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FURTHER FREE-STREAM CHARACTERISTICS OF SEMI-BALANCED SHIP SKEG-RUDDERS

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SUMMARY

The results of free-stream wind tunnel experiments on semi-balanced skeg rudders are presented.

The tests on these rudders are an extension to earlier tests on a parent skeg rudder, which were the subject of a separate report, and complete a series of tests on three skeg rudders having taper ratios of 0.59, 0.80 and 1.00.

The experiments establish a better understanding of the working and performance of semi-balanced skeg rudders, and provide design data. Results are presented as lift and drag coefficients and centre of pressure for the rudder plus skeg combinations, for the rudders alone and skegs alone; complete ranges of rudder angles of attack were tested for selected positive and negative angles of attack on the skegs.

Supplementary tests were carried out to determine the influences of Reynolds No., the size of the gap between rudder and tunnel floor, the transition strip and the effect of sealing the gap between rudder and skeg.

In order to provide bases for comparison, the all-movable cases were simulated for each rudder by sealing the gap between rudder and skeg and varying the angles of attack on rudder and skeg simultaneously. The results for the all-movable cases compare very satisfactorily with existing published data.

The results for the skeg rudders show that with increasing angle of attack, discontinuities occur in the growth of lift together with a large movement of centre of pressure. Sealing the gap between rudder and skeg was seen to lead to a significant improvement in the lift developed at higher rudder angles of attack. The results for the three skeg rudders are compared, and the flow breakdown accounting for the discontinuities in the skeg rudder characteristics is discussed.

CONTENTS

1. INTRODUCTION

The need for free-stream experiments on skeg rudders was outlined in Ref. 1. In that Report the reasons for the choice of the principal characteristics of a projected series of three skeg rudders was outlined, and the results of tests on the first of the three rudders (designated Rudder No 1 in this Report) were described and discussed.

Further wind tunnel experiments have been carried out on Rudder No 1 and tests completed on Rudder Nos 2 and 3. This Report presents the results of these experiments. Data on Rudder No 1, from the earlier tests reported on in Ref. 1, have also been included as necessary for the purpose of making comparisons between the three rudders; for this reason, the principal design particulars of Rudder No. 1 are repeated in this Report.

Rudder Nos 2 and 3 are similar to Rudder No 1 in all respects except for taper ratio and sweep. The taper ratio of 0.59 for Rudder No 1 was increased to 0.80 and 1.00 for Rudder Nos 2 and 3 respectively. Since sweep is closely related to skeg and balance area ratios, an increase in sweep for Rudder Nos 2 and 3 was a necessary design feature in order to maintain the same skeg characteristics.

The further tests on Rudder No 1 were carried out to investigate the influences of Reynolds No, the size of the gap between the rudder and the tunnel floor, the transition strip and the effect of sealing the gap between rudder and skeg.

The tests on Rudder Nos. 2 and 3 took the relatively routine form of those carried out earlier on Rudder No 1 and reported in Ref. 1.

2. DESCRIPTION OF MODELS

The models were laminated from jelutong with a mean geometric chord $\bar{c}$ of approximately 450 mm. This value was chosen as being the largest size possible commensurate with acceptable limits on corrections due to wall effects.

The principal design characteristics of Rudder Nos 2 and 3, together with those for Rudder No 1 which are brought forward from Ref. 1, are as follows :

Rudder Number	1	2	3
Mean Chord $\bar{c}$ mm	457	450	452
Span S mm	680	675	675
Geometric Aspect Ratio AR_G	1.49	1.50	1.49
Taper Ratio C_T/C_R	0.59	0.80	1.00
Thickness / Chord Ratio t/c	0.20	0.20	0.20
Section	N.A.C.A. 0020 Root and Tip with square tips		
Skeg Depth / Span	0.5	0.5	0.5
Skeg Area Ratio	20.5%	20.5%	21%
Balance Area Ratio	19%	19%	20%
Horizontal and Vertical Gaps	4 mm	4 mm	4 mm

For each rudder, the overall N.A.C.A. 0020 section shape was maintained in way of the skeg for the rudder plus skeg combination; the nose radius of the portion of movable rudder behind the skeg was approximately one-half the local section thickness at the centreline of stock. Further particulars of the rudders are given in Fig. 1.

Leading edge roughness (a turbulence strip) was applied to both sides of the rudders, and consisted of 0.0059 in Diameter carborundum grit (No 100) spread evenly over double-sided adhesive tape of 10 mm width; the leading edge of the roughness strip was located 5% aft of the leading edge of the chord.

3. APPARATUS AND TESTS

The tests were carried out in the 7' x 5' low-speed wind tunnel at Southampton University, Ref. 2.

The rudders were mounted through the tunnel floor and, for all the basic tests the gap between the rudder and the floor was approximately 2.5 mm (0.0055 $\bar{c}$). Additional tests were carried out on Rudder No 1 with gaps of 1.5 mm, 5 mm and 12 mm.

Force and moment measurements were made using the strain-gauge dynamometer described in Ref. 3; this dynamometer is capable of the measurement of five components leading to the deviation of lift, drag and centre of pressure chordwise and spanwise, can measure the rudder and skeg forces either separately or combined and allows independent adjustment of angle of attack for both rudder and skeg about a common axis. The accuracy of the dynamometer is within ± 1.2% for torque and within ± 0.4% for the remaining components.

Photographs of Rudder No 1 in the wind tunnel were given in Ref. 1.

The tests for each rudder were carried out in the ahead condition for variation in the rudder angle of attack δ, in $2\frac{1}{2}^{\circ}$ increments, over a range of angles up to stall; this range of tests was carried out for fixed values of skeg angle β of approximately 0°, $\pm 5^{\circ}$, $\pm 10^{\circ}$ and $\pm 15^{\circ}$.

All the basic tests were carried out at a nominal Reynolds Number of 1.2×10^6. In order to determine the influence of Reynolds Number, extra tests were carried out with Rudder No 1 at nominal Reynolds Numbers of 1.0×10^6, 0.9×10^6 and 0.5×10^6.

Further tests were carried out on rudder No 1 (at $\beta = 0.25^{\circ}$) with the leading edge roughness removed for both the rudder plus skeg and rudder alone conditions.

The influence of gap flow, discussed in Ref. 1, was investigated further by sealing with plasticine all the gaps between the rudder and skeg for Rudder No 1 for a fixed skeg angle and various rudder angles. Further miscellaneous gap experiments were carried out including the sealing of the horizontal gap only and the sealing of the low and high pressure sides separately.

Tuft studies were carried out for Rudder No 3 in order to observe the flow over the rudder; white wool tufts, approximately 25 mm long, were attached to the rudder with clear adhesive tape and sketches made of the orientation of the tufts for both sides of the rudder at various angles of attack. Leading edge roughness, as for the force measurements, was applied for the tuft studies.

In order to provide data for comparison with the skeg rudders, and to provide comparisons with existing published all-movable data, tests were carried out on simulated all-movable rudders of the same dimensions as the rudder plus skeg combinations; this was achieved for each rudder by sealing the gaps between the rudder and skeg with plasticine and black adhesive tape, and varying the angles of attack of rudder and skeg simultaneously. The simulated all-movable condition was repeated for Rudder No 1 with the gaps between rudder and skeg left open. Leading edge roughness was applied for these simulated all-movable cases.

4. DATA REDUCTION AND CORRECTIONS

A computer program, Ref. 4, was used to provide the final data in coefficient form; the program incorporates the dynamometer five-component interaction matrix and correction formulae, the resolution of forces and moments from instrument axes to stream axes as necessary, and includes corrections for wind tunnel boundary effects.

The raw data was zero corrected before insertion in the analysis program; a cross plot of zero-corrected raw data yielded the angular misalignment in the rig which amounted to 0.20° and this correction was applied to all measured angles before insertion in the program.

Tunnel boundary corrections were applied as described in Ref. 5 and outlined in Ref. 4 and amounted to corrections due to solid blocking, streamline curvature and downwash. The net corrections for the three rudders are summarised as follows :-

$$\left.\begin{aligned} C_{L_C} &= 0.9956\ C_{L_u} \\ \alpha_c &= \alpha_u + 0.7710\ C_{L_C} \\ C_{D_C} &= 0.9956\ C_{D_u} + 0.0110\ {C_{L_C}}^2 \end{aligned}\right\} \quad \text{Rudder No 1}$$

$$\left.\begin{aligned} C_{L_C} &= 0.9956\ C_{L_u} \\ \alpha_c &= \alpha_u + 0.7512\ C_{L_C} \\ C_{D_C} &= 0.9956\ C_{D_u} + 0.0107\ {C_{L_C}}^2 \end{aligned}\right\} \quad \text{Rudder No 2}$$

$$\left.\begin{aligned} C_{L_C} &= 0.9956\ C_{L_u} \\ \alpha_c &= \alpha_u + 0.7552\ C_{L_C} \\ C_{D_C} &= 0.9956\ C_{D_u} + 0.0108\ {C_{L_C}}^2 \end{aligned}\right\} \quad \text{Rudder No 3}$$

Where suffixes 'u' and 'c' indicate the uncorrected and corrected values respectively.

The boundary correction to rudder angle α is not applied to the skeg angle β; this correction varies typically from zero up to about 0.7° at maximum rudder angle and, without cross-fairing, its application would not allow direct comparison between results for different fixed vlaues of β for variations in rudder angle.

5. PRESENTATION OF DATA

The notation of the angles and coefficients used in the presentation is given in Fig. 2.

The results of the tests are tabulated in non-dimensional form in Appendix A1 and are presented graphically in Figs. 3 to 10. These plots show force coefficients, centre of pressure chordwise (as a percentage of mean chord from leading edge) and centre of pressure spanwise (as a percentage of span from root) versus angle of attack. In the test results the total area of rudder plus skeg is also used in deriving the force coefficients for rudder alone and skeg alone; this allows direct comparisons to be made between the absolute forces on the rudder, skeg and rudder plus skeg.

Fig. 3 shows the results for the all-movable rudders plotted to a base of α, the rudder angle relative to the wind.

Figs. 4, 5, 6 and 7 show the results of tests on Rudder No 1 to determine the influences of Reynolds number, rudder root gap, the transition strip and sealing the gaps between rudder and skeg.

In Figs. 8a to 8g the results for Rudder No 2 for both rudder plus skeg and rudder along are plotted to a base of α, the angle of rudder relative to wind, for various fixed values of skeg angle β.

In Figs. 9a to 9g the results for Rudder No 3 for both rudder plus skeg and rudder along are plotted to a base of α, the angle of rudder relative to wind, for various fixed values of skeg angle β.

Fig. 10 compares the force coefficients and centre of pressure location at skeg angle $\beta = -0.25^{\circ}$ for the three skeg rudders.

6. DISCUSSION OF RESULTS

6.1 All-movable Rudders : Rudder Nos 1, 2 and 3 :

The results for the simulated all-movable rudders are shown in Fig. 3. The results for Rudder No 1 are for repeat experiments and, except near stall, show insignificant differences compared with the earlier results presented in Ref. 1; the maximum lift coefficient has increased from 0.91 to 0.95 and the drag coefficient at stall has decreased from about 0.17 to 0.14. When compared with other published data, however, these changes tend to lead to slightly better agreement than that reported in Ref. 1 for the original tests.

It is seen from Fig. 3 that there are no significant differences between the lift and drag characteristics for all three rudders. Published free stream experiments on all-movable control surfaces would suggest that as taper ratio is increased, small increases in maximum lift and stall angle would be expected. The present experiments do not substantiate this trend.

No significant differences were observed between the three rudders for chordwise centre of pressure, $CP_{\bar{c}}$. The spanwise centre of pressure, CP_S, is seen to move about 1% S to 2% S down the rudder as taper ratio is increased from 0.59 (Rudder 1) up to 1.00 (Rudder 3), and this is in general agreement with existing published data.

Also included in Fig. 3 is the case of Rudder No 1 (All-Movable) with the gaps between rudder and skeg left open. It is interesting to note that the decrease in lift and increase in drag is relatively small compared with the gaps sealed condition.

6.2 Skeg Rudder Characteristics : Rudder No 1 :

6.2.1 Reynolds Number.

Fig. 4 illustrates the influence of Reynold's Number for Rudder No 1. These results form an extension of, and are in agreement with, the limited tests carried out earlier and reported in Ref. 1.

As would be expected there is no significant change in the lift curve slope with change in Reynold's number Rn. C_{Lmax} and α_{STALL} are increased by small amounts as Rn is increased, which follows expected trends.

It is seen, however, that the reduction in lift curve slope at $\alpha = 10^o$ to 15^o occurs at lower angles of attack as Rn is increased. There is a significant change as Rn is increased from 0.52×10^6 up to 0.90×10^6, but the differences become very small as Rn is further increased up to 1.23×10^6. These results are important in that they show that the data obtained at Rn = 1.1 to 1.2×10^6 (the maximum Rn attainable, and used for the majority of the basic test work) should be free from any significant Reynold's number effect.

The possible significance of the result at low Rn, is considered further in the discussion on gap flow and separation effects in Section 6.5.

6.2.2 Rudder Root Gap :

Fig. 5 shows the influence of varying the gap size between rudder and tunnel floor for Rudder No 1. The differences in results between the smallest gap (1.5 mm) and the largest gap (12 mm) are small.

As gap is increased from 1.5 mm there is a small decrease in lift curve slope up to a rudder angle of attack of about 10^o. Above 10^o there is no simple relationship between gap size and lift. At 25^o the lift coefficient for the 5 mm gap is relatively high and there is no immediate explanation for this. Variations in floor gap flow are likely to have accounted for the small changes in lift above 10^o, and maximum lift recorded, for the different gap sizes.

It is felt that no specific conclusions can be drawn from these tests on gap size. The results do however indicate that small departures from the required nominal 2.5 mm gap, when setting up the experimental rig for the basic test work, will not be of significance.

A useful extension to these tests would be to increase the floor gap size to significantly larger values, say up to 50 mm, in order to simulate typical full scale working situations.

6.2.3 Transition Strip :

Fig. 6 illustrates the influence of the removal of the transition strip for Rudder No 1. The results for the rudder plus skeg condition are in general agreement with those obtained earlier and reported in Ref. 1.

The earlier experiments were extended to include the rudder alone case without transition strip. For the rudder alone it is seen that the attractive force between the rudder and skeg causing the "negative" drag is larger than when the transition strip is fitted; also, the attractive force would appear to be present for much larger angles of attack. This result is consistent with the tentative conclusions drawn in Ref. 1 concerning the relative influences of laminar and turbulent flow on gap flow and separation effects.

The new position of the centre of pressure with the transition strip removed is consistent with the delayed separation aft of the skeg and subsequent new distribution of lift over the rudder.

6.2.4 Sealed Gaps :

The influence of sealing all the gaps between the skeg and movable part of the rudder, for Rudder No 1, are shown in Figs. 7a and 7b.

Fig. 7a, for $\beta = -5.25^{\circ}$, illustrates how the sealed gaps delay separation in the region $\alpha = 10^{\circ}$ to 15° with consequent increase in lift and decrease in drag. Decrease in Reynolds Number further delays the onset of separation. For the higher Reynolds Numbers it is noted that after separation has developed aft of the skeg the lift curve begins to rise again. Similar trends were observed for the $\beta = -0.25^{\circ}$ case, Fig. 7b.

Fig. 7b also shows the results of sealing the vertical gaps on the high and low pressure sides independently. With the low pressure side alone sealed the lift developed is only a little less than with all gaps sealed, and for the high pressure side gap sealed independently there is only a small further loss in lift.

Rudder No 1 was also tested for $\beta = -0.25^{\circ}$ with the horizontal gap alone sealed on the high pressure side, and the results are tabulated in Appendix A.1. Inspection of this data for the horizontal gap sealed condition reveals no significant change in performance characteristics compared with the "all-gaps-open" case. Similarly, tests with a simulated lower pintle between rudder and skeg (by means of plasticine), data for which are tabulated in Appendix A.1, reveal insignificant changes compared with all the other rudder tests in which, for ease of manufacture and satisfactory testing, the pintle was not included.

6.3 Skeg Rudder Characteristics :

6.3.1 Basic Test Results : Rudder No 1

The results of the basic tests on skeg rudder No 1 were presented and fully discussed in Ref. 1.

The discussion drew attention to the discontinuity in the lift and drag curves as separation developed aft of the skeg and the relatively large movement of the centre of pressure compared with the all-movable rudder.

6.3.2 Basic Test Results : Rudder No 2

The lift, drag and centre of pressure characteristics for Rudder No 2 for skeg angles varying from -15.25° to $+14.75^{\circ}$ are shown in Figs. 8a to 8g.

The characteristics show very similar trends to those for Rudder No 1 which were discussed in some detail in Ref. 1.

There is a discontinuity in the rate of increase of lift and drag for both the rudder plus skeg and rudder alone conditions. These discontinuities take place approximately at the completion of early separation of the portion of movable rudder behind the skeg, and are more pronounced as negative angle of attack on the skeg is increased. The relatively large movements of the centre of pressure observed for Rudder No 2 were of a similar magnitude to those recorded for Rudder No 1.

6.3.3 Basic Test Results : Rudder No 3

The lift, drag and centre of pressure characteristics for Rudder No 3 for skeg angles varying from -15.25° to $+14.75^{\circ}$ are shown in Figs. 9a to 9g.

The characteristics show very similar trends to those for Rudder No 1 discussed in some detail in Ref. 1 and Rudder No 2 which were discussed briefly in the last section.

6.3.4 Visual Flow Studies : Rudder No 3

The flow studies for $\beta = 0^{\circ}$ and variation in rudder angle δ were recorded by means of sketches. The flow characteristics generally showed similar trends to those recorded by photographs for Rudder No 1 and presented in Ref. 1, hence it was not felt necessary to present the sketches of the flow for Rudder No 3 in this report. The following general observations on the flow characteristics for Rudder No 3 are however given.

On the back (low pressure) side, separation behind the skeg commenced between $\delta = 3^{\circ}$ and 5°, being located initially aft of the pintle position. By $\delta = 10^{\circ}$ a large area behind the skeg had separated and by 15° complete reversal of the tufts (and hence separation) had ocurred behind the skeg. With further increase in angle of attack separation commenced on, and moved over, the upper 'all-movable' portion of the rudder until at $\delta = 35^{\circ}$ complete separation on the low pressure side had ocurred.

On the face (high pressure) side reversal of one tuft into the vertical gap at $\delta = 5^{\circ}$ indicated the start of a strong gap flow; by $\delta = 10^{\circ}$ most of the tufts were reversed into the gap. This complete reversal into the gap ocurred at a much lower angle than that recorded for Rudder No 1.

6.4 Comparison Between the Three Skeg Rudders :

The characteristics for the three skeg rudders, for $\beta = -0.25^{\circ}$, are given in Fig. 10.

The lift curves for the rudder plus skeg combinations are similar up to a rudder angle of atack of about 10°. Above $10^{\circ} - 15^{\circ}$ as taper ratio is increased from 0.59 (Rudder No 1) to 0.80 (Rudder No 2) and then up to 1.00 (Rudder No 3) there is an improvement in the lift developed. This would be expected since increasing taper ratio has the effect of removing area from the less efficient part of the movable rudder aft of the skeg to the more efficient 'all-movable' part of the rudder.

The lift for rudder alone for Rudder Nos 2 and 3 is seen to be less than Rudder No 1 in the range $\alpha = 7\frac{1}{2}^{\circ}$ to 15°. Whilst the lift for Rudder No 3 above 15° is a little larger than Rudder No 1, the lift for Rudder No 2 is less than for Rudder No 1 throughout the whole range. This suggests that separation occurs earlier and is more pronounced for both Rudder Nos 2 and 3.

Similarly for drag, whilst the values for the rudder plus skeg combinations are of the same order of magnitude, for the rudder alone cases the drag for Rudder No 3 is lower, and that for Rudder No 2 significantly lower than that for Rudder No 1. The larger differences in drag between the rudder alone and rudder plus skeg cases for Rudder Nos 2 and 3 compared with Rudder No 1 are also present for the positive angles of attack on the skeg shown in Figs. 8e to 8g and 9e to 9g.

These differences are due, in part, to the attractive force between the movable rudder and skeg as discussed in Ref. 1. Comparison between the three rudders suggests that the gap flows are dissimilar resulting in possible modification to the pressure distributions which in turn could influence the magnitude of the attractive forces.

The results in Fig. 10 for the centre of pressure position also show an irregularity in going from Rudder No 1 to Rudder No 3. Whilst the chordwise centre of pressure $CP_{\bar{c}}$ for Rudder No 2 is approximately the same as Rudder No 1 and has moved aft for Rudder No 3, which would be expected for increase in taper ratio, the spanwise centre of pressure is seen to move towards the tip of the rudder more for Rudder No 2 than Rudder No 3.

The general pattern of differences in lift, drag and centre of pressure characteristics between the three rudders for $\beta = -0.25^{\circ}$ in Fig. 10 was repeated for the other skeg angles tested.

It is evident that separation is dependent on gap flow and that gap flow is likely to be sensitive to the geometry of the gap and the lips of the skeg at the entry / exit of the gap. It is concluded from the data available at present that the relatively small manufacturing differences which existed between the skegs and gaps of the rudders tested were probably responsible for some of the differences recorded between the rudder alone characteristics for the three rudders.

6.5 Separation and Gap Effects :

Discontinuities in the lift and drag curves, illustrated in Figs. 8a to g and 9a to g are evidently due to early separation behind the skeg.

Flow through the vertical gap from high pressure side to low pressure side is evident from the visual studies described in Ref. 1 for Rudder No 1 and in Section 6.3.4 of this Report for Rudder No 3. The visual studies also indicated that this gap flow was associated with early separation behind the skeg. Whilst slots have been successfully used for the boundary layer control of flapped aircraft control surfaces, such slots are usually asymmetric. It is also a well tested and documented fact that, unless very carefully designed, the flow through the slot (gap) is likely to stimulate rather than suppress flow breakaway over the flap. It has generally been found for aircraft plain flaps (analogous to the skeg rudders under discussion) that the gap precipitates the stalling of the flap, the presence of a gap allowing a flow of air over the nose of the flap which tends to reduce the pressure peaks that exist at the hinge axis when the gap is sealed; hence the early separation aft of the skeg observed on these skeg rudders follows expected trends. It was also observed that tests on the all-movable rudder (without flap hinge axis pressure peaks) with all gaps open (Section 6.1 and Fig. 3) showed no discontinuities in the performance characteristics, and changes in lift and drag were relatively small compared with the all-movable gaps sealed condition.

Tests on skeg Rudder No 1 with only the horizontal gap sealed had very little influence on the performance characteristics whereas sealing the vertical gap alone led to a significant improvement in performance up to the stall angle.

The results for the high or low pressure sides of the vertical gap sealed independently are shown in Fig. 7b. and were discussed in Section 6.2.4. In each case the lift developed is only a little lower than for all gaps sealed, and is significantly higher than for all gaps open, although the sealed gaps had little influence on the maximum lift attained. This result is important in that it follows that any form of seal in the vertical gap is likely to lead to a significant improvement in the lift developed by skeg rudders between rudder angles of attack of about $7\frac{1}{2}^{\circ}$ and stall angle.

The results for the high pressure side alone sealed also indicate that, whilst the gap flow from high pressure to low pressure side is a contributory cause in the development of separation, the discontinuity on the surface on the low pressure side in way of the gap does not appear to have a marked influence.

The tuft studies described in Section 6.3.4 indicated earlier gap flow for Rudder No 3 than for Rudder No 1. This result, which confirms the measured differences in the rudder alone characteristics between the three rudders indicates that the gap flow (e.g. ability of fluid on high pressure side to turn into gap) is very sensitive to gap and skeg lip geometry which did vary by small amounts between the three rudders.

The results shown in Fig. 6 for Rudder No 1 at $\beta = -0.25^{\circ}$ without the transition strip are similar to those recorded earlier and discussed in Ref. 1. Namely, extended laminar flow is likely without the use of roughness and, with the thin turbulent boundary layer which then develops downstream, separation is likely to be delayed. The delayed separation observed for Rudder No 1 with transition strip but at the low Reynold's Number of 0.52×10^{6} (Fig. 4 and Section 6.2.1) is likely to have ocurred due to a similar extension of the laminar flow. Further, the reduced momentum in the laminar boundary layer in the case of the tests without transition strip, or the extended laminar boundary layer for the reduced Reynold's Number case, is less capable of promoting gap flow.

It is to be noted that whilst the tests without transition strip and at low Reynold's Number help to provide an understanding of the operation of the skeg rudder, the Reynold's Numbers for ships (even at low speed) and the turbulent nature of the water in way of rudder are likely to lead to turbulent flow in all realistic full scale cases.

7. CONCLUSIONS AND RECOMMENDATIONS

7.1 All-Movable Rudders :

Only small differences were recorded between the three simulated all-movable rudders of different taper ratio. The principal change was in the spanwise centre of pressure which moved towards the tip of the rudder a small amount (up to 2% of the span) with increasing taper ratio. This effect should be given consideration when calculating the bending moments on all-movable (spade) rudders.

7.2 Variations in Reynold's Number :

Above a Reynold's Number of about 1.0×10^6 no significant changes in rudder characteristics up to stall were observed. This confirms the findings of other published work on the free stream characteristics of lifting surfaces. Some increase in α_{STALL} and C_{Lmax} would be expected with further increase in Reynold's Number, but the test facilities used for the present work limited the maximum Reynold's Number to about 1.2×10^6.

7.3 Rudder Root Gap :

The majority of tests were carried out with a nominal root gap of 2.5 mm (0.0055 $\bar{c}$). Variation in gap size between 1.5 mm and 12 mm had a very small influence on the skeg rudder characteristics. It may be concluded that any small errors in setting up the nominal 2.5 mm root gap are likely to have no significant effect on the basic characteristics.

A useful extension to the tests would be to increase the floor gap size in way of the movable part of the rudder to significantly larger values, say up to 50 mm, in order to simulate typical full scale working situations.

7.4 General Skeg Rudder Characteristics :

The general conclusions for Rudder No 1 given in Ref. 1 can similarly be applied to Rudder Nos 2 and 3. The skeg rudder displays a characteristic discontinuity in the growth of lift with increasing angle of attack, the discontinuity being caused by the build up of separation leading to the early stall of the movable part of the rudder behind the skeg. Whilst the maximum lift coefficient developed by the skeg rudder is only a little lower than the equivalent all-movable rudder, its rate of increase of lift for increasing angle of attack is considerably less, and the movement of its centre of pressure is much larger. For the same developed lift, the skeg rudder has much higher drag than the equivalent all-movable rudder.

7.5 Gap Flow :

The force measurements, gap sealed experiments and tuft studies on the rudders showed that the early separation of the movable rudder aft of the skeg was stimulated by gap flow from the high pressure side to the low pressure side of the rudders. The characteristics for the cases of rudder alone did not vary systematically with change in taper ratio for the three rudders which suggests that gap flow is very sensitive to even small variations in gap geometry.

7.6 Sealed Gaps :

The results of the gap sealed tests indicated that only small improvements are made by sealing the horizontal break between skeg and movable rudder. Whilst having little influence on the maximum lift attained, any form of seal in the vertical gap between rudder and skeg is likely to lead to significant improvements in the rate of lift development up to stall by skeg rudders above rudder angles of about $7\frac{1}{2}^{\circ}$. An investigation into the feasibility of sealing the vertical gaps of skeg rudders could therefore be of value; improvements in lift performance would be most beneficial where skeg rudders are to be applied to vessels requiring good manoeuvring characteristics at larger rudder angles of attack and possibly lower speeds.

7.7 Taper Ratio :

The differences between the three skeg rudders tested, having taper ratios of 0.59, 0.80 and 1.00, were not large. The most significant difference was in the lift developed by the rudder plus skeg combinations for which the results showed that increasing the taper ratio improved the lift at larger angles of attack. This would be expected since increasing taper ratio has the effect of removing area from the less efficient part of the movable rudder aft of the skeg to the more efficient 'all-movable' part of the rudder. This increase in lift at larger angles is however associated with a movement of the centre of pressure down the rudder of up to 3% span when going from a taper ratio of 0.59 to a taper ratio of 1.00, with consequent increase in bending moments.

These changes in lift and centre of pressure with increasing taper ratio may be more significant in the full scale case where the ship boundary layer is likely to be relatively thicker than the boundary layer in the wind tunnel.

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NOMENCLATURE

The notation of angles and coefficients is further depicted in Fig. 2.

