EXPERIMENTS ON RIGID AIRSHIP R.29.

By J. R. PANNELL, A.M.I.M.E., and A. H. BELL.

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SUMMARY.—(a) *Introductory.* (*Reasons for Inquiry.*)—Airship R.29 was the last ship of the 27 Class and it was considered desirable that a record of her performance should be obtained before she was placed out of commission. Arrangements were, therefore, made for the experiments described below to be carried out.

Other reports dealing with full-scale experiments are :—

R. & M. 537. " A flight in R.26."
R. & M. 674. " Experiments on R.26."
R. & M. 668. " Experiments on R.33."

(b) *Range of the Investigation.*—The principal experiments were :—

Section (i).—Turning trials at various speeds and rudder angles for the original ship (R.29) ; with 303 sq. ft. of fabric removed from the upper fixed fin (R.29a) ; and with the whole of the fabric removed from the upper fixed fin (R.29b).

Section (ii).—Course with rudders amidships or at small angles

Section (iii).—Deceleration Trials.

Section (iv).—Airspeed for various engine combinations.

Section (v).—Attempted thrust measurements by pressure difference at amidships airscrew.

Section (vi).—Distribution of speed in various localities.

(c) *Conclusions.*—*Section* (i).—The variation of turning diameter with speed does not exceed the observational error. Expressing the diameter of the turning circle in terms of the length of the ship (turning coefficient) the minimum coefficient for the original ship is 9·9 whereas the values for R.29a and R.29b are 9·0 and 6·7 respectively ; the latter figure is only 7 per cent. greater than that for R.33. R.29b is thought to be less unstable than R.33. A comparison of R.33, R.29, R.29a, R.29b and R.26 is made in Table 6.

Section (ii).—The course with rudders locked amidships indicates that R.29 and R.29a are probably stable, while R.29b is unstable, for rectilinear flight.

Section (iii).—The mean resistance coefficient is found to be 0·0227 as compared with 0·0247 for R.26 and 0·0173 for R.33. The excess of 9 per cent. in the resistance of R.26 over that of R.29 is judged to be due approximately as to 4 per cent. to the external keel, and as to 5 per cent. to the improved form of head on the latter ship.

Section (iv).—The average maximum airspeed attained was 79 ft/sec. (46·8 knots).

Section (v).—The measurements of thrust were rendered of little value owing to the interference of the neighbouring radiator. It is shown that a correction can be applied which gives a value of the thrust coefficient of the same order as that obtained on the model.

Section (vi).—The distribution of speed was explored below the forward car and an increase of 17 per cent. was measured at a point 1 ft. below the under surface. Observations of speed were also taken behind the amidships radiator. The speed amidships was 11 per cent. low when the forward airscrews were at rest; but it was 16 per cent. high when the forward airscrews were running.

SYNOPSIS OF RESULTS.

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	,, ,, 10°	—	14	—	—
	,, ,, 15°	—	15	—	—
	Upper fixed fin reduced (R.29a). — ,, ,, 5°	—	16	—	—
	,, ,, 10°	—	17	—	—
	,, ,, 15°	—	18	—	—
	All fabric removed from upper fixed fin (R.29b). — Rudders at 5°	—	19	—	—
	,, ,, 10°	—	20	—	—
	,, ,, 15°	—	21	—	—

SYNOPSIS OF RESULTS—*contd.*

INTRODUCTION.

In August, 1919, information was obtained to the effect that Airship R.29 was to be deleted and broken up. A schedule of trials was drawn up and the ship placed at the disposal of the staff of the N.P.L. for a limited period.

Continuance of the experiments was prevented by instructions to proceed with the strength tests which were to be carried out during the destruction of the ship.

The observations were made during four flights taken respectively on September 15th and 16th, and October 7th and 9th, 1919, from the aerodrome at East Fortune in Haddingtonshire, Scotland.

Two representatives of the N.P.L. were on the ship for each flight, the place of Mr. A. H. Bell being taken on the 3rd and 4th flights by Mr. E. F. Relf, A.R.C.Sc.

At the conclusion of the experiments the engineer officer of R.29, Lieut. H. N. Hasler, supplied measurements of airspeed which he had taken during a flight on September 14th. These speeds were observed by means of a flying head and the Ogilvie indicator fitted to the airship. This anemometer was compared with the N.P.L. instrument in flight, and the two found to be in close agreement when a correction had been applied for calibration error of the airspeed indicator on the ship.

DESCRIPTION OF APPARATUS.

Anemometer.—The airspeed of the ship was measured by means of the flying head and Ogilvie indicator employed in the experiments on airship R.33 and described in R. & M. 668. Dimensions and details of its construction are given in Fig. 2 of the present report.

Yawmeter.—The observations from which the angle of yaw during the turning trials was deduced were taken by means of a yaw head of the ordinary type. The head was rotated until the Ogilvie manometer, to which it was connected, indicated equality of pressure in the two tubes. This apparatus is shown in Fig. 3, and is described in detail in R. & M. 668.

Manipulation of Rudders.—Experience on R.33 showed that it was essential to lock the rudders at the after end of the ship when it was necessary to maintain a constant known rudder angle. This was effected for each rudder by clamping together the two cables which run to it. When a given rudder angle was required, word was sent by telephone to an assistant at the auxiliary control station in the after car, from which point the rudders were manipulated. The angle of the rudders was read from scales fitted aft near the position at which the cables were clamped. Communication between this point and the after car was effected by voice pipe.

Apparatus for Pressure Measurement at the Amidships Airscrew.—The observations were made with a view to the measurement of thrust by the method employed on models and described in R. & M. 460*. An anemometer head was fitted up-stream of the airscrew, and in a position about 3 ft. from the starboard side of the car, at which point the interference of the car was believed to be negligible. On the after side of the airscrew a length of duralumin channel was fixed in the hull in such a position that it projected downwards past the axis of the airscrew. A length of copper tube was fitted with a guide to slide over this piece of channel, and at the lower end of the tube a smaller pipe was fitted

* On a method of estimating, from observations on the slip-stream of an airscrew, the performance of the elements of the blades, and the total thrust of the screw. By Dr. Stanton and Miss Marshall.

at right angles to form a pitot tube. This pitot tube was manipulated from the walking way and the distribution of total head in the slip-stream was measured from the axis of the airscrew to within 11 ins. of the hull (*i.e.*, 19 ins. beyond the tip of the airscrew). The horizontal distance from the plane of the airscrew to the mouth of the pitot tube was 26·5 ins.

METHOD OF EXPERIMENT AND REDUCTION OF RESULTS.

Turning Trials. Section (i).—It has long been realised that the use of a compass for measurement of the path of an aircraft during angular motion was open to objection. The error was not expected to be serious for a large airship which turns comparatively slowly, and as the fitting of a sun-dial was inconvenient in the trials of airship R.33, observations were made by means of a compass only. It was found, however, that the compass reading during what was believed to be a steady turn, plotted on a time base, gave a slightly sinuous curve instead of a straight line, and it was apparent that in view of the comparatively short time which could be expended on each turn the accuracy with which the mean slope could be determined was appreciably reduced due to this characteristic of the compass.

For the trials of R.29, therefore, a sun-dial was mounted at the top of the climbing shaft. This sun-dial consisted of a cardboard disc about 15 ins. in diameter, graduated from 0° to 360° by intervals of two degrees. The cardboard was fixed to a wooden board, and a brass rod about 0·3 in. in diameter and 18 ins. long was mounted perpendicular to the disc at its centre. Owing to the apparent motion of the sun the readings of the sun-dial require correction to the extent of 15° per hour; in the present experiments the error is unimportant and no correction has been applied.

The master compass, which is mounted on top of the ship about 10 ft. aft of the climbing shaft, was, for these experiments, supported in a temporary mounting beside the sun-dial. In the early experiments observations were taken throughout at 10-second intervals alternately on the sun-dial and compass. Subsequently when the sun was available to cast a shadow, only the sun-dial was observed.

To facilitate comparison, representative sets of observations of the compass have been plotted for experiments in which sun-dial readings are available. In Fig. 15, Experiment 17, observations are plotted for the sun-dial, master compass and compass in the after car. Neglecting the first three values, the observations of the sun-dial lie on a close approximation to a straight line; but both sets of compass readings follow a sinuous path of approximately the same average slope. Similar points on this curve occur at angles of approximately 50° and 410° indicating a complete period in 360°. This sinuous form with a period of 360° can be observed in varying degrees in all turns for the higher rudder angles. It is found that the compass always lags in turning away from North a deviation which is in accordance with experience on aeroplanes (see R. & M. 156).

The results have been reduced by the method of R. & M. 668. If V be the speed and $\dot{\psi}$ the rate of turn in radians per second, then

$$R = V/\dot{\psi}$$

where R is the radius of the turning circle. Further, if β be the true angle of yaw (*i.e.* at the centre of gravity), and β_1, the angle of yaw measured at a point distant l from the C.G.

$$\tan\beta = \tan\beta_1 + l\dot{\psi}/V \sec\beta_1.$$

Turning to the experiments with small rudder angles, Figs. 13 and 16, it is remarkable how faithfully the compass readings follow those of the sun-dial even through local deviations from the mean direction; a striking instance is afforded by Experiment 3 in Fig. 13 for which the compass and sun-dial readings are in close agreement even during the disturbance at 6 mins. Similar evidence may be found in Experiments 2 and 4, Fig. 13, and Experiments 66–74, Figs. 6 and 6a. On the contrary, however, in Experiment 1, Fig. 13, there is a considerable departure; but local departures of the compass such as those which occur in Experiment 24, Fig. 16, are thought to be due to observational error.

Fig. 18 is a typical example of the results obtained with the sun-dial under satisfactory atmospheric conditions, while Experiment 38, Fig. 19, shows an interesting example of reversal in direction during a low speed experiment with rudders at 5°.

These comparisons make it abundantly clear that under steady conditions the use of a sun-dial in place of a compass will admit of considerable economy of time in experiments during which the angular velocity is high.

Deceleration. Section (iii).—In reporting on the trials of R.33 it was remarked that the method of carrying out a deceleration experiment by means of visual observations on an Ogilvie indicator connected to a flying anemometer head, was not entirely satisfactory. In order to define the curve accurately it is necessary, during the early portion of the experiment, to take observations rapidly, and it was decided to employ a cinematograph camera for taking photographs of the Ogilvie indicator and a stop watch. This plan allowed the readings of pressure and time to be read off at leisure in the Laboratory.

In order to guard against the possible loss of the results due to failure of the film, a number of visual observations were also taken; these were found to be in very good agreement with the values read off from the film.

The procedure of R. & M. 668 has again been followed in reducing the results: if l be the cube root of the volume, and S the slope of the curves in Fig. 7, then $C = lS$, where C is the non-dimensional coefficient defined on page 212.

Speeds for various Engine Combinations. Section (iv).—Owing to the limited time at disposal, the measurements of speed were not carried out in such a manner as to afford very comprehensive data. By including the results obtained by Lieut. Hasler it has, however, been possible to prepare a curve in the same manner as in the report on R.33* for the prediction of speed with the forward engine stopped, the amidships engine at constant speed and the after engine at varying speed. Owing to paucity of observations, however, the curve cannot be defined without resort to the method of calculation described in R. & M. 668. It is there shown that over the range of speed where the resistance R is proportional to the square of the speed V, the sum of the thrust coefficients is equal to a constant. If all engines are running at the same speed a constant total thrust coefficient requires a constant value of V/ND, where the variable N is the rotational speed common to all the engines, so that changes in v will be proportional to those in N. Values of V/N have been calculated from those observations of speed in the present experiments where the rotational speed of all the engines running is the same.

In the case where the engines are running at differing speeds, N_1, N_2, N_3, it will be readily seen that when N_1, N_2, N_3 (or as many engines as are running) all vary in a given ratio V must vary in the same ratio in order that V/ND for each engine (and in consequence the sum of the thrust coefficients) may remain constant. Thus if N_1 is zero, N_2 800 r.p.m. and N_3 1,000 r.p.m. a change of N_2 to 1,200 r.p.m. and of N_3 to 1,500 r.p.m. will cause the speed, V, to increase to 1·5 times its former value. This principle has been employed in converting observations of speed in which engines 2 and 3 only were running, so that they could be employed in plotting the curve for R.29 in Fig. 8.

Thrust Experiments. Section (v).—The observations of pressure difference at the amidships airscrew were taken by means of an Ogilvie indicator connected on the one side to the pitot tube of the fixed head up-stream of the airscrew and on the other to the adjustable pitot tube which was located in the slip stream at varying values of the radii. The speed of inflow at the airscrew was measured on a second Ogilvie indicator connected to the fixed anemometer head. Experiments were carried out at various values of V/nD (n denotes the rotational speed of the airscrew)† both with and without the forward airscrews running.

The method of calculating the thrust coefficient (T_c) from the measurements of pressure difference ($p_2 - p_1$) is the same as that given in R. & M. 460. The non-dimensional quantity

$$\pi \times \frac{(p_2 - p_1)}{\frac{1}{2}\rho V^2} \times \frac{r}{D} = T'$$

* R. & M. 668. Pannell and Frazer.

† To conform with the usual practice of engineers, engine speed (N) is given in r.p.m.; *airscrew* speeds (n) are in revs. per sec.

where r and D are respectively the radius and diameter of the airscrew, is plotted as ordinate on a base of r/D, and the value of T_c obtained from the resulting curve by graphical integration.

Distribution of Airspeed.—The speed gradient below the forward car was determined by hauling in the N.P.L. flying head by 5 ft. intervals and comparing the readings of the Ogilvie indicator connected to it with those of the ship's anemometer. The exploration at the after side of the amidships radiator was carried out by means of an anemometer head fixed to a staff, and projected through a hole cut for the purpose in the outer cover. In this case the head fixed to the side of the car was used to give a reference speed. This radiator was 4 ft. square (16 sq. ft. in area), and replaced a circular one which had been used until shortly before the trials.

Variations of the airspeed of the ship during the experiments were taken into account by multiplying the reading of the exploring anemometer at a given time by the ratio of the *mean* reference speed for the experiments to the *actual* reference speed at that time.

DISCUSSION OF RESULTS.

Turning Trials. Section (i).—The results of the turning trials are given in Tables 2, 3, 4, and 5, and are plotted on a speed base in Fig. 4. The variation of the turning coefficient with speed is less well defined than for R.33, and does not appear to exceed the observational error. In this connection it may be remarked that the atmospheric conditions on the fourth flight, when the results for R.29b were obtained, were markedly less steady than for the other flights.

No account is, therefore, taken of variation of the turning coefficient with speed, and the values used in plotting the curve in Fig. 5 were obtained by calculating the arithmetical means for each rudder angle. It will be noticed that values for port and starboard rudder angles fall on distinct curves, and a mean curve has been drawn to represent the 29 Class with each condition of the upper fin.

Calling the condition with the reduced upper fin R.29a, and that with the whole of the fabric removed from the upper fixed fin R.29b, the various modifications give rise to the following effects on the turning circle. With the rudder at 5° the diameter of the turning circle expressed as a fraction of that with the original fin is 0·76 for R.29a and 0·50 for R.29b ; at 15° the effect is much less, the former being 0·87, the latter 0·66.

A comparison is made in Table 6 between the minimum turning coefficients* of R.33 (R. & M. 668), R.29, R.29a, R.29b and R.26

* The " turning coefficient " for any particular rudder setting on an airship has been defined in R. & M. 668 as the diameter of the turning circle divided by the length of the airship.

(R. & M. 674). These quantities are 6·22, 9·92 and 11·78 respectively for R.33, R.29 and R.26 when the rudders are at 19° (approximately the maximum attainable). The greater diameter for R.26 than for R.29 is probably due jointly to the greater fin area on the former and to its external keel. On removal of the whole of the fabric from the upper fixed fin of R.29 (R.29b) the value falls from 9·92 to 6·67, a quantity which does not differ greatly from that for R.33 (6·22).

The results obtained with R.33 and R.29b represent the order of controllability which would be expected on a modern ship and, therefore, they only need be considered in further comparison. It is worthy of note that though the minimum turning coefficients of R.33 and R.29b are approximately equal, this departure from rectilinear flight is produced in the first case by the inclination of rudders which constitute only 0·25 of the area of the total vertical stabilising surface while the corresponding fraction on R.29b is 0·40. If it be conceded that it is legitimate to compare turning coefficients for ships of different sizes, it appears that if all the rudders are equally efficient it is permissible to assume a lower degree of stability in rectilinear flight for R.33 than for R.29b. For the turning coefficients are approximately the same for the same rudder angles, and since the rudders on R.29b constitute 0·40 of the total vertical surface as against 0·25 on R.33, it may be argued that *the departure of R.33 from a straight course is produced by a smaller disturbing force than on R.29b and that the stability of the former ship is therefore lower.*

For the purpose of the present discussion a stable airship may be defined as one which, for a certain rudder angle, will fly on a straight path, and after a disturbance will tend to return to motion along a straight path, though that path may not be the original or one parallel to it.

It should be noted however that, since, in R.29b the upper rudder does not operate behind a fixed fin, its efficiency may well differ from that of the lower rudder. Experiments in the wind channel* show that the lateral force on a rudder alone is 10 per cent. greater than when a fin is in place before it. This experiment is probably analogous to the use of an airship rudder during approximately straight flight, and would serve to emphasize the conclusions drawn above as to stability. In considering the flow in the neighbourhood of the rudder during turning it appears probable that in using the rudder to stop a turn the rudder alone will be more efficient ; but, on the other hand, during a steady turn the absence of the fin is likely to render the rudder less effective. In view of the large difference in the proportion of the fin area which the rudders on the two ships constitute it is unlikely that the efficiency of the upper rudder on R.29b will be sufficiently reduced to invalidate the argument as to the relative stability of R.29b and R.33.

* R. & M. 156. Table 21.

An alternative means of estimating the relative stability of R.29b and R.33 would be to compare the turning coefficients when the rudders are set for rectilinear flight; but the observations on R.29b were only taken at one speed and owing to paucity of observation the speed effect on R.33 is not accurately defined. On R.29b at 65 ft/sec. the turning coefficient is 47, while the corresponding figure for R.33 is 22 if it be legitimate to compare at the same speed. R.33 is therefore again shown to be markedly less stable than R.29b, though for the reasons stated above the quantitative comparison cannot be regarded as accurate.

The following table shows the magnitude of certain quantities which affect the stability of the ships :—

	R.33.	R.29b.	$\frac{\text{R.33.}}{\text{R.29b.}}$
Area of hull projected upon a vertical plane (sq. ft.).	39,800	26,480	1·51
Total vertical fin area (sq. ft.)	1,880	1,069	1·76
Distance from C.G. to centre of area of fins divided by total length of ship.	0·47	0·45	1·05

These values show that the increase of fin area on R.33 over that on R.29b is proportionally greater than that of the projected area of the hull and further that on the former airship the leverage of the fins is proportionally 5 per cent. greater; these differences should increase the stability of R.33 relative to that of R.29b. It has been shown, however, that there are good reasons for believing R.29b to be less unstable than R.33, and it therefore appears that the fins of the latter ship are less efficient, or that the hull itself is more unstable. In all probability the reduced stability of R.33 is due jointly to the two causes.

