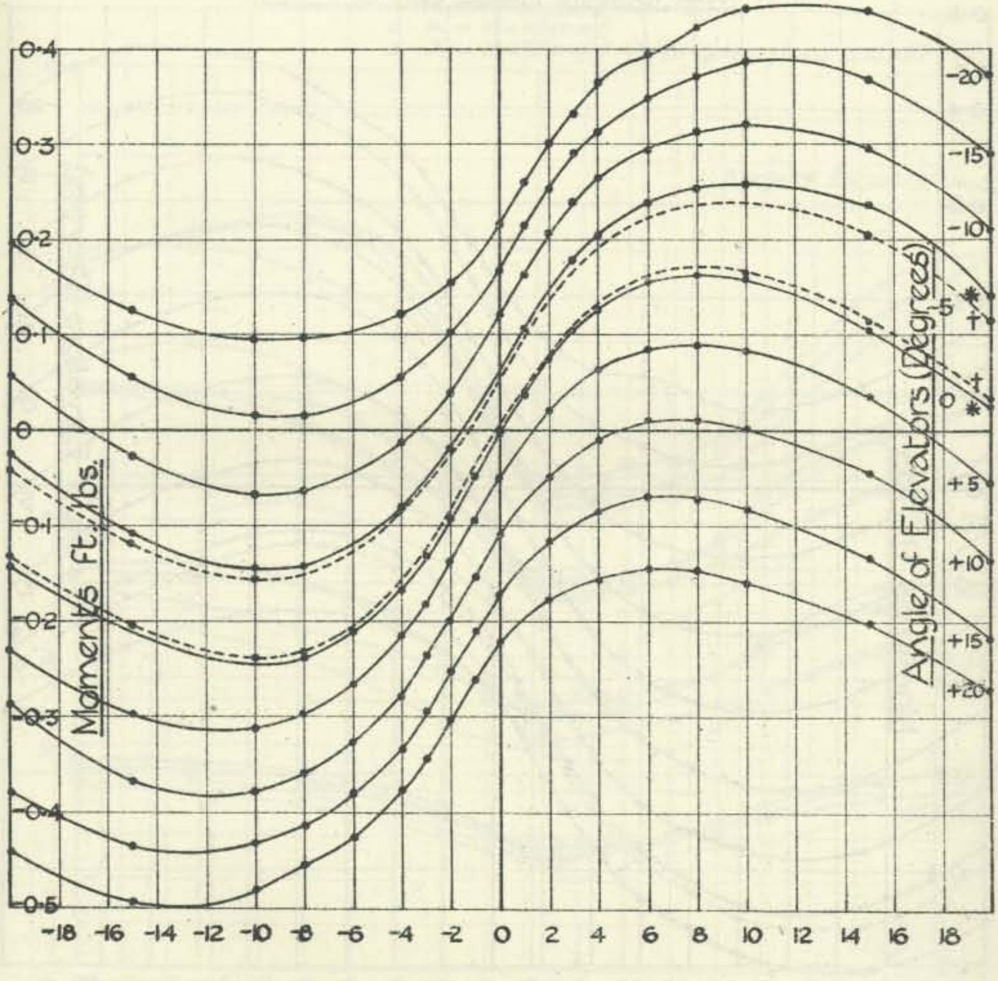
$A = 11 \times 19\,mm^2$



BALANCED CONTROLS FOR RIGID AIRSHIPS.

VARIATION OF MOMENTS WITH ANGLE OF PITCH AND ELEVATOR ANGLE.

A = 16 × 19 mm²



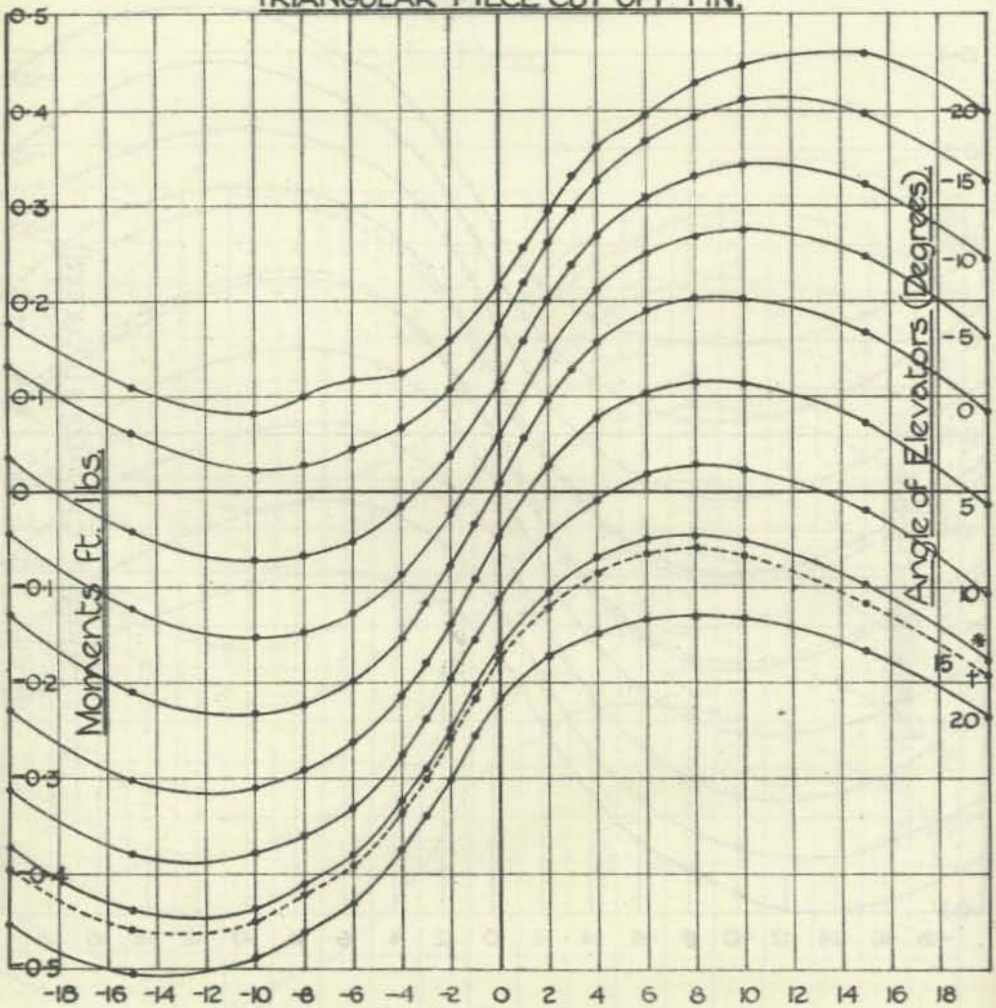
* Actual observed Moments, probable angle of Elevators 0·5°
† Probable value of Moments with Elevators at 0°

BALANCED CONTROLS FOR RIGID AIRSHIPS.