AR_G	=	Geomtric aspect ratio
C	=	Chord
$\bar{c}$	=	Mean chord
C_T	=	Tip chord
C_R	=	Root chord
$CP_{\bar{c}}$	=	Centre of pressure chordwise, measured from leading edge.
CPs	=	Centre of pressure spanwise, measured from root.
C_D	=	Drag Coefficient
C_L	=	Lift Coefficient
C_{Lmax}	=	Maximum lift coefficient
C_N	=	Normal force coefficient, normal to rudder
C_Y	=	Normal force coefficient, normal to skeg or ship.
Rn	=	Reynolds Number
S	=	Rudder span
t	=	Rudder section thickness
X-Axis	=	Air flow axis = longitudinal axis of tunnel
Xβ-Axis	=	Skeg axis
Y-Axis	=	Axis normal to air flow
Yβ-Axis	=	Axis normal to skeg
α	=	Rudder angle relative to flow
α_{STALL}	=	Rudder stall angle relative to flow
β	=	Skeg angle relative to flow (or ship drift angle at rudder.)
δ	=	Rudder angle relative to skeg, or ship
Ω	=	Sweep of quarter chord

$$\text{Skeg Area Ratio} = \frac{\text{Skeg area (assumed to ℄ of stock)}}{\text{Total area (movable + skeg)}}$$

$$\text{Balance Area Ratio} = \frac{\text{Movable area forward of ℄ of stock}}{\text{Total movable area}}$$

Total Movable Area = Total area (movable + skeg) - Skeg area (assumed to ℄ of stock).

REFERENCES

1. Molland, A.F. : "The Free-Stream Characteristics of a Semi-Balanced Ship Skeg-Rudder". University of Southampton, Ship Science Report No 3/77, 1977.

2. Davies, P.A.O.L. : "The New 7' x 5½' and 15' x 12' Low Speed Wind Tunnel at the University of Southampton." A.A.S.U. Report No 202.

3. Molland, A.F. : "The Design, Construction and Calibration of a Five-Component Strain Gauge Wind Tunnel Dynamometer". University of Southampton, Ship Science Report No. 1/77, 1976.

4. Molland, A.F. : "A Computer Program for the Analysis of Wind Tunnel Control Surface Data". University of Southampton, Ship Science Report No. 2/77, 1977.

5. Pope, A. and Harper, J.J. : "Low Speed Wind Tunnel Testing". John Wiley & Sons Inc.

APPENDIX A1

TABULATED TEST RESULTS : RUDDER No. 1

WIND TUNNEL RUDDER DATA ANALYSIS

RUDDER NUMBER = 1
DATE OF TEST = 2/8/77
WIND SPEED = 31,62 M/S

AA=RUDDER ANGLE,ALPHA(DEG,), AD=RUDDER ANGLE,DELTA(DEG,)
CL=LIFT COEFFIENT, CN=RUDDER NORMAL COEFFICIENT
CY=SHIP NORMAL COEFFIENT, CD=DRAG COEFFICIENT
CPC=C OF P CHORD(%C), CPS=C OF P SPAN(%S)
ALL COEFFICIENTS BASED ON TOTAL AREA OF RUDDER PLUS SKEG

(A)=RUDDER PLUS SKEG, (B)=RUDDER ALONE, (C)=SKEG ALONE

REYNOLDS NO, = 880000

ALL-MOVABLE RUDDER

	AA	AD	CL	CN	CY	CD	CPC	CPS
(A)	-4,98	-,18	-,235	-,236	-,236	,027	16,61	43,5
(A)	-3,94	-,14	-,185	-,186	-,186	,026	16,94	43,32
(A)	-2,9	-,1	-,134	-,135	-,135	,025	21,89	42,49
(A)	-2,87	-,07	-,088	-,089	-,089	,023	16,2	43,92
(A)	-,83	-,03	-,04	-,04	-,04	,018	15,7	42,06
(A)	,21	,01	,01	,01	,011	,018	,37	61,68
(A)	1,25	,05	,059	,059	,059	,018	15,35	49,05
(A)	2,28	,08	,104	,105	,104	,018	14,74	49
(A)	3,31	,11	,147	,148	,147	,018	17,52	47,96
(A)	4,35	,15	,194	,195	,194	,017	15,12	47,25
(A)	5,39	,19	,244	,245	,245	,018	16,75	46,84
(A)	10,58	,38	,487	,486	,486	,04	18,2	46,44
(A)	15,77	,57	,737	,732	,732	,082	20,36	47,26
(A)	20,94	,74	,954	,942	,942	,144	23,68	48,27
(A)	23,38	,68	,876	,9	,898	,242	30,76	39,41
(A)	25,67	,47	,664	,623	,622	,182	28,15	62,9

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LOGGED OUT 10112134 - 03 NOV

WIND TUNNEL RUDDER DATA ANALYSIS

RUDDER NUMBER = 1
DATE OF TEST = 2/8/77
WIND SPEED = 31,68 M/S

AA=RUDDER ANGLE,ALPHA(DEG,), AD=RUDDER ANGLE,DELTA(DEG,)
CL=LIFT COEFFIENT, CN=RUDDER NORMAL COEFFICIENT
CY=SHIP NORMAL COEFFIENT, CD=DRAG COEFFICIENT
CPC=C OF P CHORD(%C), CPS=C OF P SPAN(%S)
ALL COEFFICIENTS BASED ON TOTAL AREA OF RUDDER PLUS SKEG

(A)=RUDDER PLUS SKEG, (B)=RUDDER ALONE, (C)=SKEG ALONE

REYNOLDS NO, = 880000

ALL-MOVABLE RUDDER (GAPS OPEN)

	AA	AD	CL	CN	CY	CD	CPC	CPS
(A)	-1,86	-,06	-,075	-,076	-,076	,025	17,32	43,9
(A)	,21	,01	,007	,007	,007	,021	-48,14	73,82
(A)	5,37	,17	,217	,219	,219	,029	13,4	48
(A)	10,55	,35	,448	,45	,45	,052	18,25	46,67
(A)	15,73	,53	,681	,683	,682	,1	22	47,99
(A)	20,89	,69	,9	,923	,921	,23	26,89	44
(A)	23,28	,58	,756	,802	,8	,271	29,68	57,06

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LOGGED OUT 21143158 - 27 OCT

APPENDIX A1 (CONTINUED)

TABULATED TEST RESULTS : RUDDER No. 1

WIND TUNNEL RUDDER DATA ANALYSIS

RUDDER NUMBER = 1
DATE OF TEST = 3/8/77
WIND SPEED = 18,67 M/S

AA=RUDDER ANGLE,ALPHA(DEG,), AD=RUDDER ANGLE,DELTA(DEG,)
CL=LIFT COEFFIENT, CN=RUDDER NORMAL COEFFICIENT
CY=SHIP NORMAL COEFFIENT, CD=DRAG COEFFICIENT
CPC=C OF P CHORD(%C), CPS=C OF P SPAN(%S)
ALL COEFFICIENTS BASED ON TOTAL AREA OF RUDDER PLUS SKEG

(A)=RUDDER PLUS SKEG, (B)=RUDDER ALONE, (C)=SKEG ALONE

REYNOLDS NO, = 520000

SKEG ANGLE,BETA(DEG,) = -,25

	AA	AD	CL	CN	CY	CD	CPC	CPS
(A)	-5,41	-5,16	-,206	-,209	-,206	,039	25,34	45,1
(A)	-2,83	-2,58	-,108	-,109	-,108	,023	25,14	42,98
(A)	-,27	-,02	-,022	-,022	-,022	,02	40,82	14,2
(A)	2,31	2,56	,08	,081	,08	,025	22,02	52,31
(A)	4,88	5,13	,171	,173	,171	,026	21,17	51,78
(A)	7,47	7,72	,284	,287	,284	,04	24,48	48,66
(A)	10,05	10,3	,391	,394	,391	,054	25,41	48,07
(A)	12,63	12,88	,487	,491	,486	,072	28,59	50,6
(A)	15,14	15,39	,507	,517	,506	,104	31,17	52,94
(A)	17,68	17,93	,554	,567	,554	,13	32,1	54,35
(A)	20,21	20,46	,596	,614	,596	,159	31,96	54,51
(A)	22,76	23,01	,655	,672	,654	,176	32,3	53,19
(A)	25,32	25,57	,734	,755	,733	,214	32,89	52,9
(A)	27,85	28,1	,781	,804	,78	,243	33,97	53,65
(A)	30,39	30,64	,833	,867	,832	,293	34,46	54,05
(A)	32,73	32,98	,628	,718	,626	,351	38,94	45,26

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LOGGED OUT 12:51:16 - 09 NOV.

WIND TUNNEL RUDDER DATA ANALYSIS

RUDDER NUMBER = 1
DATE OF TEST = 3/8/77
WIND SPEED = 31,32 M/S

AA=RUDDER ANGLE,ALPHA(DEG,), AD=RUDDER ANGLE,DELTA(DEG,)
CL=LIFT COEFFIENT, CN=RUDDER NORMAL COEFFICIENT
CY=SHIP NORMAL COEFFIENT, CD=DRAG COEFFICIENT
CPC=C OF P CHORD(%C), CPS=C OF P SPAN(%S)
ALL COEFFICIENTS BASED ON TOTAL AREA OF RUDDER PLUS SKEG

(A)=RUDDER PLUS SKEG, (B)=RUDDER ALONE, (C)=SKEG ALONE

REYNOLDS NO, = 900000

SKEG ANGLE,BETA(DEG,) = -,25

	AA	AD	CL	CN	CY	CD	CPC	CPS
(A)	-5,41	-5,16	-,205	-,207	-,205	,035	24,17	46,97
(A)	-2,83	-2,58	-,105	-,106	-,106	,023	23,05	46,96
(A)	-,26	-,01	-,019	-,019	-,019	,021	32,04	38,73
(A)	2,31	2,56	,08	,081	,08	,022	19,55	47,77
(A)	4,88	5,13	,167	,169	,167	,026	21,07	49,17
(A)	7,46	7,71	,266	,268	,266	,036	24,67	49,74
(A)	10,03	10,28	,364	,368	,364	,057	28,2	48,4
(A)	12,56	12,81	,397	,404	,397	,076	29,99	52,02
(A)	15,08	15,33	,43	,44	,429	,097	30,06	54,53
(A)	17,63	17,88	,494	,506	,494	,117	30,72	54,1
(A)	20,2	20,45	,583	,598	,582	,148	31,92	53,38
(A)	22,76	23,01	,657	,672	,656	,172	32,5	52,83
(A)	25,31	25,56	,723	,743	,722	,21	33,1	52,99
(A)	27,84	28,09	,76	,787	,759	,246	34,6	55,05
(A)	30,39	30,64	,832	,868	,831	,298	35,35	51,77
(A)	32,91	33,16	,859	,908	,858	,344	37,3	53,07
(A)	35,23	35,48	,624	,728	,622	,378	40,07	47,18

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TABULATED TEST RESULTS : RUDDER No. 1

WIND TUNNEL RUDDER DATA ANALYSIS

RUDDER NUMBER = 1
DATE OF TEST = 3/8/77
WIND SPEED = 36,94 M/S

AA=RUDDER ANGLE,ALPHA(DEG.), AD=RUDDER ANGLE,DELTA(DEG.)
CL=LIFT COEFFIENT, CN=RUDDER NORMAL COEFFICIENT
CY=SHIP NORMAL COEFFIENT, CD=DRAG COEFFICIENT
CPC=C OF P CHORD(%C), CPS=C OF P SPAN(%S)
ALL COEFFICIENTS BASED ON TOTAL AREA OF RUDDER PLUS SKEG

(A)=RUDDER PLUS SKEG, (B)=RUDDER ALONE, (C)=SKEG ALONE

REYNOLDS NO. = 1,01000E+06

SKEG ANGLE,BETA(DEG.) = -,25

	AA	AD	CL	CN	CY	CD	CPC	CPS
(A)	-5,41	-5,16	-,202	-,204	-,202	,033	24,49	47,74
(A)	-2,83	-2,58	-,104	-,105	-,104	,023	22,8	82,61
(A)	-,26	-,01	-,019	-,019	-,019	,02	32,58	36,11
(A)	2,31	2,56	,077	,078	,077	,023	18,71	50,14
(A)	4,88	5,13	,17	,172	,169	,025	21,83	46,99
(A)	7,46	7,71	,267	,27	,267	,038	24,78	49,33
(A)	10,02	10,27	,351	,356	,351	,057	28,03	49,74
(A)	12,55	12,8	,392	,4	,392	,078	30	51,46
(A)	15,08	15,33	,433	,444	,432	,099	30,27	53,44
(A)	17,63	17,88	,493	,506	,492	,118	30,61	53,28
(A)	20,2	20,45	,585	,598	,584	,142	31,78	53,05
(A)	22,75	23	,65	,667	,649	,176	32,32	53,11
(A)	25,31	25,56	,725	,745	,724	,21	33	53,16
(A)	27,84	28,09	,769	,793	,768	,243	34,66	54,11
(A)	30,39	30,64	,825	,865	,824	,303	35,51	53,35
(A)	32,91	33,16	,862	,912	,86	,346	37,42	53,56
(A)	35,23	35,48	,622	,732	,621	,389	40,34	46,65

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WIND TUNNEL RUDDER DATA ANALYSIS

RUDDER NUMBER = 1
DATE OF TEST = 3/8/77
WIND SPEED = 43,64 M/S

AA=RUDDER ANGLE,ALPHA(DEG.), AD=RUDDER ANGLE,DELTA(DEG.)
CL=LIFT COEFFIENT, CN=RUDDER NORMAL COEFFICIENT
CY=SHIP NORMAL COEFFIENT, CD=DRAG COEFFICIENT
CPC=C OF P CHORD(%C), CPS=C OF P SPAN(%S)
ALL COEFFICIENTS BASED ON TOTAL AREA OF RUDDER PLUS SKEG

(A)=RUDDER PLUS SKEG, (B)=RUDDER ALONE, (C)=SKEG ALONE

REYNOLDS NO. = 1,14000E+06

SKEG ANGLE,BETA(DEG.) = -,25

	AA	AD	CL	CN	CY	CD	CPC	CPS
(A)	-5,4	-5,15	-,201	-,203	-,201	,035	24,15	47,59
(A)	-2,83	-2,56	-,106	-,107	-,106	,024	23,21	45,64
(A)	-,27	-,02	-,02	-,02	-,02	,021	33,23	30,78
(A)	2,31	2,56	,076	,077	,076	,021	19,24	49,31
(A)	4,87	5,12	,162	,164	,162	,025	21,09	49,97
(A)	7,46	7,71	,267	,27	,267	,037	24,94	48,18
(A)	10,02	10,27	,349	,353	,349	,054	28,57	49,2
(A)	12,55	12,8	,386	,395	,385	,082	29,9	52,35
(A)	15,08	15,33	,434	,444	,434	,097	30,22	53,01
(A)	17,63	17,88	,493	,506	,492	,12	30,61	54,48
(A)	20,18	20,43	,562	,576	,562	,14	31,48	54,45
(A)	22,75	23	,645	,661	,644	,172	32,29	53,52
(A)	25,3	25,55	,713	,735	,712	,211	33,22	53,61
(A)	27,85	28,1	,781	,81	,78	,256	35,03	51,42
(A)	30,38	30,63	,822	,862	,821	,302	36,17	53,16
(A)	32,91	33,16	,851	,902	,85	,346	37,14	52,5
(A)	35,23	35,48	,621	,733	,619	,392	40,24	46,1

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APPENDIX A1 (CONTINUED)

TABULATED TEST RESULTS : RUDDER No. 1

WIND TUNNEL RUDDER DATA ANALYSIS

RUDDER NUMBER = 1
DATE OF TEST = 18/8/77
WIND SPEED = 42,39 M/S

AA=RUDDER ANGLE,ALPHA(DEG.), AD=RUDDER ANGLE,DELTA(DEG.)
CL=LIFT COEFFIENT, CN=RUDDER NORMAL COEFFICIENT
CY=SHIP NORMAL COEFFIENT, CD=DRAG COEFFICIENT
CPC=C OF P CHORD(%C), CPS=C OF P SPAN(%S)
ALL COEFFICIENTS BASED ON TOTAL AREA OF RUDDER PLUS SKEG

(A)=RUDDER PLUS SKEG, (B)=RUDDER ALONE, (C)=SKEG ALONE

REYNOLDS NO. = 1,22000E+06

SKEG ANGLE,BETA(DEG.) = -,25 (RUDDER ROOT GAP = 1.5mm)

	AA	AD	CL	CN	CY	CD	CPC	CPS
(A)	-2,85	-2,6	-,134	-,135	-,134	,024	26,52	43,55
(A)	-,27	-,02	-,029	-,029	-,029	,02	35,77	35,46
(A)	4,88	5,13	,167	,169	,167	,026	22,01	49,58
(A)	10,04	10,29	,372	,375	,371	,051	27,4	48,97
(A)	12,55	12,8	,388	,395	,388	,075	29,56	50,17
(A)	15,09	15,34	,444	,454	,444	,097	30,46	53
(A)	20,19	20,44	,576	,589	,576	,141	31,9	53,94
(A)	25,31	25,56	,72	,739	,719	,207	33,19	53,4
(A)	30,39	30,64	,83	,868	,829	,3	36,16	52,61
(A)	32,9	33,15	,838	,895	,837	,352	37,04	54,77
(A)	35,42	35,67	,865	,934	,863	,396	37,98	52,85
(A)	37,95	38,2	,654	,778	,652	,427	40,95	47,42

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WIND TUNNEL RUDDER DATA ANALYSIS

RUDDER NUMBER = 1
DATE OF TEST = 18/8/77
WIND SPEED = 42,87 M/S

AA=RUDDER ANGLE,ALPHA(DEG.), AD=RUDDER ANGLE,DELTA(DEG.)
CL=LIFT COEFFIENT, CN=RUDDER NORMAL COEFFICIENT
CY=SHIP NORMAL COEFFIENT, CD=DRAG COEFFICIENT
CPC=C OF P CHORD(%C), CPS=C OF P SPAN(%S)
ALL COEFFICIENTS BASED ON TOTAL AREA OF RUDDER PLUS SKEG

(A)=RUDDER PLUS SKEG, (B)=RUDDER ALONE, (C)=SKEG ALONE

REYNOLDS NO. = 1,19000E+06

SKEG ANGLE,BETA(DEG.) = -,25 (RUDDER ROOT GAP = 2.5mm)

	AA	AD	CL	CN	CY	CD	CPC	CPS
(A)	-2,85	-2,6	-,13	-,131	-,13	,024	25,84	45,29
(A)	-,27	-,02	-,026	-,026	-,026	,02	33,83	38,49
(A)	4,88	5,13	,165	,167	,165	,027	22,16	49,22
(A)	10,03	10,28	,369	,373	,368	,055	28,14	47,35
(A)	12,54	12,79	,377	,385	,376	,076	29,88	50,65
(A)	15,09	15,34	,435	,446	,435	,099	30,36	53,49
(A)	20,2	20,45	,578	,592	,577	,143	31,72	53,37
(A)	25,3	25,55	,713	,734	,712	,209	33,21	53,43
(A)	30,37	30,62	,81	,851	,808	,3	36,09	54,4
(A)	32,91	33,16	,86	,911	,859	,347	36,94	52,77
(A)	35,42	35,67	,868	,937	,866	,397	37,75	51,79
(A)	37,95	38,2	,646	,776	,644	,434	40,85	46,31

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REYNOLDS NO. = 1,19000E+06

SKEG ANGLE,BETA(DEG.) = -,25 (RUDDER ROOT GAP = 5mm)

	AA	AD	CL	CN	CY	CD	CPC	CPS
(A)	-,27	-,02	-,024	-,024	-,024	,019	31,5	36,94
(A)	4,88	5,13	,163	,165	,163	,028	22,17	49,65
(A)	10,03	10,28	,364	,367	,364	,052	28,05	49,21
(A)	12,54	12,79	,379	,386	,378	,075	30,18	51,76
(A)	15,08	15,33	,43	,441	,43	,099	31,09	54,39
(A)	20,22	20,47	,61	,623	,61	,146	32,34	50,33
(A)	25,35	25,6	,776	,795	,776	,22	34,4	51,01
(A)	30,37	30,62	,8	,838	,799	,292	36,12	54,83
(A)	35,4	35,65	,846	,92	,845	,398	38,02	53,23

REYNOLDS NO. = 1,19000E+06

SKEG ANGLE,BETA(DEG.) = -,25 (RUDDER ROOT GAP = 12mm)

	AA	AD	CL	CN	CY	CD	CPC	CPS
(A)	-,26	-,01	-,019	-,019	-,019	,022	38,69	59
(A)	4,87	5,12	,152	,154	,152	,029	21,82	52,22
(A)	10,03	10,28	,363	,367	,363	,053	27,96	49,6
(A)	12,56	12,81	,406	,414	,406	,08	31,01	52,19
(A)	15,11	15,36	,461	,472	,46	,104	31,9	53,13
(A)	20,2	20,45	,588	,605	,588	,154	33,11	55,32
(A)	25,31	25,56	,723	,746	,722	,216	34,12	53,57
(A)	30,41	30,66	,854	,895	,852	,313	37,05	51,46
(A)	35,44	35,69	,894	,961	,892	,401	38,4	52,65
(A)	37,95	38,2	,642	,775	,64	,437	42,62	46,01

APPENDIX A1 (CONTINUED)

TABULATED TEST RESULTS : RUDDER NO.1

WIND TUNNEL RUDDER DATA ANALYSIS

RUDDER NUMBER = 1
DATE OF TEST = 19/8/77
WIND SPEED = 42,7 M/S

AA=RUDDER ANGLE,ALPHA(DEG,), AD=RUDDER ANGLE,DELTA(DEG,)
CL=LIFT COEFFIENT, CN=RUDDER NORMAL COEFFICIENT
CY=SHIP NORMAL COEFFIENT, CD=DRAG COEFFICIENT
CPC=C OF P CHORD(%C), CPS=C OF P SPAN(%S)
ALL COEFFICIENTS BASED ON TOTAL AREA OF RUDDER PLUS SKEG

(A)=RUDDER PLUS SKEG, (B)=RUDDER ALONE, (C)=SKEG ALONE

REYNOLDS NØ, = 1,20000E+06

SKEG ANGLE,BETA(DEG,) = -,25 (WITHOUT TRANSITION STRIP)

	AA	AD	CL	CN	CY	CD	CPC	CPS
(A)	-,27	-,02	-,027	-,027	-,027	,019	31,99	37,38
(B)	-,27	-,02	-,009	-,009	-,009	-,015	66,6	68,52
(C)	-,27	-,02	-,018			,034	16,11	23,09
(A)	4,88	5,13	,167	,168	,167	,022	21,65	48,69
(B)	4,88	5,13	,129	,128	,129	-,003	24,69	43,86
(C)	4,88	5,13	,038			,025	10,76	66,44
(A)	10.06	10.31	.396	.398	.395	.045	26.04	46.96
(B)	10.06	10.31	.296	.295	.296	.022	31.47	49.22
(C)	10.06	10.31	.1			.023	9.65	41.76
(A)	12,64	12,89	,506	,51	,506	,073	29,02	47,95
(B)	12,64	12,89	,372	,374	,372	,049	34,53	52,23
(C)	12,64	12,89	,134			,024	13,56	37,7
(A)	15,24	15,49	,634	,636	,634	,093	31,32	47,15
(B)	15,24	15,49	,462	,46	,462	,055	37,09	54,94
(C)	15,24	15,49	,172			,038	15,72	28,62
(A)	17,78	18,03	,692	,699	,692	,132	31,97	45,21
(B)	17,78	18,03	,526	,534	,526	,108	39,1	49,82
(C)	17,78	18,03	,166			,024	9,08	30,06
(A)	20.35	20.6	.777	.782	.776	.153	33.14	48.37
(B)	20.35	20.6	.565	.577	.565	.136	40.03	53.85
(C)	20.35	20.6	.212			.017	14.44	33.27
(A)	22,88	23,13	,815	,824	,815	,169	33,92	49,78
(B)	22,88	23,13	,615	,632	,615	,169	40,1	54,75
(C)	22,88	23,13	,2			,02	14,48	34,14
(A)	25,43	25,68	,88	,892	,879	,226	35,26	49,17
(B)	25,43	25,68	,603	,628	,602	,194	40,1	53,98
(C)	25,43	25,68	,277			,032	24,35	36,02
(A)	30,37	30,62	,81	,851	,809	,301	36,23	53,91
(B)	30,37	30,62	,633	,682	,632	,268	42,02	60,9
(C)	30,37	30,62	,177			,033	14	30,17
(A)	35,42	35,67	,87	,931	,869	,383	37,21	51,04
(B)	35,42	35,67	,69	,761	,689	,343	43,53	58,17
(C)	35,42	35,67	,16			,04	16,46	15,66
(A)	38,11	38,36	,858	,934	,856	,42	38,5	53,61
(B)	38,11	38,36	,638	,726	,636	,363	45,97	55,47
(C)	38,11	38,36	,22			,057	13,77	53,66

APPENDIX A1 (CONTINUED)

TABULATED TEST RESULTS : RUDDER No.1

WIND TUNNEL RUDDER DATA ANALYSIS

RUDDER NUMBER = [illegible]
DATE OF TEST = 4/8/77
WIND SPEED = 19,64 M/S

AA=RUDDER ANGLE,ALPHA(DEG,), AD=RUDDER ANGLE,DELTA(DEG,)
CL=LIFT COEFFIENT, CN=RUDDER NORMAL COEFFICIENT
CY=SHIP NORMAL COEFFIENT, CD=DRAG COEFFICIENT
CPC=C OF P CHORD(XC), CPS=C OF P SPAN(XS)
ALL COEFFICIENTS BASED ON TOTAL AREA OF RUDDER PLUS SKEG

(A)=RUDDER PLUS SKEG, (B)=RUDDER ALONE, (C)=SKEG ALONE

REYNOLDS NO, = 520000

SKEG ANGLE,BETA(DEG,) = -5,25 (ALL GAPS SEALED)

	AA	AD	CL	CN	CY	CD	CPC	CPS
(A)	10,08	15,33	,428	,429	,422	,045	29,22	47,14
(A)	15,27	20,52	,671	,67	,661	,085	30,77	48,58
(A)	20,43	25,68	,878	,872	,863	,141	31,16	48,6
(A)	25,35	30,6	,775	,82	,747	,279	38,3	37,48

BYE

***F [illegible] = [illegible]
WIND SPEED = 31,62 M/S

AA=RUDDER ANGLE,ALPHA(DEG,), AD=RUDDER ANGLE,DELTA(DEG,)
CL=LIFT COEFFIENT, CN=RUDDER NORMAL COEFFICIENT
CY=SHIP NORMAL COEFFIENT, CD=DRAG COEFFICIENT
CPC=C OF P CHORD(XC), CPS=C OF P SPAN(XS)
ALL COEFFICIENTS BASED ON TOTAL AREA OF RUDDER PLUS SKEG

(A)=RUDDER PLUS SKEG, (B)=RUDDER ALONE, (C)=SKEG ALONE

REYNOLDS NO, = 880000

SKEG ANGLE,BETA(DEG,) = -5,25 (ALL GAPS SEALED)

	AA	AD	CL	CN	CY	CD	CPC	CPS
(A)	10,1	15,35	,459	,458	,454	,037	29,66	41,71
(A)	15,26	20,51	,664	,661	,654	,073	30,03	48,2
(A)	20,23	25,54	,705	,713	,688	,15	33,95	51,66
(A)	25,2	30,45	,588	,634	,564	,24	38,01	49,39

BYE

***F

WIND TUNNEL RUDDER DATA ANALYSIS

RUDDER NUMBER = 1
DATE OF TEST = 4/8/77
WIND SPEED = 36,73 M/S

AA=RUDDER ANGLE,ALPHA(DEG,), AD=RUDDER ANGLE,DELTA(DEG,)
CL=LIFT COEFFIENT, CN=RUDDER NORMAL COEFFICIENT
CY=SHIP NORMAL COEFFIENT, CD=DRAG COEFFICIENT
CPC=C OF P CHORD(XC), CPS=C OF P SPAN(XS)
ALL COEFFICIENTS BASED ON TOTAL AREA OF RUDDER PLUS SKEG

(A)=RUDDER PLUS SKEG, (B)=RUDDER ALONE, (C)=SKEG ALONE

REYNOLDS NO, = 1,02000E+06

SKEG ANGLE,BETA(DEG,) = -5,25 (ALL GAPS SEALED)

	AA	AD	CL	CN	CY	CD	CPC	CPS
(A)	10,07	15,32	,418	,418	,413	,038	29,11	47,73
(A)	15,26	20,51	,655	,652	,646	,076	30,02	47,97
(A)	20,27	25,52	,676	,683	,661	,141	33,96	50,81
(A)	25,35	30,6	,782	,791	,761	,196	34,09	52,75