Course with Rudders approximately Amidships. Section (ii).—The observations taken with rudders approximately amidships are plotted in Fig. 6 and the quantities derived from them given in Table 7. Reference to Fig. 6 shows that for R.29 the departure from a straight course is very slight and it is highly probable that, had time permitted, a rudder angle could have been found for which the path would have been practically straight. The turning coefficient is given in Table 7 as 71·5 at 36 ft/sec. and 162·5 at 67 ft. per sec. Though these results show an effect due to speed in the same direction as that observed on R.33 it should be remembered that, in spite of the slight curvature of the path, R.29 is believed to be stable and, therefore, the change has not the same significance as on R.33.

The mean path of R.29a (303 sq. ft. of canvas removed) for rudders amidships has been taken as straight; at 61 ft. per sec. the deviation was less than for R.29, while at 35 ft. per sec. the ship turned slightly first to port and then to starboard.

In the case of R.29b (all fabric removed from upper fixed fin) there was a decided turn when the rudders were clamped amidships, the turning coefficient being reduced to 47 as against 162, and infinity for R.29 and R.29a at approximately the same speed. The value of the three remaining turns at lower speed on R.29b was seriously impaired by the unclamping of the rudders which occurred as the result of a misunderstanding. The angle of the rudders was observed approximately by the rating on duty as about 1° starboard (see Table 7) which, as the ship was already turning to starboard, resulted in an increased rate of turn. This error precludes the possibility of an accurate estimate of the speed effect in the only case where it was likely to be of interest, viz., the unstable condition. The reason for dividing the low speed experiment into three parts (Expts. No. 71, 72 and 73) is that for the first three minutes the speed was higher than during the remainder of the experiment, while between time $6\frac{1}{2}$ and 9 minutes there was scarcely any departure from a straight course.

Though these results are far from complete the authors are of the opinion that they indicate a condition of instability for R.29b, while both R.29 and R.29a are probably stable for rectilinear flight in a horizontal plane.

During the second flight in R.29 (original fins) some observations were taken to indicate the behaviour of the airship in yaw while being flown on a given compass course. These values are plotted in Fig. 6a in comparison with similar observations taken on R.33 (see R. & M. 668, Fig. 8), the personal element being to some extent eliminated by the same observer manipulating the helm on the two airships. The experiment on R.29 may be regarded as commencing at time 5 mins., and it will be noted that though the experiment was continued for 22 minutes the rudder angle was only changed twice and the deviation from the mean course was less than 20°. On R.33, the rudder angle was changed 11 times in the same period and it was only by keeping the closest watch that the variations of course shown in the figure were not exceeded. The variation of course for R.33 was about 35° on either side of the mean as compared with about 18° for R.29. The greater departure of R.33 from a straight course would result in the distance flown by that ship during a flight from one point to another being appreciably greater than for R.29. The path of R.33 would, of course, have been more nearly straight (by close application the deviation can be reduced to a very small magnitude) had larger rudder angles been employed, but this would have the concomitant disadvantage of increasing the resistance.

This comparison appears to bring out very forcibly the advantage of stability in an airship. A given course can be flown with much greater accuracy and, as may be seen by comparison of the movements of the rudders on the two ships, with a greatly reduced effort on the part of the helmsman. The latter advantage would be of very great value on a long voyage such as a flight to America. The authors fully realize that excessive stability is objectionable under disturbed atmospheric conditions, and it is possible that since the dimensions of a gust may be comparable with the length of the ship, even a condition of neutrality might be objectionable. Practical experience will probably form the best guide to the degree of stability most suited to the flying in all weathers.

It is probable that a straight course would have been steered with equal ease and accuracy on R.29a. No records of this nature were taken on R.29b ; but it may be confidently asserted that for the same rudder angles a straight course could not have been steered so readily as on R.29. It was interesting to note that the helmsmen found R.29b markedly more difficult to steer than R.29 and were frankly of the opinion that the ship was unsatisfactory. Yet R.29b was probably more controllable for straight flight than R.33, and on this point it would have been of interest to have had the opinion of a helmsman from R.33.

It will be urged that though the degree of stability possessed by R.29 or R.29a may be of value in straight flight the controllability in turning is reduced to an inadmissible extent. Reference to Table 6 shows that the minimum turning coefficients exceed that for R.33 by the following amounts, R.29, 60 per cent. ; R.29a, 44 per cent., and R.29b, 7 per cent. It is probable that of these only R.29b would be regarded as satisfactorily controllable for manœuvring and here the stability is shown to be sufficiently reduced to impair ease of steering in straight flight. *To secure a high degree of both stability and controllability it appears that such control surfaces must constitute a larger proportion of the total area of stabilizing surface than do those at present in use.*

This plan is adopted on the Italian airships where, with the occasional exception of a small upper plane, the whole of the stabilizing surface is moveable. No experiments were carried out on airship S.R.1 (an Italian built semi-rigid) before she was dismantled ; but it is understood that the controllability of Italian ships is regarded as satisfactory if the minimum diameter of turning circle does not exceed eight times the length. No information is available as to the stability of these ships.

In concluding this section it may be remarked that, though no records were taken, the advantage of R.29 over R.33 in the facility with which a given height could be maintained under steady conditions, was as great as in steering a course. Since control in a vertical plane is of prime importance and always requires close attention, the reduction of effort would be much appreciated by the height coxswain.

Deceleration. Section (iii).—Three experiments were carried out on deceleration, but at the conclusion of the first the rubber tube to the airspeed indicator was found to be kinked so that this set of observations was rejected. The values obtained from the two remaining experiments are plotted in Fig. 22, a line representing the estimated mean slope being drawn through each set of points. Values of $1/V$ are here carried as far as 0·06 as compared with 0·04 on R.33 and this difference is largely responsible for the more erratic behaviour of the observations on R.29 at the lower speeds. These observations at low speed were taken with the object of determining if there was any consistent departure of the resistance from proportionality to V^2, as shown by the failure of the observations plotted in Fig. 22 to lie upon a straight line. Although at low speeds there is considerable departure from the mean line, it is in opposite directions in the two experiments, and is probably due to unsteady atmospheric conditions.

The mean value of the resistance coefficient C* is 0·0227, from which the value for each experiment differs by 3 per cent.

The following comparison may be made with R.26 and R.33 :—

	R.29.	R.26 (R. & M. 674.)	R.33 (R. & M. 668.)
Resistance coefficient C ...	0·0227	0·0247	0·0173
Coefficient in terms of R.29 ...	1·00	1·09	0·77

It will be seen from this comparison that R.33 has a resistance 0·77 times, and R.26 1·09 times, that of R.29. Experiments on models are not yet available for the prediction of the relative resistances of R.33 and R.29, but since the difference between the latter ship and R.26 is confined to the external keel and a slight modification in the form of head, the comparison between these two ships may be attempted. In R. & M. 619† it is stated (Table 1) that the resistance of the keel is about 8 per cent. of that of hull and keel, and Table 5 gives the resistance of hull and keel as 62 per cent. of the total. The results from the model, therefore, indicate that due to the keel the resistance of R.29 should be 5 per cent. less than that of R.26. The resistance coefficient of the model hull is falling rapidly at the highest value of Vl obtained so that the difference due to the keel on the actual ship should be less than 5 per cent.

As a result of experiments in the wind channel, the head chosen for R.29 consisted of a modification of that on R.26 made by increasing the length slightly, and reducing the curvature near the cylindrical portion at the expense of an increase of curvature near the nose. It may be inferred from the present comparison that this modification resulted in a reduction in resistance of the whole ship of about 5 per cent.

Air Speed for various Engine Combinations. Section (iv).—Examination of the results shows that the speeds obtained with R.29a and R.29b were decidedly lower than that for R.29 (original

* $R = C\rho V^2 l^2$ where l equals the cube root of the volume.

† The prediction from models of the Resistance of an Airship of the 23 Class. R. & M. 619. Pannell, Jones and Pell.

fins). Tables 9, 9a, and 9b give mean values of the speed under these three conditions, and show that the speed of R.29 is approximately 5 per cent. higher than that of R.29a or R.29b when the rudders are amidships or at 5°. The observations are not sufficiently complete to establish any difference in speed between R.29a and R.29b. This increase in resistance of 10 per cent. due to uncovering the girder work of the upper fin on such a high resistance ship as R.29 provides a striking illustration of the manner in which resistance may be caused by objects of relatively small dimensions.

Dealing, then, with the results in Table 9 only, the observations constitute a comparison of speeds for various engine combinations; but they do not afford a direct measure of the maximum speed of the airship. In view of this omission the speeds attained during turning trials on R.29 (Table 2) were examined in order to discover whether the mean values for experiments with the rudder at 5° could be employed in the present section of the report without serious error.

It was found that the angle of yaw was only about 2°, and values of V/N (where V is the airspeed and N the rotational speed of the engine in revolutions per minute*) calculated from these observations did not differ from the mean by as much as certain of the direct observations with all engines running at a like speed. The mean speeds for Experiments Nos. 1 and 5 (Table 2) have, therefore, been employed without correction in compiling Table 10.

The average maximum speed is given in Table 10 as 79·2 ft/sec. (46·8 knots) and a value of V/N of 0·048 is calculated for all engines running at a like speed. With engines 2 and 3 at a like speed V/N was 0·042, while a value of 0·030 was obtained for engine No. 2 only running.

A curve is given in Fig. 8 showing the airspeed for various rotational speeds of the after engine when the forward engine is at rest, and the amidships engine is running at 1,400 r.p.m. As previously stated (see p. 206) it was necessary to resort to calculation in preparing this curve as only three of the direct observations were of the required type. It should also be stated that the majority of the values employed in this figure were based on observations taken by Lieut. Hasler. Curves of this type may be readily prepared for any rotational speed of the amidships engine; 1,400 r.p.m. was chosen as a normal running speed.

Thrust Measurement. Section (v).—The observations of pressure difference at the amidships airscrew are given in Table 12 and are plotted for Experiments No. 100 and 102 in Figs. 9 and 10. It will be noticed that the mean curve through the observations

* To conform with the usual practice of engineers, engine speed (N) is given in r.p.m.; *airscrew* speeds (n) are in revs. per sec.

becomes negative in the regions of the boss and the tip. The negative portion at the tip is so important that on calculating values of T′* and obtaining the value of the thrust coefficient T_c, it was found that in each case this latter quantity was very much lower than the corresponding value obtained on a model. It was realised from the outset that a correction would probably be necessary for the effect of the radiator which is situated between the car and the hull, filling the entire space. With the object of evaluating such corrections the observations of speed behind the radiator (Fig. 12) were made ; but the accurate use of them in calculating a correction is prevented by the lack of information as to the value of the static pressure in that region.

The distance from the tip of the airscrew to the hull was 2·5 ft., and observations were taken to a distance of 19 ins. beyond the tip. Reference to Table 12 shows that beyond the tip the curve of pressure difference is horizontal to the accuracy of the observations, and it may, therefore, be assumed that there is no marked effect over this region due to the proximity of the hull, so that the reading of the travelling pitot tube when in this position affords a measure of the true value of the datum. Under these circumstances it appears legitimate to assume the datum line in the neighbourhood of the tip to be in such a position as to render the pressure difference there zero. This conclusion is supported by the recent investigation carried out on models by Messrs. Fage and Howard to check the results of R. & M. 565 ; they found that if the pressure difference was measured as close as possible to the airscrew on either side of it, and at the same radius on the inflow and outflow sides, the pressure difference at the tip was approximately zero.

An attempt to apply an approximate correction to the present results has, therefore, been made in the following manner. The datum in the region of the tip of the airscrew has been taken so as to make the pressure difference there zero, and this datum has been assumed to apply down to a radius of 60 ins. ($r/D = 0{\cdot}37$) which is the position of the roof of the car. There was no reason for supposing that the radiator caused an error in the region of the boss of the airscrew and the measured datum was assumed to be correct up to a radius of 20 ins. ($r/D = 0{\cdot}123$)† ; these data were connected by the arbitrary curves shown in Figs. 9 and 10, and values of the pressure difference were scaled off using this new datum curve. From the quantities thus obtained T′ was calculated and the thrust coefficient T_c evaluated graphically in the manner explained on page 206, the process being carried through for one experiment in which the forward airscrews were running,

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$$* \; T' = \pi \times \frac{p_2 - p_1}{\frac{1}{2}\rho V^2} \times \frac{r}{D}$$

† It may be remarked that for the highest accuracy in future experiments it will be advisable to travel both pitot tubes.

and for another in which they were at rest. The results obtained are given in the following table :—

VALUES OF T_c.

	Expt. No. 100. (V/nD = 0·38).	Expt. No. 101. (V/nD = 0·34).	Expt. No. 102. (V/nD = 0·31).
	T_c	T_c	T_c
Full scale (original observations)	0·041	0·12	0·20
Full scale (new datum) ...	0·34	—	0·54
Model	0·39	0·54	0·65

Note.—The observations were not carried to the tip of the airscrew in Experiment No. 99; T_c has not been calculated for that experiment.

It will be seen that the values of T_c derived by the use of the arbitrary datum are from 15 to 20 per cent. lower than the values from the model, so that by the use of a slightly different but no more improbable datum line, the full-scale results could be brought into agreement with those obtained on the model.

The results obtained are, of course, of no value as measurements of the thrust of this airscrew, but it appears to the authors that the method of dealing with them which has been adopted indicates that under more favourable circumstances a satisfactory measurement of thrust might be obtained.

In calculating T_c from the original observations (Table 12) it was found that for all three Experiments (100, 101, 102) the value of T' at the tip was approximately the same. If the exploring pitot tube when at the radius of the tip of the airscrew is regarded as beyond the influence of the slip-stream, a constant value of T' means that the ratio of the pressure difference between the travelling pitot tube and the pitot tube fixed at the side of the car to $\frac{1}{2}\rho V^2$ is constant. It should be noted that this constancy is maintained, though in experiment 100 the forward airscrews were running, while in experiment 102 they were at rest. It may, therefore, be inferred that the influence of the slip-stream from the forward airscrews was felt equally on both pitot tubes at the amidships car, though one projects 3 feet from the side of the car and the other is in the neighbourhood of the hull.

Distribution of Speed in Various Localities.—The distribution of speed below the forward car (see Fig. 11) is of the type expected; the highest value observed (at a position approximately one foot below the bottom of the car) was 17 per cent. above the mean forward speed of the ship. The local speed did not exceed the mean forward speed by more than 1 per cent. when the length of tube let out was 30 ft. During the experiments on R.33 (R. & M. 668) it was found that at a speed of 68 ft. the flying head was deflected horizontally 20 feet, when 45 ft. of tubing was lowered. In making an approximate estimate of the position of the flying head it may be assumed that the tube takes up the form of a circular arc, under which circumstances the vertical distance to the head will be 38 ft. when 45 ft. of tubing are lowered.

The distribution of speed along a vertical line behind the amidships radiator is given for three values of the forward speed, in Fig. 12. The curves show a reduction of speed of the order of 70 per cent. with a marked dip in the curve near the centre of the radiator. Of the two maxima observed on this line the one on the side nearest the hull is rather lower.

A comparison was also made between the airspeed as given by the flying head at the forward car and by the fixed head at the amidships car, both with and without the forward airscrews running. The results obtained were as follows :—

Expt. Nos.	r.p.m. of Engines.			Mean Air Speed (ft./sec.).		Forward Car. / Amidships Car.
	No. 1.	No. 2.	No. 3.	At Forward Car.	At Amidships Car.	
107	Stop	1,200	Full	60·2	53·7	1·12
85, 86 & 100	1,200	1,200	1,200	56·5	65·5	0·86

The speeds given in Experiment 107 are each derived from about 25 observations, while the remaining speeds are mean values from the experiments quoted.

It will be seen that whereas when the forward airscrew is at rest the ratio of the speed by the flying head to that at the amidships car is 1·12, when all the airscrews run at 1,200 the ratio is only 0·86. The high value of 1·12 is thought to be due to the "wash" from the forward car and the reduction to 0·86 presumably represents the effect of the slip-stream.

It must, however, be remarked that the second ratio is liable to error because the value 65·5 ft./sec. is the mean speed during Experiment 100, while the value 56·5 ft./sec. is the mean value from the speed trials carried out at various times with all engines at 1,200. If, however, extreme values had been chosen so as to make the second ratio a maximum it would still have been less than unity.

In concluding the report the authors desire to tender their thanks to those who assisted in carrying out the trials. The Commanding Officer of R.29, Captain A. H. Wann, navigated the airship throughout in such a manner as to secure the best possible conditions for the experiments. In constructing and fitting up the apparatus the engineer officer, Lieut. H. N. Hasler, rendered invaluable assistance.

For the manipulation of the helm from the after car, and for numerous observations of the compass fitted there the authors are indebted to Sergt. F. Smith, R.A.F.

Many of the observations on the two last flights were taken by Mr. E. F. Relf, A.R.C.Sc., of the Aeronautical staff of the N.P.L.; the authors are also indebted to him for criticism of the report.

TABLE 1 (see Fig. 1).

VARIOUS PARTICULARS OF R.29.

Displacement	$1 \cdot 06 \times 10^6$ cu. ft.
Volume of Gas	990,000 cu. ft.
Length overall	539·5 ft.
Maximum Diameter	53 ft.

Engines :—Forward and aft cars. One 275 h.p. Rolls-Royce driving two swivelling airscrews.
Amidships car. One 275 h.p. Rolls-Royce driving one airscrew.

Airscrews :—Forward and aft, each of 10 ft. diameter, four-bladed, swivelling, Integral.
A idships, one 2-bladed Farringdon, 13·5 ft. diameter.

Gear Ratio :—Forward and aft 0·512 to 1.
Amidships 0·64 to 1.

Stabilizing Surfaces.	R.29. (Sq. ft.).	R.29a. (Sq. ft.).	R.29b. (Sq. ft.).
Total fixed vertical area	1274·9	971·9	643·4
Total moveable vertical area	425·4	425·4	425·4
Total fixed horizontal area	1263·0	1263·0	1263·0
Total moveable horizontal area	425·4	425·4	425·4

DEDUCED FROM PRESENT EXPERIMENTS.

Maximum speed 79 ft/sec. (46·8 knots).

	Feet.	In Terms of Length of Airship.
Minimum diameter of Turning circle R.29 ...	5,350	9·92
Minimum diameter of Turning circle R.29a ...	4,850	9·00
Minimum diameter of Turning circle R.29b ...	3,600	6·67

TABLE 2 (see Figs. 4 and 5).