VARIATION OF MOMENTS WITH ANGLE OF PITCH AND ELEVATOR ANGLE.

A = 16 x 19 mm²

TRIANGULAR PIECE CUT OFF FIN.



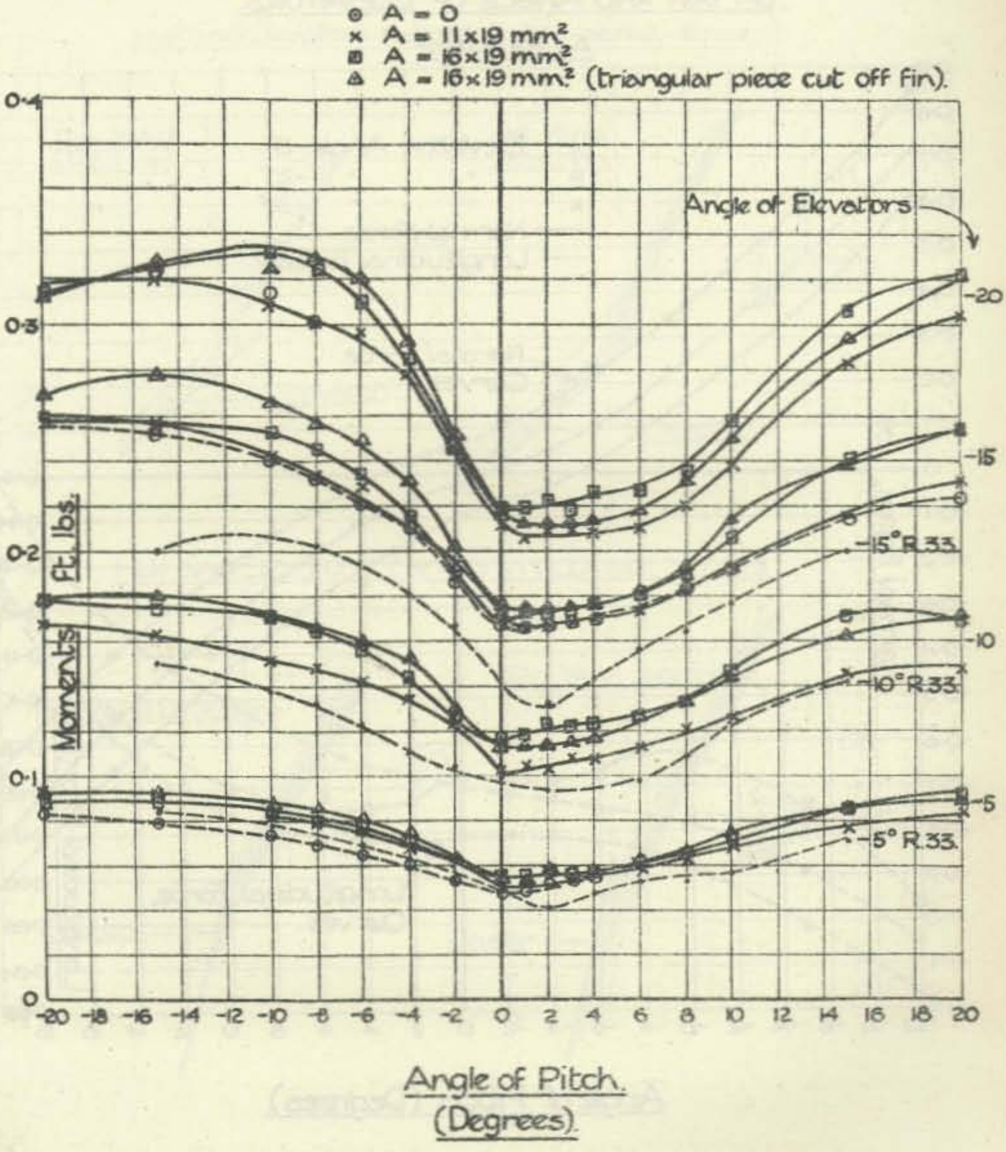
Angle of Pitch (Degrees).

* Actual observed moments, probable angle of Elevators 13·5°

† Probable values of Moments with Elevators at 15°

BALANCED CONTROLS FOR RIGID AIRSHIPS.

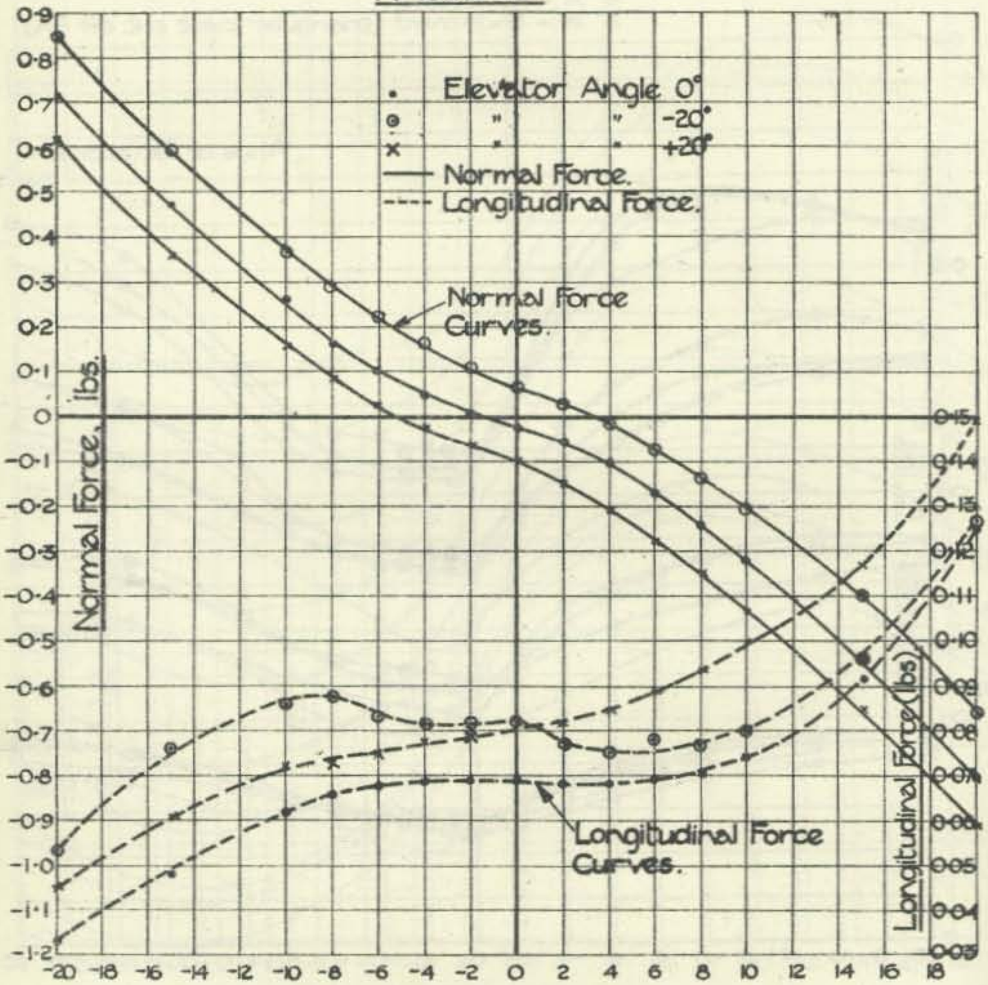
MOMENTS DUE TO ELEVATORS.