BYE

WIND SPEED = 42,74 M/S

AA=RUDDER ANGLE,ALPHA(DEG,), AD=RUDDER ANGLE,DELTA(DEG,)
CL=LIFT COEFFIENT, CN=RUDDER NORMAL COEFFICIENT
CY=SHIP NORMAL COEFFIENT, CD=DRAG COEFFICIENT
CPC=C OF P CHORD(XC), CPS=C OF P SPAN(XS)
ALL COEFFICIENTS BASED ON TOTAL AREA OF RUDDER PLUS SKEG

(A)=RUDDER PLUS SKEG, (B)=RUDDER ALONE, (C)=SKEG ALONE

REYNOLDS NO, = 1,19000E+06

SKEG ANGLE,BETA(DEG,) = -5,25 (ALL GAPS SEALED)

	AA	AD	CL	CN	CY	CD	CPC	CPS
(A)	10,07	15,32	,416	,416	,41	,036	28,9	47,36
(A)	15,26	20,51	,655	,652	,645	,076	29,89	47,64
(A)	20,24	25,49	,641	,65	,626	,14	33,75	54,5
(A)	25,35	30,6	,773	,784	,752	,199	34,08	53,63

BYE

APPENDIX A1 (CONTINUED)

TABULATED TEST RESULTS : RUDDER No.1

WIND TUNNEL RUDDER DATA ANALYSIS

RUDDER NUMBER = 1
DATE OF TEST = 3/8/77,4/8/77
WIND SPEED = 31,74 M/S

AA=RUDDER ANGLE,ALPHA(DEG,), AD=RUDDER ANGLE,DELTA(DEG,)
CL=LIFT COEFFIENT, CN=RUDDER NORMAL COEFFICIENT
CY=SHIP NORMAL COEFFIENT, CD=DRAG COEFFICIENT
CPC=C OF P CHORD(%C), CPS=C OF P SPAN(%S)
ALL COEFFICIENTS BASED ON TOTAL AREA OF RUDDER PLUS SKEG

(A)=RUDDER PLUS SKEG, (B)=RUDDER ALONE, (C)=SKEG ALONE

REYNOLDS NØ, = 874000

SKEG ANGLE,BETA(DEG,) = -,25 (ALL GAPS SEALED)

	AA	AD	CL	CN	CY	CD	CPC	CPS
(A)	4,91	5,16	,205	,206	,205	,022	23,18	47,48
(A)	10,09	10,34	,44	,44	,44	,04	25,06	46,3
(A)	15,27	15,52	,674	,67	,674	,077	27,13	47,61
(A)	20,33	20,58	,748	,752	,747	,146	31,23	49,84
(A)	25,23	25,48	,617	,658	,616	,234	35,48	48,89
(A)	27,76	28,01	,661	,713	,66	,274	36,07	45,62
(A)	30,28	30,53	,684	,747	,683	,31	37,06	46,15

BYE

WIND TUNNEL RUDDER DATA ANALYSIS

RUDDER NUMBER = 1
DATE OF TEST = 3/8/77,4/8/77
WIND SPEED = 18,72 M/S

AA=RUDDER ANGLE,ALPHA(DEG,), AD=RUDDER ANGLE,DELTA(DEG,)
CL=LIFT COEFFIENT, CN=RUDDER NORMAL COEFFICIENT
CY=SHIP NORMAL COEFFIENT, CD=DRAG COEFFICIENT
CPC=C OF P CHORD(%C), CPS=C OF P SPAN(%S)
ALL COEFFICIENTS BASED ON TOTAL AREA OF RUDDER PLUS SKEG

(A)=RUDDER PLUS SKEG, (B)=RUDDER ALONE, (C)=SKEG ALONE

REYNOLDS NØ, = 520000

SKEG ANGLE,BETA(DEG,) = -,25 (ALL GAPS SEALED)

	AA	AD	CL	CN	CY	CD	CPC	CPS
(A)	4,91	5,16	,209	,21	,209	,018	24,35	47,2
(A)	10,1	10,35	,456	,456	,455	,039	25,53	46,51
(A)	15,3	15,55	,707	,704	,707	,084	28,14	47,81
(A)	20,45	20,7	,914	,906	,914	,142	29,09	46,69
(A)	20,3	20,55	,708	,734	,707	,202	31,65	52,96
(A)	25,32	25,57	,733	,786	,731	,289	38,03	44,87
(A)	27,81	28,06	,731	,783	,73	,293	37,53	47,28
(A)	30,31	30,56	,726	,793	,724	,329	37,18	44,71

BYE

REYNOLDS NØ, = 1,02000E+06

SKEG ANGLE,BETA(DEG,) = -,25 (ALL GAPS SEALED)

	AA	AD	CL	CN	CY	CD	CPC	CPS
(A)	4,91	5,16	,204	,205	,204	,022	23,06	46,73
(A)	10,08	10,33	,432	,432	,432	,038	24,83	47,16
(A)	15,27	15,52	,672	,668	,672	,076	27,01	47,14
(A)	20,31	20,56	,727	,731	,727	,142	31,33	50,97
(A)	25,23	25,48	,626	,67	,625	,243	35,26	47,26
(A)	27,76	28,01	,658	,708	,657	,269	36,03	46,02
(A)	30,27	30,52	,673	,735	,672	,306	36,5	47,64

BYE

***F

REYNOLDS NØ, = 1,18000E+06

SKEG ANGLE,BETA(DEG,) = -,25 (ALL GAPS SEALED)

	AA	AD	CL	CN	CY	CD	CPC	CPS
(A)	4,91	5,16	,203	,204	,203	,021	22,77	46,4
(A)	10.08	10.33	.43	.43	.43	.038	24.73	47.19
(A)	15,26	15,51	,667	,663	,666	,075	27,01	47,61
(A)	20,31	20,56	,721	,724	,72	,138	31,25	51,1
(A)	25,4	25,65	,839	,846	,838	,206	31,95	53
(A)	27,76	28,01	,657	,708	,658	,271	35,89	45,46
(A)	30,27	30,52	,672	,739	,67	,314	36,57	46,52

BYE

***F

APPENDIX A1 (CONTINUED)

TABULATED TEST RESULTS : RUDDER No.1

WIND TUNNEL RUDDER DATA ANALYSIS

RUDDER NUMBER = 1
DATE OF TEST = 3/8/77
WIND SPEED = 18,75 M/S

AA=RUDDER ANGLE,ALPHA(DEG.), AD=RUDDER ANGLE,DELTA(DEG.)
CL=LIFT COEFFIENT, CN=RUDDER NORMAL COEFFICIENT
CY=SHIP NORMAL COEFFIENT, CD=DRAG COEFFICIENT
CPC=C OF P CHORD(%C), CPS=C OF P SPAN(%S)
ALL COEFFICIENTS BASED ON TOTAL AREA OF RUDDER PLUS SKEG

(A)=RUDDER PLUS SKEG, (B)=RUDDER ALONE, (C)=SKEG ALONE

REYNOLDS NO. = 510000

SKEG ANGLE,BETA(DEG.) = -,25 (ALL GAPS SEALED,WITHOUT TRANSITION STRIP)

	AA	AD	CL	CN	CY	CD	CPC	CPS
(A)	10,11	10,36	,467	,468	,466	,047	26,98	46,18
(A)	15,32	15,57	,734	,73	,734	,085	28,59	47,01

BYE

***F
***F

WIND TUNNEL RUDDER DATA ANALYSIS

RUDDER NUMBER = 1
DATE OF TEST = 3/8/77
WIND SPEED = 31,8 M/S

AA=RUDDER ANGLE,ALPHA(DEG.), AD=RUDDER ANGLE,DELTA(DEG.)
CL=LIFT COEFFIENT, CN=RUDDER NORMAL COEFFICIENT
CY=SHIP NORMAL COEFFIENT, CD=DRAG COEFFICIENT
CPC=C OF P CHORD(%C), CPS=C OF P SPAN(%S)
ALL COEFFICIENTS BASED ON TOTAL AREA OF RUDDER PLUS SKEG

(A)=RUDDER PLUS SKEG, (B)=RUDDER ALONE, (C)=SKEG ALONE

REYNOLDS NO. = 870000

SKEG ANGLE,BETA(DEG.) = -,25 (ALL GAPS SEALED,WITHOUT TRANSITION STRIP)

	AA	AD	CL	CN	CY	CD	CPC	CPS
(A)	10,11	10,36	,464	,464	,464	,039	26,12	46,32
(A)	15,3	15,55	,717	,712	,717	,076	27,76	47,59

BYE

***F

WIND TUNNEL RUDDER DATA ANALYSIS

RUDDER NUMBER = 1
DATE OF TEST = 3/8/77
WIND SPEED = 35.94 M/S

AA=RUDDER ANGLE,ALPHA(DEG.), AD=RUDDER ANGLE,DELTA(DEG.)
CL=LIFT COEFFIENT, CN=RUDDER NORMAL COEFFICIENT
CY=SHIP NORMAL COEFFIENT, CD=DRAG COEFFICIENT
CPC=C OF P CHORD(%C), CPS=C OF P SPAN(%S)
ALL COEFFICIENTS BASED ON TOTAL AREA OF RUDDER PLUS SKEG

(A)=RUDDER PLUS SKEG, (B)=RUDDER ALONE, (C)=SKEG ALONE

REYNOLDS NO. = 1,01000E+06

SKEG ANGLE,BETA(DEG.) = -,25 (ALL GAPS SEALED,WITHOUT TRANSITION STRIP)

	AA	AD	CL	CN	CY	CD	CPC	CPS
(A)	10.11	10,36	,463	,462	,463	,038	26.07	45,88
(A)	15,31	15.56	.721	,715	,72	,076	27,67	46,8

BYE

***F
***F

WIND TUNNEL RUDDER DATA ANALYSIS

RUDDER NUMBER = 1
DATE OF TEST = 3/8/77
WIND SPEED = 42,98 M/S

AA=RUDDER ANGLE,ALPHA(DEG.), AD=RUDDER ANGLE,DELTA(DEG.)
CL=LIFT COEFFIENT, CN=RUDDER NORMAL COEFFICIENT
CY=SHIP NORMAL COEFFIENT, CD=DRAG COEFFICIENT
CPC=C OF P CHORD(%C), CPS=C OF P SPAN(%S)
ALL COEFFICIENTS BASED ON TOTAL AREA OF RUDDER PLUS SKEG

(A)=RUDDER PLUS SKEG, (B)=RUDDER ALONE, (C)=SKEG ALONE

REYNOLDS NO. = 1,18000E+06

SKEG ANGLE,BETA(DEG.) = -,25 (ALL GAPS SEALED,WITHOUT TRANSITION STRIP)

	AA	AD	CL	CN	CY	CD	CPC	CPS
(A)	10,1	10,35	,459	,459	,459	,038	25,91	46,2
(A)	15,3	15,55	,715	,709	,714	,075	27,53	47,13

BYE

***F

WIND TUNNEL RUDDER DATA ANALYSIS

RUDDER NUMBER = 1
DATE OF TEST = 19/8/77
WIND SPEED = 42,54 M/S

AA=RUDDER ANGLE,ALPHA(DEG,), AD=RUDDER ANGLE,DELTA(DEG,)
CL=LIFT COEFFIENT, CN=RUDDER NORMAL COEFFICIENT
CY=SHIP NORMAL COEFFIENT, CD=DRAG COEFFICIENT
CPC=C OF P CHORD(%C), CPS=C OF P SPAN(%S)
ALL COEFFICIENTS BASED ON TOTAL AREA OF RUDDER PLUS SKEG

(A)=RUDDER PLUS SKEG, (B)=RUDDER ALONE, (C)=SKEG ALONE

REYNOLDS NO, = 1,22000E+06

SKEG ANGLE,BETA(DEG,) = -,25 (VERTICAL GAP SEALED,ONE SIDE)

		AA	AD	CL	CN	CY	CD	CPC	CPS
(LOW PRESSURE SIDE)	(A)	4,88	5,13	,175	,177	,175	,026	22,32	48,19
	(A)	10,06	10,31	,405	,408	,404	,053	27,27	47,26
	(A)	15,19	15,44	,576	,583	,576	,104	25,63	52,5
	(A)	20,33	20,58	,755	,761	,755	,154	32,83	48,76
	(A)	25,35	25,6	,779	,797	,779	,217	36,3	54,54
	(A)	27,87	28,12	,801	,829	,8	,258	34,83	53,5
(HIGH PRESSURE SIDE)	(A)	4,89	5,14	,177	,178	,177	,025	22,76	47,95
	(A)	10,05	10,3	,392	,395	,392	,051	26,67	47,66
	(A)	15,15	15,4	,524	,533	,523	,104	30,2	49,63
	(A)	20,23	20,48	,627	,641	,626	,153	31,77	50,82
	(A)	20,33	20,58	,748	,756	,748	,157	32,7	47,72
	(A)	25,41	25,66	,857	,873	,856	,231	34,88	49,26

REYNOLDS NO, = 1,21000E+06

SKEG ANGLE,BETA(DEG,) = -,25 (HORIZONTAL GAP SEALED, HIGH PRESSURE SIDE)

		AA	AD	CL	CN	CY	CD	CPC	CPS
	(A)	7,46	7,71	,271	,273	,271	,036	25,1	49.3
	(A)	12,57	12,82	,417	,423	,416	,072	30,14	51,01
	(A)	17,65	17,9	,524	,536	,524	,121	31,43	52,17
	(A)	22,77	23,02	,675	,694	,674	,186	33,58	53.43
(PLUS VERTICAL GAP IN-WAY OF PINTLE)	(A)	12,61	12,86	,462	,464	,462	,062	29,81	50,31
	(A)	17,66	17,91	,535	,544	,534	,113	30,41	53,24
	(A)	22,8	23,05	,71	,721	,709	,172	32,19	51,27

WIND TUNNEL RUDDER DATA ANALYSIS

RUDDER NUMBER = 1
DATE OF TEST = 5/8/77
WIND SPEED = 42,21 M/S

AA=RUDDER ANGLE,ALPHA(DEG,), AD=RUDDER ANGLE,DELTA(DEG,)
CL=LIFT COEFFIENT, CN=RUDDER NORMAL COEFFICIENT
CY=SHIP NORMAL COEFFIENT, CD=DRAG COEFFICIENT
CPC=C OF P CHORD(%C), CPS=C OF P SPAN(%S)
ALL COEFFICIENTS BASED ON TOTAL AREA OF RUDDER PLUS SKEG

(A)=RUDDER PLUS SKEG, (B)=RUDDER ALONE, (C)=SKEG ALONE

REYNOLDS NO, = 1,23000E+06

SKEG ANGLE,BETA(DEG,) = -,25 (PINTLE SIMULATED)

	AA	AD	CL	CN	CY	CD	CPC	CPS
(A)	-,27	-,02	-,022	-,022	-,022	,021	29,9	34,91
(A)	4,83	5,13	,17	,172	,17	,026	23,02	49,01
(A)	7,46	7,71	,273	,275	,273	,036	25,17	48,63
(A)	10,04	10,29	,377	,38	,376	,053	28,15	48,98
(A)	12,57	12,82	,41	,416	,41	,074	30,33	51,56
(A)	15,1	15,35	,452	,462	,451	,098	30,71	52,12
(A)	17,65	17,9	,515	,527	,515	,118	31,2	52,56
(A)	20,21	20,46	,593	,606	,592	,144	31,81	52,37
(A)	22,77	23,02	,673	,688	,672	,174	32,68	52,49
(A)	25,31	25,56	,728	,749	,727	,212	33,43	52,66
(A)	27,86	28,11	,795	,822	,794	,255	34,91	51,6
(A)	30,38	30,63	,811	,857	,809	,311	36,43	53,75
(A)	32,9	33,15	,846	,899	,844	,348	37,21	53,65
(A)	35,23	35,48	,628	,733	,626	,382	39,95	47,1

BYE

APPENDIX A1 (CONTINUED)

TABULATED TEST RESULTS : RUDDER No.2

WIND TUNNEL RUDDER DATA ANALYSIS

RUDDER NUMBER = 2
DATE OF TEST = 18/8/77
WIND SPEED = 31,25 M/S

AA=RUDDER ANGLE,ALPHA(DEG,), AD=RUDDER ANGLE,DELTA(DEG,)
CL=LIFT COEFFIENT, CN=RUDDER NORMAL COEFFICIENT
CY=SHIP NORMAL COEFFIENT, CD=DRAG COEFFICIENT
CPC=C OF P CHORD(%C), CPS=C OF P SPAN(%S)
ALL COEFFICIENTS BASED ON TOTAL AREA OF RUDDER PLUS SKEG

(A)=RUDDER PLUS SKEG, (B)=RUDDER ALONE, (C)=SKEG ALONE

REYNOLDS NO, = 900000

ALL-MOVABLE RUDDER

	AA	AD	CL	CN	CY	CD	CPC	CPS
(A)	-1,86	-,06	-,084	-,085	-,085	,017	11,72	39,92
(A)	-,83	-,03	-,037	-,037	-,037	,016	3,92	31,45
(A)	,21	,01	,011	,011	,011	,016	32,44	93,89
(A)	5,39	,19	,25	,251	,251	,018	18,57	47,39
(A)	10,57	,37	,493	,492	,492	,039	19,06	47,8
(A)	15,76	,56	,742	,736	,735	,079	20,57	47,49
(A)	18,34	,64	,855	,846	,846	,11	22,37	48,03
(A)	19,88	,68	,9	,899	,898	,154	23,97	46,33
(A)	20,91	,71	,948	,949	,947	,177	25,87	43,03
(A)	23,3	,6	,793	,81	,809	,207	30,73	46,37
(A)	24,81	,61	,808	,843	,841	,26	29,75	49

BYE

TABULATED TEST RESULTS : RUDDER No. 2

WIND TUNNEL RUDDER DATA ANALYSIS

RUDDER NUMBER = 2
DATE OF TEST = 16/8/77,17/8/77
WIND SPEED = 42,89 M/S

AA=RUDDER ANGLE,ALPHA(DEG,), AD=RUDDER ANGLE,DELTA(DEG,)
CL=LIFT COEFFIENT, CN=RUDDER NORMAL COEFFICIENT
CY=SHIP NORMAL COEFFIENT, CD=DRAG COEFFICIENT
CPC=C OF P CHORD(%C), CPS=C OF P SPAN(%S)
ALL COEFFICIENTS BASED ON TOTAL AREA OF RUDDER PLUS SKEG

(A)=RUDDER PLUS SKEG, (B)=RUDDER ALONE, (C)=SKEG ALONE

REYNOLDS NØ,. = 1,17000E+06

SKEG ANGLE,BETA(DEG,) = -,25

	AA	AD	CL	CN	CY	CD	CPC	CPS
(A)	-5,37	-5,12	-,155	-,158	-,155	,036	23,57	50,55
(B)	-5,37	-5,12	-,115	-,115	-,115	,002	24,81	62,92
(C)	-5,37	-5,12	-,04			,034	19,22	17,94
(A)	-2,82	-2,57	-,087	-,088	-,087	,024	17,8	47,41
(B)	-2,82	-2,57	-,063	-,062	-,063	-,012	20,6	63,44
(C)	-2,82	-2,57	-,024			,036	9,09	-6,3
(A)	-,26	-,01	-,011	-,011	-,011	,019	11,82	33,61
(B)	-,26	-,01	-,006	-,006	-,006	-,015	13,26	40,26
(C)	-,26	-,01	-,005			,034	10,18	25,98
(A)	2,31	2,56	,08	,081	,08	,019	22,56	54,12
(B)	2,31	2,56	,055	,054	,055	-,013	22,35	62,41
(C)	2,31	2,56	,025			,032	22,3	37,72
(A)	4,87	5,12	,155	,157	,155	,025	21,91	52,61
(B)	4,87	5,12	,113	,112	,113	-,006	27,14	61,25
(C)	4,87	5,12	,042			,031	7,22	31,44
(A)	7,44	7,69	,249	,252	,249	,038	27,26	51,1
(B)	7,44	7,69	,177	,177	,177	,015	30,7	61,27
(C)	7,44	7,69	,072			,023	18,42	26,92
(A)	9,97	10,22	,294	,299	,294	,055	28,68	55,45
(B)	9,97	10,22	,218	,22	,218	,032	33,57	63,36
(C)	9,97	10,22	,076			,023	14,13	33,36
(A)	12,51	12,76	,351	,359	,35	,074	28,96	56,42
(B)	12,51	12,76	,269	,273	,268	,05	33,06	63,55
(C)	12,51	12,76	,082			,024	15,08	34,53
(A)	15,07	15,32	,421	,429	,421	,085	28,94	56,11
(B)	15,07	15,32	,319	,325	,319	,067	33,52	63,45
(C)	15,07	15,32	,102			,018	14,33	33,29
(A)	17,63	17,88	,509	,519	,509	,111	29,95	56,41
(B)	17,63	17,88	,377	,385	,376	,086	34,52	65,36
(C)	17,63	17,88	,132			,025	16,62	31,6
(A)	20,19	20,44	,592	,603	,592	,136	30,78	55,42
(B)	20,19	20,44	,439	,45	,439	,111	35,96	63,92
(C)	20,19	20,44	,153			,025	15,58	30,83
(A)	22,75	23	,671	,683	,671	,167	31,86	55,21
(B)	22,75	23	,509	,523	,508	,139	37,05	63,29
(C)	22,75	23	,162			,028	15,21	29,97
(A)	25,31	25,56	,74	,75	,74	,19	32,64	54,17
(B)	25,31	25,56	,543	,563	,542	,168	37,95	64,52
(C)	25,31	25,56	,197			,022	17,68	22,47
(A)	27,85	28,1	,798	,819	,797	,242	34,18	55,87
(B)	27,85	28,1	,61	,536	,609	,206	39,76	63,76
(C)	27,85	28,1	,188			,236	15,35	28,54
(A)	30,38	30,63	,838	,87	,837	,29	35,65	56,24
(B)	30,38	30,63	,659	,698	,658	,257	41,37	62,4
(C)	30,38	30,63	,179			,033	14,28	32,04
(A)	32,92	33,17	,889	,931	,888	,34	36,99	55,77
(B)	32,92	33,17	,668	,727	,667	,306	43,39	64,51
(C)	32,92	33,17	,221			,034	15,9	24,09
(A)	35,43	35,68	,905	,956	,904	,377	37,21	54,28
(B)	35,43	35,68	,687	,749	,686	,326	43,55	61,96
(C)	35,43	35,68	,218			,051	15,42	29,17
(A)	37,96	38,21	,682	,888	,68	,44	39,8	45,4
(B)	37,96	38,21	,461	,582	,459	,356	48,63	55,36
(C)	37,96	38,21	,221			,084	16,77	22,14

BYE

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DAFM [21 , 1]   23-Jun-79   17:40

WIND TUNNEL RUDDER DATA ANALYSIS

RUDDER NUMBER = 2
DATE OF TEST = 16/8/77,17/8/77
WIND SPEED = 42.91 M/S

AA=RUDDER ANGLE,ALPHA(DEG.), AD=RUDDER ANGLE,DELTA(DEG.)
CL=LIFT COEFFICIENT, CN=RUDDER NORMAL COEFFICIENT
CY=SHIP NORMAL COEFFICIENT, CD=DRAG COEFFICIENT
CPC=C OF P CHORD(%C), CPS=C OF P SPAN(%S)
ALL COEFFICIENTS BASED ON TOTAL AREA OF RUDDER PLUS SKEG

(A)=RUDDER PLUS SKEG, (B)=RUDDER ALONE, (C)=SKEG ALONE

REYNOLDS NO. = .116E 7

SKEG ANGLE,BETA(DEG.) = -5.25

	AA	AD	CL	CN	CY	CD	CPC	CPS
(A)	-7.98	-2.73	-.307	-.311	-.311	.052	20.63	45.09
(B)	-7.98	-2.73	-.178	-.178	-.178	.013	26.5	65.35
(C)	-7.98	-2.73	-.129			.039	12.64	18.04
(A)	-5.41	-.16	-.218	-.22	-.22	.032	15.34	47.31
(B)	-5.41	-.16	-.125	-.124	-.124	-.005	22.97	65.09
(C)	-5.41	-.16	-.093			.037	5.5	24.4
(A)	-2.85	2.4	-.139	-.14	-.141	.024	12.37	43.18
(B)	-2.85	2.4	-.059	-.058	-.057	-.015	19.91	73.49
(C)	-2.85	2.4	-.08			.039	7.51	21.72
(A)	-.29	4.96	-.048	-.048	-.05	.022	-5.28	36.82
(B)	-.29	4.96	.003	.003	.005	-.014	77.7	-145.71
(C)	-.29	4.96	-.051			.036	1.95	24.95
(A)	2.27	7.52	.025	.026	.023	.023	60	84.4
(B)	2.27	7.52	.057	.056	.058	-.014	24.67	48.08
(C)	2.27	7.52	-.032			.037	.01	17.78
(A)	4.83	10.08	.113	.115	.11	.03	36.98	57.48
(B)	4.83	10.08	.124	.123	.124	-.004	31.86	54.08
(C)	4.83	10.08	-.011			.034	-9.75	11.35
(A)	7.39	12.64	.192	.196	.187	.045	37.26	54.9
(B)	7.39	12.64	.179	.18	.177	.017	34.77	53.95
(C)	7.39	12.64	.013			.028	83.08	94.26
(A)	9.93	15.18	.242	.25	.235	.068	36.03	57.23
(B)	9.93	15.18	.222	.226	.217	.043	35.16	56.24
(C)	9.93	15.18	.02			.025	47.34	84.08
(A)	12.48	17.73	.304	.313	.296	.076	34.36	58.37
(B)	12.48	17.73	.268	.274	.262	.056	33.86	60.34
(C)	12.48	17.73	.036			.02	38.19	43.87
(A)	15.03	20.28	.378	.39	.368	.095	33.48	58.12
(B)	15.03	20.28	.32	.327	.312	.07	34.65	64.37
(C)	15.03	20.28	.058			.025	26.34	25.71
(A)	17.6	22.85	.47	.483	.458	.117	33.45	56.11
(B)	17.6	22.85	.389	.398	.379	.09	35.47	63.23
(C)	17.6	22.85	.081			.027	23.01	24.96
(A)	20.16	25.41	.546	.562	.531	.143	33.97	57.28
(B)	20.16	25.41	.444	.458	.432	.119	36.26	61.75
(C)	20.16	25.41	.102			.024	23.31	38.81
(A)	22.71	27.96	.608	.627	.59	.172	34.51	56.45
(B)	22.71	27.96	.493	.51	.478	.142	37.82	63.5
(C)	22.71	27.96	.115			.03	19.36	27.53
(A)	25.25	30.5	.66	.681	.639	.198	34.9	57.66
(B)	25.25	30.5	.526	.549	.508	.171	38.54	64.58
(C)	25.25	30.5	.134			.027	19.71	31.36
(A)	27.81	33.06	.746	.774	.721	.244	35.77	55.98
(B)	27.81	33.06	.596	.626	.574	.211	39.78	64.08
(C)	27.81	33.06	.15			.033	18.76	24.18
(A)	30.37	35.62	.821	.853	.792	.287	36.8	56.5
(B)	30.37	35.62	.648	.685	.623	.25	41.13	64.78
(C)	30.37	35.62	.173			.037	19.37	27.1
(A)	33.1	38.35	.859	.902	.826	.334	38.19	58.16
(B)	33.1	38.35	.687	.74	.657	.302	42.95	64.71
(C)	33.1	38.35	.172			.032	17.34	26.43

DAFM [21 : 1]   27-Jun-78   09:40

WIND TUNNEL RUDDER DATA ANALYSIS

RUDDER NUMBER = 2
DATE OF TEST = 16/8/77,18/8/77
WIND SPEED = 31.31 M/S

AA=RUDDER ANGLE,ALPHA(DEG.), AD=RUDDER ANGLE,DELTA(DEG.)
CL=LIFT COEFFICIENT, CN=RUDDER NORMAL COEFFICIENT
CY=SHIP NORMAL COEFFICIENT, CD=DRAG COEFFICIENT
CPC=C OF P CHORD(%C), CPS=C OF P SPAN(%S)
ALL COEFFICIENTS BASED ON TOTAL AREA OF RUDDER PLUS SKEG