TURNING TRIALS—R.29 (ORIGINAL FINS).

Calculation of Diameter of Turning Circle, &c.

Expt. No.	Angle of Rudders (Deg.).	Engine Combinations.*			Speed V Ft./sec.	Rate of Turn. $\dot{\psi}$ Rad./sec.	Diameter of Turning Circle.		Mean Inclination. (Deg.).	True Angle of Yaw, β (Deg.).
		No. 1 (r.p.m.).	No. 2 (r.p.m.).	No. 3 (r.p.m.).			Feet.	Turning Coefficient.†		
1	5° port	1,650	1,600	1,700	79·2	0·0108	14,680	27·2	0	− 1·96
2	5° ,, ...	1,200	1,200	1,200	57·6	0·00809	14,300	26·5	− 5·0	− 2·90
3	5° ,, ...	1,200	1,200	0	48·7	0·00699	13,900	25·8	− 1·0	− 1·99
4	5° ,, ...	0	1,200	0	37·0	0·00596	12,400	23·0	− 1·0	− 2·70
5	5° starboard ...	1,600	1,600	1,700	77·5	0·0103	15,050	27·9	—	—
6	5° ,, ...	1,400	1,200	1,200	57·0	0·00803	14,200	26·35	—	—
7	5° ,, ...	1,200	1,200	0	46·3	0·00646	14,330	26·6	− 2·0	+ 0·26
8	5° ,, ...	0	1,200	0	35·6	0·00489	14,580	27·05	− 1·75	− 0·29
9	10° port	1,600	1,600	1,700	78·5	0·0187	8,400	15·59	—	− 2·98
10	10° ,, ...	1,200	1,200	1,200	57·6	0·01415	8,150	15·11	− 3·5	− 3·30
11	10° ,, ...	1,200	1,200	?	48·8	0·0116	8,420	15·62	− 4·0	− 3·12
12	10° ,, ...	0	1,200	0	35·6	0·00879	8,110	15·05	− 4·5	− 3·69

* Forward engine ... No. 1.
Amidships ,, ... No. 2.
Aft ,, ... No. 3.

† Turning Coefficient $= \dfrac{\text{Diameter of Turning Circle.}}{\text{Length of Airship.}}$

TABLE 2 (*contd.*).

TURNING TRIALS—R.29 (ORIGINAL FINS).

Calculation of Diameter of Turning Circle, &c.

Expt. No.	Angle of Rudders (Deg.).	Engine Combinations.			Speed V Ft /sec.	Rate of Turn. $\dot{\psi}$ Rad. /sec.	Diameter of Turning Circle.		Mean Inclination. (Deg.).	True Angle of Yaw, β (Deg.).
		No. 1 (r.p.m.).	No. 2 (r.p.m.).	No. 3 (r.p.m.).			Feet.	* Turning Coefficient.		
13	10° starboard ...	1,600	1,580	1,700	75·1	0·0173	8,690	16·10	—	+ 2·52
14	10° ,, ...	1,200	1,400	1,200	59·0	0·0140	8,440	15·65	− 2·0	+ 2·45
15	10° ,, ...	1,200	1,400	0	51·3	0·0116	8,850	16·42	− 4·0	+ 2·15
16	10° ,, ...	1,000	1,000	0	39·3	0·00886	8,870	16·45	− 1·0	+ 2·03
17	15° port	1,600	1,580	1,700	74·9	0·0242	6,195	11·49	− 2·5	− 3·93
18	15° ,, ...	1,400	1,400	?	54·6	0·0178	6,140	11·38	− 1·0	− 4·10
19	15° ,, ...	0	1,200	0	31·6	0·0108	5,855	10·87	− 6·5	− 4·31
20	15° starboard ...	1,600	1,560	1,700	74·0	0·0225	6,580	12·20	− 1·0	+ 2·99
21	15° ,, ...	1,400	1,400	?	54·3	0·0171	6,355	11·80	− 4·0	+ 3·75
22	15° ,, ...	0	1,400	0	34·8	0·01065	6,540	12·12	− 3·0	+ 3·57

$$* \text{Turning Coefficient} = \frac{\text{Diameter of Turning Circle.}}{\text{Length of Airship.}}$$

TABLE 3 (see Figs. 4 and 5).

TURNING TRIALS—R.29A (Upper fixed fin area reduced by 303 sq. ft.).

Calculation of Diameter of Turning Circle, &c.

Expt. No.	Angle of Rudders (Deg.).	Engine Combinations.			Speed V Ft /sec.	Rate of Turn. $\dot{\psi}$ Rad. /sec.	Diameter of Turning Circle.		Mean Inclination. (Deg.).	True Angle of Yaw, β (Deg.).
		No. 1 (r.p.m.).	No. 2 (r.p.m.).	No. 3 (r.p.m.).			Feet.	* Turning Coefficient.		
23	5° port	1,600	1,700	1,700	73·5	0·0140	10,500	19·48	+ 3·0	− 2·58
24	5° ,, ...	1,400	1,400	1,400	63·0	0·0125	10,100	18·72	− 2·0	− 3·13
25	5° ,, ...	1,200	1,200	1,200	52·6	0·0101	10,400	19·29	− 1·0	− 2·99
26	5° ,, ...	0	1,000	1,000	36·0	0·00699	10,300	19·10	− 8·0	− 2·52
27	5° starboard ...	1,600	1,700	1,700	74·8	0·0130	11,500	21·30	− 1·5	+ 2·11
28	5° ,, ...	1,400	1,400	1,400	63·0	0·0112	11,250	20·85	− 3·5	+ 2·47
29	5° ,, ...	1,200	1,200	1,200	55·0	0·0102	10,800	20·02	− 4·6	+ 2·19
30	5° ,, ...	1,000	1,000	0	39·0	0·00686	11,350	21·05	− 5·2	+ 1·96
31	10° port	1,600	1,700	1,700	72·5	0·0215	6,750	12·50	− 3·0	− 4·76
32	10° ,, ...	1,200	1,200	1,200	52·8	0·0166	6,360	11·80	− 2·0	− 4·43
33	10° ,, ...	1,000	1,000	0	35·2	0·0106	6,640	12·30	− 6·0	− 3·77
34	10° starboard ...	1,600	1,700	1,700	69·2	0·0191	7,250	13·45	− 4·0	+ 3·59
35	10° ,, ...	1,400	1,400	1,400	61·0	0·0169	7,220	13·40	− 3·7	+ 3·28
36	10° ,, ...	1,200	1,200	1,200	52·9	0·0147	7,250	13·45	− 4·3	+ 3·37
37	10° ,, ...	1,000	1,000	0	35·9	0·0105	6,850	12·70	− 4·3	+ 3·32

$$* \text{Turning Coefficient} = \frac{\text{Diameter of Turning Circle.}}{\text{Length of Airship.}}$$

TABLE 3 (*contd.*).

TURNING TRIALS—R.29A (Upper fixed fin area reduced by 303 sq. ft.).

Calculation of Diameter of Turning Circle, &c.

Expt. No.	Angle of Rudders (Deg.).	Engine Combinations.			Speed V Ft./sec.	Rate of Turn. $\dot{\psi}$ Rad./sec.	Diameter of Turning Circle.		Mean Inclination. (Deg.).	True Angle of Yaw, β (Deg.).
		No. 1 (r.p.m.).	No. 2 (r.p.m.).	No. 3 (r.p.m.).			Feet.	* Turning Coefficient.		
38	15° port	1,200	1,600	1,650–75	69·0	0·0262	5,270	9·77	− 5·5	− 5·28
39	15° „	1,200	1,200	1,200	50·9	0·01985	5,140	9·53	− 4·6	− 5·69
40	15° „	1,000	1,000	0	34·7	0·0133	5,215	9·66	− 7·3	− 5·48
41	15° starboard ...	1,600	1,700	1,700	70·5	0·0244	5,790	10·71	+ 2·0	+ 4·13
42	15° „ ...	1,400	1,400	1,400	57·8	0·0205	5,640	10·44	− 1·0	+ 4·11
43	15° „ ...	1,200	1,200	1,200	52·8	0·0186	5,690	10·53	0	+ 4·00
44	15° „ ...	1,000	1,000	0	36·25	0·0125	5,800	10·75	− 4·0	+ 3·87

$$* \text{Turning Coefficient} = \frac{\text{Diameter of Turning Circle.}}{\text{Length of Airship.}}$$

TABLE 4 (see Figs. 4 and 5).

TURNING TRIALS—R.29B (Whole of fabric removed from upper fixed fin).

Calculation of Diameter of Turning Circle, &c.

Expt. No.	Angle of Rudders (Deg.).	Engine Combinations.			Speed V Ft./sec.	Rate of Turn. $\dot{\psi}$ Rad./sec.	Diameter of Turning Circle.		Mean Inclination. (Deg.).	True Angle of Yaw, β (Deg.).
		No. 1 (r.p.m.).	No. 2 (r.p.m.).	No. 3 (r.p.m.).			Feet.	* Turning Coefficient.		
45	5° port	1,600	1,700	1,700	72·75	0·0211	6,900	12·80	− 1·0	− 4·46
46	5° ,, ...	1,400	1,400	1,400	62·7	0·0186	6,750	12·50	− 4·7	− 3·95
47	5° ,, ...	1,200	1,200	1,200	51·5	0·01595	6,470	12·00	− 4·3	− 4·12
48	5° ,, ...	1,200	1,200	0	42·8	0·0117	7,320	13·58	− 6·5	− 2·92
49	5° starboard ...	1,600	1,700	1,600	71·1	0·0205	6,950	12·89	− 4·0	+ 3·65
50	5° ,, ...	1,400	1,400	1,400	62·1	0·0182	6,840	12·67	− 3·5	+ 3·79
51	5° ,, ...	1,200	1,200	1,200	52·2	0·01425	7,340	13·60	− 7·0	+ 2·58
52	5° ,, ...	1,200	1,200	0	42·4	0·01105	7,670	14·21	− 8·7	+ 2·55
53	10° port	1,600	1,700	1,600	69·9	0·0283	4,950	9·18	− 4·0	− 5·16
54	10° ,, ...	1,200	1,200	1,400	54·5	0·0234	4,670	8·65	− 5·7	− 5·52
55	10° ,, ...	1,200	1,200	0	41·1	0·0166	4,950	9·18	− 6·3	− 5·20
56	10° starboard ...	1,600	1,700	1,600	63·7	0·0232	5,500	10·20	− 2·5	+ 4·22
57	10° ,, ...	1,200	1,200	1,400	55·6	0·0210	5,300	9·83	− 9·3	+ 4·73
58	10° ,, ...	1,200	1,200	0	41·2	0·0170	4,850	8·99	− 9·7	+ 5·40

$$\text{* Turning Coefficient} = \frac{\text{Diameter of Turning Circle.}}{\text{Length of Airship.}}$$

TABLE 4 (*contd.*).

TURNING TRIALS—R.29B (Whole of fabric removed from upper fixed fin).

Calculation of Diameter of Turning Circle, &c.

Expt. No.	Angle of Rudders (Deg.).	Engine Combinations.			Speed V Ft./sec.	Rate of Turn. ψ Rad./sec.	Diameter of Turning Circle.		Mean Inclination. (Deg.).	True Angle of Yaw, β (Deg.).
		No. 1 (r.p.m.).	No. 2 (r.p.m.).	No. 3 (r.p.m.).			Feet.	* Turning Coefficient.		
59	15° port	1,600	1,700	1,600	65·7	0·0325	4,050	7·51	− 6·3	− 6·71
60	15° ,, ...	1,400	1,400	0	46·9	0·0244	3,850	7·14	−10·0	− 6·32
61	15° ,, ...	1,200	1,200	0	37·8	0·0192	3,940	7·31	− 8·7	− 6·40
62	15° starboard ...	1,600	1,700	1,600	69·0	0·0314	4,400	8·16	− 4·3	+ 5·58
63	15° ,, ...	1,400	1,400	1,400	59·8	0·0285	4,200	7·79	− 5·5	+ 5·73
64	15° ,, ...	1,200	1,200	1,400	51·8	0·0241	4,300	7·96	− 5·4	+ 5·57
65	15° ,, ...	1,200	1,200	0	38·3	0·0175	4,380	8·13	− 8·2	+ 5·82

$$\text{* Turning Coefficient} = \frac{\text{Diameter of Turning Circle.}}{\text{Length of Airship.}}$$

Table 5 (see Fig. 5).

MEAN DIAMETER OF TURNING CIRCLES.

Rudder Angle (Deg.)	Diameter of Turning Circle.							Angle of Yaw.
	Port.		Starboard.		Mean of Port and Starboard.		As Fraction of Value for R.29.	Mean of Port and Starboard (Deg.).
	Feet.	Turning Coefficient ‡.	Feet.	Turning Coefficient ‡.	Feet.	Turning Coefficient ‡.		
			With original fin area.		R.29.			
5	13,820	25·61	14,540	26·92	14,180	26·3	1·00	1·7
10	8,270	15·32	8,712	16·15	8,491	15·75	1·00	2·8
15	6,063	11·25	6,492	12·04	6,278	11·64	1·00	3·8
19*	—	—	—	—	5,350†	9·92†	1·00	—
			With 303 sq. ft. of fabric removed from upper fin.			R.29a.		
5	10,325	19·15	11,225	20·80	10,775	19·98	0·76	2·5
10	6,583	12·21	7,142	13·24	6,863	12·73	0·81	3·9
15	5,208	9·66	5,730	10·62	5,469	10·14	0·87	4·8
19*	—	—	—	—	4,850†	9·00†	0·91	—
			With whole of fabric removed from upper fin.			R.29b.		
5	6,860	12·71	7,200	13·34	7,030	13·03	0·50	3·5
10	4,856	9·00	5,217	9·66	5,036	9·34	0·59	5·0
15	3,947	7·32	4,320	8·01	4,134	7·66	0·66	6·1
19*	—	—	—	—	3,600†	6·67†	0·67	—

* Approximate value for "hard over." † By extrapolation.

‡ Turning coefficient $= \dfrac{\text{Diameter of Turning Circle.}}{\text{Length of Airship.}}$

TABLE 6.

TURNING TRIALS.

Comparison of R.29 with R.26 and R.33.

Rudder Angle. (Deg.).	Mean Diameter of Turning Circle.									
	R.29.		R.29A.		R.29B.		R.26.		R.33.	
	With Original Fin Area.		* With 303 sq. ft. of Fabric removed from Upper Fin.		With Whole of Fabric removed from Upper Fin.					
	Feet.	Turning Coefft.‡	Feet.	Turning Coefft.‡	Feet.	Turning Coefft.‡	Feet.	Turning Coefft.‡	Feet.	Turning Coefft.‡
5	14,180	26·30	10,775	19·98	7,030	13·03	15,800	29·55	7,340	11·40
10	8,491	15·75	6,863	12·73	5,036	9·34	9,400	17·58	5,816	9·04
15	6,278	11·64	5,469	10·14	4,134	7·66	6,800	12·70	4,738	7·35
19†	5,350	9·92	4,850	9·00	3,600	6·67	6,300	11·78	4,000	6·22
Total area of vertical surface (sq. ft.) ...	1700·3		1397·3		1068·8		1789		1880	
Area of fixed vertical surface (sq. ft.) ...	1274·9		971·9		643·4		1339		1410	
Area of rudders (sq. ft.)	425·4		425·4		425·4		450		470	
$\frac{\text{Area of rudders}}{\text{Area of total vertical surface}}$	0·250		0·305		0·399		0·252		0·250	
Length (ft.)	539		539		539		535		644	
Displacement of hull (cubic ft.) ...	$1{\cdot}06 \times 10^6$		$1{\cdot}06 \times 10^6$		$1{\cdot}06 \times 10^6$		$1{\cdot}05 \times 10^6$		$2{\cdot}2 \times 10^6$	

* 303 sq. ft. = 0·48 of upper fixed fin area. † Extrapolated, approximately the maximum attainable.

$$‡\ \text{Turning Coefficient} = \frac{\text{Diameter of Turning Circle.}}{\text{Length of Airship.}}$$

TABLE 7 (see Fig. 6).

CURVATURE OF PATH WITH RUDDERS AMIDSHIPS OR AT SMALL ANGLES, FOR R.29, R.29A AND R.29B.

Expt. No.	Angle of Rudders (Deg.).	Engine Combinations.			Speed V Ft /sec.	Rate of Turn. $\dot{\psi}$ Rad. /sec.	Diameter of Turning Circle.		Mean Inclination. (Deg.).	True Angle of Yaw, β (Deg.).
		No. 1 (r.p.m.).	No. 2 (r.p.m.).	No. 3 (r.p.m.).			Feet.	† Turning Coefficient.		
				Airship R.29.						
66	Amidships ...	1,400	1,400	1,400	67·5	0·00154 port	87,700	162·5	− 3·0	− 0·46
67	Amidships ...	0	1,200	0	35·9	0·00186 port	38,550	71·5	− 0·5	− 0·22
				Airship R.29a.						
68	Amidships ...	1,400	1,400	1,400	61·1	—	Inf.	Inf.	− 5·0	—
69	Amidships ...	0	1,000	1,000	34·6	—	Inf.	Inf.	− 6·5	—
				Airship R.29b.						
70	Amidships ...	1,400	1,400	1,400	64·6	0·00512 starboard	25,300	46·9	− 3·0	+ 0·81
71	{*U 1°S. / L ½°S.}	0	1,000	1,000	37·2	0·00466 starboard	15,950	29·6	− 10·0	—
72	* Do.	0	1,000	1,000	32·3	0·00405 starboard	15,950	29·6	− 10·0	—
73	* Do.	0	1,000	1,000	31·9	0·00358 starboard	17,800	33·0	− 10·0	—

* Estimated.

† Turning Coefficient $= \dfrac{\text{Diameter of Turning Circle.}}{\text{Length of Airship.}}$

TABLE 8.

RESISTANCE COEFFICIENT CALCULATED FROM DECELERATION EXPERIMENTS.

Expt. No.	$\frac{1}{V^2} \times \frac{dV}{dt}$	Coefficient C* $\frac{l}{V^2} \times \frac{dV}{dt}$
75	$2 \cdot 30 \times 10^{-4}$	0·0234
76	$2 \cdot 16 \times 10^{-4}$	0·0220
Mean		0·0227

* $R = C\rho V^2 l^2$
$l = \text{vol.}^{1/3} = 101{\cdot}9$ ft.

TABLE 9.

FORWARD SPEED FOR VARIOUS ENGINE COMBINATIONS.—R.29.