BALANCED CONTROL FOR RIGID AIRSHIPS.

VARIATION OF NORMAL AND LONGITUDINAL FORCE WITH ANGLE OF YAW AND ANGLE OF ELEVATORS.

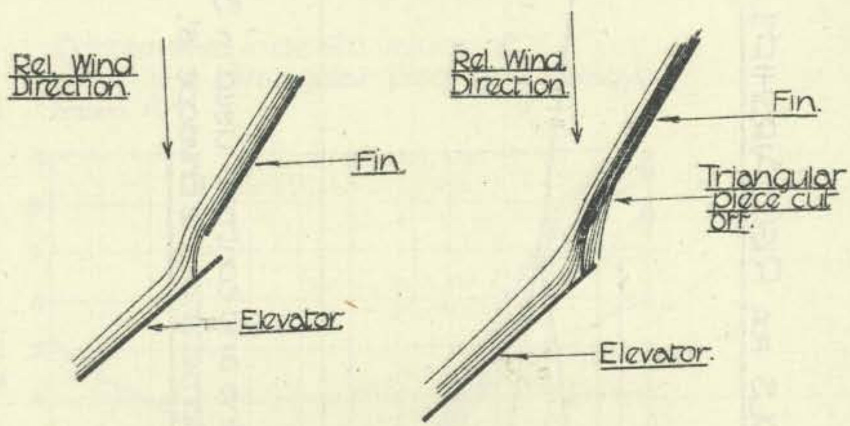
A = 16 X 19 mm²



Angle of Pitch (Degrees).

BALANCED CONTROLS FOR RIGID AIRSHIPS.

Hull and Elevators turned in the same sense.



Hull and Elevators turned in opposite senses.

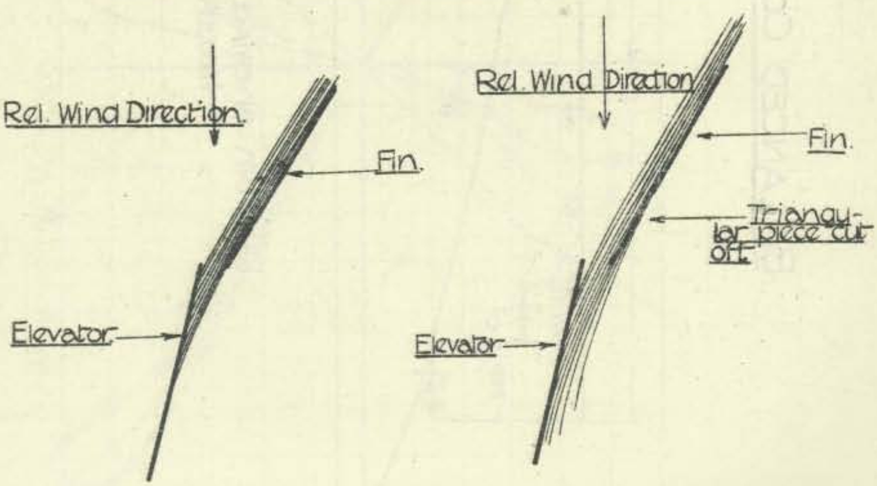


FIG. 9.

BALANCED CONTROLS FOR RIGID AIRSHIPS.