(A)=RUDDER PLUS SKEG, (B)=RUDDER ALONE, (C)=SKEG ALONE

REYNOLDS NO. = 890000

SKEG ANGLE,BETA(DEG.) = 4.75

	AA	AD	CL	CN	CY	CD	CPC	CPS
(A)	-5.33	-10.08	-.105	-.108	-.101	.042	36.68	60.68
(B)	-5.33	-10.08	-.123	-.124	-.122	.012	32.77	49.92
(C)	-5.33	-10.08	.018			.03	13.18	-15.99
(A)	-2.77	-7.52	-.032	-.033	-.03	.028	37.95	67.98
(B)	-2.77	-7.52	-.059	-.058	-.06	-.011	22.02	44.66
(C)	-2.77	-7.52	.027			.039	6.86	13.94
(A)	-.22	-4.97	.04	.04	.042	.02	-.48	37.24
(B)	-.22	-4.97	-.008	-.008	-.009	-.01	5.67	-44.21
(C)	-.22	-4.97	.048			.03	2.22	24.23
(A)	2.34	-2.41	.117	.118	.118	.017	12.65	48.62
(B)	2.34	-2.41	.054	.053	.053	-.014	24.83	80.13
(C)	2.34	-2.41	.063			.031	3.22	22.7
(A)	4.91	.16	.215	.216	.216	.023	17.49	48.04
(B)	4.91	.16	.12	.119	.119	-.008	25.49	67.53
(C)	4.91	.16	.095			.031	7.73	24.24
(A)	7.47	2.72	.291	.293	.292	.034	19.15	49.96
(B)	7.47	2.72	.18	.179	.179	.002	26.26	64.6
(C)	7.47	2.72	.111			.032	7.81	27.1
(A)	10.03	5.28	.379	.382	.382	.05	23.7	49.29
(B)	10.03	5.28	.24	.241	.241	.024	31.4	64.52
(C)	10.03	5.28	.139			.026	10.48	23.52
(A)	12.59	7.84	.453	.458	.458	.075	26.17	48.58
(B)	12.59	7.84	.295	.298	.298	.046	32.61	63.67
(C)	12.59	7.84	.158			.029	14.17	20.91
(A)	15.14	10.39	.513	.519	.518	.092	26.82	51.53
(B)	15.14	10.39	.342	.348	.346	.068	33.61	65.01
(C)	15.14	10.39	.171			.024	13.16	24.16
(A)	17.69	12.94	.591	.597	.598	.113	27.93	53.1
(B)	17.69	12.94	.401	.407	.406	.081	34.4	66.39
(C)	17.69	12.94	.19			.032	14.25	25.14
(A)	20.26	15.51	.673	.678	.681	.135	29.17	53.25
(B)	20.26	15.51	.462	.473	.47	.115	36.35	64.25
(C)	20.26	15.51	.211			.02	13.34	27.73
(A)	22.8	18.05	.732	.74	.743	.169	29.62	54.45
(B)	22.8	18.05	.513	.525	.522	.135	36.62	65.52
(C)	22.8	18.05	.219			.034	13.22	28.39
(A)	25.34	20.59	.79	.799	.803	.199	30.36	55.09
(B)	25.34	20.59	.553	.571	.564	.166	37.67	66.25
(C)	25.34	20.59	.237			.033	13.15	27.52
(A)	27.87	23.12	.819	.844	.837	.257	33.58	55.62
(B)	27.87	23.12	.605	.632	.62	.208	40.08	64.78
(C)	27.87	23.12	.214			.049	14.72	29.39
(A)	30.4	25.65	.871	.895	.891	.285	34.75	54.13
(B)	30.4	25.65	.628	.67	.647	.253	42.13	64.12
(C)	30.4	25.65	.243			.032	14.65	23.2
(A)	32.95	28.2	.931	.97	.956	.347	36.18	54.19
(B)	32.95	28.2	.666	.726	.688	.307	43.63	64.8
(C)	32.95	28.2	.265			.04	16.04	22.02
(A)	35.23	30.48	.642	.749	.671	.389	38.67	48.06
(B)	35.23	30.48	.423	.538	.449	.333	48.62	58.59
(C)	35.23	30.48	.219			.056	14.61	22.69

DAFM [21 , 1]   27-Jun-78   10:08

WIND TUNNEL RUDDER DATA ANALYSIS

RUDDER NUMBER = 2
DATE OF TEST = 16/8/77,17/8/77
WIND SPEED = 43.27 M/S

AA=RUDDER ANGLE,ALPHA(DEG.), AD=RUDDER ANGLE,DELTA(DEG.)
CL=LIFT COEFFICIENT, CN=RUDDER NORMAL COEFFICIENT
CY=SHIP NORMAL COEFFICIENT, CD=DRAG COEFFICIENT
CPC=C OF P CHORD(%C), CPS=C OF P SPAN(%S)
ALL COEFFICIENTS BASED ON TOTAL AREA OF RUDDER PLUS SKEG

(A)=RUDDER PLUS SKEG, (B)=RUDDER ALONE, (C)=SKEG ALONE

REYNOLDS NO. = .115E 7

SKEG ANGLE,BETA(DEG.) = -10.25

	AA	AD	CL	CN	CY	CD	CPC	CPS
(A)	-13.15	-2.9	-.529	-.535	-.536	.089	22.84	48.57
(B)	-13.15	-2.9	-.318	-.321	-.321	.049	31.11	64.85
(C)	-13.15	-2.9	-.211			.04	10.49	24.23
(A)	-10.59	-.34	-.447	-.452	-.452	.067	19.58	46.6
(B)	-10.59	-.34	-.247	-.247	-.247	.025	26.68	66.32
(C)	-10.59	-.34	-.2			.042	11.03	22.83
(A)	-8.02	2.23	-.359	-.362	-.362	.047	15.99	45.77
(B)	-8.02	2.23	-.186	-.185	-.183	.005	22.99	68.01
(C)	-8.02	2.23	-.173			.042	8.82	22.76
(A)	-5.46	4.79	-.275	-.277	-.276	.034	13.46	44.17
(B)	-5.46	4.79	-.12	-.119	-.117	-.008	21.21	72.55
(C)	-5.46	4.79	-.155			.042	7.91	22.83
(A)	-2.89	7.36	-.181	-.182	-.182	.026	9.09	41.45
(B)	-2.89	7.36	-.054	-.053	-.051	-.011	17.09	89.62
(C)	-2.89	7.36	-.127			.037	6.44	21.73
(A)	-.33	9.92	-.104	-.104	-.107	.026	2.04	35.07
(B)	-.33	9.92	.001	.001	.002	-.009	287.58	-1463.33
(C)	-.33	9.92	-.105			.035	5.67	22.81
(A)	2.23	12.48	-.025	-.024	-.03	.031	-90	-14.7
(B)	2.23	12.48	.061	.061	.061	-.008	38.76	31.11
(C)	2.23	12.48	-.086			.039	5.44	18.86
(A)	4.79	15.04	.056	.059	.048	.043	85.15	81.54
(B)	4.79	15.04	.119	.12	.115	.014	39.91	47.91
(C)	4.79	15.04	-.063			.029	-.89	15.27
(A)	7.33	17.58	.112	.12	.098	.067	60.92	65.29
(B)	7.33	17.58	.177	.179	.169	.025	38.16	50.61
(C)	7.33	17.58	-.065			.042	-.27	19.49
(A)	9.89	20.14	.191	.2	.176	.071	47.35	58.62
(B)	9.89	20.14	.217	.221	.206	.04	37.89	55.9
(C)	9.89	20.14	-.026			.031	-24.58	26.2
(A)	12.43	22.68	.243	.256	.224	.087	42.59	66.5
(B)	12.43	22.68	.265	.271	.251	.057	35.7	60.99
(C)	12.43	22.68	-.022			.03	-30.99	-7.23
(A)	14.99	25.24	.326	.342	.303	.104	39	60.98
(B)	14.99	25.24	.327	.335	.309	.075	36.03	60.78
(C)	14.99	25.24	-.001			.029	-132.84	-41.25
(A)	17.56	27.81	.407	.426	.379	.126	37.98	59.77
(B)	17.56	27.81	.382	.392	.36	.092	36.91	60.03
(C)	17.56	27.81	.025			.034	62.52	97.18
(A)	20.11	30.36	.479	.501	.445	.15	37.88	59.35
(B)	20.11	30.36	.431	.445	.403	.118	37.1	60.91
(C)	20.11	30.36	.048			.032	46.95	55.98
(A)	22.67	32.92	.557	.586	.515	.188	37.97	59.11
(B)	22.67	32.92	.488	.507	.455	.147	38.64	63.02
(C)	22.67	32.92	.069			.041	33.09	47.52
(A)	25.22	35.47	.622	.652	.575	.21	37.54	57.62
(B)	25.22	35.47	.542	.564	.504	.172	38.97	61.92
(C)	25.22	35.47	.08			.038	26.76	36.99
(A)	27.97	38.22	.697	.735	.642	.255	38.09	58.13
(B)	27.97	38.22	.594	.627	.547	.218	40.31	63.22
(C)	27.97	38.22	.103			.037	23.82	31.97

TABULATED TEST RESULTS - RUDDER No. 2

DAFM [21 , 1] 27-Jun-78 10:44

WIND TUNNEL RUDDER DATA ANALYSIS

RUDDER NUMBER = 2
DATE OF TEST = 16/8/77,18/8/77
WIND SPEED = 31.36 M/S

AA=RUDDER ANGLE,ALPHA(DEG.), AD=RUDDER ANGLE,DELTA(DEG.)
CL=LIFT COEFFICIENT, CN=RUDDER NORMAL COEFFICIENT
CY=SHIP NORMAL COEFFICIENT, CD=DRAG COEFFICIENT
CPC=C OF P CHORD(%C), CPS=C OF P SPAN(%S)
ALL COEFFICIENTS BASED ON TOTAL AREA OF RUDDER PLUS SKEG

(A)=RUDDER PLUS SKEG, (B)=RUDDER ALONE, (C)=SKEG ALONE

REYNOLDS NO. = 890000

SKEG ANGLE,BETA(DEG.) = 9.75

	AA	AD	CL	CN	CY	CD	CPC	CPS
(A)	-5.28	-15.03	-.039	-.044	-.028	.057	94.57	95.94
(B)	-5.28	-15.03	-.118	-.119	-.112	.021	38.87	46.49
(C)	-5.28	-15.03	.079			.036	9.54	16.98
(A)	-2.74	-12.49	.016	.014	.022	.036	-151.49	-46.43
(B)	-2.74	-12.49	-.072	-.072	-.071	-.004	32.83	36.37
(C)	-2.74	-12.49	.088			.04	4.66	22.36
(A)	-.19	-9.94	.083	.083	.086	.024	-1.92	39.17
(B)	-.19	-9.94	-.011	-.011	-.012	-.007	29.71	-92.57
(C)	-.19	-9.94	.094			.031	3.06	24.37
(A)	2.37	-7.38	.163	.164	.165	.023	9.53	44.04
(B)	2.37	-7.38	.044	.044	.042	-.01	19.17	101.51
(C)	2.37	-7.38	.119			.033	7.03	23.03
(A)	4.94	-4.81	.251	.252	.252	.023	13.62	46.36
(B)	4.94	-4.81	.113	.112	.109	-.012	22.52	76.02
(C)	4.94	-4.81	.138			.035	6.91	23.06
(A)	7.52	-2.23	.354	.355	.353	.029	16.81	46.7
(B)	7.52	-2.23	.183	.18	.179	-.008	24.56	69.55
(C)	7.52	-2.23	.171			.037	8.81	22.93
(A)	10.08	.33	.433	.434	.434	.045	18.97	47.83
(B)	10.08	.33	.236	.234	.234	.012	26.92	68.22
(C)	10.08	.33	.197			.033	9.67	23.94
(A)	12.64	2.89	.524	.526	.527	.067	22.48	49.11
(B)	12.64	2.89	.309	.309	.31	.035	31.11	64.28
(C)	12.64	2.89	.215			.032	10.26	25.02
(A)	15.18	5.43	.578	.581	.584	.088	24.28	51.94
(B)	15.18	5.43	.366	.368	.37	.058	32.81	65.34
(C)	15.18	5.43	.212			.03	9.68	28.65
(A)	17.75	8	.664	.668	.673	.117	25.93	51.1
(B)	17.75	8	.419	.424	.426	.083	34.25	66.01
(C)	17.75	8	.245			.034	11.78	25.19
(A)	20.3	10.55	.734	.738	.747	.143	27.22	53.83
(B)	20.3	10.55	.483	.49	.494	.107	35.52	65.33
(C)	20.3	10.55	.251			.036	11.36	31.1
(A)	22.86	13.11	.817	.818	.832	.168	27.82	51.33
(B)	22.86	13.11	.528	.539	.542	.136	36.09	65.89
(C)	22.86	13.11	.289			.032	12.77	23.05
(A)	25.4	15.65	.866	.869	.887	.203	29.41	52.63
(B)	25.4	15.65	.571	.586	.589	.163	38.01	66.26
(C)	25.4	15.65	.295			.04	12.86	24.72
(A)	27.9	18.15	.869	.904	.904	.291	33.76	52.6
(B)	27.9	18.15	.592	.624	.619	.216	42.43	66.65
(C)	27.9	18.15	.277			.075	14.9	22.02
(A)	30.44	20.69	.912	.952	.953	.327	34.74	52.2
(B)	30.44	20.69	.636	.675	.667	.251	43.23	63.85
(C)	30.44	20.69	.276			.076	14.78	24.52
(A)	32.97	23.22	.958	.999	1.004	.359	35.51	45.29
(B)	32.97	23.22	.681	.732	.72	.296	42.79	62.03
(C)	32.97	23.22	.277			.063	16.84	-2.28
(A)	35.27	25.52	.693	.805	.752	.415	37.25	44.35
(B)	35.27	25.52	.422	.526	.468	.314	49.09	59.94
(C)	35.27	25.52	.271			.101	15.42	19.93

TABULATED TEST RESULTS : RUDDER No.2

DAFM [21 , 1]   27-Jun-78   14:54

WIND TUNNEL RUDDER DATA ANALYSIS

RUDDER NUMBER = 2
DATE OF TEST = 16/8/77,17/8/77
WIND SPEED = 43.45 M/S

AA=RUDDER ANGLE,ALPHA(DEG.), AD=RUDDER ANGLE,DELTA(DEG.)
CL=LIFT COEFFICIENT, CN=RUDDER NORMAL COEFFICIENT
CY=SHIP NORMAL COEFFICIENT, CD=DRAG COEFFICIENT
CPC=C OF P CHORD(%C), CPS=C OF P SPAN(%S)
ALL COEFFICIENTS BASED ON TOTAL AREA OF RUDDER PLUS SKEG

(A)=RUDDER PLUS SKEG, (B)=RUDDER ALONE, (C)=SKEG ALONE

REYNOLDS NO. = .114E 7

SKEG ANGLE,BETA(DEG.) = -15.25

	AA	AD	CL	CN	CY	CD	CPC	CPS
(A)	-18.31	-3.06	-.752	-.762	-.764	.153	24.62	51.13
(B)	-18.31	-3.06	-.466	-.476	-.476	.108	34.08	65.55
(C)	-18.31	-3.06	-.286			.045	9.07	27.13
(A)	-15.77	-.52	-.688	-.697	-.696	.128	22.79	47.5
(B)	-15.77	-.52	-.402	-.407	-.406	.074	32.17	64.42
(C)	-15.77	-.52	-.286			.054	9.68	23.84
(A)	-13.19	2.06	-.588	-.593	-.59	.09	19.54	48.01
(B)	-13.19	2.06	-.325	-.325	-.323	.039	27.95	65.88
(C)	-13.19	2.06	-.263			.051	9.24	26.36
(A)	-10.62	4.63	-.494	-.498	-.493	.066	15.87	46.92
(B)	-10.62	4.63	-.257	-.255	-.251	.015	24.46	68.83
(C)	-10.62	4.63	-.237			.051	6.83	24.1
(A)	-8.06	7.19	-.411	-.414	-.41	.051	14.41	45.31
(B)	-8.06	7.19	-.186	-.184	-.179	0	23.2	71.66
(C)	-8.06	7.19	-.225			.051	7.44	24.43
(A)	-5.49	9.76	-.313	-.315	-.312	.04	11.61	43.45
(B)	-5.49	9.76	-.121	-.12	-.115	-.006	22.12	76.52
(C)	-5.49	9.76	-.192			.046	5.47	23.61
(A)	-2.92	12.33	-.23	-.231	-.231	.033	8.84	40.95
(B)	-2.92	12.33	-.063	-.063	-.058	-.008	21.66	89.42
(C)	-2.92	12.33	-.167			.041	4.73	23.68
(A)	-.36	14.89	-.149	-.149	-.153	.036	-1.52	35.61
(B)	-.36	14.89	.005	.005	.005	-.002	216.55	-298.19
(C)	-.36	14.89	-.154			.038	6.63	24.75
(A)	2.2	17.45	-.066	-.064	-.075	.044	-51.79	23.61
(B)	2.2	17.45	.072	.072	.066	.014	47.99	15.75
(C)	2.2	17.45	-.138			.03	2.37	21.28
(A)	4.75	20	-.005	0	-.02	.058	22287	9950.03
(B)	4.75	20	.118	.119	.108	.022	44.74	44.06
(C)	4.75	20	-.123			.036	3.5	25.03
(A)	7.29	22.54	.052	.061	.032	.071	115.89	95.56
(B)	7.29	22.54	.16	.163	.145	.035	41.27	48.04
(C)	7.29	22.54	-.108			.036	1	20.18
(A)	9.84	25.09	.12	.132	.094	.081	67.38	75.99
(B)	9.84	25.09	.212	.217	.191	.05	36.51	55.46
(C)	9.84	25.09	-.092			.031	-5.57	24.82
(A)	12.4	27.65	.2	.216	.168	.094	51.4	66.8
(B)	12.4	27.65	.268	.275	.243	.06	36.91	56.38
(C)	12.4	27.65	-.068			.034	-5.18	20.37
(A)	14.96	30.21	.277	.297	.238	.113	45.54	64.38
(B)	14.96	30.21	.326	.335	.294	.079	36.74	58.03
(C)	14.96	30.21	-.049			.034	-9.98	11.99
(A)	17.52	32.77	.358	.381	.31	.133	42.74	61.87
(B)	17.52	32.77	.374	.387	.335	.101	37.4	60.13
(C)	17.52	32.77	-.016			.032	-47.32	4.67
(A)	20.08	35.33	.433	.462	.376	.162	41.67	61.69
(B)	20.08	35.33	.42	.437	.374	.123	38.28	62.41
(C)	20.08	35.33	.013			.039	801.01	420.62
(A)	22.85	38.1	.529	.562	.461	.193	40.86	60.21
(B)	22.85	38.1	.497	.52	.438	.16	39.49	61.52
(C)	22.85	38.1	.032			.033	77.14	61.49

TABULATED TEST RESULTS : RUDDER No.2

DAFM [21 , 1] 27-Jun-78 14:27

WIND TUNNEL RUDDER DATA ANALYSIS

RUDDER NUMBER = 2
DATE OF TEST = 16/8/77,18/8/77
WIND SPEED = 31.33 M/S

AA=RUDDER ANGLE,ALPHA(DEG.), AD=RUDDER ANGLE,DELTA(DEG.)
CL=LIFT COEFFICIENT, CN=RUDDER NORMAL COEFFICIENT
CY=SHIP NORMAL COEFFICIENT, CD=DRAG COEFFICIENT
CPC=C OF P CHORD(%C), CPS=C OF P SPAN(%S)
ALL COEFFICIENTS BASED ON TOTAL AREA OF RUDDER PLUS SKEG

(A)=RUDDER PLUS SKEG, (B)=RUDDER ALONE, (C)=SKEG ALONE

REYNOLDS NO. = 890000

SKEG ANGLE,BETA(DEG.) = 14.75

	AA	AD	CL	CN	CY	CD	CPC	CPS
(A)	-5.25	-20	.006	0	.021	.062	-25965.2	-22651.6
(B)	-5.25	-20	.105	.097	.122	.079	23.56	-112.71
(C)	-5.25	-20	-.099			-.017	70.54	-74.33
(A)	-2.7	-17.45	.061	.059	.07	.045	-46.67	12.68
(B)	-2.7	-17.45	-.088	-.088	-.086	-.005	41.24	23.58
(C)	-2.7	-17.45	.149			.05	7.98	19.64
(A)	-.15	-14.9	.131	.131	.134	.032	-3.8	36.91
(B)	-.15	-14.9	-.014	-.014	-.016	-.011	60.22	-96.98
(C)	-.15	-14.9	.145			.043	3.81	23.98
(A)	2.42	-12.33	.222	.223	.221	.027	9.75	40.79
(B)	2.42	-12.33	.048	.047	.043	-.014	20.47	107.64
(C)	2.42	-12.33	.174			.041	7.33	22.8
(A)	4.97	-9.78	.294	.295	.291	.026	12.45	44.57
(B)	4.97	-9.78	.107	.106	.101	-.011	21.17	81.55
(C)	4.97	-9.78	.187			.037	7.71	24.15
(A)	7.54	-7.21	.388	.389	.383	.035	14.75	46.15
(B)	7.54	-7.21	.174	.171	.166	-.008	22.49	74.72
(C)	7.54	-7.21	.214			.043	8.69	23.77
(A)	10.11	-4.64	.485	.485	.48	.044	16.9	47.01
(B)	10.11	-4.64	.247	.244	.24	.006	24.91	69.64
(C)	10.11	-4.64	.238			.038	8.64	24.2
(A)	12.67	-2.08	.559	.559	.556	.063	18.76	48.02
(B)	12.67	-2.08	.304	.301	.299	.022	27.04	67.92
(C)	12.67	-2.08	.255			.041	9.02	24.84
(A)	15.24	.49	.649	.648	.648	.084	22.24	48.78
(B)	15.24	.49	.371	.371	.371	.051	31.72	67.11
(C)	15.24	.49	.278			.033	9.56	24.26
(A)	17.8	3.05	.727	.728	.732	.116	24.55	49.88
(B)	17.8	3.05	.429	.432	.433	.076	32.83	67.66
(C)	17.8	3.05	.298			.04	12.69	24.06
(A)	20.36	5.61	.812	.812	.821	.146	26.15	50.33
(B)	20.36	5.61	.492	.497	.501	.104	35.06	66.01
(C)	20.36	5.61	.32			.042	12.49	25.56
(A)	22.9	8.15	.861	.859	.874	.17	26.39	51.27
(B)	22.9	8.15	.546	.554	.559	.13	35.4	65.43
(C)	22.9	8.15	.315			.04	10.84	25.69
(A)	25.44	10.69	.925	.926	.946	.21	28.39	50.89
(B)	25.44	10.69	.578	.592	.598	.163	37.41	67.6
(C)	25.44	10.69	.347			.047	13.35	21.32
(A)	27.91	13.16	.878	.912	.921	.29	32.31	53.78
(B)	27.91	13.16	.629	.655	.66	.211	41.1	61.92
(C)	27.91	13.16	.249			.079	10.33	33.35
(A)	30.44	15.69	.917	.971	.975	.356	33.11	49.77
(B)	30.44	15.69	.611	.644	.648	.231	44.83	61.17
(C)	30.44	15.69	.306			.125	10.18	29.91
(A)	32.82	18.07	.757	.842	.827	.379	34.73	45.86
(B)	32.82	18.07	.516	.59	.571	.288	45.89	58.72
(C)	32.82	18.07	.241			.091	9.13	15.65

APPENDIX A1 (CONTINUED)

TABULATED TEST RESULTS : RUDDER No.3

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DAFM [ 21 , 1 ]          28-Jun-78     09:59

WIND TUNNEL RUDDER DATA ANALYSIS

RUDDER NUMBER  =   3
DATE OF TEST   =   9/8/77
WIND SPEED     =   31.48 M/S

AA=RUDDER ANGLE,ALPHA(DEG.), AD=RUDDER ANGLE,DELTA(DEG.)
CL=LIFT COEFFICIENT, CN=RUDDER NORMAL COEFFICIENT
CY=SHIP NORMAL COEFFICIENT, CD=DRAG COEFFICIENT
CPC=C OF P CHORD(%C), CPS=C OF P SPAN(%S)
ALL COEFFICIENTS BASED ON TOTAL AREA OF RUDDER PLUS SKEG

(A)=RUDDER PLUS SKEG, (B)=RUDDER ALONE, (C)=SKEG ALONE

REYNOLDS NO.   =   880000
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ALL-MOVABLE RUDDER

	AA	AD	CL	CN	CY	CD	CPC	CPS
(A)	-1.51	-.06	-.076	-.076	-.077	.018	6.39	40.26
(A)	.57	.02	.022	.022	.023	.014	40.23	73.38
(A)	1.61	.06	.075	.075	.076	.016	21.69	52.8
(A)	3.68	.13	.174	.175	.175	.02	17.66	50.13
(A)	6.8	.25	.326	.327	.328	.031	18.37	48.01
(A)	9.39	.34	.451	.452	.452	.042	18.87	47.56
(A)	11.99	.44	.581	.581	.58	.059	19.53	47.62
(A)	14.58	.53	.7	.697	.696	.078	19.87	47.91
(A)	17.16	.61	.808	.802	.801	.101	21.61	48.14
(A)	18.7	.65	.862	.859	.859	.133	24.16	46.59
(A)	19.73	.68	.906	.904	.904	.153	25.1	47.8
(A)	22.26	.71	.934	.955	.952	.238	28.86	45.56
(A)	23.24	.69	.911	.943	.941	.269	30.56	48.52
(A)	24.71	.66	.874	.92	.917	.301	30.11	45.93
(A)	27.18	.63	.829	.869	.867	.289	31.76	46.23

TABULATED TEST RESULTS - RUDDER No. 3

WIND TUNNEL RUDDER DATA ANALYSIS

RUDDER NUMBER - 3
DATE OF TEST - 10/9/77,11/8/77
WIND SPEED - 43.16 M/S

AA=RUDDER ANGLE,ALPHA(DEG.), AD=RUDDER ANGLE,DELTA(DEG.)
CL=LIFT COEFFICIENT, CN=RUDDER NORMAL COEFFICIENT
CY=SHIP NORMAL COEFFICIENT, CD=DRAG COEFFICIENT
CPC=C OF P CHORD(%C), CPS=C OF P SPAN(%S)
ALL COEFFICIENTS BASED ON TOTAL AREA OF RUDDER PLUS SKEG

(A)=RUDDER PLUS SKEG, (B)=RUDDER ALONE, (C)=SKEG ALONE

REYNOLDS NO. = .115E 7

SKEG ANGLE,BETA(DEG.) = -.25

	AA	AD	CL	CN	CY	CD	CPC	CPS
(A)	-5.38	-5.13	-.168	-.171	-.168	.039	24.77	48.63
(B)	-5.38	-5.13	-.122	-.122	-.122	.007	25.02	63.52
(C)	-5.38	-5.13	-.046			.032	23.64	10.75
(A)	-2.81	-2.56	-.083	-.084	-.083	.025	16.43	48.62
(B)	-2.81	-2.56	-.061	-.061	-.061	-.007	21.41	63.05
(C)	-2.81	-2.56	-.022			.032	2.17	9.67
(A)	-.25	0	-.004	-.004	-.004	.019	-59.06	-1.75
(B)	-.25	0	.005	.005	.005	-.012	71.33	10.72
(C)	-.25	0	-.009			.031	13.44	6.41
(A)	2.31	2.56	.079	.08	.079	.021	25.56	56.71
(B)	2.31	2.56	.062	.062	.062	-.008	26.53	60.32
(C)	2.31	2.56	.017			.029	20.51	46.83
(A)	4.88	5.13	.167	.169	.167	.025	25.96	51.52
(B)	4.88	5.13	.126	.126	.126	.004	30.62	59.47
(C)	4.88	5.13	.041			.021	11.11	28.22
(A)	7.45	7.7	.271	.274	.271	.04	29.27	50.59
(B)	7.45	7.7	.196	.197	.196	.021	34.63	59.38
(C)	7.45	7.7	.075			.019	15.02	27.95
(A)	10.01	10.26	.347	.352	.347	.059	30.78	47.99
(B)	10.01	10.26	.257	.26	.256	.04	35.73	58.52
(C)	10.01	10.26	.09			.019	16.37	18.52
(A)	12.55	12.8	.397	.405	.396	.082	30.96	54.16
(B)	12.55	12.8	.304	.311	.303	.066	36.46	62.15
(C)	12.55	12.8	.093			.016	12.41	28.81
(A)	15.11	15.36	.475	.485	.474	.103	31.71	53.02
(B)	15.11	15.36	.366	.376	.365	.086	36.94	62.02
(C)	15.11	15.36	.109			.017	13.54	22.42
(A)	17.69	17.94	.589	.598	.589	.122	31.68	54.95
(B)	17.69	17.94	.456	.468	.455	.109	37.69	57.76
(C)	17.69	17.94	.133			.013	10.66	43.41
(A)	20.27	20.52	.683	.692	.682	.147	32.83	51.79
(B)	20.27	20.52	.488	.504	.487	.133	38.75	60.46
(C)	20.27	20.52	.195			.014	17.68	27.75
(A)	22.83	23.08	.762	.77	.762	.174	32.79	52.76
(B)	22.83	23.08	.559	.58	.558	.167	38.83	62.02
(C)	22.83	23.08	.203			.007	15.88	23.06
(A)	25.36	25.61	.803	.834	.802	.253	34.79	55.71
(B)	25.36	25.61	.604	.631	.603	.198	40.75	64.29
(C)	25.36	25.61	.199			.055	15.76	33.47
(A)	27.93	28.18	.902	.931	.901	.287	35.7	51.45
(B)	27.93	28.18	.673	.711	.672	.249	42.04	64.28
(C)	27.93	28.18	.229			.038	16.09	10.99
(A)	30.46	30.71	.939	.983	.938	.343	36.42	51.14
(B)	30.46	30.71	.754	.792	.752	.281	42.68	58.56
(C)	30.46	30.71	.185			.062	9.49	25.83
(A)	32.96	33.21	.945	1.002	.944	.385	37.7	54.1
(B)	32.96	33.21	.743	.811	.742	.345	44.76	61.17
(C)	32.96	33.21	.202			.04	9.3	26.48
(A)	35.5	35.75	.988	1.028	.987	.385	37.38	55.46
(B)	35.5	35.75	.742	.82	.74	.371	44.84	62.77
(C)	35.5	35.75	.246			.014	12.62	20.6
(A)	38.02	38.27	.754	.864	.753	.438	40.38	47.8
(B)	38.02	38.27	.54	.67	.539	.397	48.28	52.54
(C)	38.02	38.27	.214			.041	15.31	27.81