Expt. No.	Date.	† Engine Speed N (r.p.m.). No. 1.	No. 2.	No. 3.	Speed V (ft./sec.). Extremes.	Mean.	No. of Obs. of Speed.	Mean Inclination. (Deg.)	Remarks.
78	Sept. 15	1,400	1,400	1,400	70·2–66·1	68·6	7	— 0·7	† No. 1 = Forward Engine. No. 2 = Amidships Engine. No. 3 = After Engine.
67	Sept. 15	1,400	1,400	1,400	70·2–62·6	67·5	9	— 3·0	
103	Sept. 16	1,400	1,400	1,400	67·5–56·8	65·6	10	—	
80	Sept. 16	0	1,200	1,700	62·7–57·5	60·4	12	— 0·7	
*81	Sept. 14	0	1,700	1,200	—	57·9	1	—	
*82	Sept. 14	0	1,700	1,000	—	56·3	1	—	
*83	Sept. 14	0	1,700	800	—	52·3	1	—	
84	Sept. 16	1,400	0	1,400	59·6–56·0	57·8	2	— 0·5	
85	Sept. 16	1,200	1,200	1,200	57·7–55·1	56·6	3	— 0·3	
86	Sept. 15	1,200	1,200	1,200	57·8–53·0	56·5	6	— 2·4	
88	Sept 16	1,200	1,000	1,200	54·5–54·3	54·4	2	0	
*89	Sept. 14	0	1,400	1,200	—	55·4	1	—	
74	Sept. 16	0	1,200	1,200	53·3–48·4	50·7	34	—	
*90	Sept 14	0	1,200	1,200	—	50·5	1	—	
*91	Sept 14	0	1,200	1,200	—	50·5	1	—	
*92	Sept 14	0	1,200	1,200	—	45·6	1	—	
*96	Sept 14	0	1,400	0	—	41·4	1	—	
*97	Sept. 14	0	1,400	0	—	39·7	1	—	
*98	Sept. 14	0	1,200	0	—	38·0	1	—	
66	Sept. 15	0	1,200	0	37·4–34·4	35·9	16	—	

* Observations from Lt. Hasler.

TABLE 9A.

FORWARD SPEED FOR VARIOUS ENGINE COMBINATIONS.—R.29A.

Expt. No.	Date.	* Engine Speed N. (r.p.m.)			Speed V (ft./sec.).		No. of Obs. of Speed.	Mean inclination (deg.).	Remarks.
		No. 1.	No. 2.	No. 3.	Extremes.	Mean.			
77	Oct. 7	1,600	1,700	1,700	77·0–72·9	75·9	8	+ 3·5	* No. 1 = Forward Engine. No. 2 = Amidships Engine. No. 3 = After Engine.
79	Oct. 7	1,400	1,400	1,400	65·8–61·5	64·2	6	– 2·2	
69	Oct. 7	1,400	1,400	1,400	63·6–53·6	61·1	12	– 5·0	
87	Oct. 7	1,200	1 200	1,200	54·8–49·2	53·1	9	– 3·6	
93	Oct. 7	1,200	0	1,200	44·7–42·0	43·8	7	– 3·6	
94	Oct. 7	1,000	1,000	1,000	45·1–39·8	43·5	6	– 3·0	
95	Oct. 7	800	800	800	40·7–35·9	38·5	6	– 5·0	
68	Oct. 7	1,000	0	1,000	36·7–32·2	34·6	27	– 6·5	

TABLE 9B.

FORWARD SPEED FOR VARIOUS ENGINE COMBINATIONS.—R.29B.

70	Oct. 9	1,400	1,400	1,400	68·1–60·7	64·6	13	– 3·0	
72–73	Oct. 9	0	1,000	1,000	34·8–30·8	32·2	22	–10·0	

TABLE 10.

FORWARD SPEED FOR VARIOUS ENGINE COMBINATIONS.—R.29.

(Engines running at a like speed.)

Expt. No.	Engine Speed N (r.p.m.).			Mean Forward Speed V (ft./sec.).	$\frac{V^*}{N}$	Inclinometer (deg.).	No. of observations of Speed.	Mean $\frac{V^*}{N}$
	No. 1.	No. 2.	No. 3.					
1	1,650	1,600	1,700	79·2†	0·0480	0	15	
5	1,600	1,600	1,700	77·5†	0·0475	—	16	
78	1,400	1,400	1,400	68·6	0·0490	– 0·75	7	
67	1,400	1,400	1,400	67·5	0·0482	– 3·0	9	
103	1,400	1,400	1,400	65·6	0·0469	—	10	
85	1,200	1,200	1,200	56·6	0·0471	– 0·3	3	
86	1,200	1,200	1,200	56·5	0·0470	– 2·4	6	0·0479
74	0	1,200	1,200	50·7	0·0423	—	34	
90	0	1,200	1,200	50·5	0·0421	—	1	
91	0	1,200	1,200	50·5	0·0421	—	1	
92	0	1,200	1,200	45·6	0·0381	—	1	0·0422
96	0	1,400	0	41·4	0·0296	—	1	
97	0	1,400	0	39·7	0·0284	—	1	
98	0	1,200	0	38·0	0·0317	—	1	
66	0	1,200	0	35·9	0·0299	– 1·0	16	0·0299

* N denotes r.p.m. of those engines running.
† Obtained during turning trial with rudder at 5° (see Table 2).

TABLE 11 (see Fig. 8).

FORWARD SPEED WITH ENGINES RUNNING AT DIFFERENT ROTATIONAL SPEEDS.

No. of Original Experiment.	Engine Speed N (r.p.m.).			Speed V (ft./sec.).	No. of Observations of Speed.	Remarks.
	No. 1.	No. 2.	No. 3.			
80	0	1,400	1,982	70·5	12	* These values are original observations. The remaining values are calculated on the principle explained in the text. (See p. 206.)
74	0	1,400	1,400	59·1	34	
90	0	1,400	1,400	58·9	1	
91	0	1,400	1,400	58·9	1	
92	0	1,400	1,400	53·3	1	
89	0	1,400*	1,200*	55·4*	1	
81	0	1,400	985	47·7	1	
82	0	1,400	825	46·4	1	
83	0	1,400	660	43·1	1	
98	0	1,400	0	44·3	1	
66	0	1,400	0	41·9	16	
96	0	1,400*	0	41·4*	1	
97	0	1,400*	0	39·7*	1	

TABLE 12 (see Figs. 9 and 10).

MEASUREMENTS OF PRESSURE DIFFERENCE AT AMIDSHIPS AIRSCREW.

Calculation of Thrust Coefficient (T_c) from original observations.

Expt. No. 100.

Radius r (ins.)	Velocity Head $\frac{1}{2}\rho V^2$ (ins. of water).	Pressure Difference (p_2-p_1) (ins. of water).	r/D	T′*
− 1	1·08	− 0·685	0·006	− 0·0120
2	1·00	− 0·685	0·012	− 0·0258
5	0·955	− 0·500	0·031	− 0·0510
8	1·035	− 0·575	0·049	− 0·0855
11	1·035	− 0·525	0·068	− 0·108
14	1·035	− 0·455	0·086	− 0·119
14	0·955	− 0·410	0·086	− 0·116
17	0·975	− 0·300	0·105	− 0·101
20	1·005	− 0·235	0·123	− 0·009
23	0·975	− 0·145	0·142	− 0·066
23	0·955	− 0·075	0·142	− 0·035
26	0·975	− 0·050	0·161	− 0·026
29	0·955	+ 0·085	0·179	+ 0·050
32	0·897	+ 0·335	0·198	+ 0·232
32	1·01	+ 0·145	0·198	+ 0·089
35	0·870	+ 0·5045	0·216	+ 0·393
38	0·920	+ 0·685	0·235	+ 0·550
41	0·940	+ 0·745	0·253	+ 0·630
44	0·915	+ 0·845	0·272	+ 0·790
44	0·975	+ 0·710	0·272	+ 0·622
47	0·940	+ 0·805	0·290	+ 0·780
47	0·890	+ 0·775	0·290	+ 0·793
47	0·890	+ 0·875	0·290	+ 0·895
47	0·900	+ 0·800	0·290	+ 0·810
47	1·035	+ 0·710	0·290	+ 0·625
47	1·000	+ 0·745	0·290	+ 0·679
50	0·955	+ 0·805	0·309	+ 0·819
53	1·005	+ 0·775	0·327	+ 0·792
56	1·005	+ 0·790	0·346	+ 0·854
59	0·990	+ 0·795	0·364	+ 0·918
62	0·990	+ 0·645	0·383	+ 0·784
65	0·990	+ 0·335	0·401	+ 0·426
66	0·940	+ 0·335	0·407	+ 0·456
66	0·87	+ 0·265	0·407	+ 0·389
66	0·975	+ 0·370	0·407	+ 0·485
66	0·975	+ 0·235	0·407	+ 0·308
67	0·975	+ 0·10	0·414	+ 0·133
68	0·975	− 1·30	0·420	− 0·176
68	0·955	+ 0·75	0·420	− 0·104
69	0·975	− 0·055	0·426	− 0·076
69	1·00	− 0·145	0·426	− 0·194
70	0·975	− 0·145	0·432	− 0·202
71	0·975	− 0·455	0·438	− 0·642
71	1·01	− 0·475	0·438	− 0·646
72	0·975	− 0·775	0·444	− 1·109
73	0·98	− 1·00	0·451	− 1·444
73	0·92	− 0·775	0·451	− 1·194
74	1·00	− 1·04	0·457	− 1·495
75	0·955	− 1·08	0·463	− 1·647
81	0·990	− 1·12	0·500	− 1·775
87	0·955	− 1·04	0·537	− 1·839
93	1·00	− 1·08	0·575	− 1·950
100	0·955	− 1·04	0·618	− 2·112

Engines—
No. 1 = 1,200 r.p.m.
No. 2 = 1,200 r.p.m.
No. 3 = 1,200 r.p.m.
D = 13·5 ft.
ρ = 0·00235.
N = 12·8 revs/sec.
V = 65·5 ft/sec.
$\frac{V}{nD}$ = 0·38.
T_c = 0·041.
T_c (model) = 0·39.

$$* \; T' = \frac{p_2 - p_1}{\frac{1}{2}\rho V^2} \times \pi \frac{r}{D}$$

TABLE 12 (*contd.*).

MEASUREMENTS OF PRESSURE DIFFERENCE AT AMIDSHIPS AIRSCREW (*contd.*).

Calculation of Thrust Coefficient (T_c) from original observations.

Expt. No. 101.

Radius r (ins.)	Velocity Head $\frac{1}{2}\rho V^2$ (ins. of water).	Pressure Difference $(p_2 - p_1)$. (ins. of water).	r/D	T′*
− 1	0·965	− 0·605	0·006	− 0·0118
2	0·995	− 0·575	0·012	− 0·0219
5	0·995	− 0·550	0·031	− 0·0537
8	0·965	− 0·525	0·049	− 0·0836
11	0·965	− 0·430	0·068	− 0·0953
14	1·02	− 0·265	0·086	− 0·0701
17	0·965	− 0·095	0·105	− 0·0325
20	0·965	+ 0·025	0·123	+ 0·0099
20	1·005	0·00	0·142	+ 0·0258
23	1·035	+ 0·060	0·142	+ 0·0340
23	0·985	+ 0·075	0·142	0·00
26	1·035	+ 0·235	0·161	+ 0·115
26	0·985	+ 0·22	0·161	+ 0·113
29	1·035	+ 0·335	0·179	+ 0·182
32	1·055	+ 0·525	0·198	+ 0·308
33	1·06	+ 0·655	0·204	+ 0·394
35	0·995	+ 0·805	0·216	+ 0·550
38	1·00	+ 1·04	0·235	+ 0·770
41	0·995	+ 1·12	0·253	+ 0·892
44	1·02	+ 1·155	0·272	+ 0·965
47	1·055	+ 1·20	0·290	+ 1·03
50	0·98	+ 1·235	0·309	+ 1·22
50	1·07	+ 1·20	0·309	+ 1·09
53	1·045	+ 1·22	0·327	+ 1·46
56	1·01	+ 1·235	0·346	+ 1·32
59	1·01	+ 1·155	0·364	+ 1·30
62	1·055	+ 1·08	0·383	+ 1·23
63	0·98	+ 0·605	0·401	+ 0·775
66	1·00	+ 0·500 to 0·550	0·407	+ 0·675
66	1·00	+ 0·500	0·407	+ 0·640
67	1·035	+ 0·475	0·414	+ 0·60
68	1·035	+ 0·145	0·420	+ 0·172
69	1·035.	0·00 to + 0·265	0·426	+ 0·172
69	1·085	− 0·03 to − 0·170	0·426	− 0·123
69	1·035	− 0·225	0·426	− 0·292
70	1·055	− 0·385	0·432	− 0·493
70	1·035	− 0·405?	0·432	− 0·530
70	0·995	− 0·235 to − 0·545	0·432	− 0·530
71	0·985	− 0·605 to − 0·715	0·438	− 0·920
72	0·985	− 0·805	0·444	− 1·14
73	1·035	− 0·880	0·451	− 1·21
74	1·005	− 1·08	0·457	− 1·55
81	0·95	− 1·08	0·500	− 1·78
89	0·995	− 1·08	0·549	− 1·86
100	0·965	− 1·04	0·618	− 2·10

Engines—
No. 1 = 1,200 r.p.m.
No. 2 = 1,400 r.p.m.
No. 3 = 1,200 r.p.m.
D = 13·5 ft.
ρ = 0·00227.
n = 14·9 revs/sec.
V = 68·1 ft/sec.
$\frac{V}{nD}$ = 0·34.
T_c = 0·12.
T_c (model) = 0·54.

* $T' = \frac{p_2 - p_1}{\frac{1}{2}\rho V^2} \times \pi \frac{r}{D}$

TABLE 12 (*contd.*).

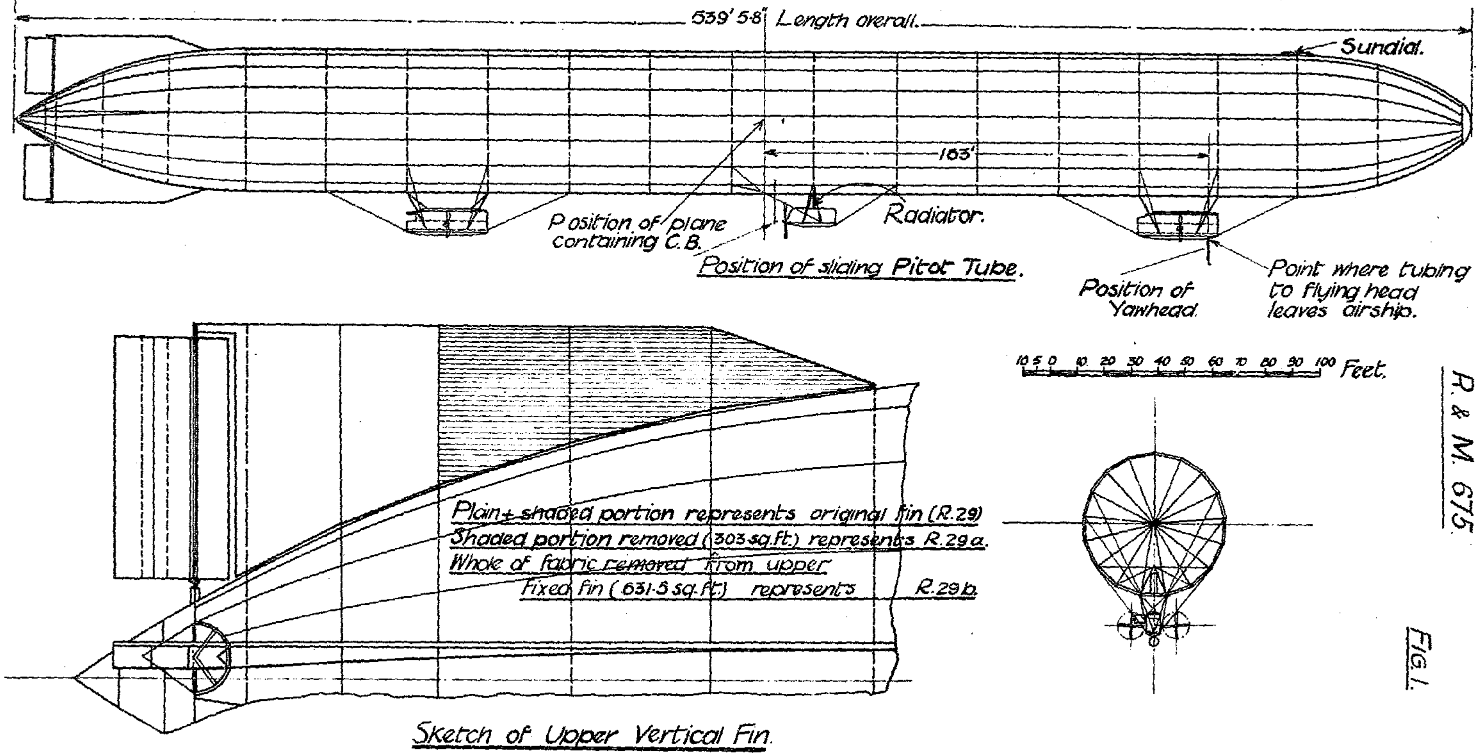
MEASUREMENTS OF PRESSURE DIFFERENCE AT AMIDSHIPS AIRSCREW (*contd.*).

Calculation of Thrust Coefficient (T_c) from original observations.

Expt. No. 102.