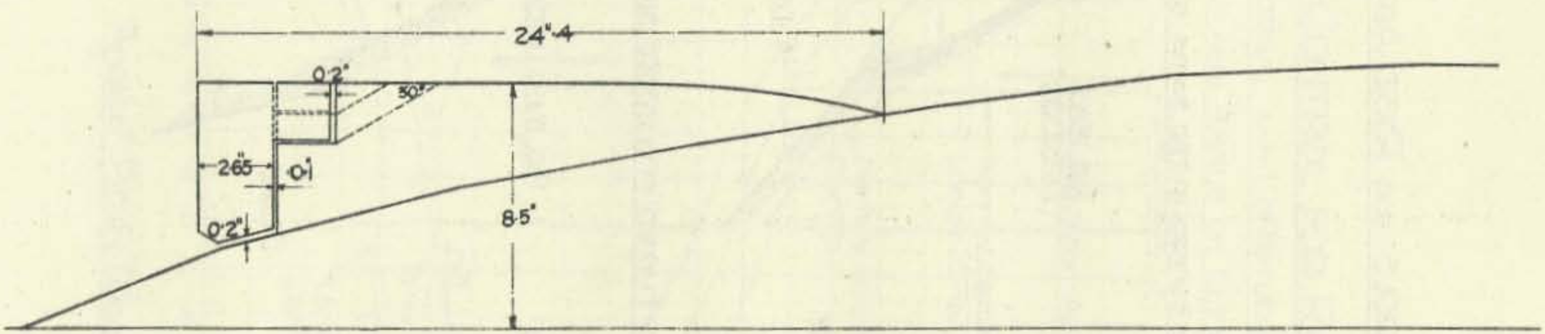
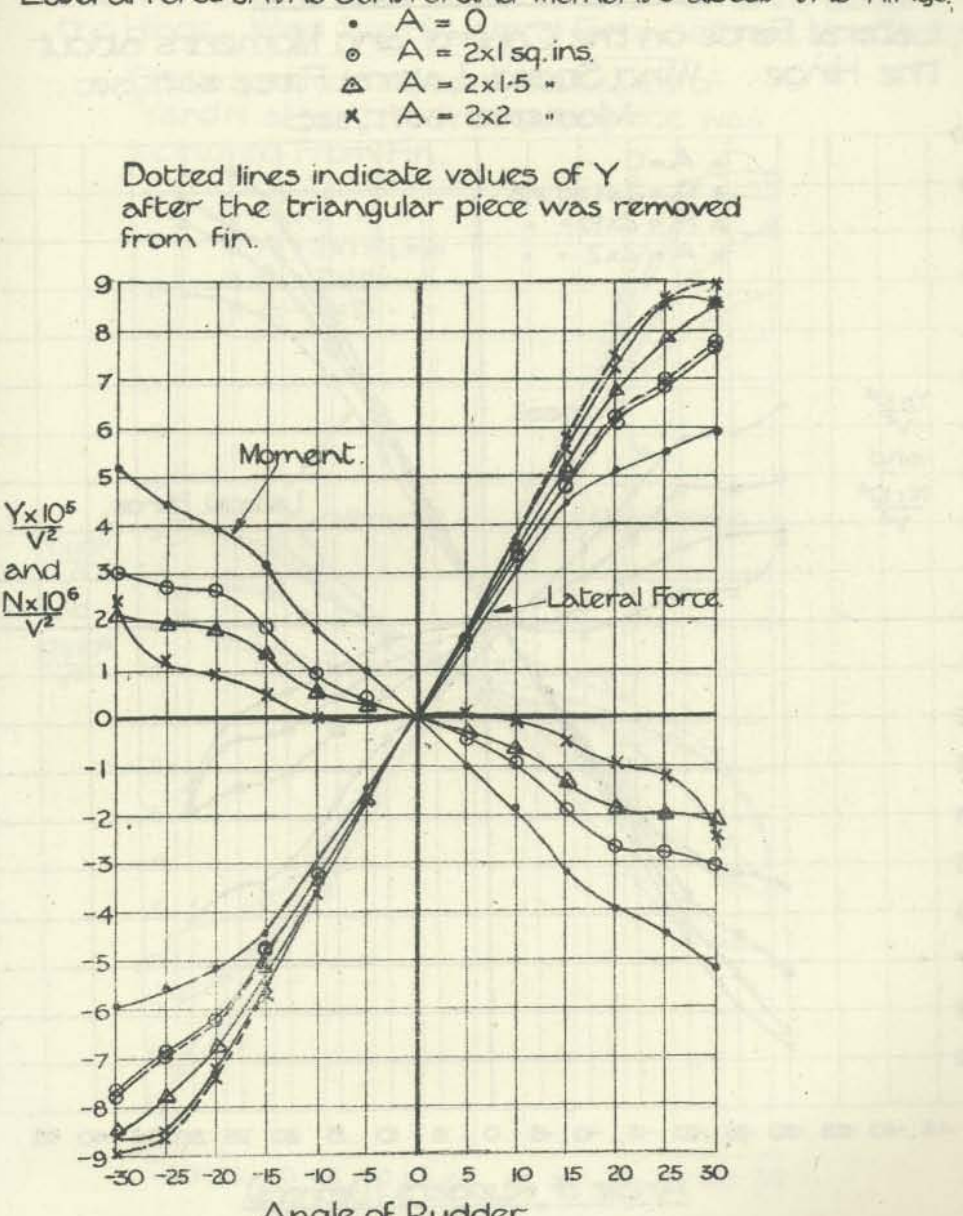


Diagram shewing the fins and controls used in Section II.
Maximum Diameter of the Envelope 18".

BALANCED CONTROLS FOR RIGID AIRSHIPS.

ANGLE OF YAW OF AIRSHIP O.

Lateral Force on the Control and Moments about the Hinge.



Wind Speed: Lateral Force: 50 ft./sec; Moments: 60 ft/s.

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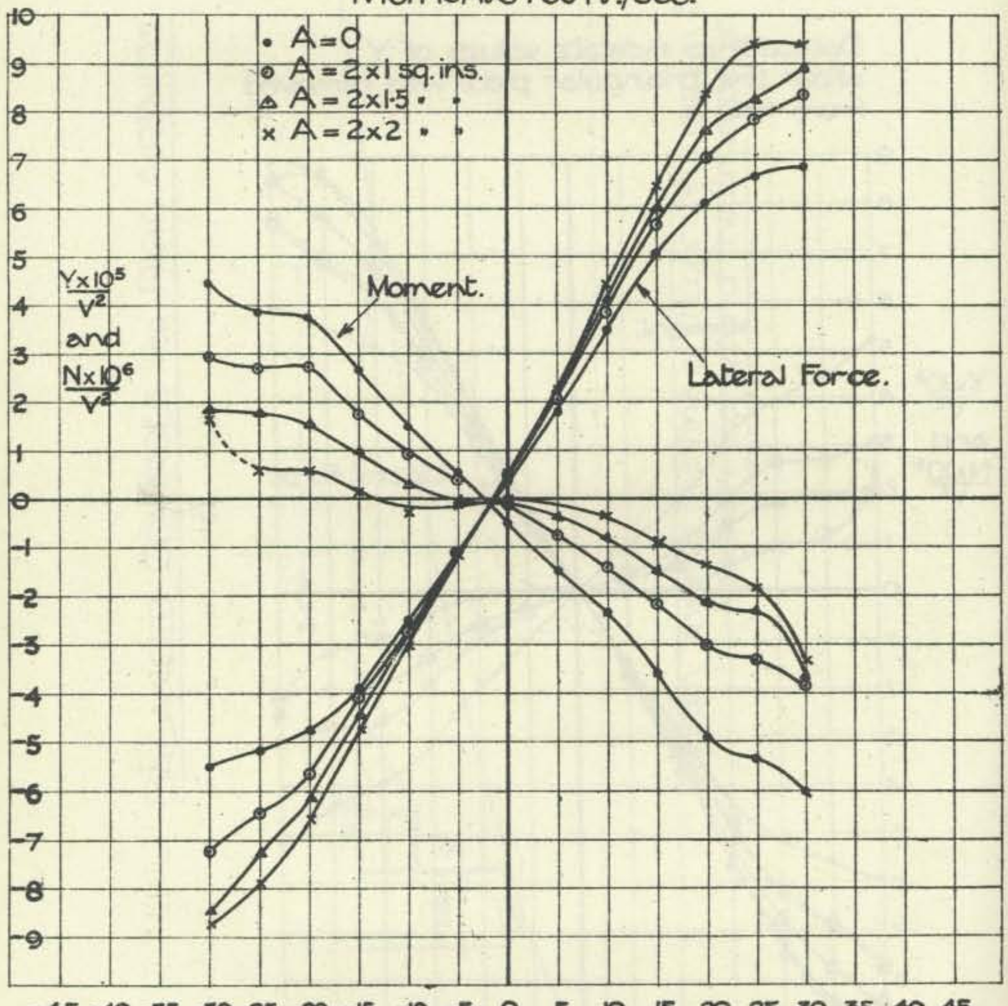
BALANCED CONTROLS FOR RIGID AIRSHIPS.