TABULATED TEST RESULTS : RUDDER No.3

WIND TUNNEL RUDDER DATA ANALYSIS

RUDDER NUMBER = 3
DATE OF TEST = 10/8/77-11/8/77
WIND SPEED = 43.49 M/S

AA=RUDDER ANGLE,ALPHA(DEG.), AD=RUDDER ANGLE,DELTA(DEG.)
CL=LIFT COEFFICIENT, CN=RUDDER NORMAL COEFFICIENT
CY=SHIP NORMAL COEFFICIENT, CD=DRAG COEFFICIENT
CPC=C OF P CHORD(%C), CPS=C OF P SPAN(%S)
ALL COEFFICIENTS BASED ON TOTAL AREA OF RUDDER PLUS SKEG

(A)=RUDDER PLUS SKEG, (B)=RUDDER ALONE, (C)=SKEG ALONE

REYNOLDS NO. = .113E 7

SKEG ANGLE,BETA(DEG.) = -5.25

	AA	AD	CL	CN	CY	CD	CPC	CPS
(A)	-10.54	-5.29	-.38	-.387	-.385	.075	23.15	50.11
(B)	-10.54	-5.29	-.26	-.264	-.263	.044	30	61.89
(C)	-10.54	-5.29	-.12			.031	9.26	24.87
(A)	-7.98	-2.73	-.298	-.302	-.301	.052	19.95	49.34
(B)	-7.98	-2.73	-.186	-.187	-.187	.02	26.01	65.39
(C)	-7.98	-2.73	-.112			.032	10.03	23.27
(A)	-5.42	-.17	-.224	-.226	-.226	.034	15.14	46.44
(B)	-5.42	-.17	-.124	-.124	-.124	.004	22.76	66.76
(C)	-5.42	-.17	-.1			.03	6.1	21.98
(A)	-2.85	2.4	-.133	-.134	-.135	.024	9.48	42.95
(B)	-2.85	2.4	-.057	-.057	-.056	-.008	17.78	74.39
(C)	-2.85	2.4	-.076			.032	4.23	20.59
(A)	-.29	4.96	-.051	-.051	-.053	.022	-9.82	31.76
(B)	-.29	4.96	.004	.004	.005	-.01	107.31	-107.16
(C)	-.29	4.96	-.055			.032	1.4	21.15
(A)	1.76	7.01	.014	.015	.012	.024	132.93	116.42
(B)	1.76	7.01	.055	.055	.055	-.002	35.69	44.48
(C)	1.76	7.01	-.041			.026	2.4	18.2
(A)	4.85	10.1	.137	.14	.134	.036	41.53	54.01
(B)	4.85	10.1	.149	.149	.147	.012	37.37	44.81
(C)	4.85	10.1	-.012			.024	-3.73	-58.63
(A)	7.41	12.66	.215	.219	.21	.047	38.86	53.82
(B)	7.41	12.66	.194	.197	.19	.032	38.18	55.2
(C)	7.41	12.66	.021			.015	45.87	43.36
(A)	9.97	15.22	.286	.293	.279	.067	38.54	52.31
(B)	9.97	15.22	.258	.263	.253	.049	37.53	56.1
(C)	9.97	15.22	.028			.018	49.37	22.25
(A)	12.54	17.79	.379	.388	.37	.082	37.03	48.5
(B)	12.54	17.79	.317	.324	.309	.066	38.09	57.34
(C)	12.54	17.79	.062			.016	31.31	2.15
(A)	15.08	20.33	.439	.453	.427	.112	35.82	53.99
(B)	15.08	20.33	.39	.403	.38	.103	38.08	59.18
(C)	15.08	20.33	.049			.009	16.62	10.69
(A)	17.65	22.9	.527	.544	.512	.137	35.48	55.6
(B)	17.65	22.9	.445	.457	.434	.109	38.33	56.24
(C)	17.65	22.9	.082			.028	18.48	61.24
(A)	20.23	25.48	.638	.653	.621	.158	35.54	52.58
(B)	20.23	25.48	.515	.535	.499	.151	38.56	58.19
(C)	20.23	25.48	.123			.007	22.22	26.85
(A)	22.75	28	.662	.68	.643	.18	35.24	57.77
(B)	22.75	28	.582	.607	.564	.183	39.02	58.85
(C)	22.75	28	.08			-.003	6.62	43.26
(A)	25.3	30.55	.734	.754	.712	.211	35.46	57.92
(B)	25.3	30.55	.635	.663	.614	.207	39.44	61.24
(C)	25.3	30.55	.099			.004	8.52	28.87
(A)	27.86	33.11	.814	.836	.788	.249	35.89	57.6
(B)	27.86	33.11	.673	.707	.649	.239	40.01	63.3
(C)	27.86	33.11	.141			.01	15.14	29.57
(A)	30.41	35.66	.874	.899	.845	.286	36.38	58.16
(B)	30.41	35.66	.723	.769	.694	.288	40.77	64.9
(C)	30.41	35.66	.151			-.002	14.06	17.42
(A)	33.16	38.41	.936	.971	.902	.342	37.98	56.92
(B)	33.16	38.41	.747	.808	.714	.334	42.69	64.41
(C)	33.16	38.41	.189			.008	17.61	17.15
(A)	36.07	41.32	.949	.998	.91	.393	38.57	57.79
(B)	36.07	41.32	.747	.826	.71	.378	44.04	63.66
(C)	36.07	41.32	.202			.015	15.79	23.25

APPENDIX A1 (CONTINUED)

TABULATED TEST RESULTS : RUDDER No.3

DAFM [21 , 1]   28-Jun-78   14:41

WIND TUNNEL RUDDER DATA ANALYSIS

RUDDER NUMBER = 3
DATE OF TEST = 10/8/77,12/8/77
WIND SPEED = 31.69 M/S

AA=RUDDER ANGLE,ALPHA(DEG.), AD=RUDDER ANGLE,DELTA(DEG.)
CL=LIFT COEFFICIENT, CN=RUDDER NORMAL COEFFICIENT
CY=SHIP NORMAL COEFFICIENT, CD=DRAG COEFFICIENT
CPC=C OF P CHORD(%C), CPS=C OF P SPAN(%S)
ALL COEFFICIENTS BASED ON TOTAL AREA OF RUDDER PLUS SKEG

(A)=RUDDER PLUS SKEG, (B)=RUDDER ALONE, (C)=SKEG ALONE

REYNOLDS NO. = 860000

SKEG ANGLE,BETA(DEG.) = 4.75

	AA	AD	CL	CN	CY	CD	CPC	CPS
(A)	-5.34	-10.09	-.121	-.125	-.116	.046	38.13	57.41
(B)	-5.34	-10.09	-.134	-.135	-.132	.015	31.33	51.62
(C)	-5.34	-10.09	.013			.031	-23.96	-6.73
(A)	-2.77	-7.52	-.024	-.025	-.021	.028	46.28	76.59
(B)	-2.77	-7.52	-.066	-.066	-.066	-.003	24.13	43.11
(C)	-2.77	-7.52	.042			.031	12.59	22.81
(A)	-.22	-4.97	.044	.044	.046	.022	8.02	42.89
(B)	-.22	-4.97	-.008	-.008	-.009	-.007	23.8	-40.51
(C)	-.22	-4.97	.052			.029	11.41	29.29
(A)	1.83	-2.92	.105	.106	.107	.021	15.2	47.49
(B)	1.83	-2.92	.069	.069	.068	-.008	22.54	71.59
(C)	1.83	-2.92	.036			.029	2.45	3.82
(A)	4.91	.16	.215	.217	.217	.028	19.61	49.5
(B)	4.91	.16	.12	.119	.12	-.003	26.16	68.36
(C)	4.91	.16	.095			.031	11.42	26.37
(A)	7.48	2.73	.306	.308	.308	.035	21.62	51.5
(B)	7.48	2.73	.191	.191	.191	.014	30.07	65.87
(C)	7.48	2.73	.115			.021	7.7	28.2
(A)	10.06	5.31	.411	.414	.415	.056	25.55	50.87
(B)	10.06	5.31	.263	.264	.264	.031	33.45	62.64
(C)	10.06	5.31	.148			.025	11.58	30.52
(A)	12.62	7.87	.49	.494	.494	.072	27.05	51.12
(B)	12.62	7.87	.323	.329	.326	.061	35.38	61.65
(C)	12.62	7.87	.167			.011	10.87	29.96
(A)	15.17	10.42	.552	.558	.558	.098	28.45	51.17
(B)	15.17	10.42	.384	.392	.389	.082	36.09	63.44
(C)	15.17	10.42	.168			.016	10.93	22.1
(A)	17.75	13	.663	.67	.671	.126	29.49	50.34
(B)	17.75	13	.432	.444	.439	.107	36.94	64.15
(C)	17.75	13	.231			.019	15.45	23.41
(A)	20.31	15.56	.745	.756	.756	.166	30.82	50.88
(B)	20.31	15.56	.514	.524	.522	.122	38.25	59.97
(C)	20.31	15.56	.231			.044	14.21	30.62
(A)	22.85	18.1	.797	.811	.81	.198	31.79	52.56
(B)	22.85	18.1	.559	.576	.57	.157	38.67	62.65
(C)	22.85	18.1	.238			.041	15.37	28.91
(A)	25.39	20.64	.853	.869	.868	.229	34.03	50.8
(B)	25.37	20.64	.62	.65	.635	.21	39.8	62.15
(C)	25.39	20.64	.233			.019	18.24	17.56
(A)	27.93	23.18	.906	.935	.926	.288	35.08	52.08
(B)	27.93	23.18	.707	.736	.723	.238	42.75	57.66
(C)	27.93	23.18	.199			.05	7.26	32.52
(A)	30.48	25.73	.967	.993	.988	.314	35.23	51.09
(B)	30.48	25.73	.735	.773	.755	.275	42.89	59.04
(C)	30.48	25.73	.232			.039	10.07	23.45
(A)	32.99	28.24	.982	1.027	1.008	.374	36.18	55
(B)	32.99	28.24	.77	.828	.794	.335	43.95	57.89
(C)	32.99	28.24	.212			.039	6.24	48.55
(A)	35.35	30.6	.79	.878	.82	.404	38.77	47.28
(B)	35.35	30.6	.555	.667	.583	.37	47.48	56.56
(C)	35.35	30.6	.235			.034	14.21	15.71

TABULATED TEST RESULTS : RUDDER No 3

DAFM E 21 : 1 J 29-Jun-78 09436

WIND TUNNEL RUDDER DATA ANALYSIS

RUDDER NUMBER = 3
DATE OF TEST = 10/8/77,11/8/77
WIND SPEED = 43.49 M/S

AA=RUDDER ANGLE,ALPHA(DEG.), AD=RUDDER ANGLE,DELTA(DEG.)
CL=LIFT COEFFICIENT, CN=RUDDER NORMAL COEFFICIENT
CY=SHIP NORMAL COEFFICIENT, CD=DRAG COEFFICIENT
CPC=C OF P CHORD(%C), CPS=C OF P SPAN(%S)
ALL COEFFICIENTS BASED ON TOTAL AREA OF RUDDER PLUS SKEG

(A)=RUDDER PLUS SKEG, (B)=RUDDER ALONE, (C)=SKEG ALONE

REYNOLDS NO. = .113E 7

SKEG ANGLE,BETA(DEG.) = -10.25

	AA	AD	CL	CN	CY	CD	CPC	CPS
(A)	-15.72	-5.47	-.621	-.632	-.633	.127	24.14	49.02
(B)	-15.72	-5.47	-.383	-.394	-.393	.093	32.95	65.98
(C)	-15.72	-5.47	-.238			.034	9.75	20.97
(A)	-13.15	-2.9	-.527	-.536	-.535	.099	21.26	49.43
(B)	-13.15	-2.9	-.329	-.334	-.333	.06	30.07	63.85
(C)	-13.15	-2.9	-.198			.039	6.73	25.62
(A)	-10.59	-.34	-.447	-.453	-.453	.076	18.74	47.53
(B)	-10.59	-.34	-.249	-.251	-.25	.033	26.01	66.87
(C)	-10.59	-.34	-.198			.043	9.78	23.69
(A)	-8.02	2.23	-.356	-.36	-.359	.052	14.76	46.69
(B)	-8.02	2.23	-.178	-.178	-.177	.011	22.81	70.77
(C)	-8.02	2.23	-.178			.041	7.02	23.28
(A)	-5.45	4.8	-.271	-.273	-.273	.039	11.79	44.98
(B)	-5.45	4.8	-.114	-.113	-.112	-.001	19.59	76.95
(C)	-5.45	4.8	-.157			.04	6.6	22.34
(A)	-2.88	7.37	-.175	-.176	-.177	.03	5.48	41.97
(B)	-2.88	7.37	-.047	-.047	-.045	-.008	10.34	102.71
(C)	-2.88	7.37	-.128			.038	4.55	20.36
(A)	-.31	9.94	-.084	-.084	-.087	.026	-13.77	31.48
(B)	-.31	9.94	.02	.02	.021	-.005	68.62	-34.19
(C)	-.31	9.94	-.104			.031	3.57	18.95
(A)	1.74	11.99	-.017	-.016	-.022	.026	-176.99	-29.62
(B)	1.74	11.99	.08	.08	.079	-.002	42.45	32.69
(C)	1.74	11.99	-.097			.028	6.32	22.5
(A)	4.83	15.08	.108	.111	.099	.041	62.51	56.67
(B)	4.83	15.08	.157	.158	.152	.015	41.38	42.19
(C)	4.83	15.08	-.049			.026	-2.65	9.87
(A)	7.38	17.63	.178	.184	.166	.055	51.91	58.28
(B)	7.38	17.63	.204	.207	.195	.036	40.95	52.07
(C)	7.38	17.63	-.026			.019	-28.75	7.64
(A)	9.94	20.19	.253	.262	.236	.072	46.54	57.28
(B)	9.94	20.19	.295	.299	.282	.046	39.58	52.94
(C)	9.94	20.19	-.042			.026	-.26	20.19
(A)	12.49	22.74	.317	.329	.296	.091	42.84	56.82
(B)	12.49	22.74	.356	.363	.338	.071	38.88	52.61
(C)	12.49	22.74	-.039			.02	7.56	16.3
(A)	15.06	25.31	.416	.43	.39	.11	40.65	53.5
(B)	15.06	25.31	.393	.404	.37	.094	39.27	55.63
(C)	15.06	25.31	.023			.016	70.29	25.38
(A)	17.63	27.88	.508	.524	.477	.133	39.3	55.41
(B)	17.63	27.88	.449	.468	.419	.132	39.53	58.39
(C)	17.63	27.88	.059			.001	37.41	33.87
(A)	20.15	30.4	.533	.551	.498	.147	38.48	59.63
(B)	20.15	30.4	.519	.535	.487	.139	38.93	57.77
(C)	20.15	30.4	.014			.008	18.12	159.01
(A)	22.71	32.96	.611	.634	.569	.182	38.01	58.78
(B)	22.71	32.96	.561	.583	.523	.17	37.34	59.53
(C)	22.71	32.96	.05			.012	21.4	51.09
(A)	25.27	35.52	.687	.71	.64	.209	37.82	51.6
(B)	25.27	35.52	.611	.64	.566	.206	38.94	62.7
(C)	25.27	35.52	.076			.003	28.15	-65.77
(A)	28.03	38.28	.769	.795	.714	.247	37.9	59.63
(B)	28.03	38.28	.661	.693	.61	.233	40.62	63.52
(C)	28.03	38.28	.108			.014	19.71	31.76
(A)	30.99	41.24	.85	.882	.785	.297	38.28	58.7
(B)	30.99	41.24	.73	.773	.669	.286	41.13	62.2
(C)	30.99	41.24	.12			.011	19.22	35.16

TABULATED TEST RESULTS : RUDDER No.3

DAFM [21 , 1] 29-Jun-78 10:01

WIND TUNNEL RUDDER DATA ANALYSIS

RUDDER NUMBER = 3
DATE OF TEST = 11/8/77,12/8/77
WIND SPEED = 31.27 M/S

AA=RUDDER ANGLE,ALPHA(DEG.), AD=RUDDER ANGLE,DELTA(DEG.)
CL=LIFT COEFFICIENT, CN=RUDDER NORMAL COEFFICIENT
CY=SHIP NORMAL COEFFICIENT, CD=DRAG COEFFICIENT
CPC=C OF P CHORD(%C), CPS=C OF P SPAN(%S)
ALL COEFFICIENTS BASED ON TOTAL AREA OF RUDDER PLUS SKEG

(A)=RUDDER PLUS SKEG, (B)=RUDDER ALONE, (C)=SKEG ALONE

REYNOLDS NO. = 890000

SKEG ANGLE,BETA(DEG.) = 9.75

	AA	AD	CL	CN	CY	CD	CPC	CPS
(A)	-5.32	-15.07	-.099	-.103	-.09	.046	60.02	56.3
(B)	-5.32	-15.07	.139	.133	.148	.063	35.15	-110.06
(C)	-5.32	-15.07	-.238			-.017	45.93	-38.58
(A)	-2.75	-12.5	.002	0	.007	.034	-21806.8	-4173.48
(B)	-2.75	-12.5	-.08	-.08	-.078	.002	34.57	37.96
(C)	-2.75	-12.5	.082			.032	.6	30.53
(A)	-.18	-9.93	.087	.087	.09	.021	-3.36	40
(B)	-.18	-9.93	-.019	-.019	-.02	-.003	50.75	-23.52
(C)	-.18	-9.93	.106			.024	7.23	28.39
(A)	1.86	-7.89	.149	.15	.151	.023	9.88	45.12
(B)	1.86	-7.89	.04	.04	.039	-.002	19.45	93.12
(C)	1.86	-7.89	.109			.025	6.83	27.54
(A)	4.94	-4.81	.251	.252	.252	.026	14.65	46.91
(B)	4.94	-4.81	.113	.113	.111	.001	22.68	76.57
(C)	4.94	-4.81	.138			.025	8.3	22.96
(A)	7.51	-2.24	.348	.35	.349	.035	17.8	47.27
(B)	7.51	-2.24	.18	.18	.179	.012	25.15	70.13
(C)	7.51	-2.24	.168			.023	9.99	23.04
(A)	10.08	.33	.442	.444	.444	.048	20.36	49.15
(B)	10.08	.33	.252	.253	.253	.027	29.49	67.12
(C)	10.08	.33	.19			.021	8.33	25.4
(A)	12.66	2.91	.541	.544	.545	.072	23.47	49.16
(B)	12.66	2.91	.32	.322	.322	.045	33.21	66.28
(C)	12.66	2.91	.221			.027	9.44	24.31
(A)	15.21	5.46	.612	.615	.619	.093	25.26	49.98
(B)	15.21	5.46	.388	.393	.394	.071	34.67	64.37
(C)	15.21	5.46	.224			.022	8.96	24.57
(A)	17.81	8.06	.742	.745	.752	.127	27.36	45.5
(B)	17.81	8.06	.446	.455	.456	.1	36.11	62.46
(C)	17.81	8.06	.296			.027	14.18	18.93
(A)	20.33	10.58	.767	.772	.781	.152	28.74	51.84
(B)	20.33	10.58	.536	.549	.549	.133	37.93	61.6
(C)	20.33	10.58	.231			.019	7.32	26.68
(A)	22.89	13.14	.85	.863	.871	.205	30.17	51.82
(B)	22.89	13.14	.552	.572	.57	.163	38.8	66.85
(C)	22.89	13.14	.298			.042	14.04	23.51
(A)	25.44	15.69	.909	.937	.94	.27	33.09	49.31
(B)	25.44	15.69	.601	.633	.626	.209	41.52	63.59
(C)	25.44	15.69	.308			.061	16.23	19.65
(A)	27.98	18.23	.972	1.001	1.008	.304	33.94	48.94
(B)	27.98	18.23	.682	.717	.712	.244	41.85	64.5
(C)	27.98	18.23	.29			.06	14.97	10.45
(A)	30.53	20.78	1.031	1.061	1.071	.34	34.64	49.6
(B)	30.53	20.78	.668	.72	.704	.284	44.21	64.76
(C)	30.53	20.78	.363			.056	16.16	15.03
(A)	33.01	23.26	1.093	1.051	1.052	.385	35.65	52.75
(B)	33.01	23.26	.729	.79	.772	.328	44.7	60.28
(C)	33.01	23.26	.274			.057	10.24	31
(A)	35.58	25.83	1.105	1.146	1.159	.425	35.87	51.31
(B)	35.58	25.83	.78	.842	.827	.357	44.08	63.6
(C)	35.58	25.83	.325			.068	15.27	14.71
(A)	37.84	28.09	.782	.9	.847	.46	37.03	45
(B)	37.84	28.09	.492	.625	.549	.386	48.66	56.24
(C)	37.84	28.09	.29			.074	12.77	20.52

TABULATED TEST RESULTS : RUDDER No. 3

WIND TUNNEL RUDDER DATA ANALYSIS

RUDDER NUMBER = 3
DATE OF TEST = 10/8/77,12/8/77
WIND SPEED = 42.95 M/S

AA=RUDDER ANGLE,ALPHA(DEG.), AD=RUDDER ANGLE,DELTA(DEG.)
CL=LIFT COEFFICIENT, CN=RUDDER NORMAL COEFFICIENT
CY=SHIP NORMAL COEFFICIENT, CD=DRAG COEFFICIENT
CPC=C OF P CHORD(%C), CPS=C OF P SPAN(%S)
ALL COEFFICIENTS BASED ON TOTAL AREA OF RUDDER PLUS SKEG

(A)=RUDDER PLUS SKEG, (B)=RUDDER ALONE, (C)=SKEG ALONE

REYNOLDS NO. = .116E 7

SKEG ANGLE,BETA(DEG.) = -15.25

	AA	AD	CL	CN	CY	CD	CPC	CPS
(A)	-20.91	-5.66	-.874	-.887	-.893	.197	25.65	49.33
(B)	-20.91	-5.66	-.529	-.549	-.549	.155	35.16	65.69
(C)	-20.91	-5.66	-.345			.042	10.61	20.94
(A)	-18.34	-3.09	-.779	-.79	-.792	.16	23.4	50.37
(B)	-18.34	-3.09	-.467	-.478	-.475	.11	33.6	67.71
(C)	-18.34	-3.09	-.312			.05	7.92	23.87
(A)	-15.77	-.52	-.695	-.704	-.703	.13	21.61	48.16
(B)	-15.77	-.52	-.404	-.413	-.412	.088	31.4	64.56
(C)	-15.77	-.52	-.291			.042	7.67	25.01
(A)	-13.2	2.05	-.594	-.601	-.599	.099	18.74	47.25
(B)	-13.2	2.05	-.318	-.321	-.319	.051	27.21	68.05
(C)	-13.2	2.05	-.276			.043	8.91	23.57
(A)	-10.62	4.63	-.494	-.499	-.495	.073	15.38	47.07
(B)	-10.62	4.63	-.243	-.244	-.241	.027	24.47	71.74
(C)	-10.62	4.63	-.251			.046	6.52	23.65
(A)	-8.05	7.2	-.403	-.407	-.403	.054	12.61	45.58
(B)	-8.05	7.2	-.177	-.176	-.172	.008	20.87	74.59
(C)	-8.05	7.2	-.226			.046	6.26	23.68
(A)	-5.48	9.77	-.309	-.312	-.308	.041	9.37	43.47
(B)	-5.48	9.77	-.108	-.107	-.103	-.001	17.3	84.25
(C)	-5.48	9.77	-.201			.042	5.3	22.55
(A)	-2.91	12.34	-.212	-.213	-.213	.032	2.63	41
(B)	-2.91	12.34	-.041	-.041	-.038	-.005	.68	124.53
(C)	-2.91	12.34	-.171			.037	3.47	22.05
(A)	-.33	14.92	-.112	-.112	-.115	.028	-16.52	31.95
(B)	-.33	14.92	.031	.031	.031	-.003	68.17	-30.19
(C)	-.33	14.92	-.143			.031	2.72	19.12
(A)	1.72	16.97	-.039	-.038	-.045	.03	-106.23	9.76
(B)	1.72	16.97	.098	.098	.095	-.002	45.91	25.67
(C)	1.72	16.97	-.137			.032	4.1	22.48
(A)	4.82	20.07	.088	.092	.071	.052	90.94	63.89
(B)	4.82	20.07	.172	.173	.161	.019	44.09	46.59
(C)	4.82	20.07	-.084			.033	-4.45	28.17
(A)	6.34	21.59	.118	.123	.099	.056	76.87	61.89
(B)	6.34	21.59	.194	.196	.18	.027	42.73	42.98
(C)	6.34	21.59	-.076			.029	-9.42	28.42
(A)	7.35	22.6	.139	.145	.119	.057	69.24	67.71
(B)	7.35	22.6	.229	.231	.212	.034	42.09	48.92
(C)	7.35	22.6	-.09			.023	-.69	19.41
(A)	9.93	25.18	.243	.253	.214	.077	54.88	57.72
(B)	9.93	25.18	.297	.302	.273	.052	41.6	51.22
(C)	9.93	25.18	-.054			.025	-15.33	10.96
(A)	12.5	27.75	.332	.347	.293	.105	48.13	48.64
(B)	12.5	27.75	.347	.357	.313	.082	40.95	49.49
(C)	12.5	27.75	-.013			.023	-81.51	38.64
(A)	15.07	30.32	.423	.438	.379	.113	44.96	55.76
(B)	15.07	30.32	.405	.419	.363	.106	40.83	53.64
(C)	15.07	30.32	.018			.007	162.29	76.66
(A)	17.58	32.63	.441	.463	.389	.14	43.39	59.97
(B)	17.58	32.83	.447	.461	.402	.114	39.17	57.43
(C)	17.58	32.83	-.006			.026	-107.03	-65.59
(A)	20.11	35.36	.48	.506	.422	.161	42.23	61.14
(B)	20.11	35.36	.488	.507	.433	.143	39.52	60.32
(C)	20.11	35.36	-.008			.018	-75.83	-19.1
(A)	22.88	38.13	.573	.6	.505	.186	40.99	59.33
(B)	22.88	38.13	.548	.574	.483	.177	39.8	60.86
(C)	22.88	38.13	.025			.009	73.89	1.75
(A)	25.86	41.11	.669	.7	.588	.224	40.88	59.57
(B)	25.86	41.11	.604	.635	.529	.21	40.4	62.79
(C)	25.86	41.11	.065			.014	46.5	26.14

TABULATED TEST RESULTS : RUDDER No. 3

UAFM [21 , 1]   30-Jun-78   10:05

WIND TUNNEL RUDDER DATA ANALYSIS

RUDDER NUMBER = 3
DATE OF TEST = 11/8/77,12/8/77
WIND SPEED = 31.56 M/S

AA=RUDDER ANGLE,ALPHA(DEG.), AD=RUDDER ANGLE,DELTA(DEG.)
CL=LIFT COEFFICIENT, CN=RUDDER NORMAL COEFFICIENT
CY=SHIP NORMAL COEFFICIENT, CD=DRAG COEFFICIENT
CPC=C OF P CHORD(%C), CPS=C OF P SPAN(%S)
ALL COEFFICIENTS BASED ON TOTAL AREA OF RUDDER PLUS SKEG