Radius r (ins.)	Velocity Head $\frac{1}{2}\rho V^2$ (ins. of water).	Pressure Difference $(p_2 - p_1)$. (ins. of water).	r/D	T′*	
− 1	0·65	− 0·455	0·006	− 0·0132	Engines—
− 1	0·635	− 0·410	0·006	− 0·0122	No. 1 = stopped.
2	0·600	− 0·335	0·012	− 0·0210	No. 2 = 1,200 r.p.m.
5	0·665	− 0·350	0·031	− 0·0512	No. 3 = 1,700 r.p.m.
8	0·665	− 0·385	0·049	− 0·089	D = 13·5 ft.
11	0·700	− 0·285	0·068	− 0·087	ρ = 0·00229.
14	0·690	− 0·195	0·086	− 0·0764	n = 12·8 revs/sec.
17	0·675	− 0·055	0·105	− 0·0268	V = 53·6 ft/sec.
19	0·665	− 0·010	0·117	− 0·0055	$\frac{V}{nD}$ = 0·3.
20	0·65	+ 0·025	0·123	+ 0·0149	
23	0·675	+ 0·130	0·142	+ 0·086	T_c = 0·20.
23	0·705	+ 0·115	0·142	+ 0·073	
26	0·635	+ 0·235	0·161	+ 0·187	T_c (model) = 0·65.
29	0·705	+ 0·300	0·179	+ 0·239	
29	0·700	+ 0·285	0·179	+ 0·229	
32	0·755	+ 0·775	0·198	+ 0·638	
35	0·68	+ 0·615	0·216	+ 0·614	
36	0·67	+ 0·655	0·222	+ 0·681	
38	0·665	+ 0·76	0·235	+ 0·844	
41	0·67	+ 0·86	0·253	+ 1·02	
44	0·645	+ 1·55	0·272	+ 2·05	
44	0·665	+ 0·88	0·272	+ 1·13	
47	0·645	+ 1·00	0·290	+ 1·41	
47	0·585	+ 1·00	0·290	+ 1·56	
50	0·575	+ 1·00	0·309	+ 1·69	
50	0·690	+ 0·92	0·309	+ 1·29	
53	0·615	+ 0·985	0·327	+ 1·64	
56	0·610	+ 1·00	0·346	+ 1·78	
59	0·595	+ 1·00	0·364	+ 1·92	
62	0·600	+ 0·805	0·383	+ 1·61	
65	0·675	+ 0·35	0·401	+ 0·654	
67	0·600	+ 0·145	0·414	+ 0·314	
68	0·615	+ 0·235	0·420	+ 0·503	
68	0·685	+ 0·55	0·420	+ 1·06	
69	0·705	+ 0·27	0·426	+ 0·512	
69	0·620	0·00	0·426	0·00	
69	0·600	0·00	0·426	0·00	
70	0·625	− 0·225	0·432	− 0·489	
70	0·600	− 0·100	0·432	− 0·226	
71	0·705	− 0·300	0·438	− 0·585	
71	0·705	− 0·365	0·438	− 0·71	
71	0·655	− 0·170	0·438	− 0·357	
71	0·620	− 0·235	0·438	− 0·521	
72	0·655	− 0·220	0·444	− 0·467	
73	0·690	− 0·475	0·451	− 0·975	
73	0·625	− 0·575	0·451	− 1·30	
74	0·625	− 0·715	0·457	− 1·64	
75	0·65	− 0·745	0·463	− 1·66	
81	0·645	− 0·715	0·500	− 1·74	
100	0·720	− 0·805	0·618	− 2·17	
100	0·65	− 0·715	0·618	− 2·13	

$$* \; T' = \frac{p_2 - p_1}{\frac{1}{2}\rho V^2} \times \pi \frac{r}{D}$$



Sketch of Upper Vertical Fin.

R. & M. 675.

FIG. 1.

9 203/127. 10/20. 125. 8/21.
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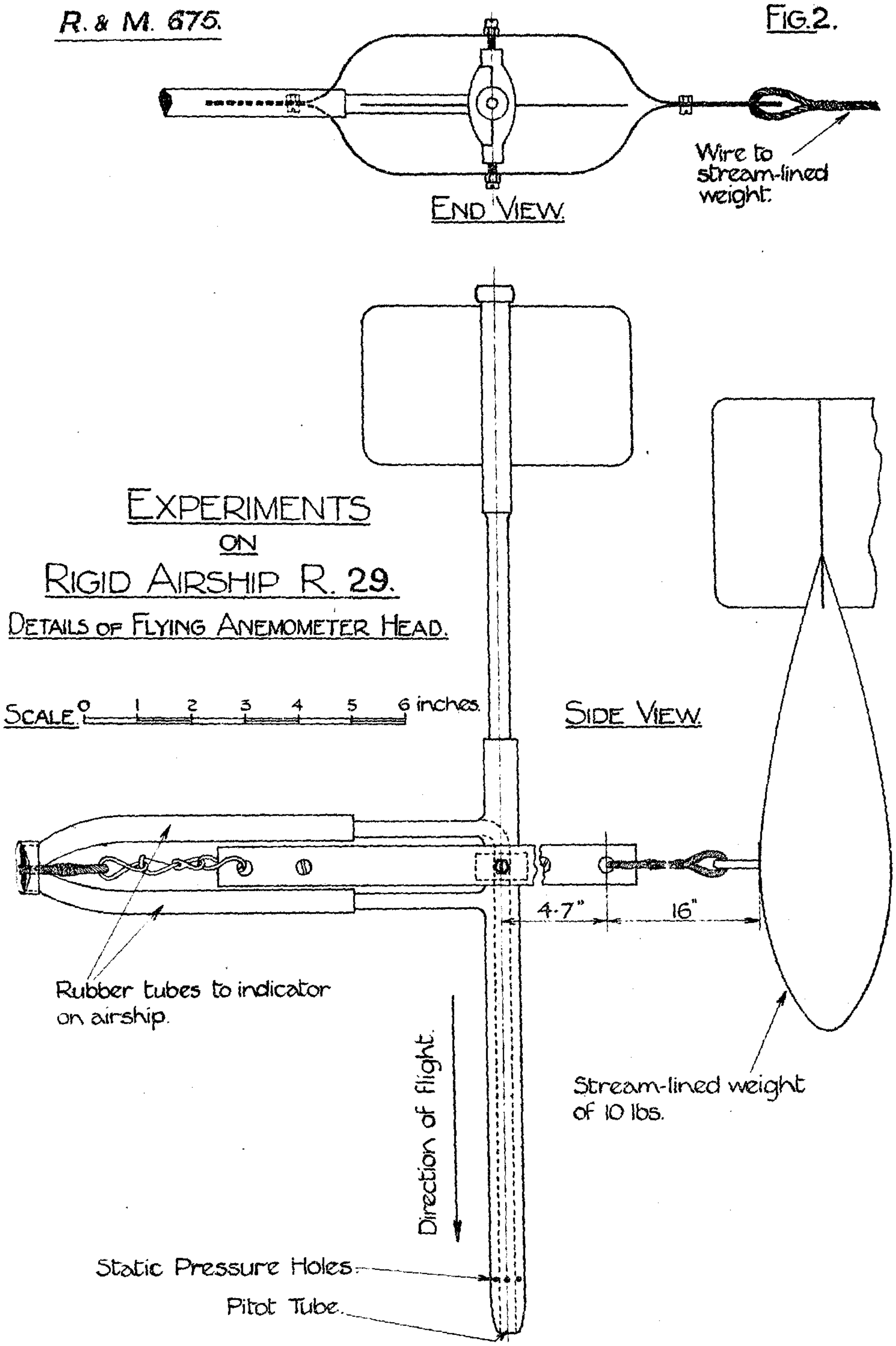
R. & M. 675.

FIG. 2.



EXPERIMENTS ON RIGID AIRSHIP R. 29.

DETAILS OF FLYING ANEMOMETER HEAD.

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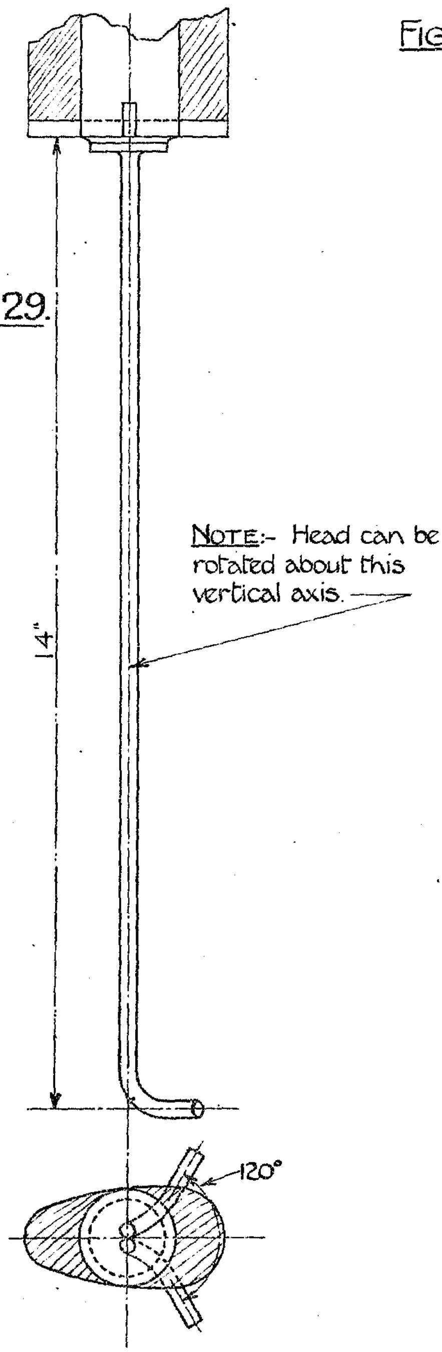
FIG. 3.

EXPERIMENTS ON RIGID AIRSHIP R.29.

THE YAWHEAD.



9. 203/127. 10/20.
1275. 8/21.

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FIG. 4.
(See tables 2,3 & 4).

EXPERIMENTS ON RIGID AIRSHIP R. 29.

VARIATION OF DIAMETER OF TURNING CIRCLE WITH SPEED FOR CONSTANT RUDDER ANGLES.

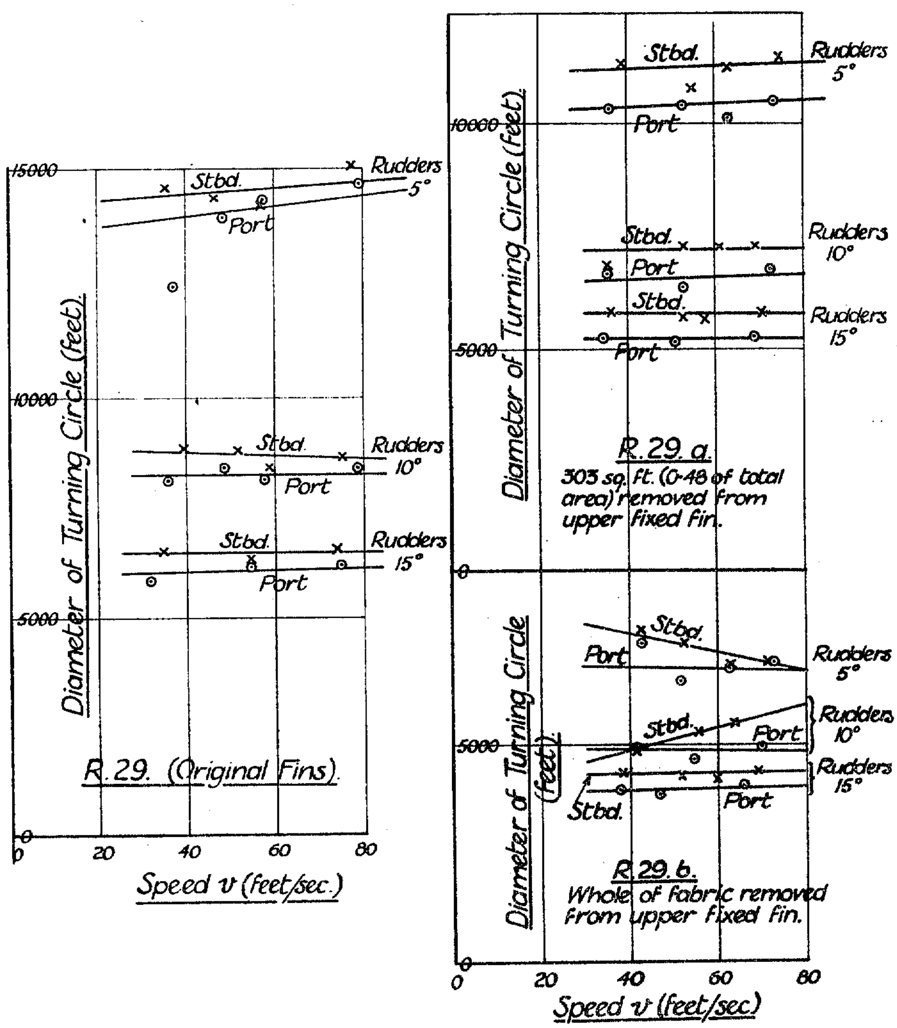
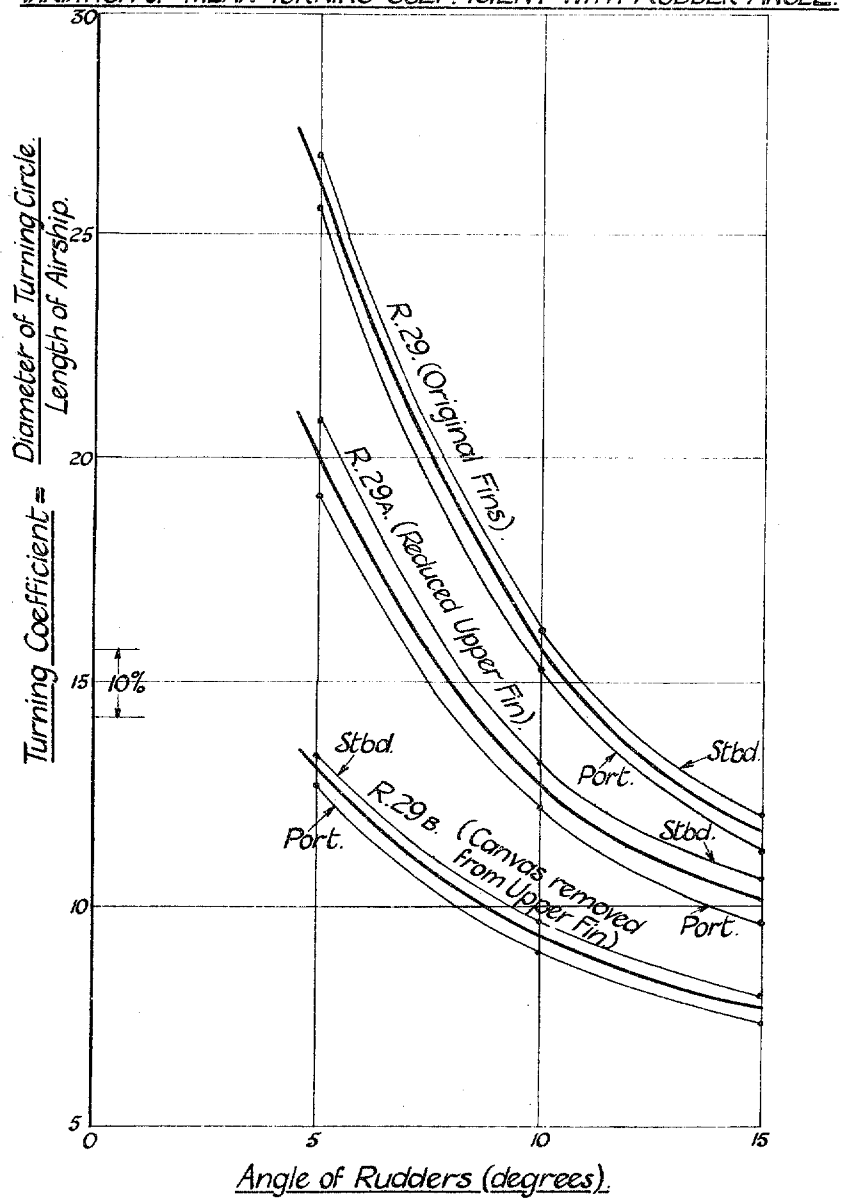


FIG. 5.
(See Tables 2,3,4 & 5.)

EXPERIMENTS ON RIGID AIRSHIP R.29.

VARIATION OF MEAN TURNING COEFFICIENT WITH RUDDER ANGLE.



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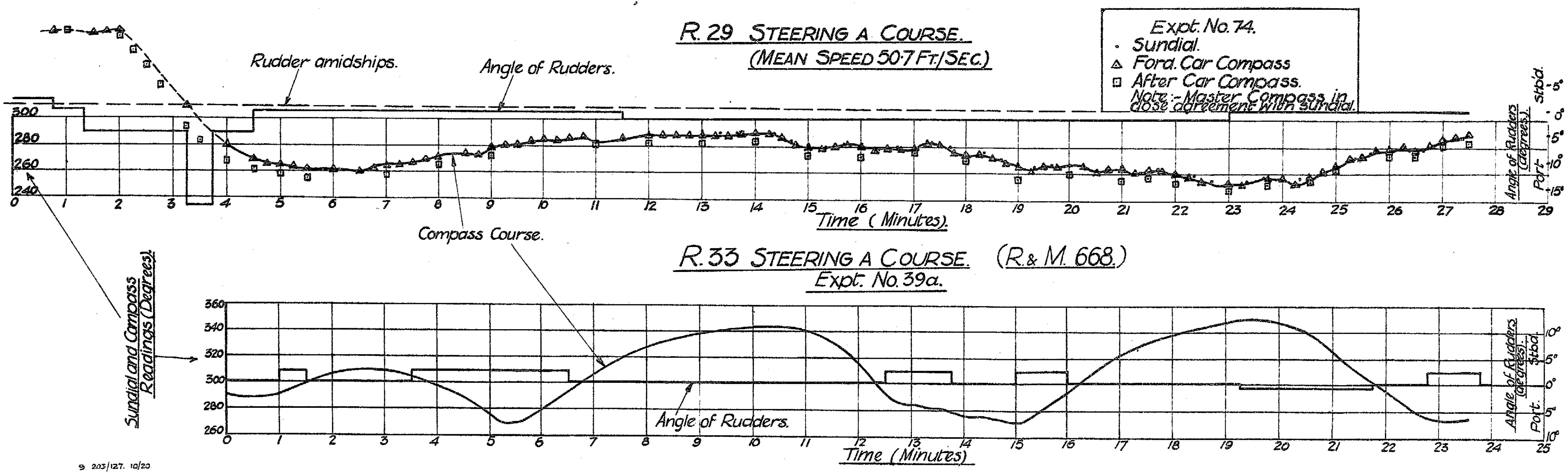
EXPERIMENTS ON RIGID AIRSHIP R. 29.