ANGLE OF YAW OF AIRSHIP 2°

Lateral Force on the Control and Moments about the Hinge. Wind Speed: Lateral Force 50 ft./sec; Moments: 60 ft./sec.



Angle of Rudders (Degrees).

BALANCED CONTROLS FOR RIGID AIRSHIPS.

ANGLE OF YAW OF AIRSHIP 5°.

Lateral Force on the Controls and Moments about the Hinge. Wind Speed: Lateral Force 50 ft./sec. Mom^{nt} 60 ft./s

Dotted curves indicate the values of Y and N after the triangular piece was removed from fin.

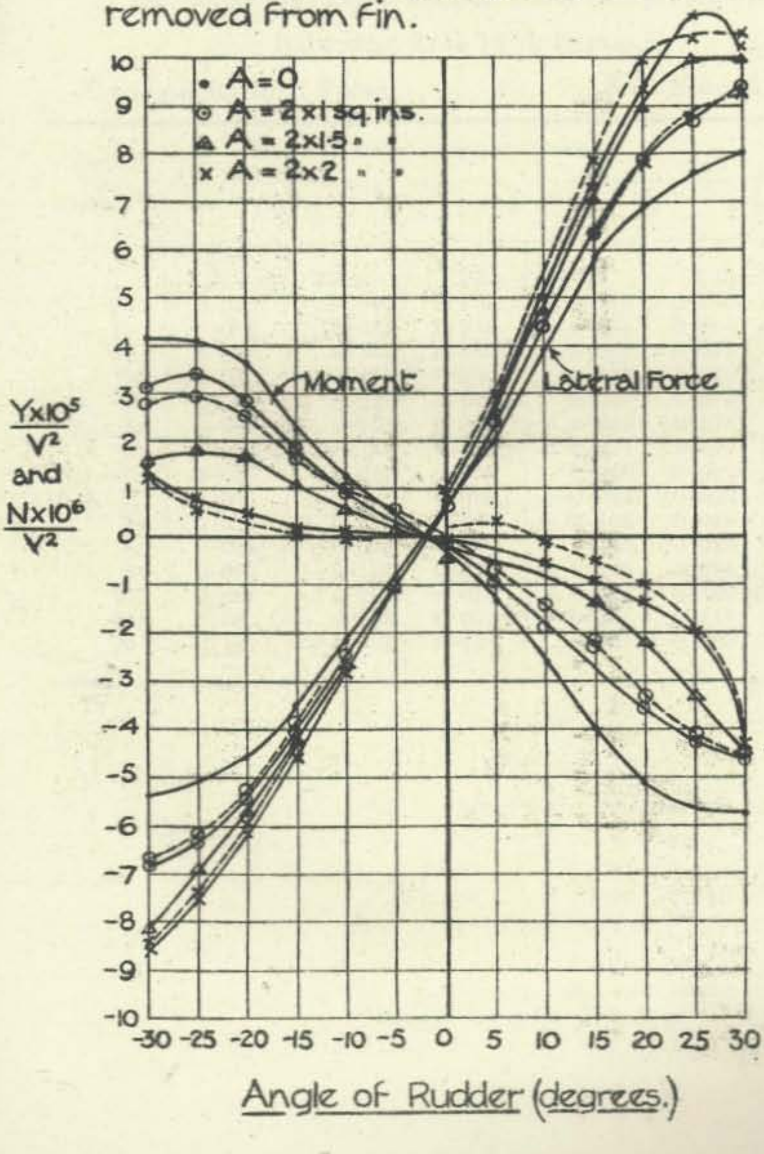


TABLE 5.

LONGITUDINAL AND NORMAL FORCES ON A MODEL OF R.33 FITTED WITH NEW ELEVATORS.

Balancing Area 16 × 19 mm.²

X = Longitudinal Force. Z = Normal Force.

Angle of Pitch (degs.).	Angle of Elevators.					
	− 20°		0°		+ 20°	
	− X lbs.	Z lbs.	− X lbs.	Z lbs.	− X lbs.	Z lbs.
− 20	0·053	+ 0·846	0·034	+ 0·716	0·045	+ 0·613
− 15	0·076	0·591	0·048	0·471	0·061	0·359
− 10	0·086	0·369	0·062	0·261	0·072	0·160
− 8	0·088	0·291	0·066	0·165	0·073	0·092
− 6	0·083	0·229	0·067	0·007	0·075	+ 0·030
− 4	0·082	0·165	0·066	0·050	0·078	− 0·210
− 2	0·082	0·110	0·069	+ 0·011	0·079	− 0·060
0	0·082	0·067	0·070	− 0·020	0·082	− 0·095
+ 2	0·077	+ 0·031	0·068	− 0·054	0·082	− 0·146
4	0·075	− 0·015	0·068	− 0·106	0·085	− 0·205
6	0·078	− 0·073	0·070	− 0·165	0·089	− 0·275
8	0·077	− 0·136	0·071	− 0·239	0·094	− 0.347
10	0·080	− 0·206	0·074	− 0·316	0·100	− 0·431
15	0·097	− 0·398	0·092	− 0·536	0·117	− 0·651
20	0·127	− 0·661	0·125	− 0·801	0·150	− 0·912

Table 6.

FORCES AND MOMENTS ON THE CONTROL SURFACES.

D = Drag, C = Cross wind force, Y lateral force on the control surface measured in lbs. and N the moment about the hinge in lbs./ft. V is the wind speed in ft/sec.

When A	=	0	2″ × 1″	2″ × 1″·5	2″ × 2″	
Area of Control Surface	=	0·0982	0·112	0·119	0·126	sq. ft.