(A)=RUDDER PLUS SKEG, (B)=RUDDER ALONE, (C)=SKEG ALONE

REYNOLDS NO. = 880000

SKEG ANGLE,BETA(DEG.) = 14.75

	AA	AD	CL	CN	CY	CD	CPC	CPS
(A)	-5.37	-20.12	-.156	-.158	-.142	.033	65.17	15.67
(B)	-5.37	-20.12	-.172	-.173	-.161	.024	39.05	41.31
(C)	-5.37	-20.12	.016			.009	-189.65	283.62
(A)	-2.78	-17.53	-.035	-.036	-.027	.026	165.35	-31.29
(B)	-2.79	-17.53	-.102	-.102	-.096	.01	38.78	29.81
(C)	-2.78	-17.53	.067			.016	-29.29	65.03
(A)	-.17	-14.92	.111	.111	.114	.027	-9.43	38.87
(B)	-.17	-14.92	-.033	-.033	-.032	0	50.56	-24.46
(C)	-.17	-14.92	.144			.027	4.77	24.82
(A)	1.89	-12.86	.18	.181	.181	.028	4.62	43.07
(B)	1.89	-12.86	.021	.021	.02	-.002	-2.98	182.85
(C)	1.89	-12.86	.159			.03	5.98	25.09
(A)	4.97	-9.78	.286	.288	.285	.034	11.42	45.75
(B)	4.97	-9.78	.101	.101	.097	0	20.62	97.46
(C)	4.97	-9.78	.185			.034	6.58	23.35
(A)	7.54	-7.21	.379	.381	.376	.039	14.45	46.34
(B)	7.54	-7.21	.17	.17	.166	.008	23.03	76.86
(C)	7.54	-7.21	.209			.031	7.49	22.18
(A)	10.11	-4.64	.474	.476	.471	.053	17.31	47.71
(B)	10.11	-4.64	.245	.245	.241	.021	26.76	70.35
(C)	10.11	-4.64	.229			.032	7.23	23.87
(A)	12.69	-2.06	.58	.581	.578	.07	20.14	48.58
(B)	12.69	-2.06	.317	.318	.316	.042	30.1	68.34
(C)	12.69	-2.06	.263			.028	8.02	24.71
(A)	15.26	.51	.676	.678	.677	.097	22.72	48.29
(B)	15.26	.51	.39	.393	.392	.063	33.03	66.51
(C)	15.26	.51	.286			.034	8.6	23.17
(A)	17.82	3.07	.761	.763	.766	.125	24.88	49.61
(B)	17.62	3.07	.447	.454	.454	.093	34.84	67.98
(C)	17.82	3.07	.314			.032	10.63	22.73
(A)	20.42	5.67	.882	.886	.894	.169	26.77	45.65
(B)	20.42	5.67	.52	.53	.531	.121	37.19	64.33
(C)	20.42	5.67	.362			.048	11.86	18.08
(A)	22.98	8.23	.961	.967	.99	.21	28.92	47.57
(B)	22.98	8.23	.576	.588	.592	.149	39.46	63.37
(C)	22.98	8.23	.385			.061	13.41	23.45
(A)	25.47	10.72	.952	.966	.981	.248	32.07	48.38
(B)	25.47	10.72	.62	.639	.644	.185	40.93	66.96
(C)	25.47	10.72	.332			.063	15.53	12.68
(A)	27.97	13.22	.948	.979	.991	.303	33.44	50.54
(B)	27.97	13.22	.658	.691	.694	.235	43.45	61.45
(C)	27.97	13.22	.29			.065	10.42	23.53
(A)	30.45	15.7	.926	.961	.975	.321	33.55	53.98
(B)	30.45	15.7	.64	.696	.689	.285	42.99	66.01
(C)	30.45	15.7	.286			.036	11.08	22.2
(A)	33.05	18.3	1.061	1.112	1.127	.409	34.24	46.02
(B)	33.05	18.3	.678	.743	.735	.321	44.82	65
(C)	33.05	18.3	.383			.088	14.51	10.58
(A)	35.34	20.59	.781	.883	.862	.425	35.21	46.28
(B)	35.34	20.59	.77	.836	.835	.36	42.49	59.54
(C)	35.34	20.59	.011			.065	-203.33	-423.29

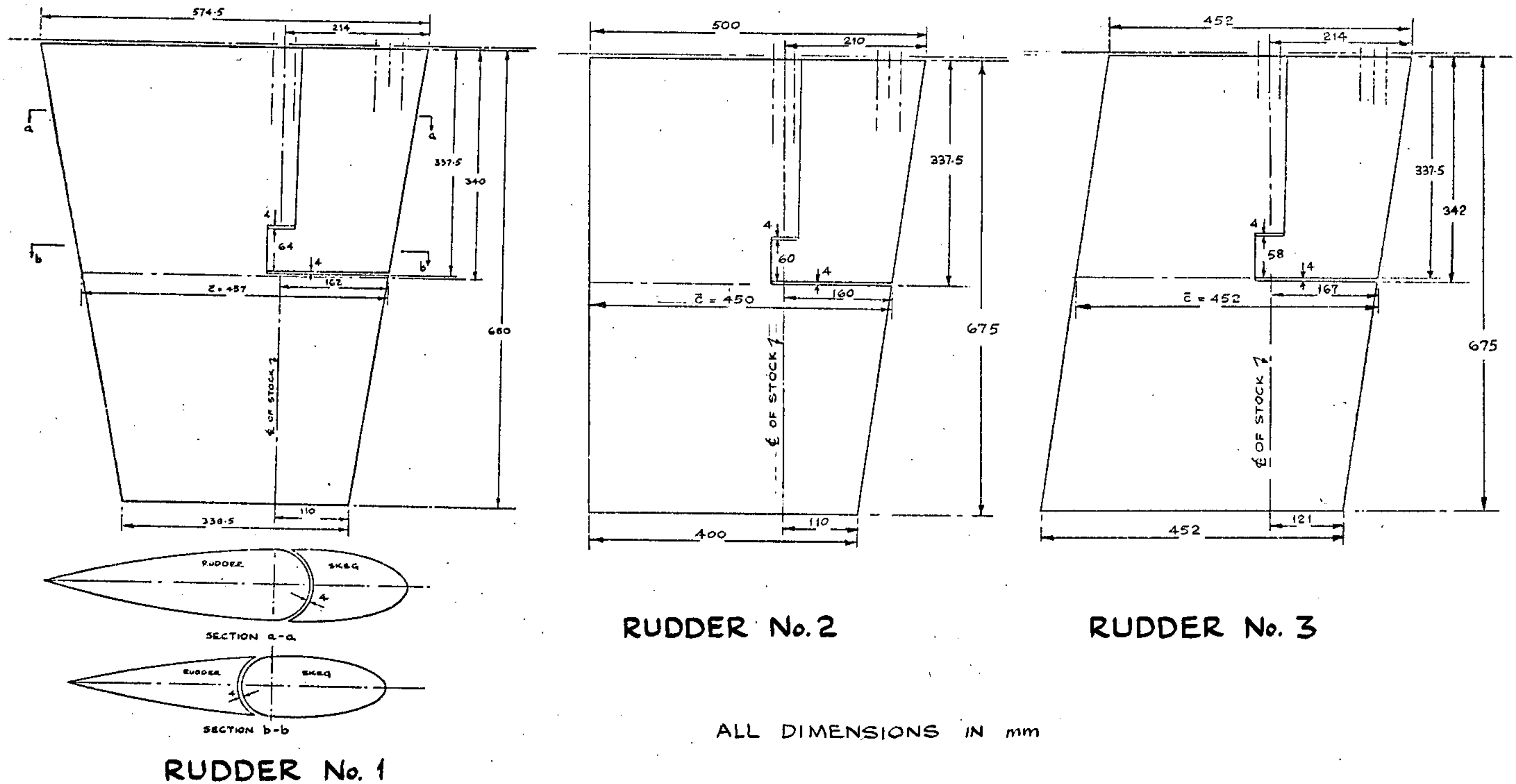


Fig. 1 DIMENSIONS OF MODEL RUDDERS

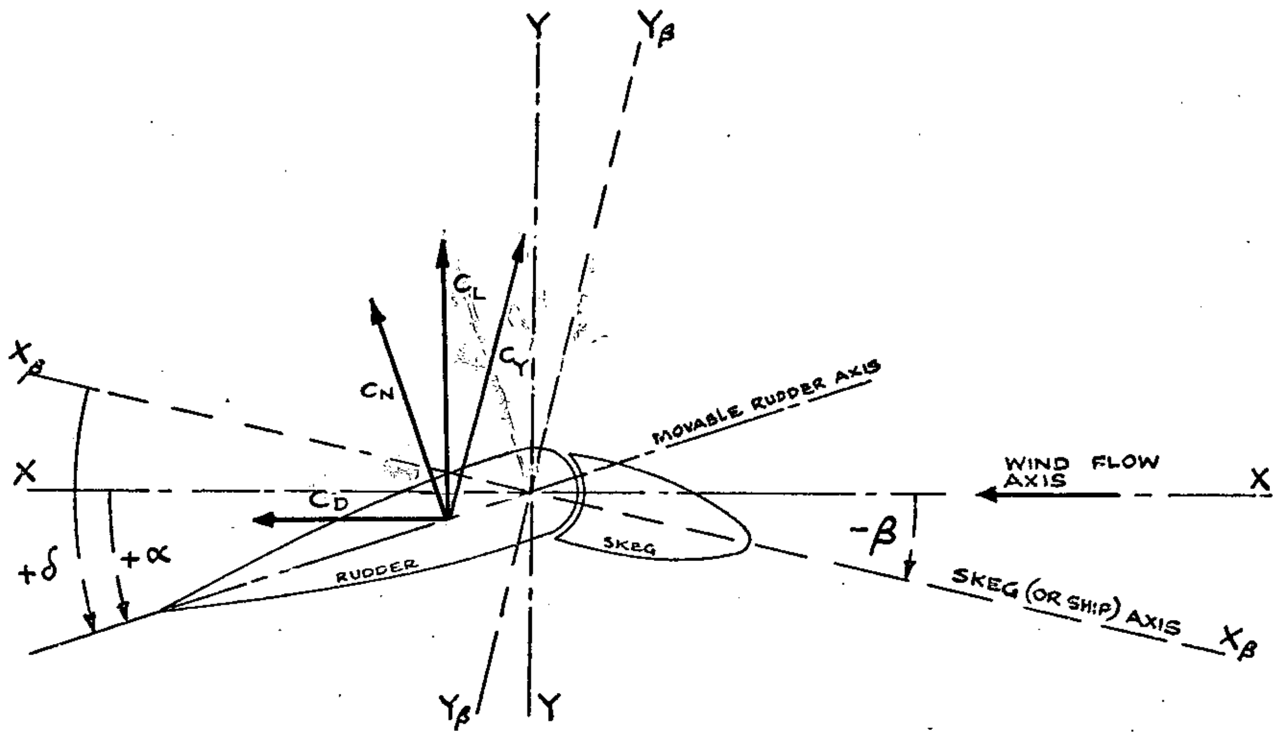


Fig. 2 NOTATION OF ANGLES AND COEFFICIENTS

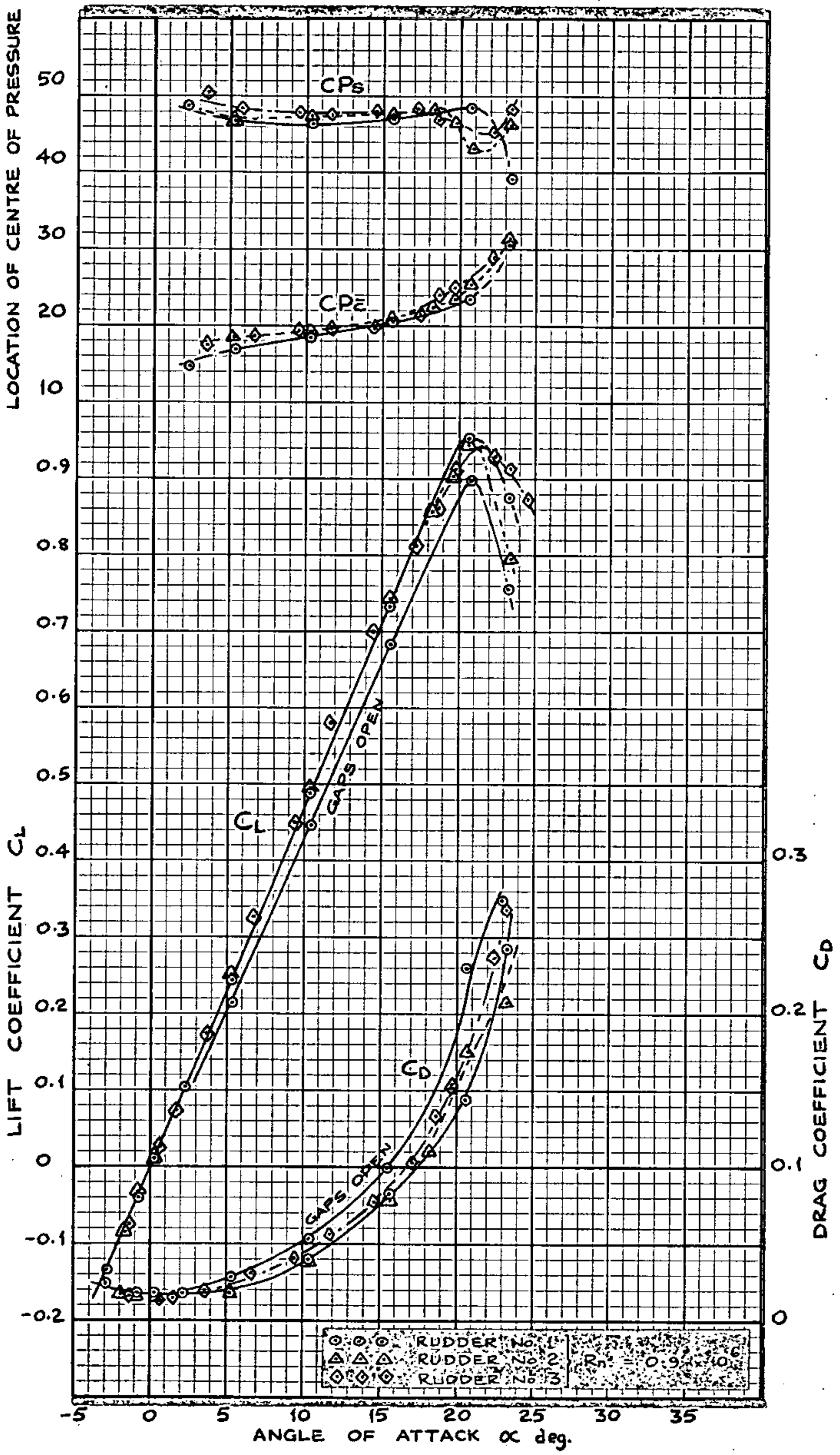


Fig. 3 LIFT, DRAG AND CENTRE OF PRESSURE CHARACTERISTICS FOR ALL-MOVABLE RUDDERS

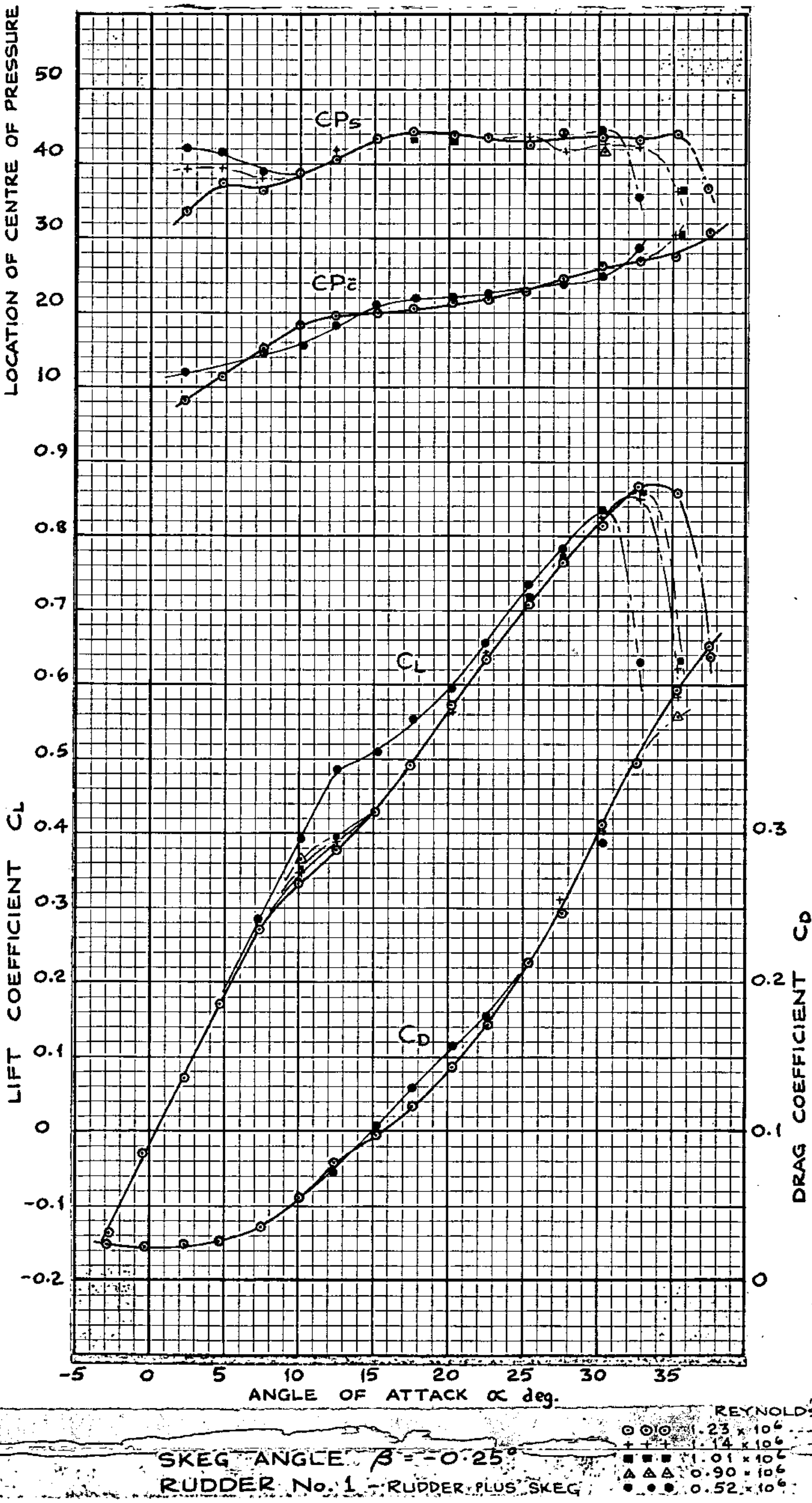
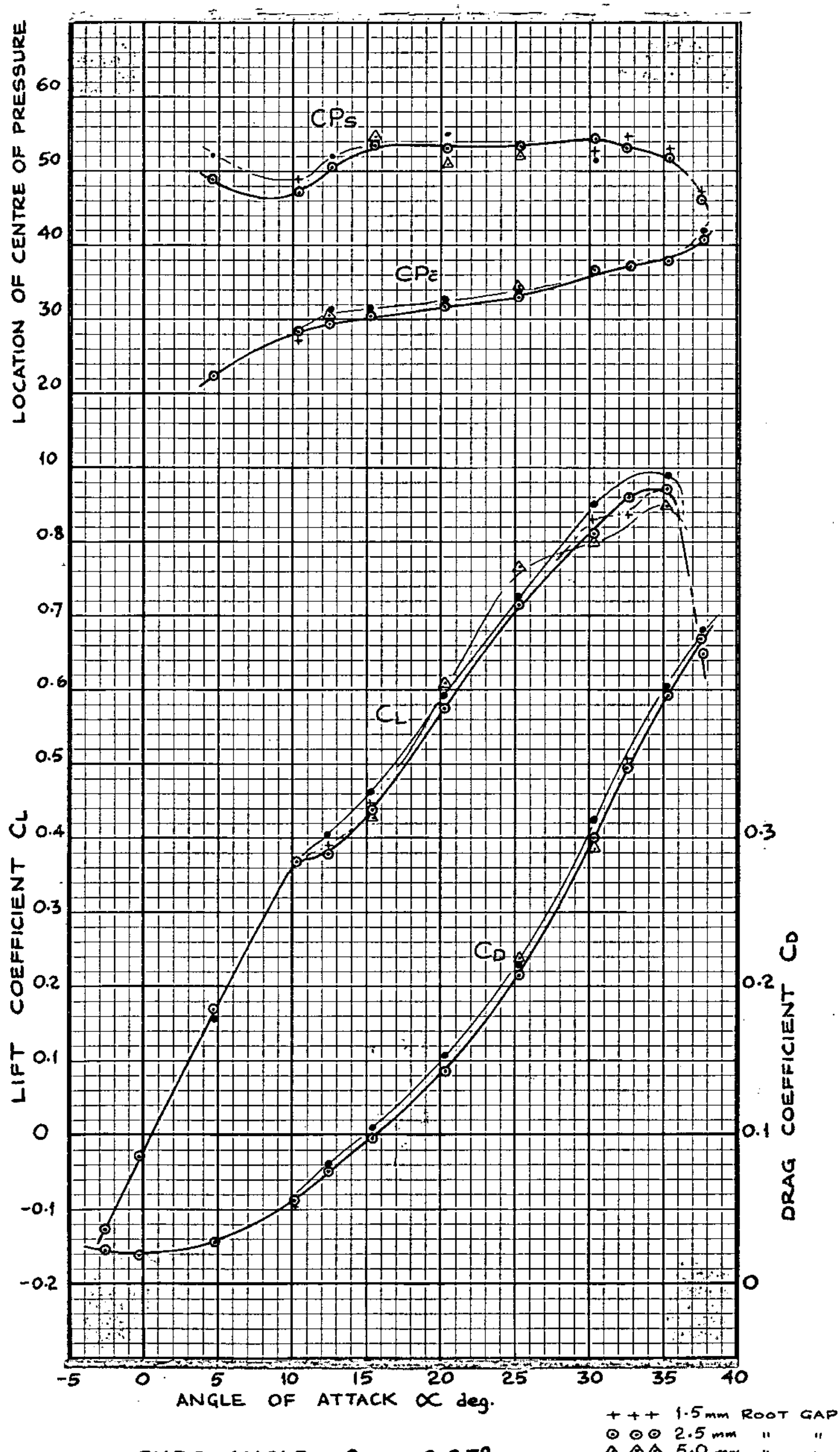


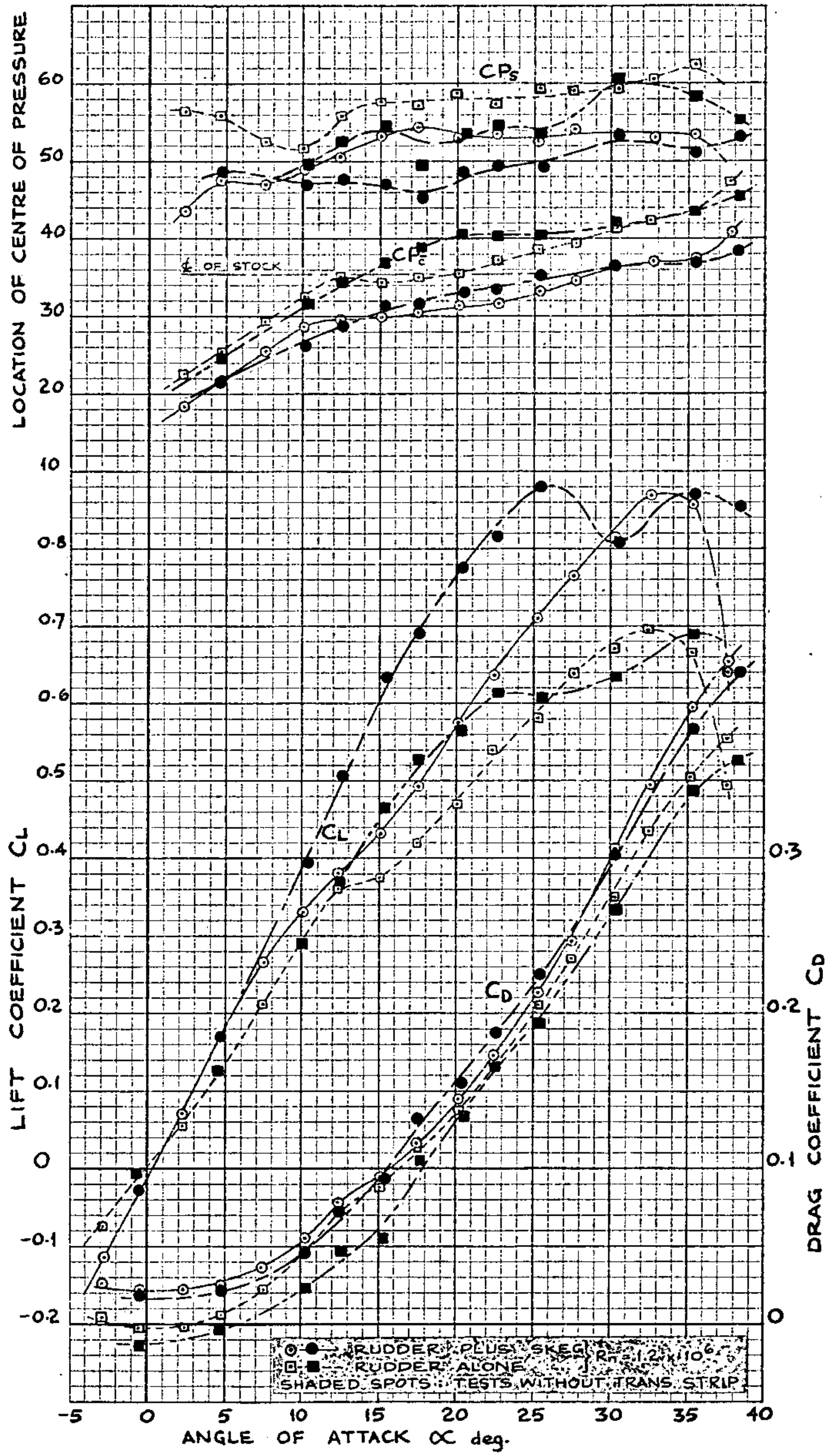
Fig. 4 INFLUENCE OF REYNOLDS NUMBER



SKEG ANGLE β = −0.25°

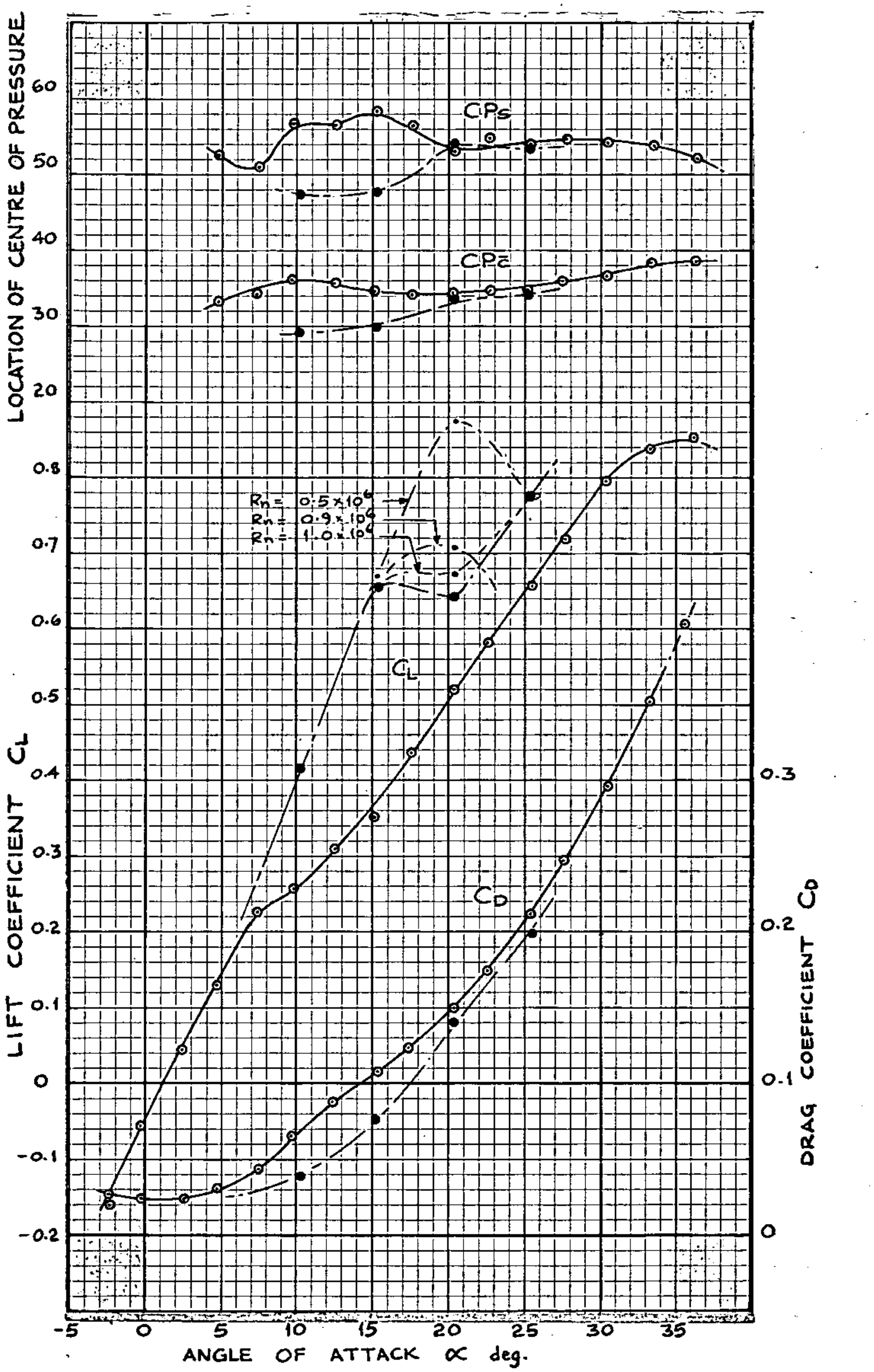
RUDDER No. 1 - RUDDER PLUS SKEG - Rn = 1.2 × 10⁶