9 203/127. 10/20
1275. 8/21.
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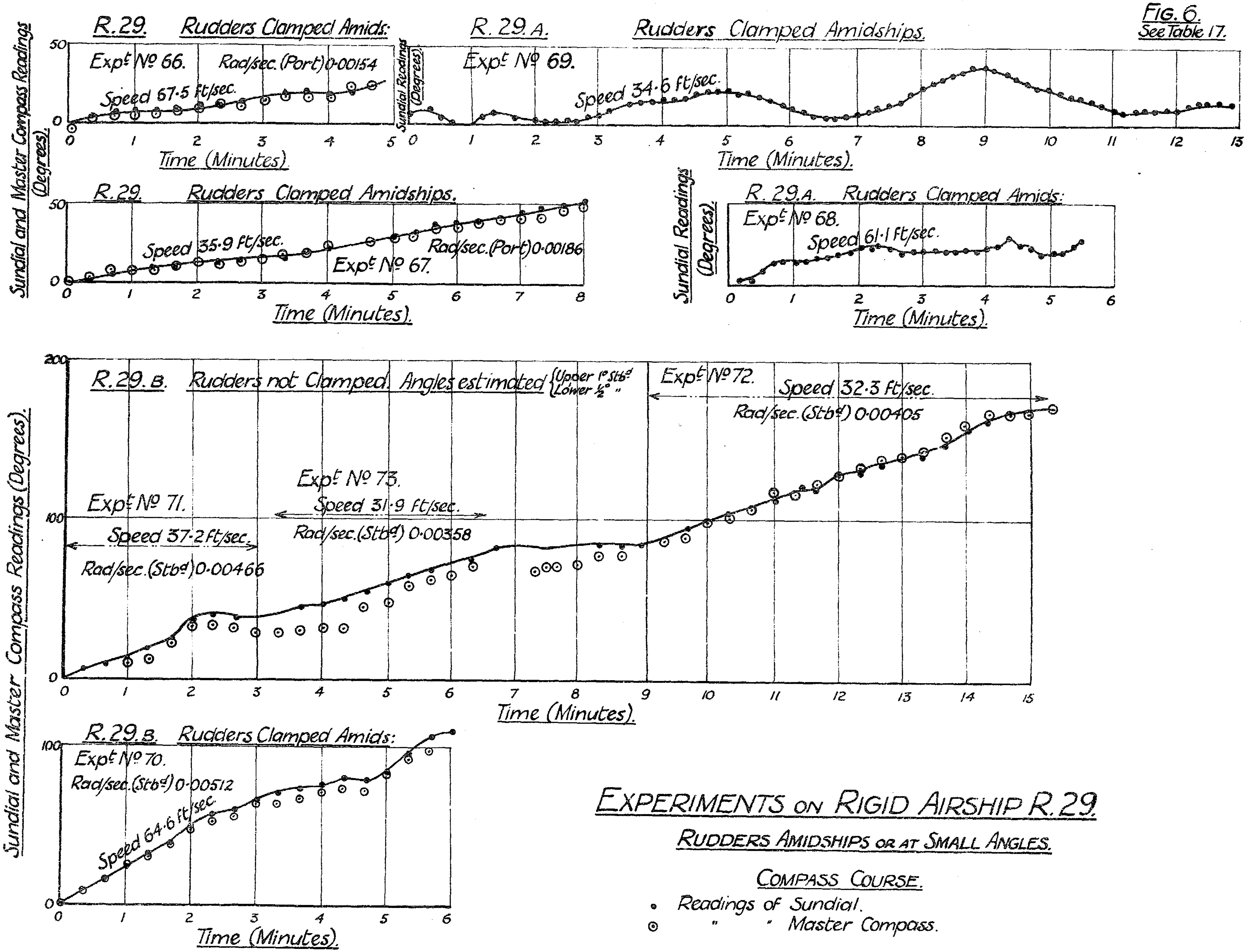
FIG. 6.
See Table 17.



EXPERIMENTS ON RIGID AIRSHIP R.29.

RUDDERS AMIDSHIPS OR AT SMALL ANGLES.

COMPASS COURSE.

• Readings of Sundial.

⊙ " " Master Compass.

EXPERIMENTS ON RIGID AIRSHIP R. 29.

DECELERATION TRIALS.

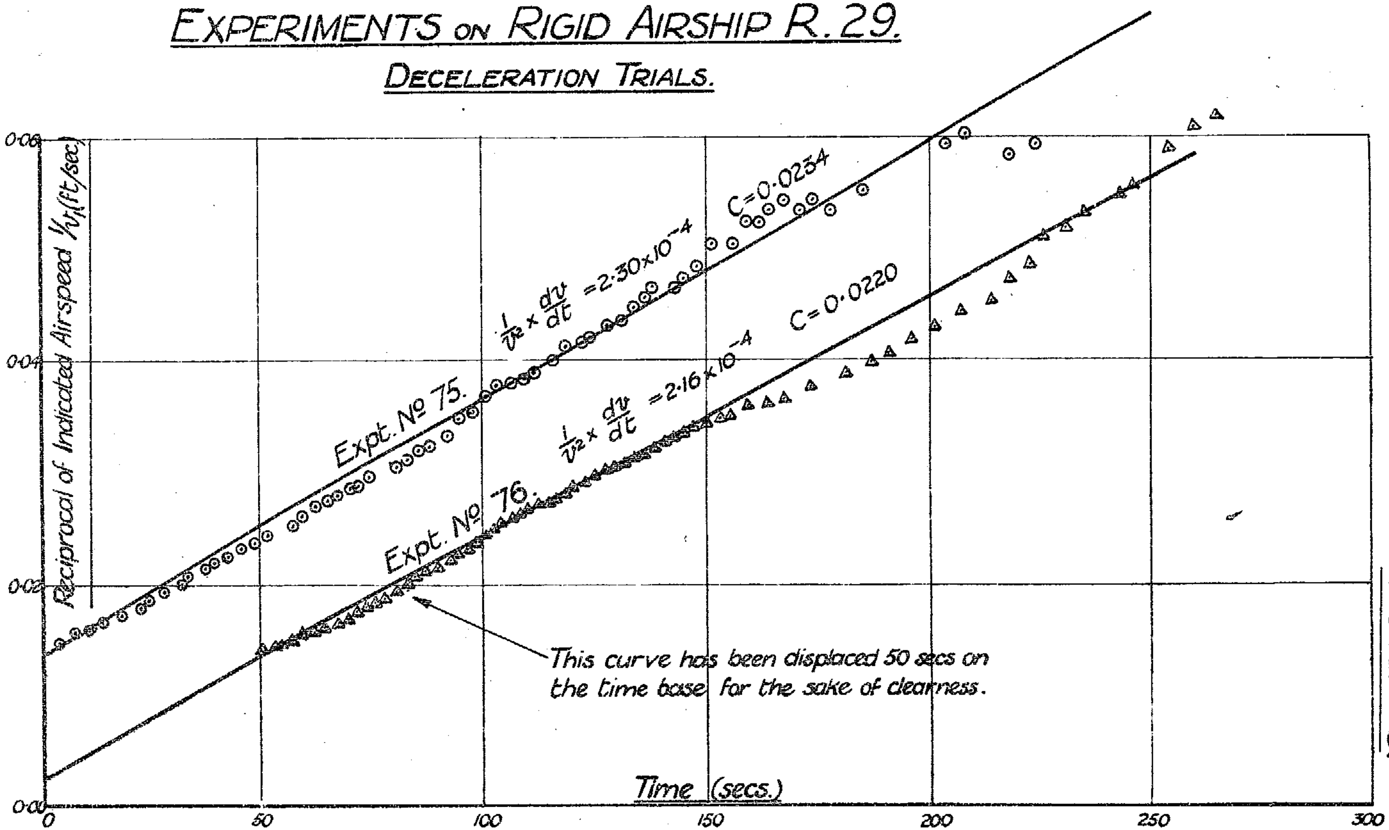


FIG. 7. See Table 8.

9. 203/127. 10/20. 1275. 8/21.
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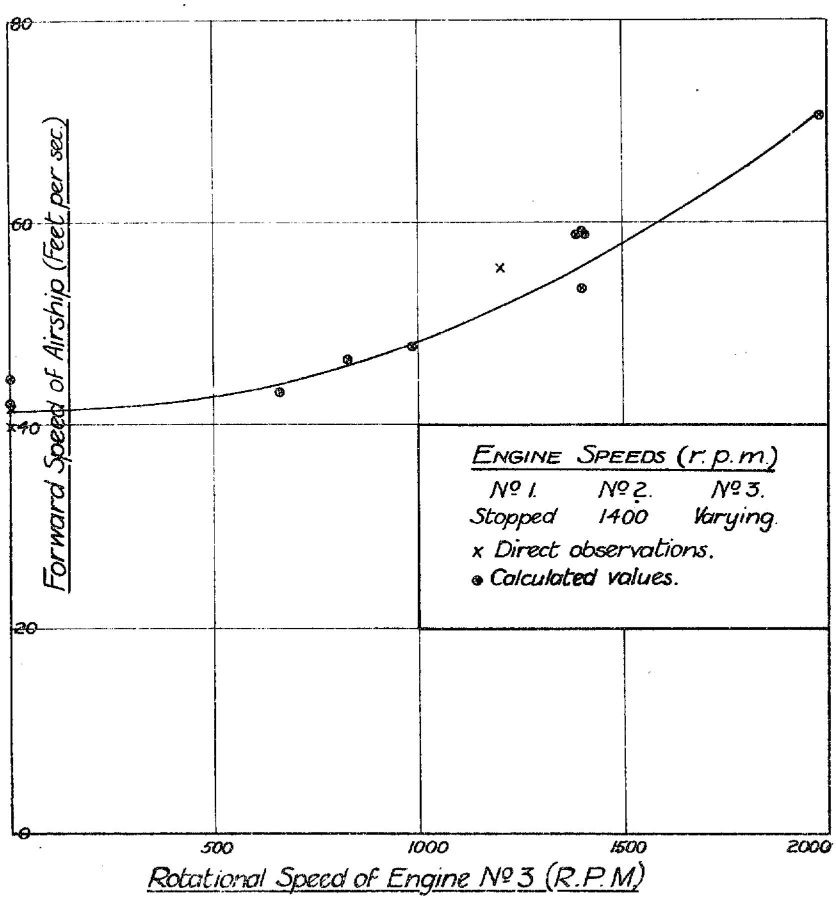
FIG. 8.
(See Table II.)

EXPERIMENTS ON RIGID AIRSHIP R. 29.

PREDICTION OF FORWARD SPEED FOR VARIOUS ENGINE COMBINATIONS.



EXPERIMENTS ON RIGID AIRSHIP R. 29.

MEASUREMENTS OF PRESSURE DIFFERENCE AT AMIDSHIPS AIRSCREW.

9.203/127. 10/20.
1275. 8/21.

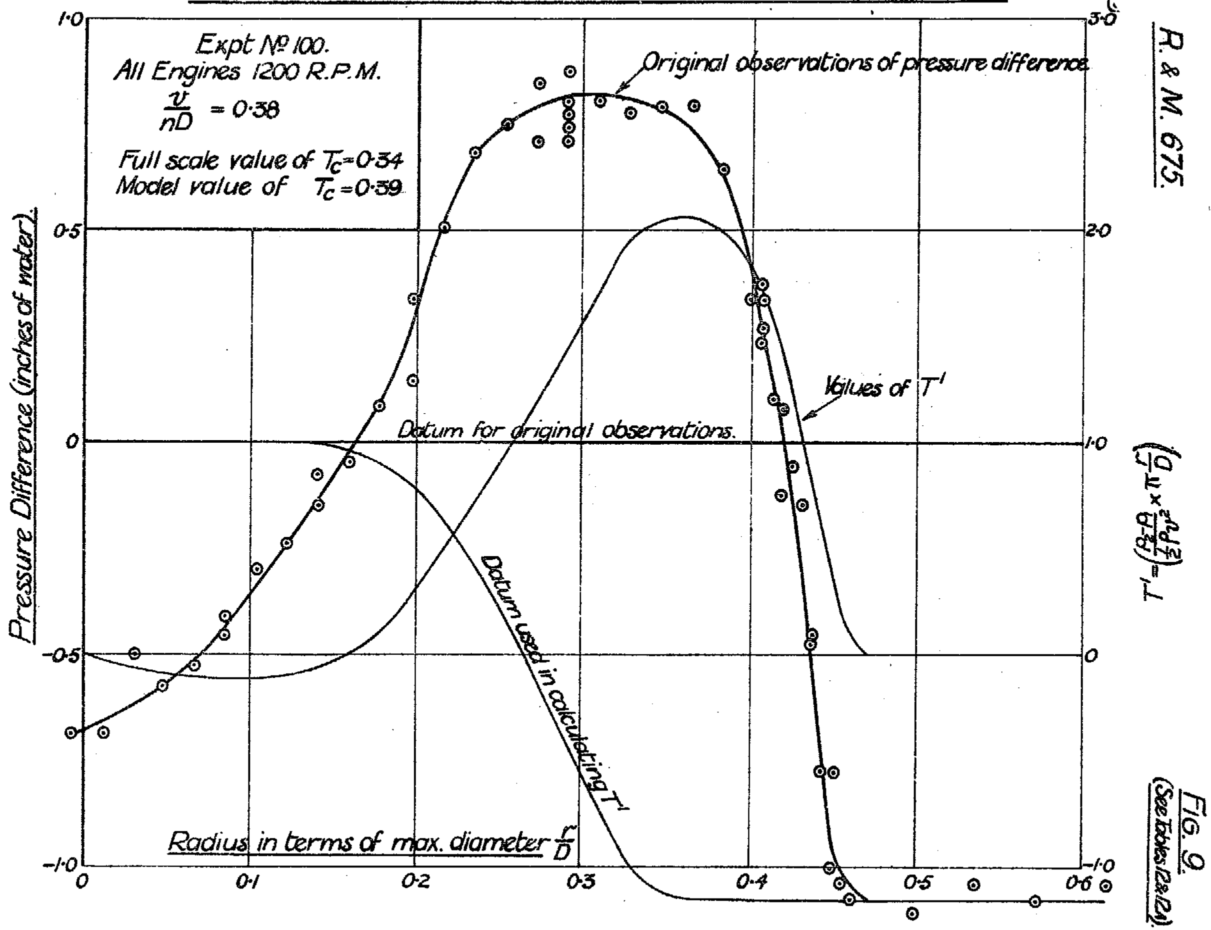


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FIG. 9.
(See Tables 12 & 12A).

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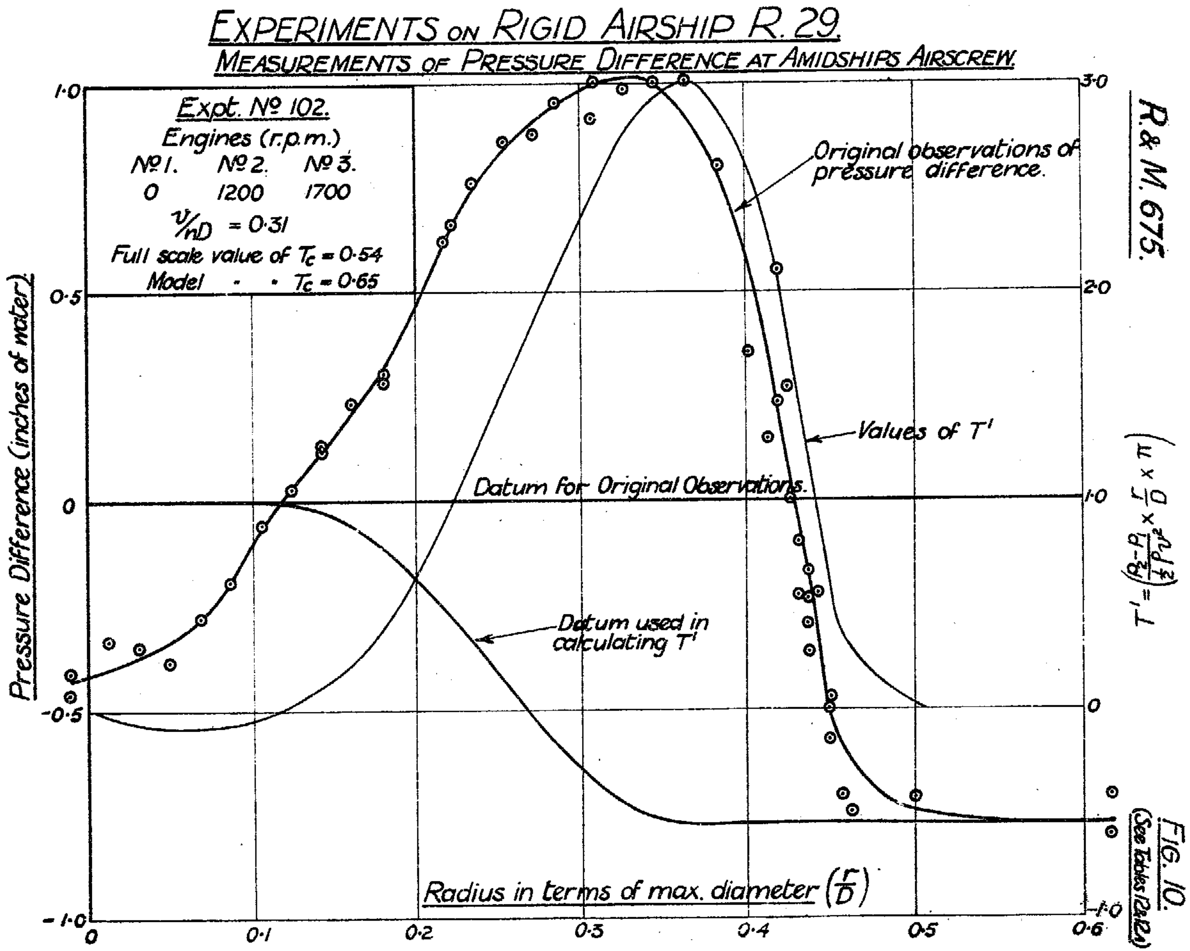


EXPERIMENTS ON RIGID AIRSHIP R. 29.
MEASUREMENTS OF PRESSURE DIFFERENCE AT AMIDSHIPS AIRSCREW.
Expt. № 102.
Engines (r.p.m.)
№ 1. № 2. № 3.
0 1200 1700
V/nD = 0·31
Full scale value of Tc = 0·54
Model " " Tc = 0·65
Original observations of pressure difference.
Values of T′
Datum for Original Observations.
Datum used in calculating T′
Pressure Difference (inches of water)
Radius in terms of max. diameter (r/D)
T′ = ((P2−P1)/(½ρv²) × r/D × π)
R. & M. 675.
FIG. 10.
(See Tables 12a & 12b)

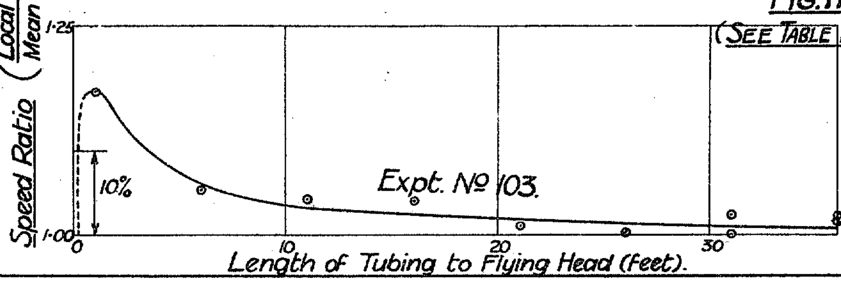
R. & M. 675.

FIGS. 11 & 12.

EXPERIMENTS ON RIGID AIRSHIP R. 29. (SEE TABLE 13.)