Angle of Yaw of Ship 0°.

A = 0.

Angle of Rudder (degs.).	Wind Speed, 40 ft/sec.			50 ft/sec.			60 ft/sec.			
	$-\frac{10^5 D}{V^2}$	$\frac{10^4 C}{V^2}$	$\frac{10^4 Y}{V^2}$	$\frac{10^5 D}{V^2}$	$\frac{10^4 C}{V^2}$	$\frac{10^4 Y}{V^2}$	$\frac{10^5 D}{V^2}$	$\frac{10^4 C}{V^2}$	$\frac{10^4 Y}{V^2}$	$\frac{10^4 N}{V^2}$
0	0·140	0	0	0·148	0	0	0·143	0	0	0
5	0·272	1·34	1·35	0·256	1·44	1·46	0·251	1·41	1·43	— 0·98
10	0·612	2·84	2·91	0·604	2·71	2·79	0·617	3·00	3·07	— 1·82
15	1·22	4·10	4·27	1·24	4·16	4·35	1·26	4·26	4·44	— 3·20
20	1·91	4·73	5·10	1·92	4·72	5·09	1·95	4·78	5·16	— 3·93
25	2·50	4·91	5·50	2·51	4·91	5·51	2·64	4·95	5·55	— 4·46
30	3·12	5·12	5·99	3·04	5·06	5·90	3·11	5·05	5·92	— 5·17

A = 2″ × 1″. B in place. B is the corner of the fin immediately in front of A cut off at angle of 30° with the axis of the ship.

0	0·203	0	0	0·215	0	0	0·220	0	0	0
5	0·400	$1{\cdot}50_5$	1·54	0·390	1·51	1·54	0·397	1·54	1·57	— 0·42
10	0·780	2·99	3·08	0·790	3·02	3·11	0·815	3·10	3·20	— 0·94
15	$1{\cdot}47_5$	4·49	4·72	1·49	4·49	4·71	1·56	4·62	4·95	— 1·89
20	2·36	5·62	6·09	2·41	5·62	6·09	2·40	5·73	6·20	— 2·62
25	3·28	6·25	7·05	3·13	6·03	6·79	3·17	6·11	6·87	— 2·76
30	4·05	6·51	7·66	4·04	6·54	7·69	4·05	6·52	7·68	— 3·02

A = 2″ × 2″. B in place.

0	0·169	0	0	0·176	0	0	0·178	0	0	0
5	0·416	1·57	1·60	0·430	1·60	1·63	0·437	1·65	1·69	0
10	0·912	3·32	3·43	0·910	3·45	3·56	0·950	3·50	3·62	0
15	1·71	4·89	5·16	1·74	5·16	5·45	1·79	5·24	5·53	— 0·45
20	2·72	6·58	7·10	2·78	6·63	7·31	2·80	6·66	7·22	— 0·90
25	3·84	7·45	8·37	3·90	7·51	8·45	3·94	7·55	8·52	— 1·18
30	4·59	7·38	8·67	6·72	7·40	8·75	4·72	7·52	8·62	— 2·41

TABLE 6—*continued.*

Angle of Rudder (degs.).	B removed. A = 2″ × 1″ V = 50 ft./sec.			V = 60 ft./sec.	B removed. A = 2″ × 2″ V = 50 ft./sec.			V = 60 ft./sec.	B in place. A = 2″ × 1″·5 V = 50 ft./sec.			V = 60 ft./sec.
	$-10^3D/V^2$	$10^3C/V^2$	$10^3Y/V^2$	$10^4N/V^2$	$-10^3D/V^2$	$10^3C/V^2$	$10^3Y/V^2$	$10^4N/V^2$	$-10^3D/V^2$	$10^3C/V^2$	$10^3Y/V^2$	$10^4N/V^2$
0	0·315	0	0	0	0·402	0	0	0	0·430	0	0	0
5	0·445	1·51	1·54	—	0·554	1·75	1·79	—	0·500	1·57	1·61	− 0·31
10	0·86	3·13	3·13	− 1·11	1·03	3·54	3·67	+ 0·28	0·950	3·21	3·32	− 0·56
15	1·54	4·53	4·78	—	1·88	5·40	5·71	—	1·69	4·87	5·13	− 1·32
20	2·42	5·72	6·21	− 2·66	2·96	6·87	7·46	− 1·04	2·67	6·23	6·75	− 1·85
25	3·24	6·19	6·98	—	4·04	7·67	8·65	—	3·62	6·91	7·80	− 1·96
30	4·12	6·60	7·78	− 2·98	4·75	7·60	8·96	− 2·38	4·50	7·27	8·54	− 2·13

Table 7.

Angle of yaw of Ship 2°. B in place.

Angle of Rudder (degs.).	A = 0.				A = 2″ × 1″.			
	V = 50 ft/sec.			V = 60 ft/sec.	V = 50 ft/sec.			V = 60 ft/sec.
	$-10^5D/V^2$	$10^5C/V^2$	$10^5Y/V^2$	$10^6N/V^2$	$-10^5D/V^2$	$10^5C/V^2$	$10^5Y/V^2$	$10^6N/V^2$
−30	2·73	−4·80	−5·52	4·44	3·55	−6·29	−7·22	2·95
−25	2·16	−4·71	−5·17	3·85	2·77	−5·84	−6·45	2·70
−20	1·65	−4·49	−4·79	3·76	1·96	−5·34	−5·68	2·75
−15	1·048	−3·76	−3·90	2·64	1·105	−3·97	−4·10	1·74
−10	0·452	$-2{\cdot}51_5$	−2·55	+1·46	0·590	−2·62	−2·75	+0·90
− 5	0·192	$-1{\cdot}13_5$	−1·14	$+0{\cdot}50_5$	0·298	−1·15	−1·16	$+0{\cdot}39_5$
0	0·170	+0·296	+0·302	$-0{\cdot}50_6$	0·202	$+0{\cdot}49_5$	+0·488	−0·17
+ 5	0·380	1·75	1·786	−1·51	0·475	1·19	2·03	$-0{\cdot}78_5$
10	0·840	3·36	3·45	−2·35	0·988	3·73	3·85	−1·43
15	1·565	4·80	5·05	−3·63	1·84	5·34	5·65	−2·18
20	2·42	5·59	6·09	−4·97	2·85	6·42	7·02	−3·03
25	3·17	5·87	6·67	−5·36	3·75	6·92	7·85	−3·34
30	3·72	5·77	6·87	−6·01	4·69	6·96	8·38	−3·88