Fig. 5 INFLUENCE OF RUDDER ROOT GAP



SKEG ANGLE $\beta = -0.25°$

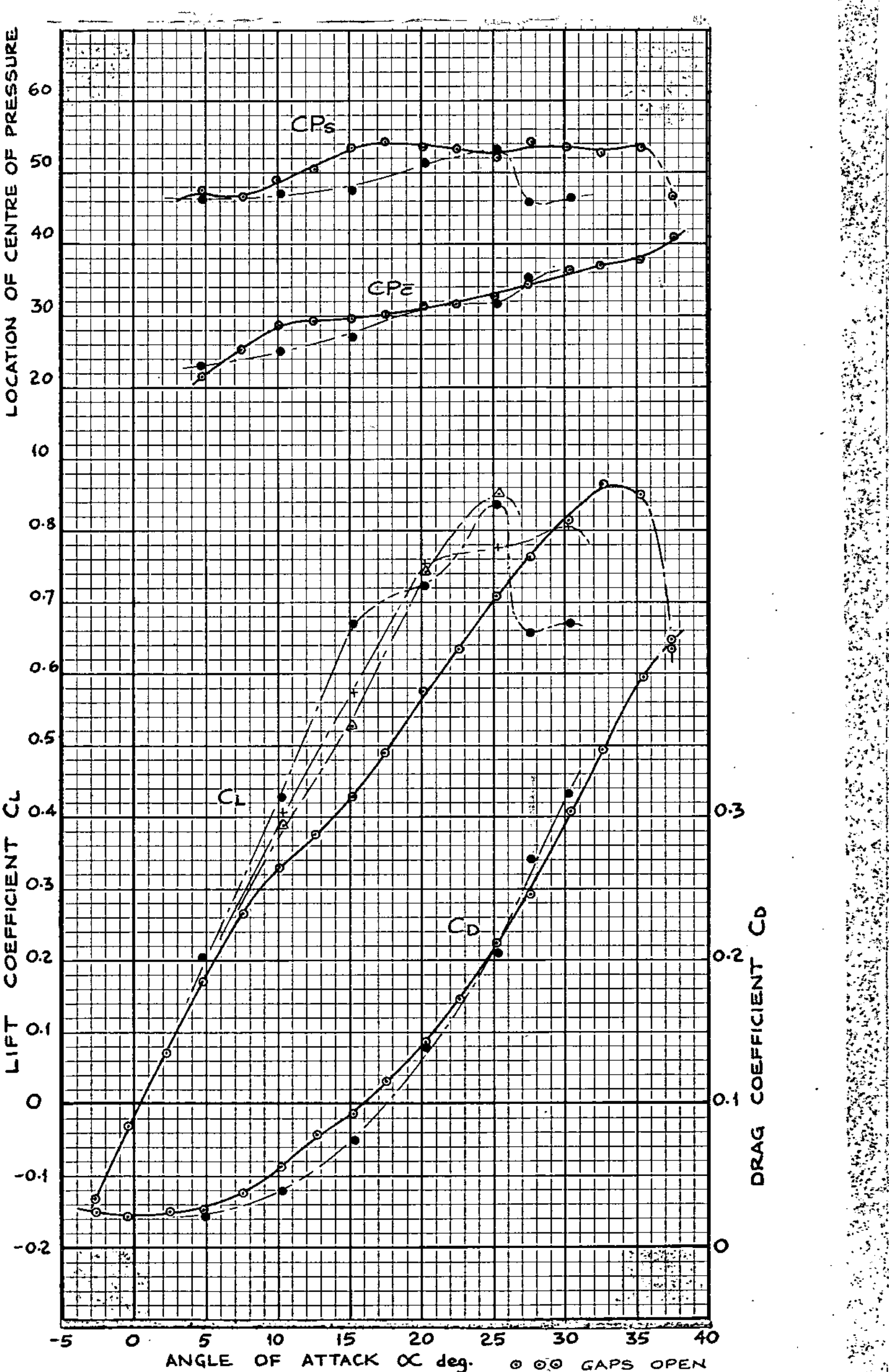
Fig. 6. LIFT, DRAG AND CENTRE OF PRESSURE CHARACTERISTICS FOR SKEG RUDDER No. 1
TESTS WITHOUT TRANSITION STRIP



SKEG ANGLE $\beta = -5.25°$

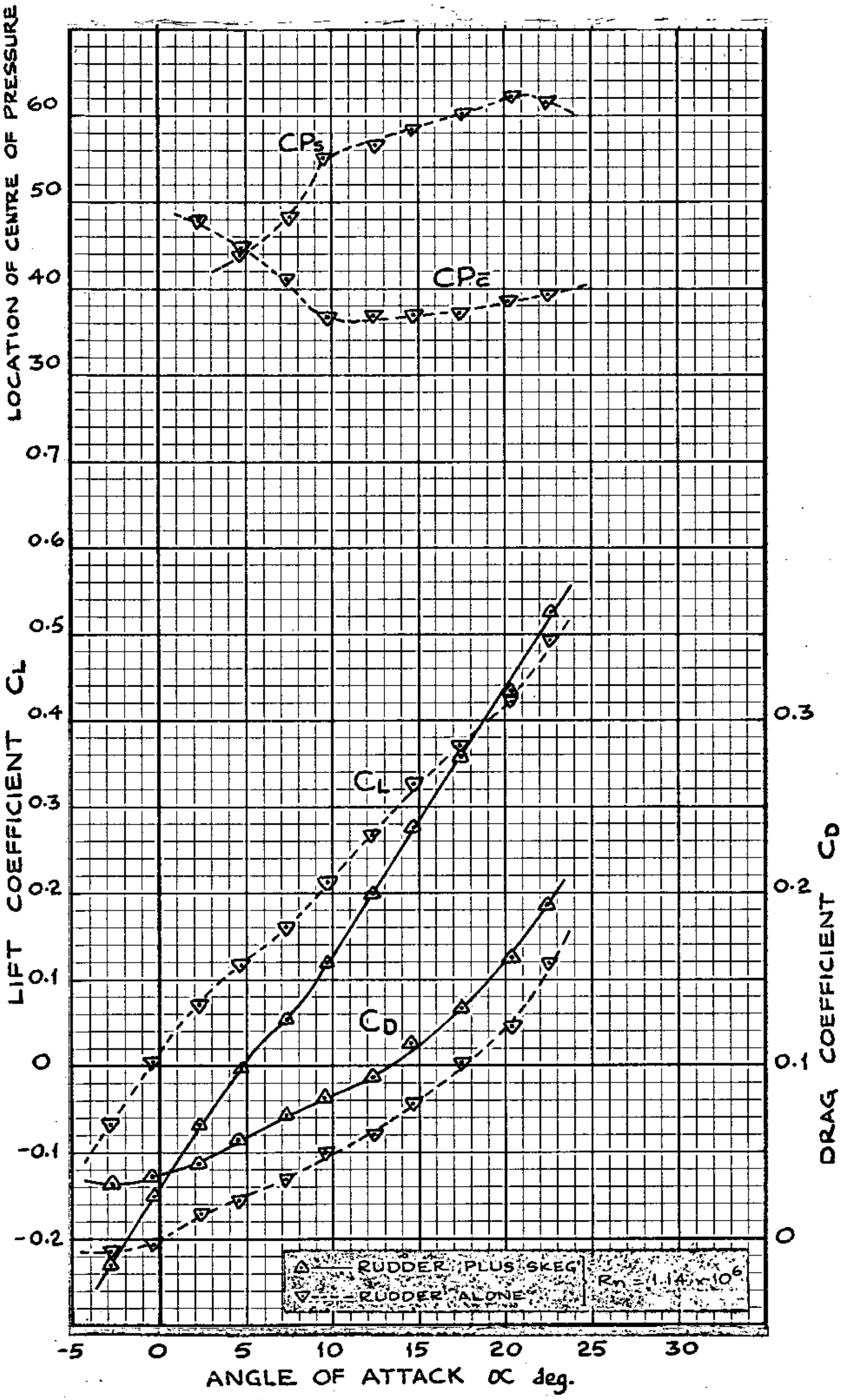
RUDDER No. 1 – RUDDER PLUS SKEG – $R_n = 1.2 \times 10^6$

Fig. 7a INFLUENCE OF SEALED GAPS



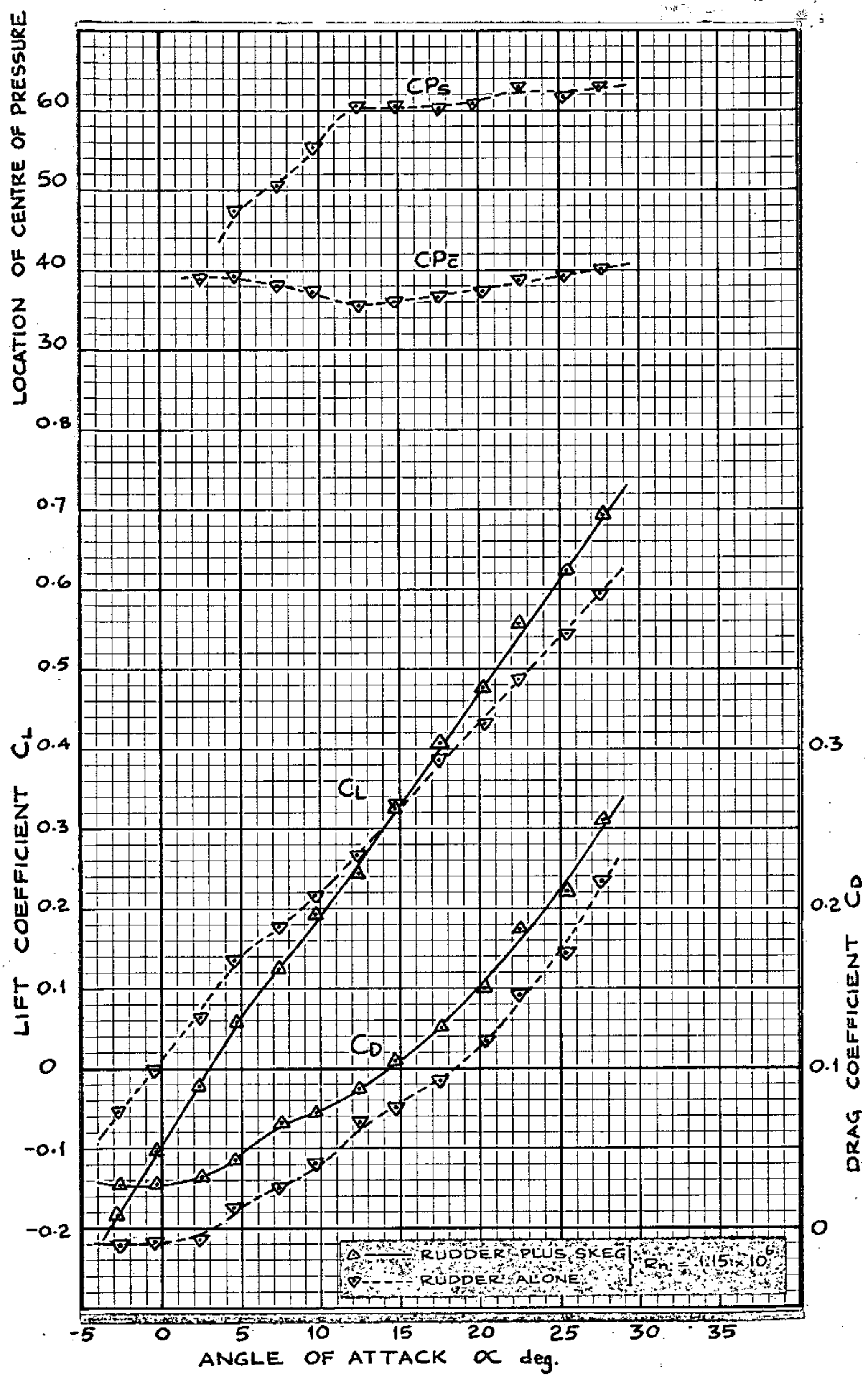
RUDDER No.1 : RUDDER PLUS SKEG : $R_n = 1.2 \times 10^6$