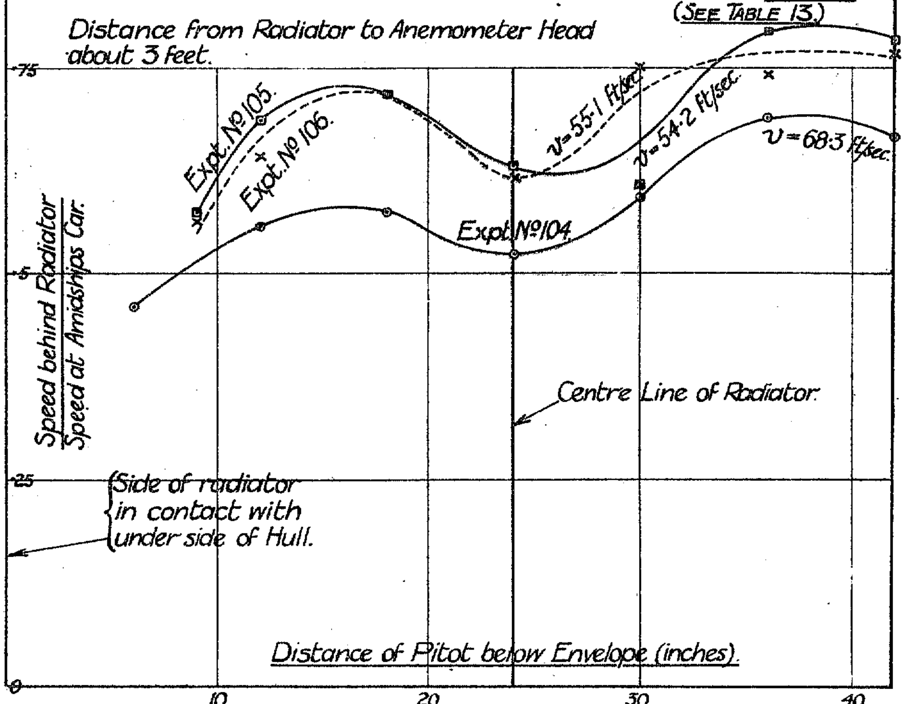
DISTRIBUTION OF SPEED BELOW FORWARD CAR.

FIG. 11.
(SEE TABLE 13.)



SPEED BEHIND AMIDSHIPS RADIATOR.

FIG. 12.
(SEE TABLE 13.)



9. 203/127. 10/20.
1275. 8/21.
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FIG. 13.

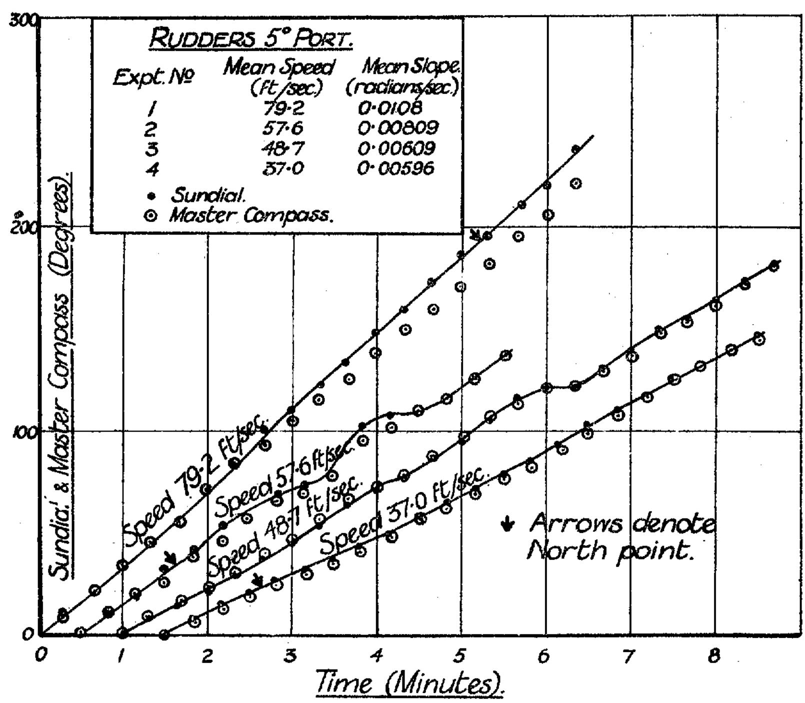
EXPERIMENTS ON RIGID AIRSHIP R. 29.

R. 29 (ORIGINAL FINS).

TURNING TRIALS.

RUDDERS CLAMPED AFT AT 5° PORT.

Observations.



9.203/127. 10/20.
1275. 8/21.

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R.& M. 675.

FIG. 14.

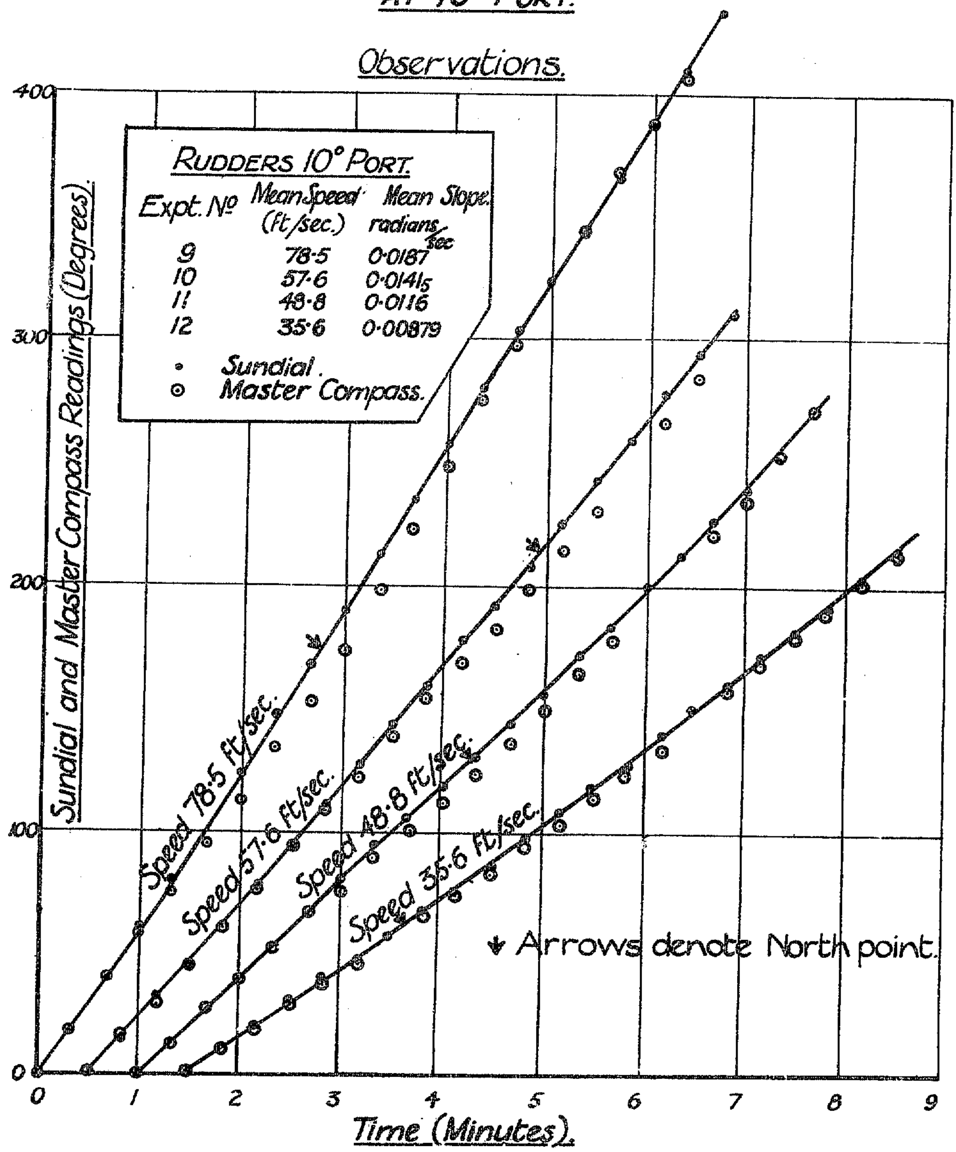
EXPERIMENTS ON RIGID AIRSHIP R.29.

R.29. (ORIGINAL FINS).

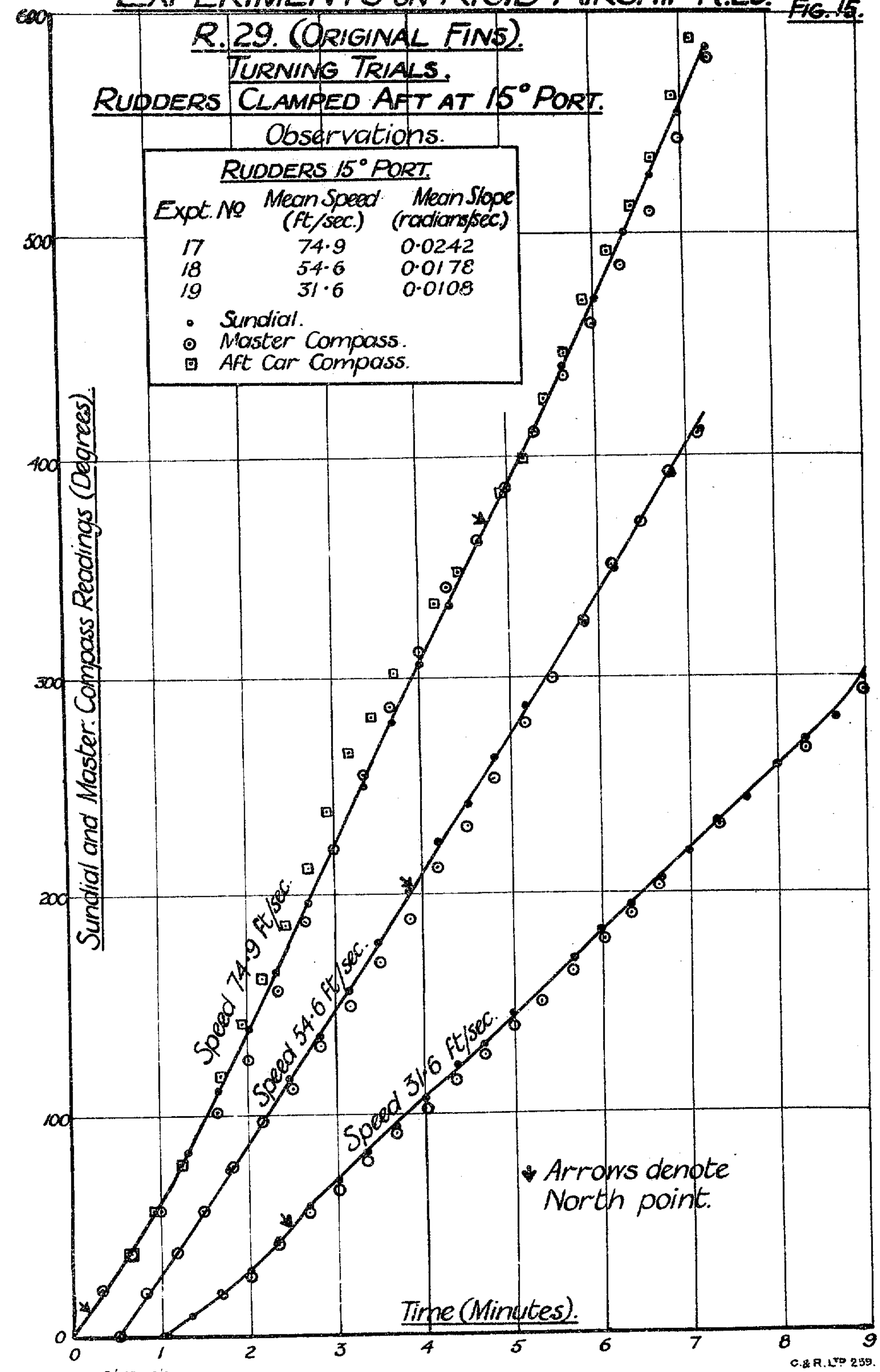
TURNING TRIALS.

RUDDERS CLAMPED AFT AT 10° PORT.

Observations.



R&M.675. EXPERIMENTS ON RIGID AIRSHIP R.29. FIG. 15.



9. 203/127. 10/20.
1275. 8/21.
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FIG. 16.

EXPERIMENTS ON RIGID AIRSHIP R.29.

R.29(A).– (UPPER FIXED FIN AREA REDUCED BY 303 SQ.FT.)

TURNING TRIALS-
RUDDERS CLAMPED AFT AT 5° PORT.

Observations.

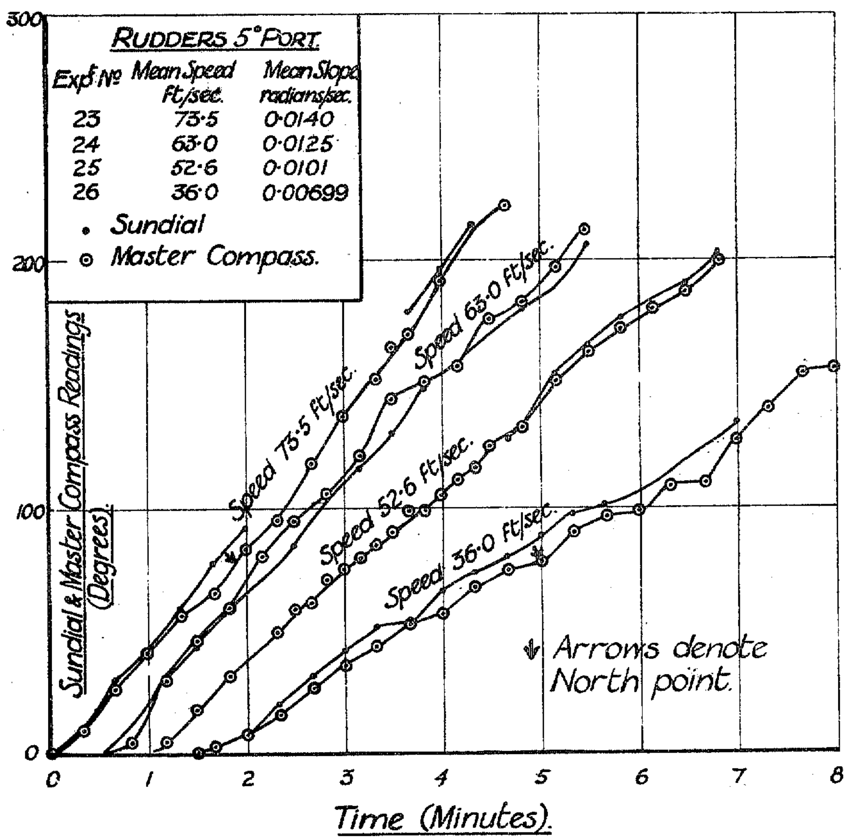


FIG. 17.

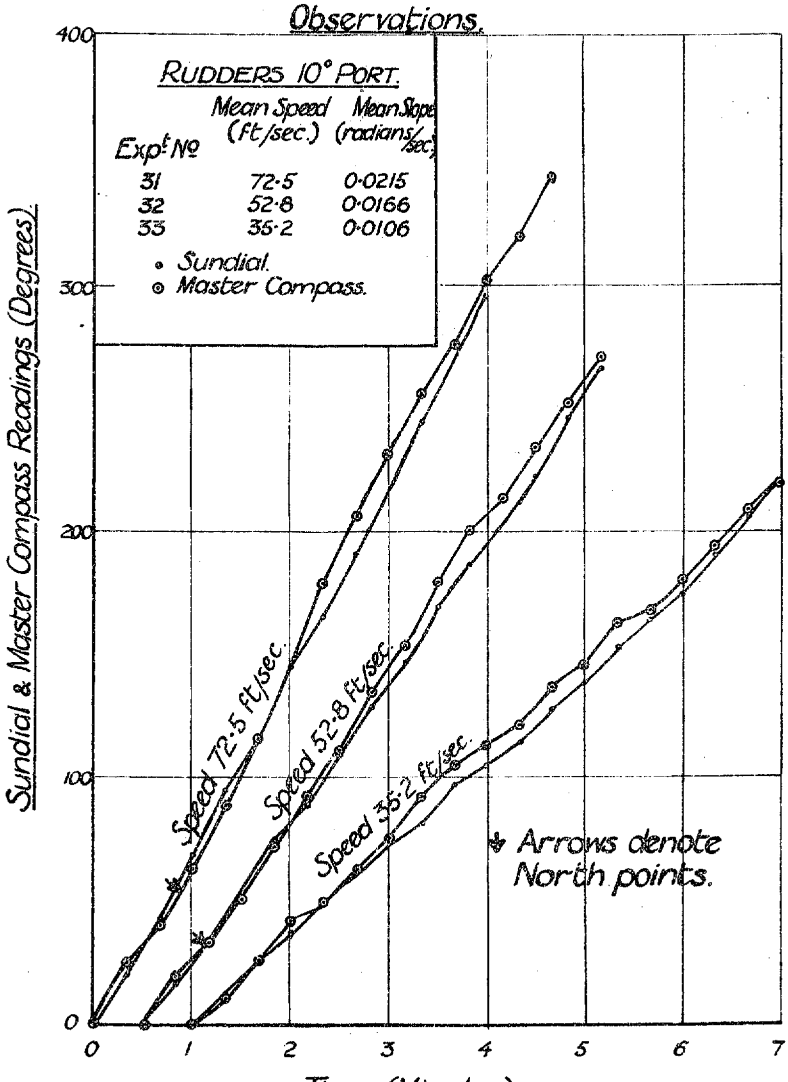
EXPERIMENTS ON RIGID AIRSHIP R. 29.

R.29(A)-(UPPER FIXED FIN AREA REDUCED BY 303 SQ. FT.)

TURNING TRIALS.

RUDDERS CLAMPED AFT AT 10° PORT.

Observations.



9.203/127. 10/20.
1275. 8/21.
C.& R. Ltd 259.

R. & M. 675.

FIG. 18.

EXPERIMENTS ON RIGID AIRSHIP R.29.

R.29(A)–(UPPER FIXED FIN AREA REDUCED BY 303 SQ.FT.)

TURNING TRIALS.

RUDDERS CLAMPED AFT AT 15° STBD.

Observations.