Angle of Rudder (degs.).	A = 2″ × 1″·5.				A = 2″ × 2″.			
−30	4·12	−7·15	−8·49	1·82	4·37	−7·60	−8·75	1·66
−25	3·07	−6·53	−7·22	1·77	3·44	−7·14	−7·90	0·56
−20	2·14	−5·75	−6·14	1·54	2·34	−6·15	−6·56	0·59
−15	1·24	+4·27	−4·43	0·98	1·39	−4·58	−4·77	+0·11
−10	0·648	2·73	−2·78	+0·28	0·740	−2·08	−3·05	−0·31
− 5	0·335	1·14	−1·15	−0·08	0·375	−1·21	−1·22	−0·11
0	0·20	0·43	+0·44	−0·11	0·215	+0·44	+0·45	0
+ 5	0·520	2·13	2·18	−0·42	0·580	2·24	2·29	−0·31
10	1·08	4·00	4·13	$-0{\cdot}81_5$	1·20	4·26	4·42	−0·36
15	1·96	5·68	6·01	$-1{\cdot}51_5$	2·17	6·07	6·44	−0·98
20	3·08	7·04	7·66	{−2·16, −1·91}	3·38	7·63	8·34	−1·40
25	4·13	7·64	8·28	−2·36	4·52	8·28	9·42	−1·85
30	4·91	7·44	8·91	−3·70	5·11	7·90	9·40	−3·40

TABLE 8.

A = 0. Angle of yaw of Ship = 5°.

Angle of Rudder (degs.).	V = 40 ft/sec.			V = 50 ft/sec.			V = 60 ft/sec.			
	$-10^3 D/V^2$	$10^3 C/V^2$	$10^3 Y/V^2$	$-10^3 D/V^2$	$10^3 C/V^2$	$10^3 Y/V^2$	$-10^3 D/V^2$	$10^3 C/V^2$	$10^3 Y/V^2$	$10^3 N/V^2$
− 30	2·34	− 4·72	− 5·27	2·43	− 4·67	− 5·26	2·48	− 4·81	− 5·41	4·15
− 25	1·83	− 4·66	− 5·01	1·88	− 4·66	− 5·01	1·94	− 4·64	− 5·10	4·10
− 20	1·27	− 4·46	− 4·64	1·32	− 4·42	− 4·62	1·46	− 4·46	− 4·68	3·68
	1·19	− 4·25	− 4·41	1·30	− 4·33	− 4·53	1·43	− 4·06	− 4·67	
− 15	0·62	− 3·34	− 3·39	0·66$_5$	− 3·40	− 3·47	0·73	− 3·59	− 3·66	2·30
− 10	0·26$_5$	− 2·18	− 2·16	0·27	− 2·39	− 2·21	0·26	− 2·27	− 2·29	1·26
− 5	0·11	− 0·88	− 0·88	0·11	− 0·79	− 0·79$_5$	0·11	− 0·81$_5$	− 0·81$_5$	+ 0·42
0	0·22	+ 0·49	+ 0·50	0·19	+ 0·53$_5$	+ 0·55	0·18$_5$	+ 0·55	+ 0·56$_5$	− 0·17
+ 5	0·47$_5$	1·92$_5$	1·97	0·49	2·06	2·11	0·49$_5$	1·77	1·83	− 1·29
10	1·11	3·64	3·80	1·06	3·70	3·85	1·10	3·78	3·94	− 2·38
15	2·04	5·15	5·54	2·00	5·33	5·69	2·00	5·48	5·82	− 3·96
20	2·94	6·13	6·80	2·94	6·16	6·82	2·94	6·24	6·91	− 5·14
25	3·76	6·44	7·46	3·81	6·59	7·60	3·86	6·61	7·65	− 6·26
30	4·58	6·61	8·05	4·59	6·54	8·00	4·54	6·49	7·93	− 6·74
A = 2″ × 1″.				B in place.						
− 30	3·20	− 6·00	− 6·79	3·20	− 5·97	− 6·76	3·30	− 6·05	− 6·88	3·06
− 25	2·45	− 5·81	− 6·30	2·50	− 5·83	− 6·34	2·61	− 5·86	− 6·41	3·40
− 20	1·65	− 5·06	− 5·32	1·69	− 5·04	− 5·31	1·73	− 5·15	− 5·43	2·86
− 15	0·90	− 3·72	− 3·82	0·93	− 3·78	− 3·88	0·93	− 3·93	− 4·04	1·82
− 10	0·47	− 2·47	− 2·50	0·43	− 2·40	− 2·42	0·45	− 2·49	− 2·52	0·90
− 5	0·23	− 1·05	− 1·05	0·24	− 0·99	− 0·99	0·23	− 1·03	− 1·03	+ 0·42
0	0·26	+ 0·48	+ 0·50	0·25	+ 0·48	+ 0·50	0·25	+ 0·48	+ 0·50	− 0·19$_5$
+ 5	0·60$_5$	2·22	2·32	0·60	2·32	2·39	0·62	2·30	2·37	− 0·98
10	1·27	4·14	4·32	1·25	4·20	4·38	1·33	4·20	4·40	− 1·99
15	2·15	5·69	6·02	2·19	5·81	6·21	2·26	5·89	6·58	− 2·35
20	3·36	7·09	7·85	3·36	7·18	7·94	3·36	7·24	7·98	− 3·62
25	4·32	7·47	8·59	4·28	7·55	8·62	4·35	7·65	8·75	− 4·30
30	5·30	7·75	9·40	5·29	7·72	9·38	5·29	7·72	9·35	− 4·66

TABLE 8—*continued*.

A = 2″ × 2″. B in place.