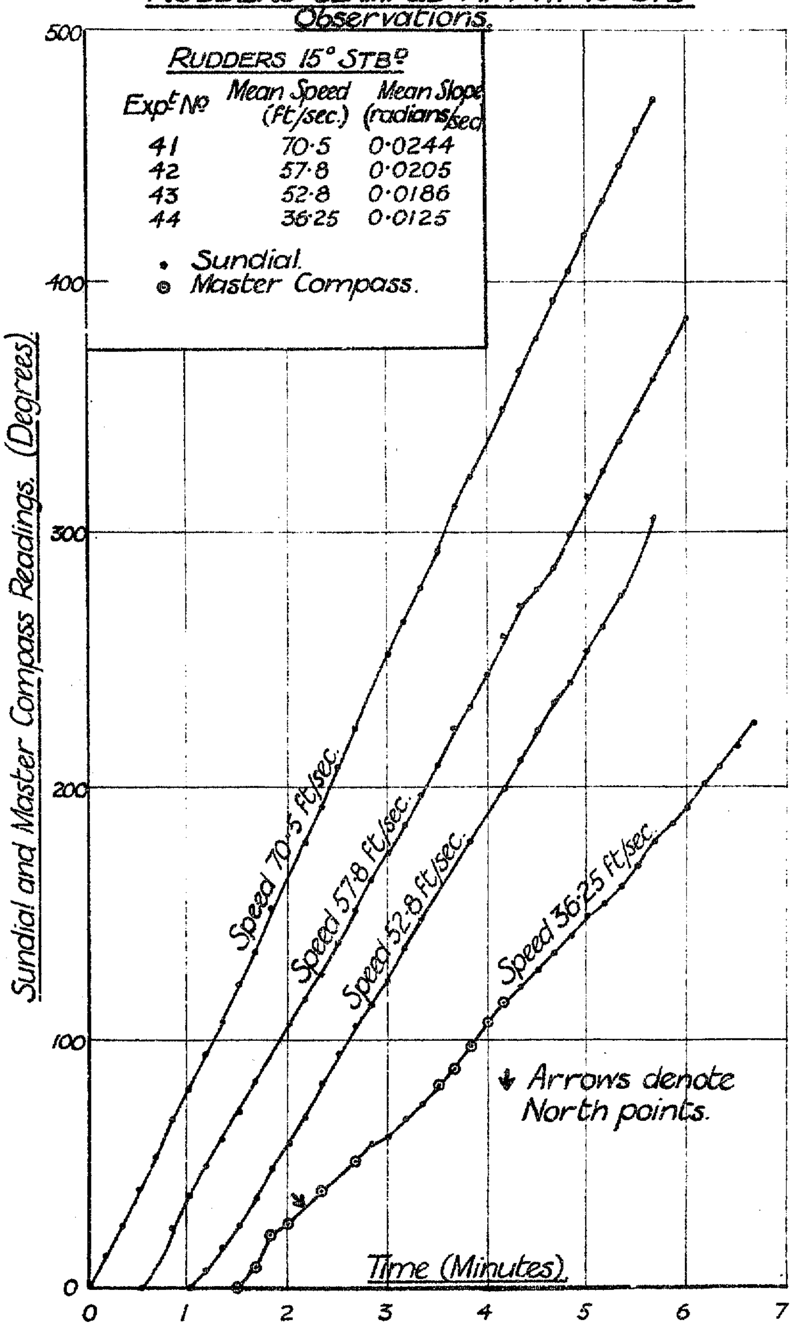


FIG. 19.

EXPERIMENTS ON RIGID AIRSHIP R. 29.

R. 29. (B) WHOLE OF FABRIC REMOVED FROM UPPER FIXED FIN

TURNING TRIALS.

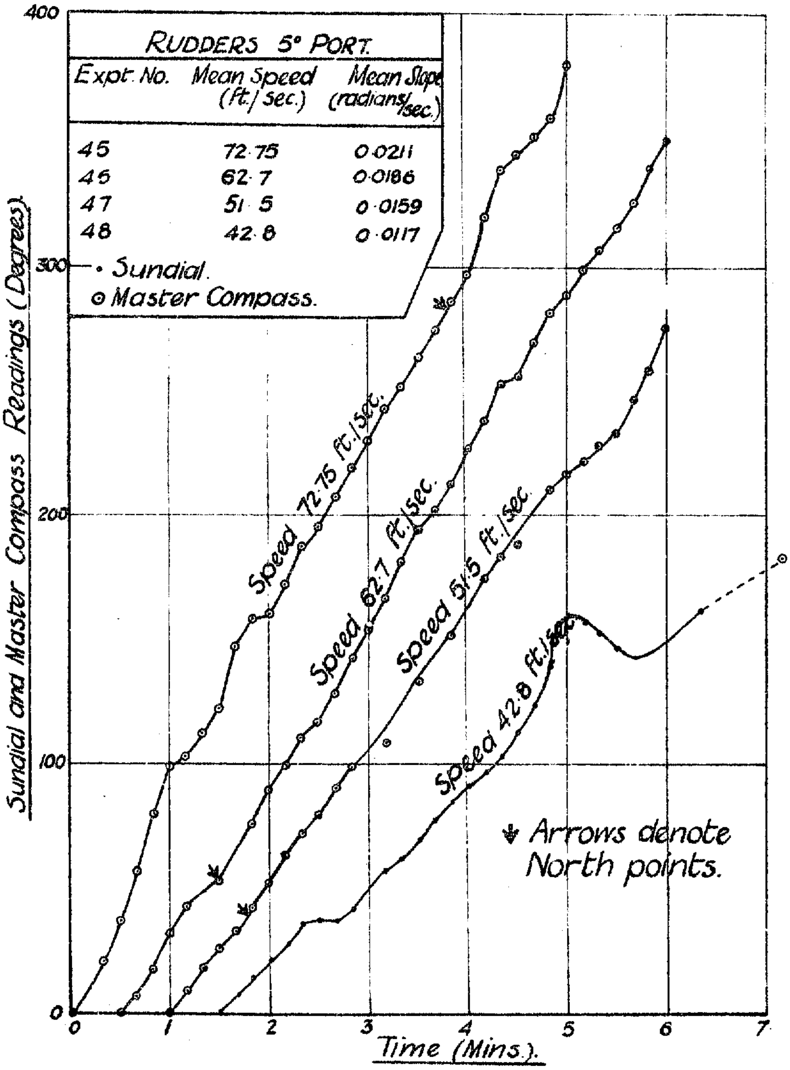
RUDDERS CLAMPED AFT AT 5° PORT.

Observations.

RUDDERS 5° PORT.

Expt. No.	Mean Speed (ft./sec.)	Mean Slope (radians/sec.)
45	72·75	0·0211
46	62·7	0·0186
47	51·5	0·0159
48	42·8	0·0117

• Sundial.
⊙ Master Compass.



9. 203/127. 10/20
1275-8/21.

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R. & M. 675.

FIG. 20.

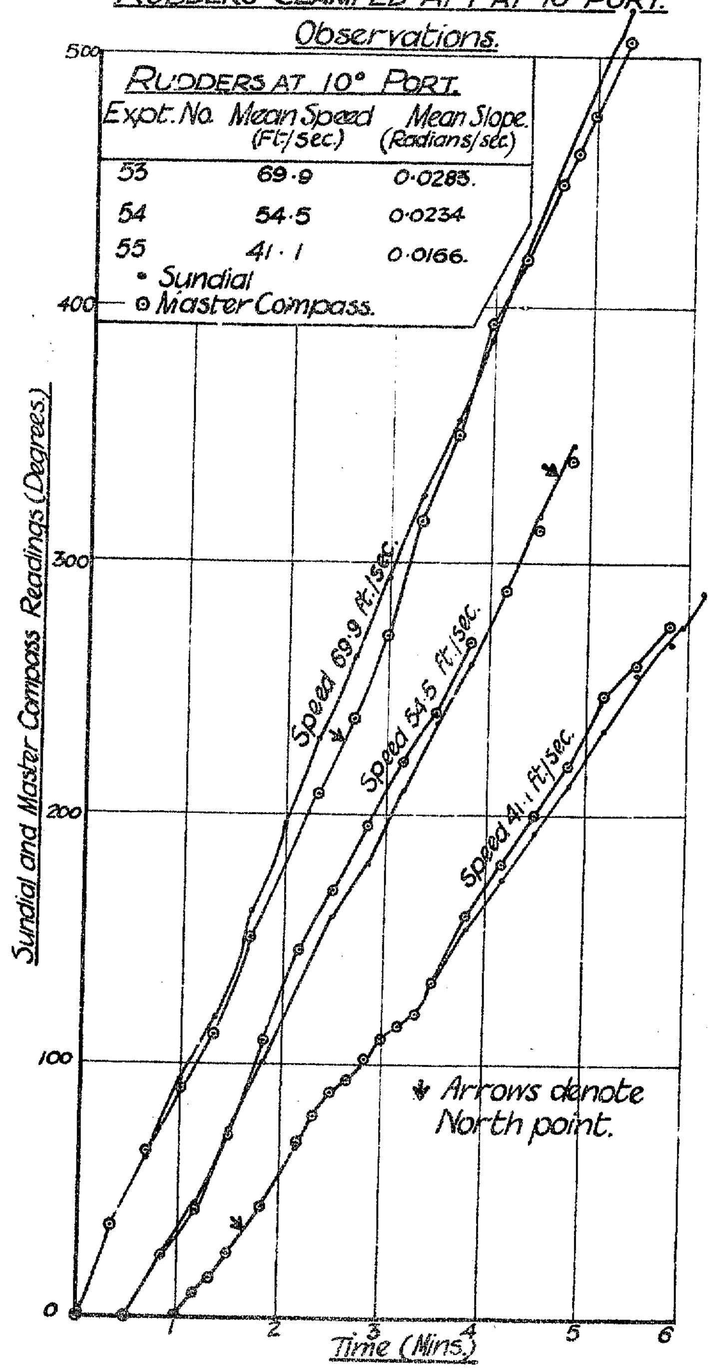
EXPERIMENTS ON RIGID AIRSHIP R.29.

R.29 (B) WHOLE OF FABRIC REMOVED FROM UPPER FIXED FIN.

TURNING TRIALS.

RUDDERS CLAMPED AFT AT 10° PORT.

Observations.



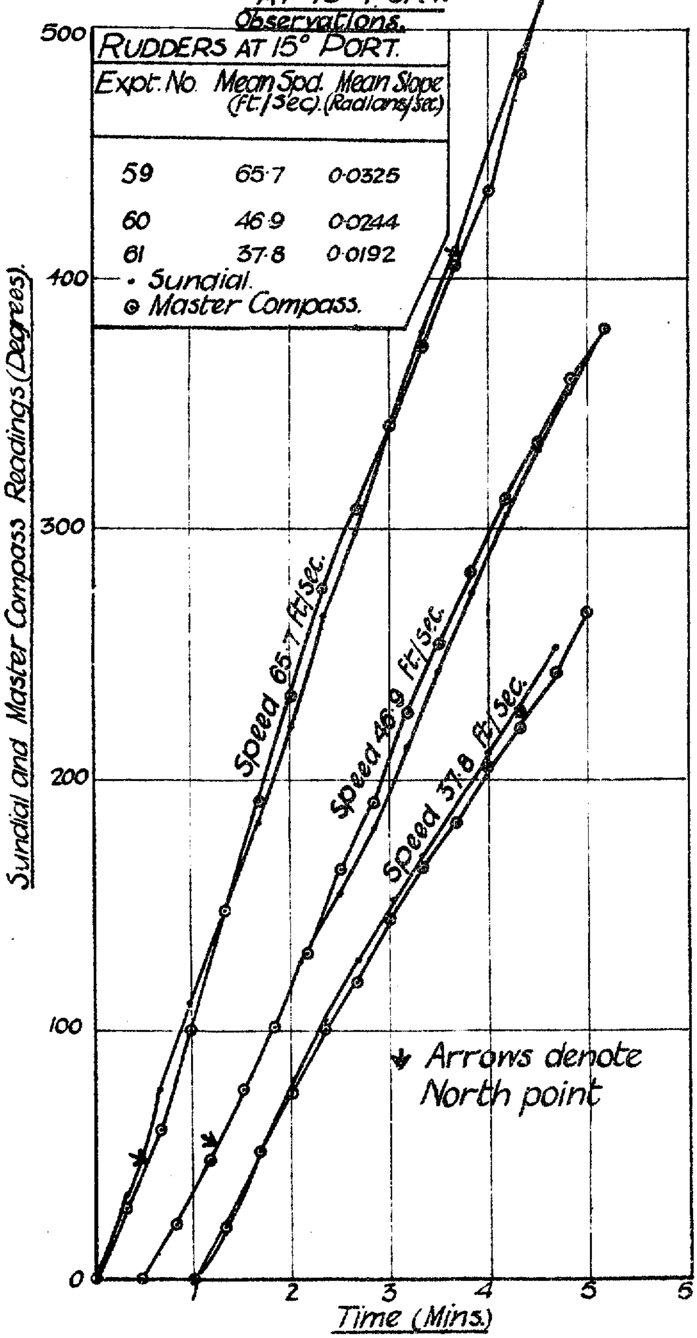
R.&M.675.

EXPERIMENTS ON RIGID AIRSHIP R.29. FIG. 21.

R.29(B) WHOLE OF FABRIC REMOVED FROM UPPER FIXED FIN.

TURNING TRIALS.

RUDDERS CLAMPED AFT AT 15° PORT.



9. 203/127. 10/20.
1275.8/21.

C.A.R. L^TD 259.

TABLE 12A (see Figs. 9 and 10).

MEASUREMENTS OF PRESSURE DIFFERENCE AT AMIDSHIPS AIRSCREW.

Calculation of Thrust Coefficient (T_c) using Arbitrary Datum.

Expt. No. 100.				Expt. No. 102.			
r/D	* Pressure Difference. (ins. water).	T′†		r/D	* Pressure Difference (ins. water).	T′†	
0	−0·67	0		0	−0·42	0	
0·025	−0·63	−0·050	Engines—	0·025	−0·38	−0·0460	Engines—
0·049	−0·57	−0·090	No. 1 = 1,200	0·049	−0·34	−0·0805	No. 1 =
0·074	−0·49	−0·117	r.p.m.	0·074	−0·25	−0·0895	stopped.
0·099	−0·38	−0·121	No. 2 = 1,200	0·099	−0·11	−0·0530	No. 2 = 1,200
0·123	−0·24	−0·095	r.p.m.	0·123	+0·03	+0·0178	r.p.m.
0·148	−0·11	−0·052	No. 3 = 1,200	0·148	+0·19	+0·1355	No. 3 = 1,700
0·173	+0·10	+0·055	r.p.m.	0·173	+0·38	+0·318	r.p.m.
0·198	+0·44	+0·280	Mean $\frac{1}{2}\rho V^2$ =	0·198	+0·64	+0·61	Mean $\frac{1}{2}\rho V^2$ =
0·222	+0·80	+0·568	0·98 ins. of	0·222	+0·94	+1·00	0·65 ins. of
0·247	+1·11	+0·880	water.	0·247	+1·20	+1·43	water.
0·271	+1·38	+1·20	$\frac{V}{nD}$ = 0·38.	0·271	+1·41	+1·85	$\frac{V}{nD}$ = 0·31.
0·296	+1·59	+1·505		0·296	+1·61	+2·30	
0·321	+1·76	+1·92	T_c = 0·34.	0·321	+1·73	+2·68	T_c = 0·54.
0·345	+1·84	+2·04		0·345	+1·77	+2·96	
0·370	+1·75	+2·06	T_c model =	0·370	+1·68	+3·00	T (model)
0·395	+1·51	+1·90	0·39.	0·395	+1·44	+2·74	= 0·65.
0·420	+1·07	+1·43		0·420	+1·00	+2·03	
0·445	+0·40	+0·57		0·445	+0·41	+0·875	
0·468	0·00	0·00		0·468	+0·10	+0·226	
0·494	0·00	0·00		0·494	+0·02	+0·0474	

* Measured from new datum (see Figs. 9 and 10

$$\dagger\, T' = \left(\frac{p_2 - p_1}{\frac{1}{2}\rho V^2}\right) \times \pi \frac{r}{D}$$

TABLE 13 (see Figs. 11 and 12).

DISTRIBUTION OF SPEED IN VARIOUS LOCALITIES.

Below Forward Car.		Behind Amidships Radiator.			
Expt. No. 103. Mean Speed 65·0 ft./sec.		Expt. No. 104. Mean Speed 68·3 ft./sec.		Expt. No. 105. Mean Speed 54·2 ft./sec.	Expt. No. 106. Mean Speed 55·1 ft./sec.
Position* (feet).	Speed Ratio.†	Distance below Hull (inches).	Speed Ratio.†	Speed Ratio.†	Speed Ratio.†
36	1·015	6	0·460	—	—
36	1·022	9	—	0·575	0·564
31	1·00	12	0·558	0·686	0·624
31	1·024	18	0·576	0·720	0·720
26	1·002	24	0·524	0·631	0·605–0·628
21	1·01	30	0·594	0·608	0·754
16	1·04	36	0·690	0·795	0·741
11	1·041	42	0·665	0·784	0·766
6	1·052				
1	1·17				

* Indicates length of tube between flying head and point at which tube leaves the airship. (See Fig. 1.)

† Denotes the ratio of local speed to the mean speed of the airship.

TABLE 14.

VALUES OF AIR DENSITY ρ.

Standard value for Air Density at 288A (15°C.) and 1,012 mb. is 0·00237.

Sept. 15th, 1919.		Sept. 16th, 1919.		Oct. 7th, 1919.		Oct. 9th, 1919.	
Time (B.S.T.). Hr. Min. Hr. Min.	ρ (Slugs/ft.^{3}).	Time (B.S.T.). Hr. Min. Hr. Min.	ρ (Slugs/ft.^{3}).	Time (G.M.T.). Hr. Min. Hr. Min.	ρ (Slugs/ft.^{3}).	Time (G.M.T.). Hr. Min. Hr. Min.	ρ (Slugs/ft.^{3}).
10 51 — 12 04	0·00236	10 17 — 10 28	0·00235	10 30 — 10 44	0·00239	10 39 — 10 58	0·00242
12 07 — 12 51	0·00235	10 41 — 11 30	0·00234	10 46 — 11 40	0·00238	11 00 — 11 05	0·00243
14 38 — 14 56	0·00234	13 15 — 14 02	0·00227	11 46 — 12 23	0·00238	11 09 — 11 28	0·00243
14 57 — 15 11	0·00234	14 02 — 14 40	0·00230	12 25 — 13 02	0·00238	11 42 — 11 48	0·00243
15 30 — 15 45	0·00234	14 48 — 14 55	0·00232	14 36 — 14 39	0·00237	11 55 — 12 53	0·00242
15 47 — 15 53	0·00233	15 16 — 15 50	0·00230	15 07 — 16 39	0·00238	12 56 — 13 51	0·00241
15 55 — 16 01	0·00233	16 01 — 16 24	0·00232			14 27 — 14 33	0·00241
16 07 — 16 10	0·00234	16 56 — 17 01 17 03 — 17 09	0·00233			14 34 — 14 40	0·00242
16 13 — 16 15	0·00232	17 45 — 17 51	0·00233			14 41 — 14 47	0·00242
16 21 — 16 34	0·00230	17 54 — 17 58	0·00232			14 49 — 14 54	0·00241
16 36 — 16 42	0·00234	18 01 — 18 05	0·00232				
16 43 — 16 50	0·00235						
16 59 — 17 06	0·00233						
17 33 — 17 37	0·00233						

NOTE.—Air Density ρ for Lieut. Hasler's observations on Sept. 14th, 1919 = 0·00235.