− 30	4·09	− 7·56	− 8·53	4·04	− 7·50	− 8·51	4·11	− 7·55	− 8·58	1·29
− 25	2·95	− 6·79	− 7·39	3·03	− 6·79	− 7·43	3·14	− 6·91	− 7·56	0·78$_5$
− 20	2·00	− 5·79	− 6·11	1·98	− 5·78	− 6·10	2·11	− 5·96	− 6·29	0·50$_5$
− 15	1·12	− 4·25	− 4·37	1·15	− 4·33	− 4·46	1·24	− 4·55	− 4·70	0·17
− 10	0·61	− 2·75	− 2·78	0·60$_5$	− 2·75	− 2·79	0·63$_5$	− 2·81	− 2·86	0·05
− 5	0·35	− 1·05	− 1·05	0·34	− 1·05$_5$	− 1·06	0·32	− 1·08	− 1·08	—
0	0·20	+ 0·66	+ 0·68	0·26	+ 0·67	+ 0·70	0·25	+ 0·69$_5$	+ 0·73	+ 0·08
+ 5	0·73$_5$	2·64	2·72	0·70$_5$	2·55	2·63	0·72$_5$	2·59	2·67	− 0·56
10	1·44	4·58	4·80	1·47	4·70	4·93	1·56	4·73	4·98	− 0·59
15	2·63	6·77	7·27	2·60$_5$	6·83	7·31	2·65	6·85	7·35	− 0·92$_5$
20	4·00	9·39	9·30	4·00$_5$	8·48	9·38	4·03	8·45	9·35	− 1·40
25	5·44	9·55	10·91	5·41	9·52	10·90	5·36	9·27	10·84	− 1·99
30	5·85	8·21	10·09	5·88	8·34	10·21	5·96	8·40	10·30	− 4·66

Angle of Rudder (degs.).	B removed. A = 2″ × 1″ V = 50 ft/sec.			V = 60 ft/sec.	B removed. A = 2″ × 2″ V = 50 ft/sec.			V = 60 ft/sec.	B in place. A = 2″ × 1″·5 V = 50 ft/sec.			V = 60 ft/sec.
	$-10^5D/V^2$	$10^5C/V^2$	$10^5Y/V^2$	$10^6N/V^2$	$-10^5D/V^2$	$10^5C/V^2$	$10^5Y/V^2$	$10^6N/V^2$	$-10^5D/V^2$	$10^5C/V^2$	$10^5Y/V^2$	$10^6N/V^2$
− 30	3·21	− 5·87	− 6·67	2·75	4·02	− 7·44	− 8·43	1·35	3·68	− 7·30	− 8·19	1·65
− 25	2·43	− 5·66	− 6·15	2·92	3·04	− 6·76	− 7·38	0·50$_5$	2·80	− 6·28	− 6·85	1·77
− 20	1·67	− 4·98	− 5·24	2·50	2·04	− 5·65	− 5·99	0·48	1·78	− 5·42	− 5·70	1·63
− 15	0·96	− 3·71	− 3·82	1·65$_5$	1·15	− 4·19	− 4·32	+ 0·05	1·04$_5$	− 4·00	− 4·12	1·01
− 10	0·47	− 2·42	− 2·49	0·98$_5$	0·60$_5$	− 2·55	− 2·60	− 0·03	0·54	− 2·57	− 2·61	0·50$_5$
− 5	0·26$_5$	− 0·99	− 0·99	+ 0·56	0·37$_5$	− 0·85$_5$	− 0·85$_5$	+ 0·28	0·29	− 1·00$_5$	− 1·00$_5$	+ 0·17
0	0·27	+ 0·51	+ 0·55	0	0·41	+ 0·87	+ 0·91	0·17	0·25	+ 0·64$_5$	+ 0·66$_5$	− 0·48
+ 5	0·60$_5$	2·28	2·35	− 0·70	0·81$_5$	2·89	2·98	+ 0·31	0·66	2·49	2·56	− 0·64$_5$
10	1·26	4·23	4·41	− 1·46	1·61	4·65	4·93	− 0·08	1·41	4·53	4·74	− 0·67$_4$
15	2·16	6·77	6·15	− 2·24	2·79	7·36	7·87	− 0·53$_5$	2·48	6·59	7·04	− 1·40
20	3·30	7·10	7·82	− 3·40	4·24	8·95	9·92	− 1·04	3·80	8·12	8·97	− 2·24
25	4·35	7·66	8·80	− 4·15	4·81	9·23	10·40	− 2·80	4·89	8·70	9·95	− 3·37
30	5·23	7·64	9·25	− 4·55	5·99	8·61	10·51	− 4·38	5·60	8·20	9·92	− 4·58

TABLE 9.

LATERAL FORCE per unit area/V^2.

Area of Control Surface—	A = 0	A = 2″ × 1″	A=2″×1″·5	A = 2″ × 2″.
	0·0982	0·112	0·119	0·126 sq. ft.

Angle of Yaw of Ship.		Angle of Control − 5°.				+ 5°.			
		B in place.			B removed.	B in place.			B removed.
		V = 40	50	60	50	40	50	60	50
0°	A=0	1·38 × 10^{-4}	1·49 × 10^{-4}	1·46 × 10^{-4}	—	—	—	—	—
	A=2×1	1·38	1·38	1·40	1·38 × 10^{-4}	—	—	—	—
	A=2×2	1·27	1·29	1·34	1·42	—	—	—	—
2°	A=0	—	1·16 × 10^{-4}	—	—	—	1·82 × 10^{-4}	—	—
	A=2×1	—	1·04	—	—	—	1·81	—	—
	A=2×1·5	—	0·97	—	—	—	1·83	—	—
	A=2×2	—	1·03	—	—	—	1·82	—	—
5°	A=0	0·90 × 10^{-4}	0·81 × 10^{-4}	0·83 × 10^{-4}	—	2·01 × 10^{-4}	2·15 × 10^{-4}	1·87 × 10^{-4}	—
	A=2×1	0·94	0·88	0·92	0·88 × 10^{-4}	2·07	2·13	2·12	2·10 × 10^{-4}
	A=2×2	0·83	0·84	0·86	0·72 × 10^{-4}	2·16	2·09	2·12	2·22
		Angle of Control − 15°.				+ 15°.			
0°	A=0	4·30 × 10^{-4}	4·43 × 10^{-4}	4·52 × 10^{-4}	—	—	—	—	—
	A=2×1	4·22	4·21	4·42	4·26 × 10^{-4}	—	—	—	—
	A=2×2	4·10	4·33	4·40	4·54	—	—	—	—
2°	A=0	—	3·97 × 10^{-4}	—	—	—	5·15 × 10^{-4}	—	—
	A=2×1	—	3·70	—	—	—	5·09	—	—
	A=2×1·5	—	3·73	—	—	—	5·05	—	—
	A=2×2	—	3·79	—	—	—	5·11	—	—
5°	A=0	3·45 × 10^{-4}	3·54 × 10^{-4}	3·73 × 10^{-4}	—	5·64 × 10^{-4}	5·79 × 10^{-4}	5·93 × 10^{-4}	—
	A=2×1	3·41	3·46	3·61	3·41 × 10^{-4}	5·38	5·55	5·88	5·49 × 10^{-4}
	A=2×2	3·47	3·54	3·73	3·43	5·78	5·80	5·84	6·25