Fig. 7b INFLUENCE OF SEALED GAPS



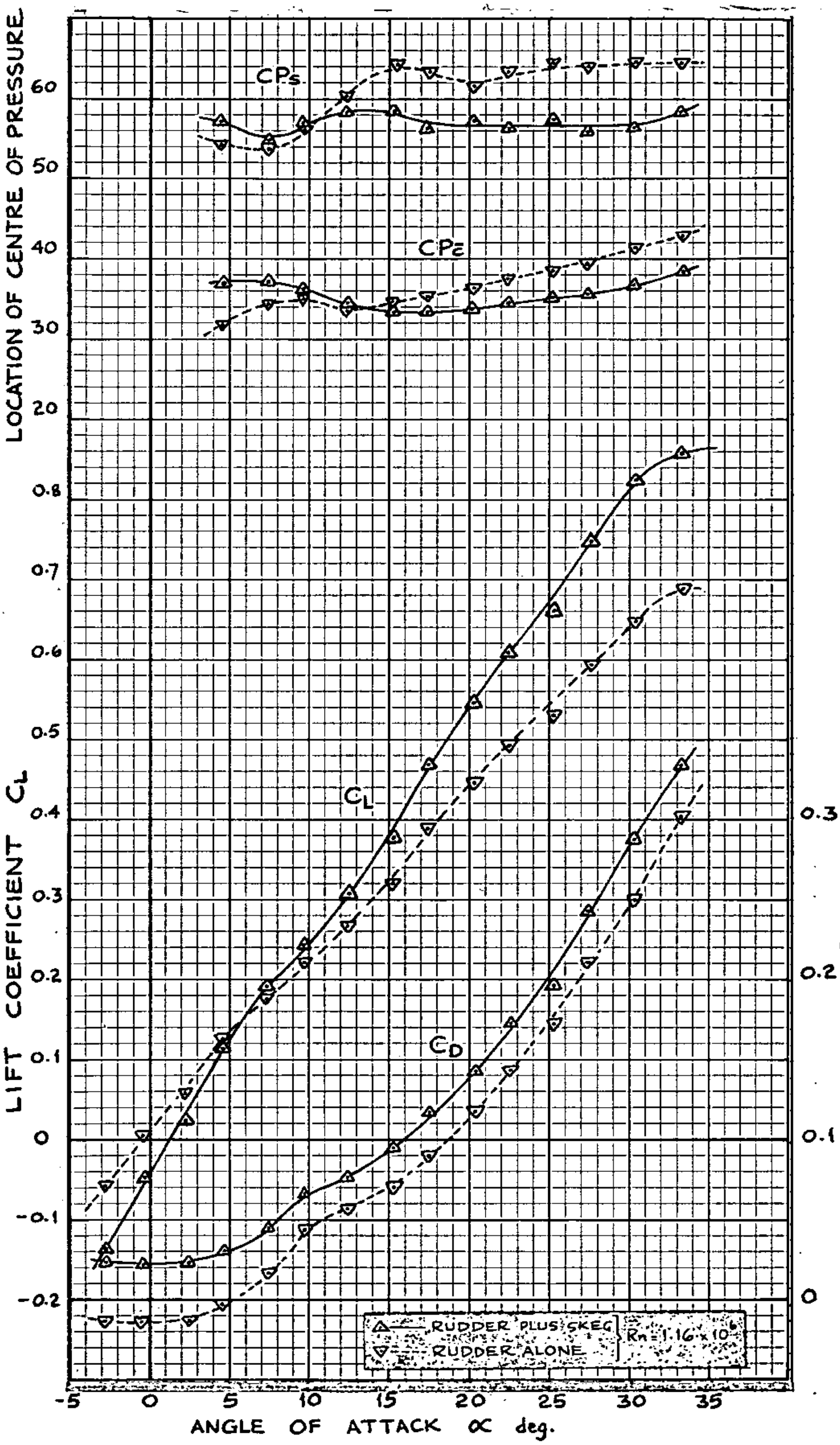
SKEG ANGLE $\beta = -15.25°$

Fig. 8a LIFT, DRAG AND CENTRE OF PRESSURE CHARACTERISTICS FOR SKEG RUDDER No. 2



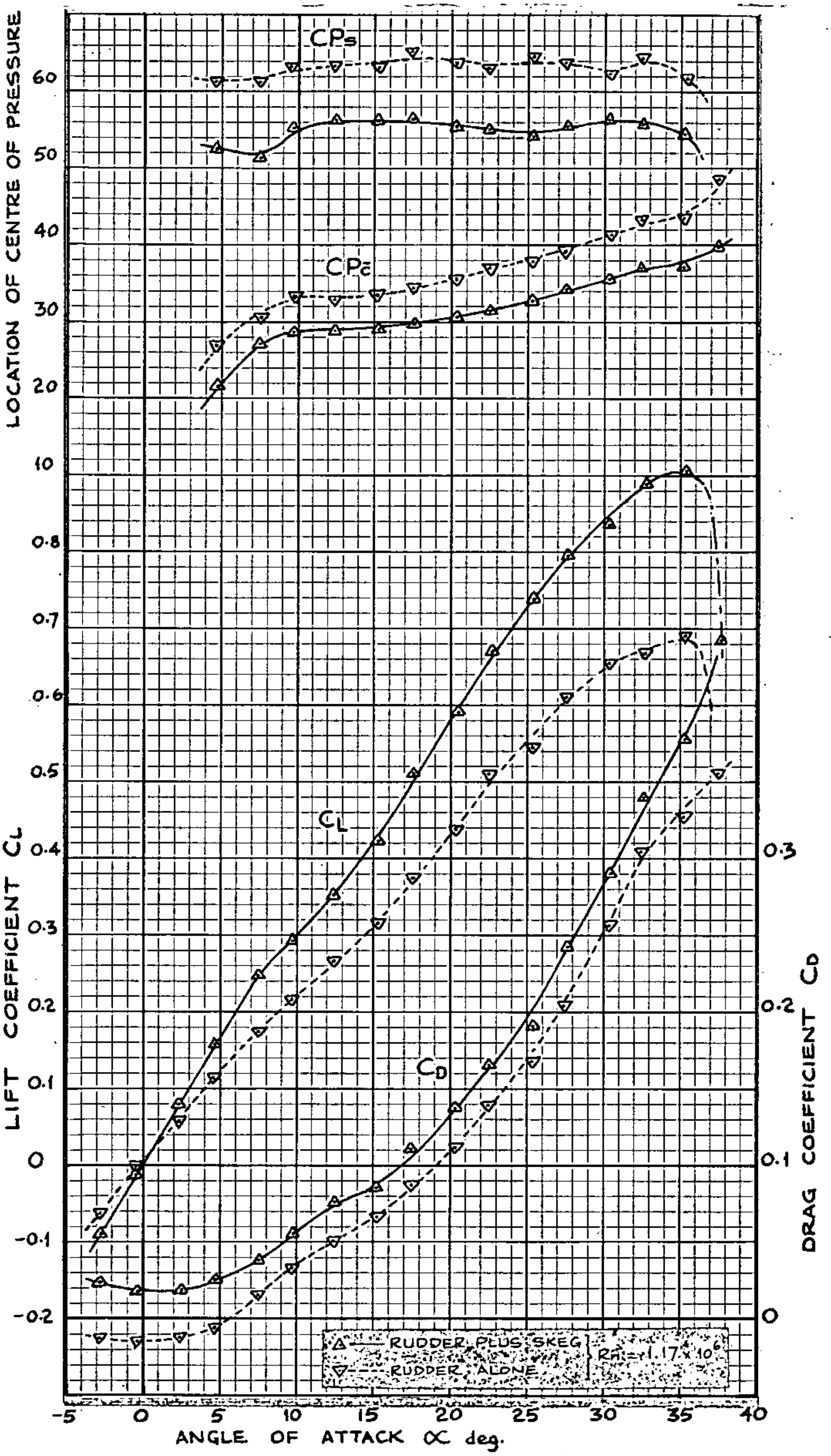
SKEG ANGLE $\beta = -10.25°$

Fig. 8b LIFT, DRAG AND CENTRE OF PRESSURE CHARACTERISTICS FOR SKEG RUDDER No. 2



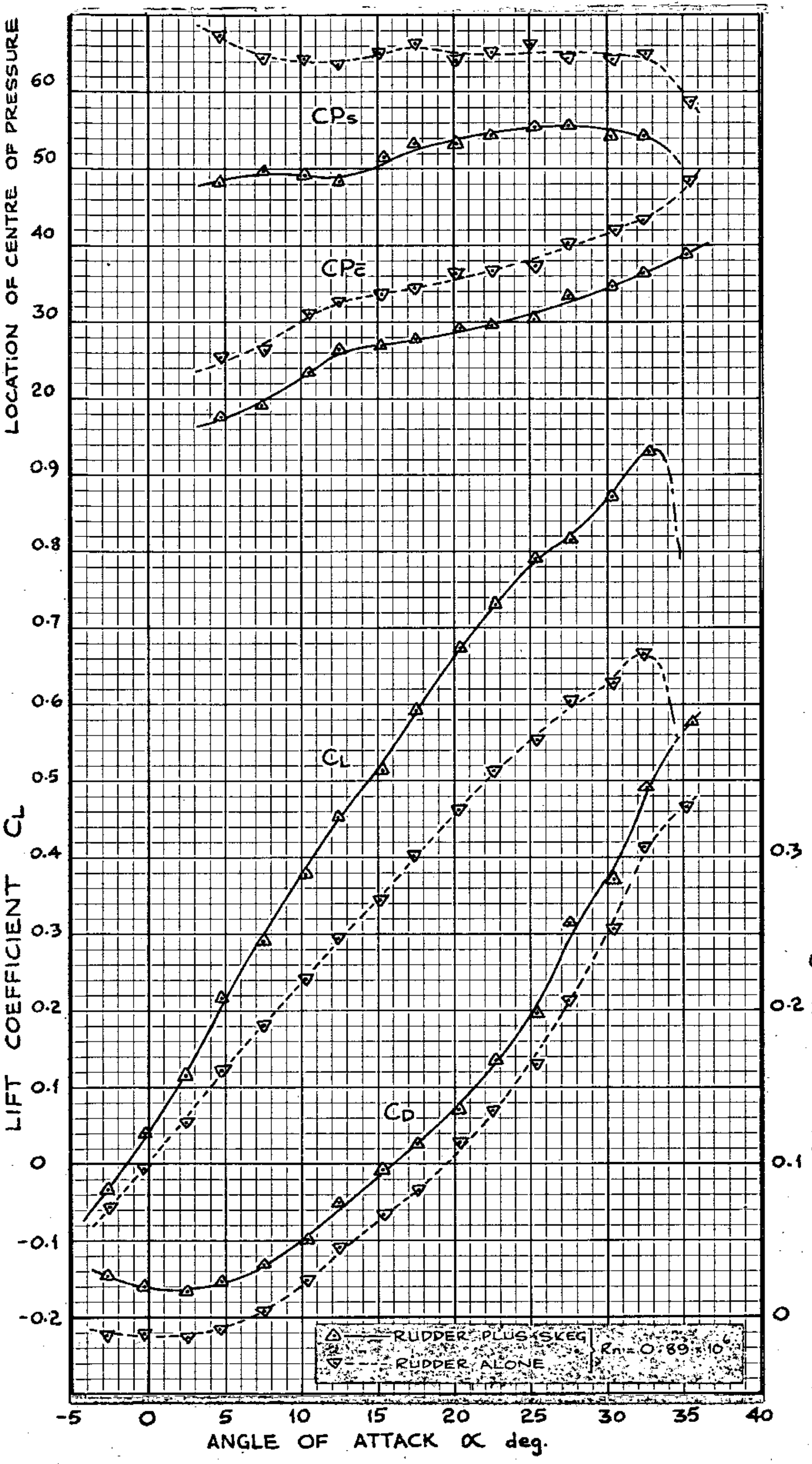
SKEG ANGLE $\beta = -5.25°$

Fig. 8c LIFT, DRAG AND CENTRE OF PRESSURE CHARACTERISTICS FOR SKEG RUDDER No. 2



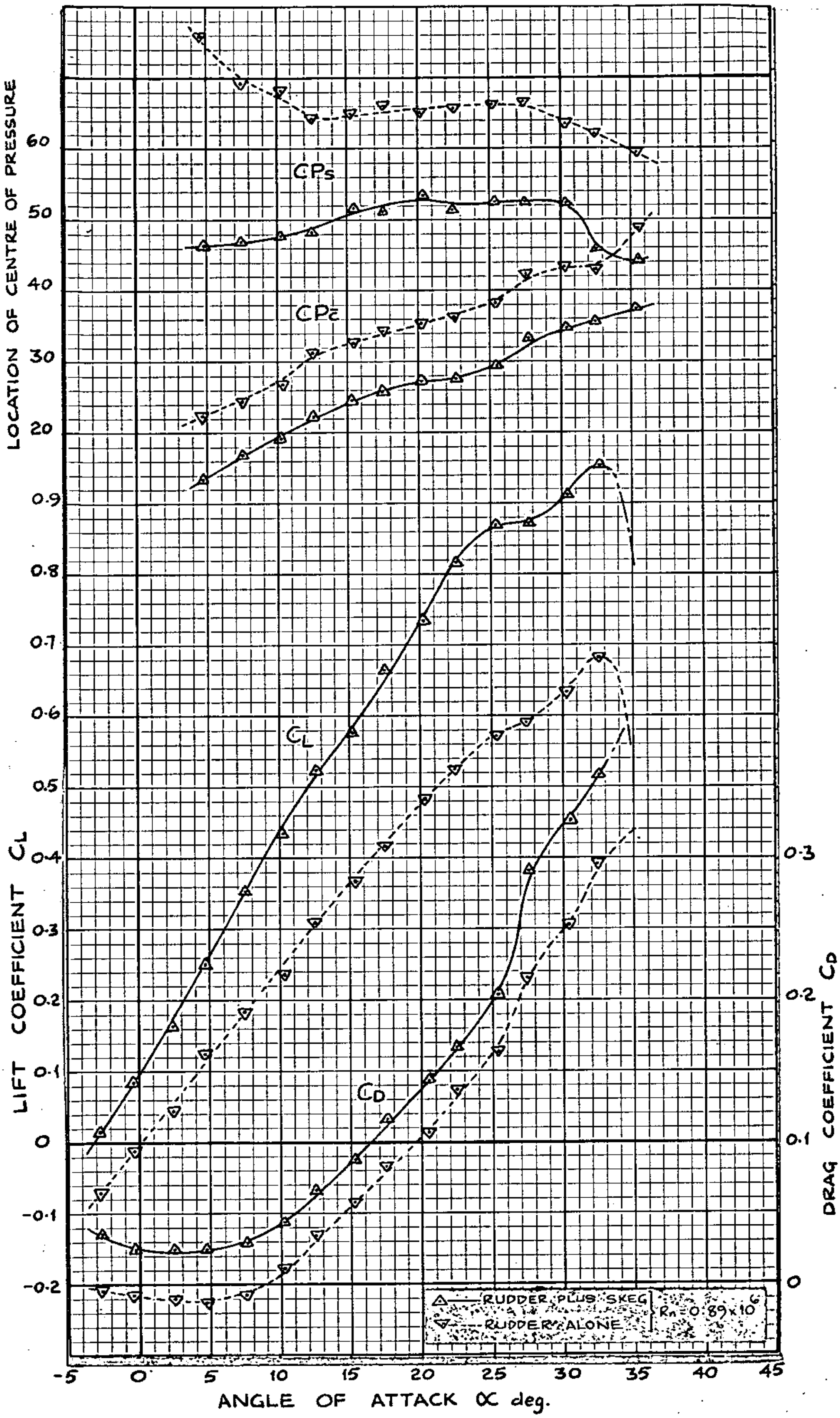
SKEG ANGLE $\beta = -0.25°$

Fig. 8d. LIFT, DRAG AND CENTRE OF PRESSURE CHARACTERISTICS FOR SKEG RUDDER No. 2



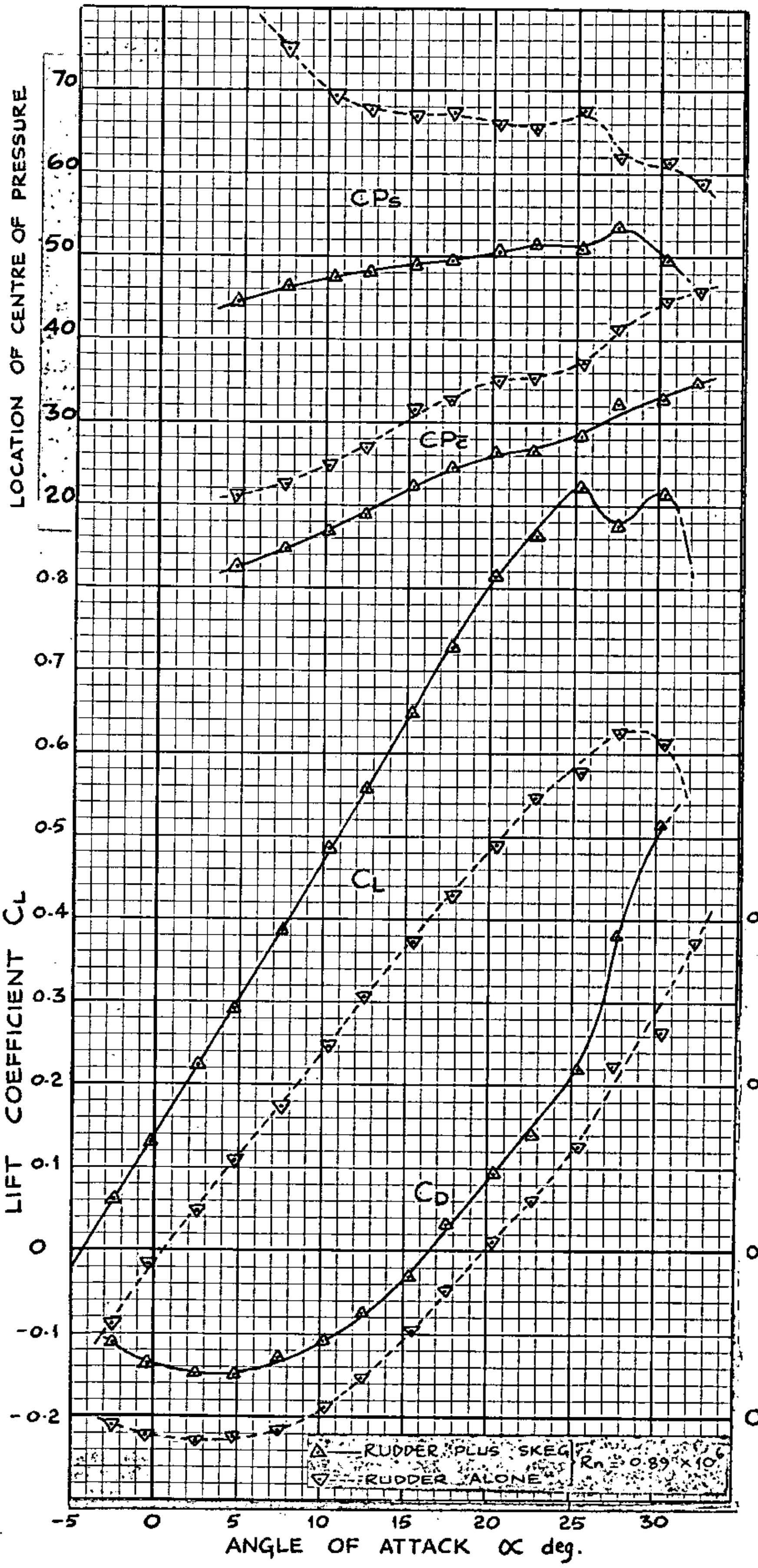
SKEG ANGLE $\beta = +4.75°$

Fig. 8e LIFT, DRAG AND CENTRE OF PRESSURE CHARACTERISTICS FOR SKEG RUDDER No. 2



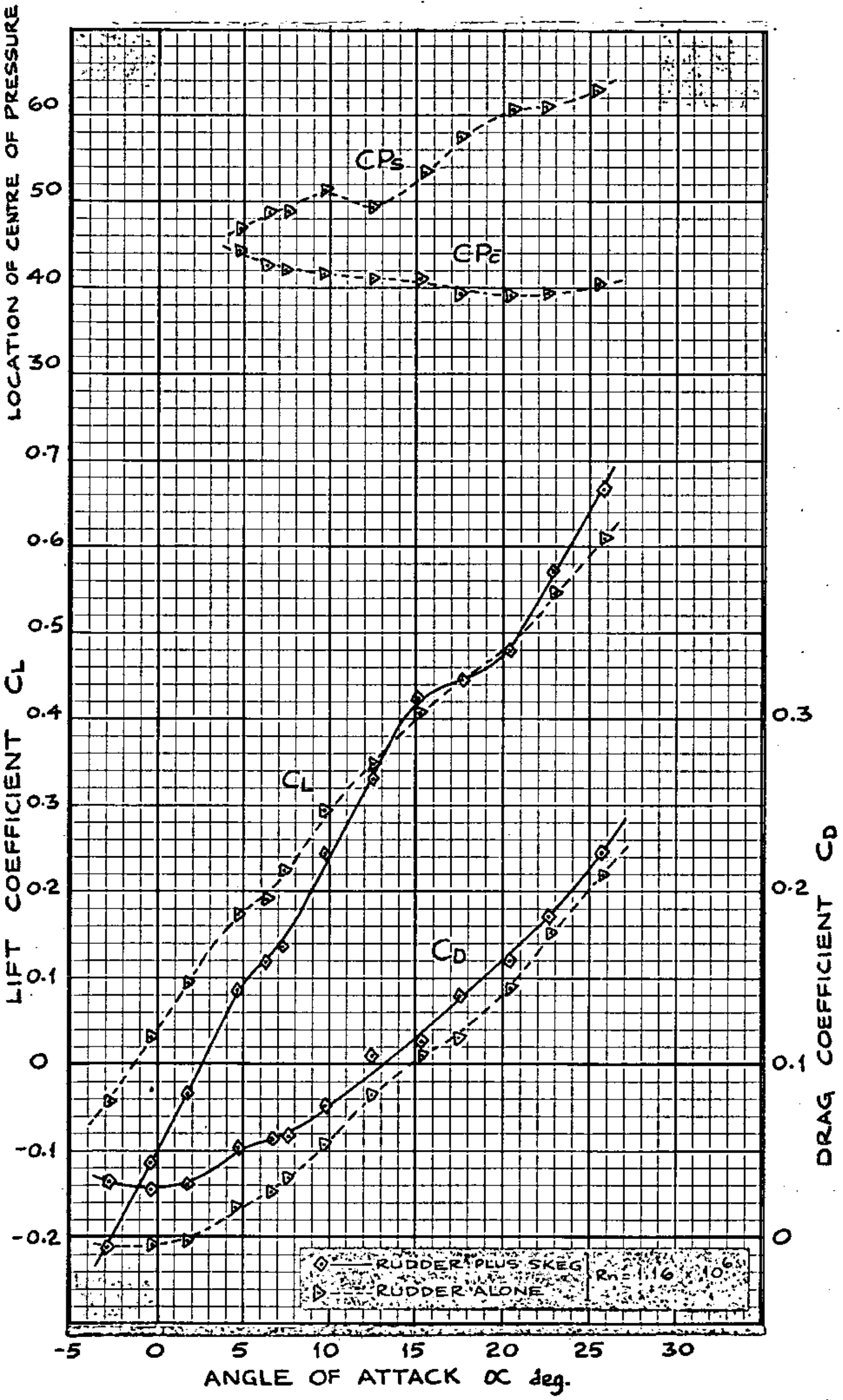
SKEG ANGLE $\beta = +9.75°$

Fig. 8f LIFT, DRAG AND CENTRE OF PRESSURE CHARACTERISTICS FOR SKEG RUDDER No. 2



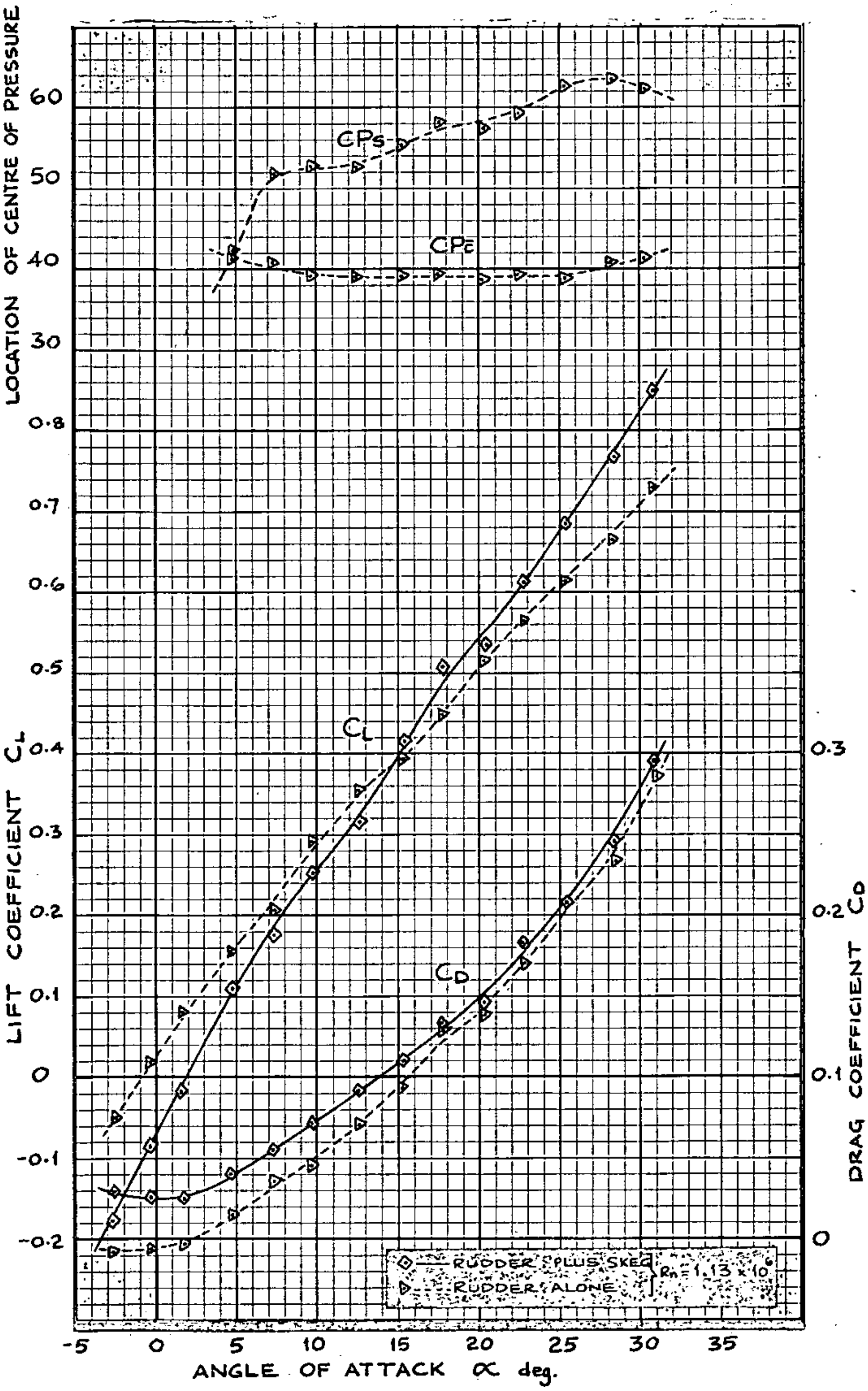
SKEG ANGLE $\beta = +14.75°$

Fig. 88 LIFT, DRAG AND CENTRE OF PRESSURE CHARACTERISTICS FOR SKEG RUDDER No. 2



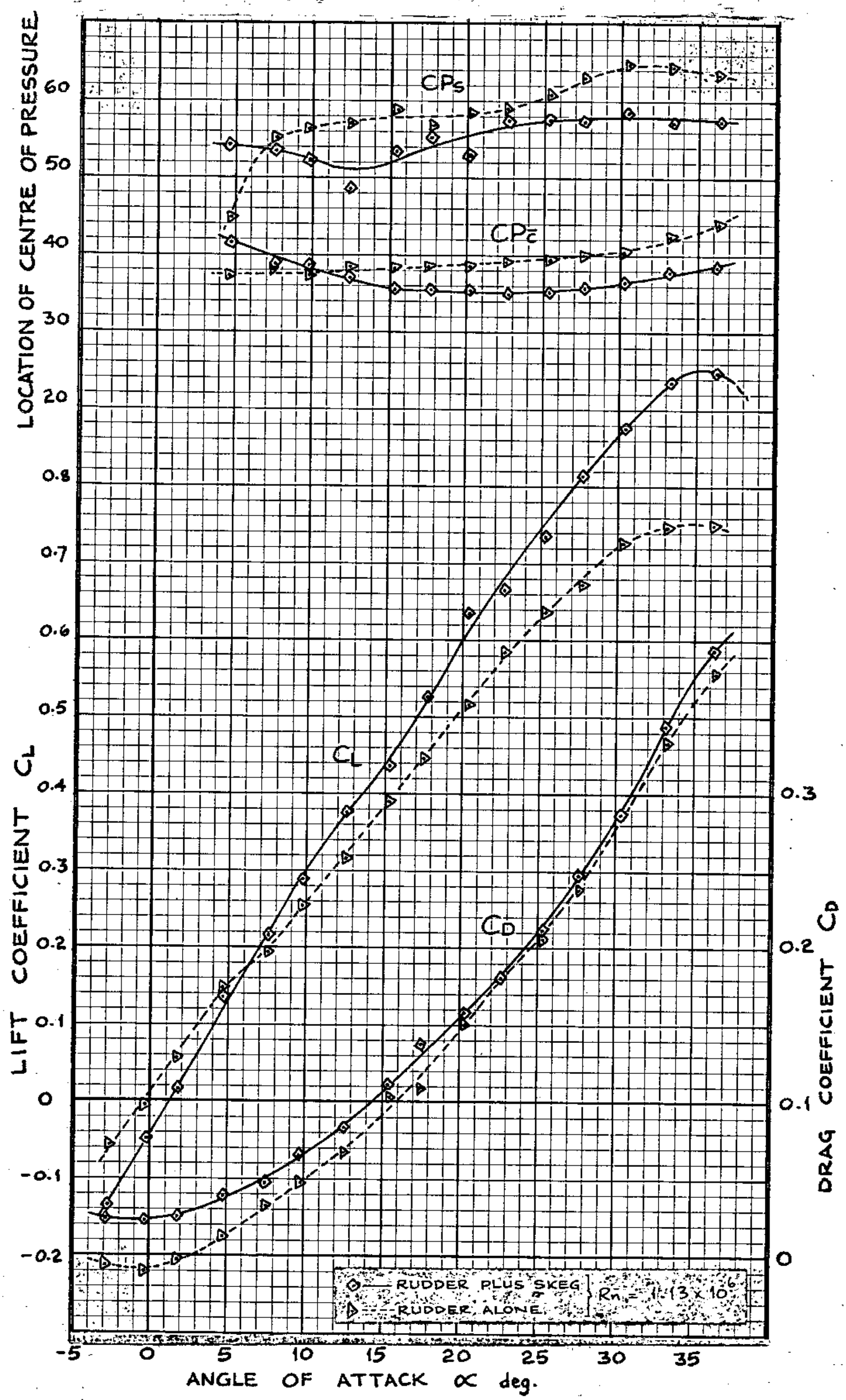
SKEG ANGLE $\beta = -15.25°$

Fig. 9a LIFT, DRAG AND CENTRE OF PRESSURE CHARACTERISTICS FOR SKEG RUDDER No. 3



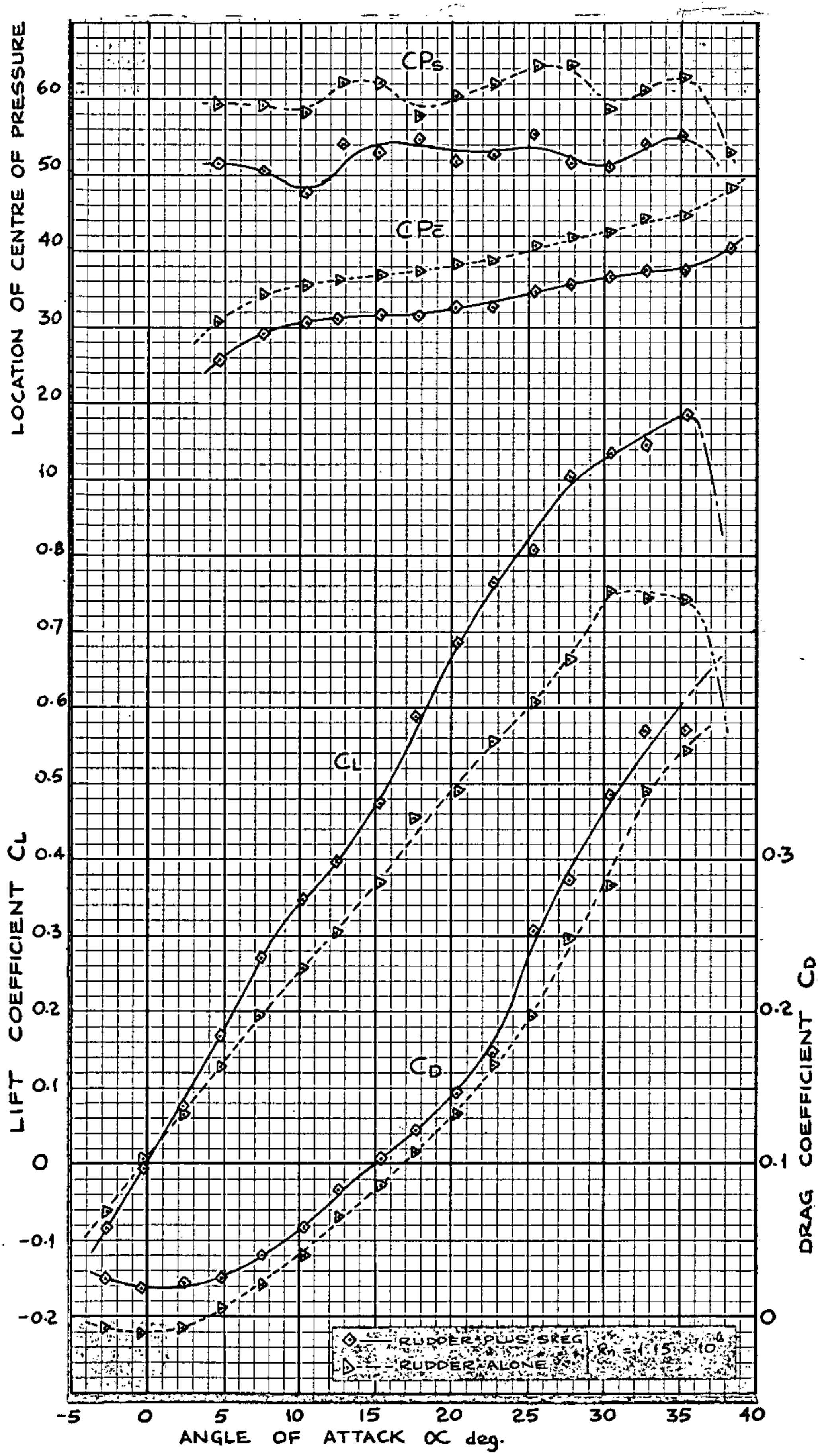
SKEG ANGLE $\beta = -10.25°$

Fig. 9b LIFT, DRAG AND CENTRE OF PRESSURE CHARACTERISTICS FOR SKEG RUDDER No. 3



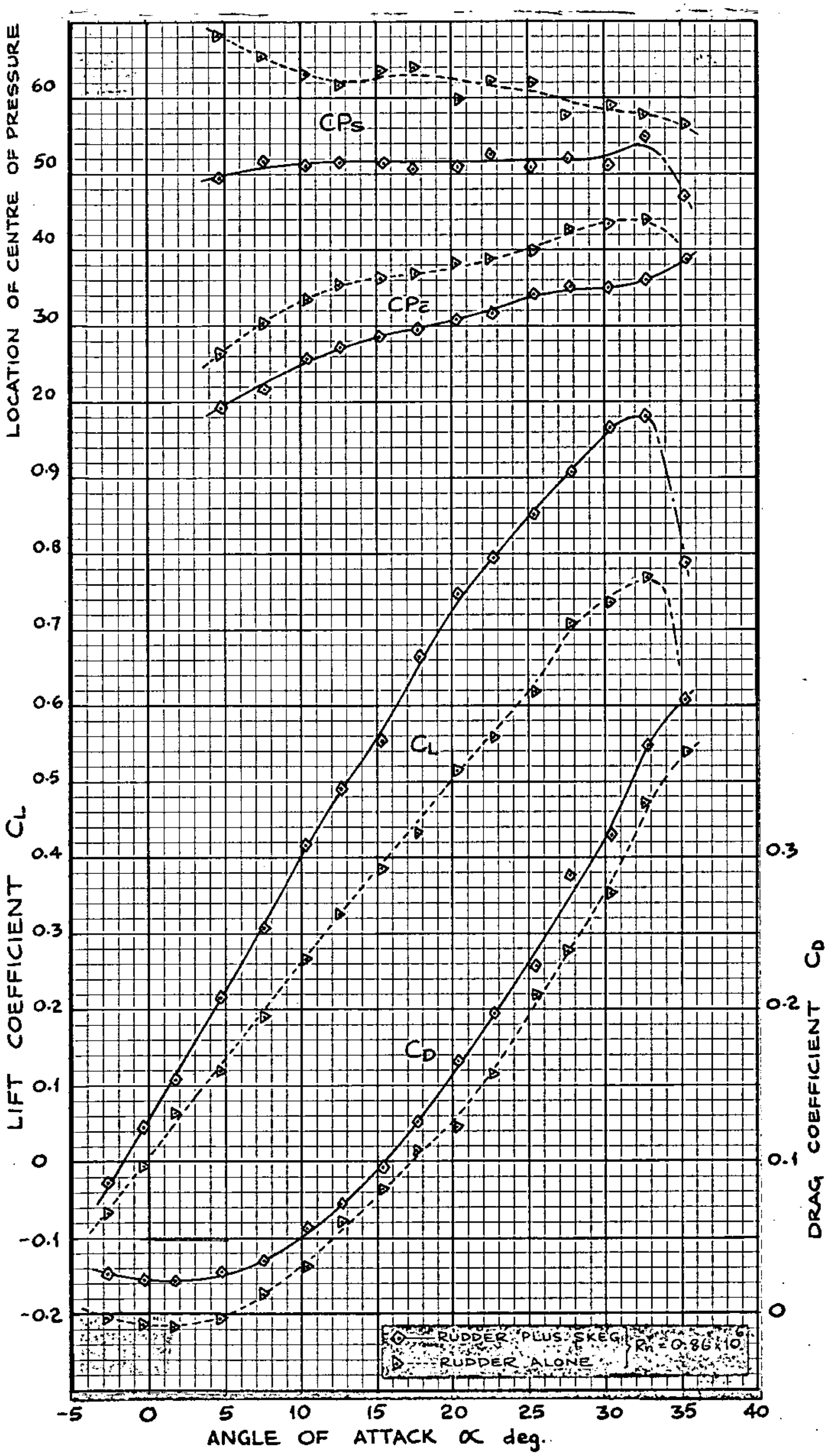
SKEG ANGLE $\beta = -5.25°$

Fig. 9C LIFT, DRAG AND CENTRE OF PRESSURE CHARACTERISTICS FOR SKEG RUDDER No.3



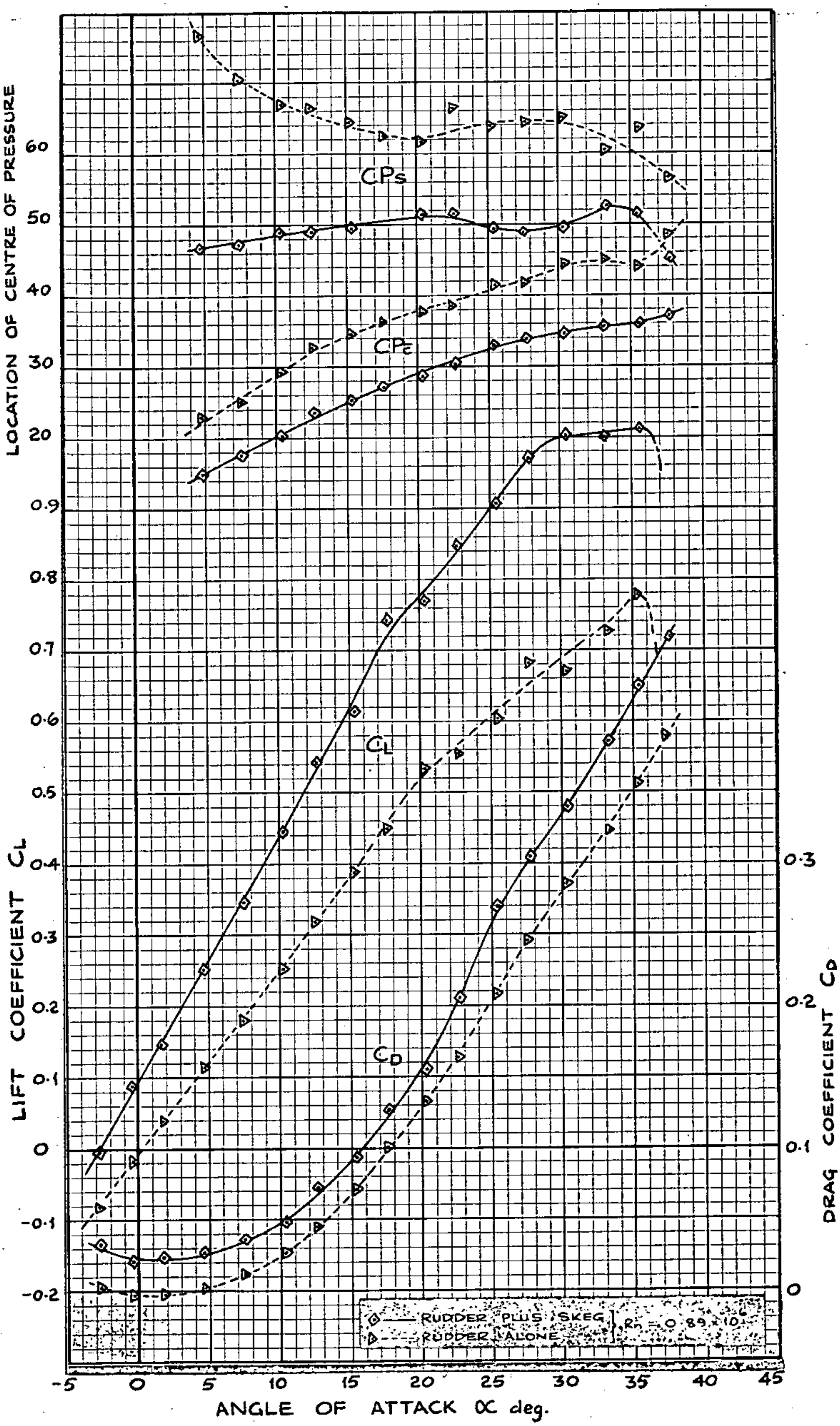
SKEG ANGLE $\beta = -0.25°$

Fig. 9d LIFT, DRAG AND CENTRE OF PRESSURE CHARACTERISTICS FOR SKEG RUDDER No. 3



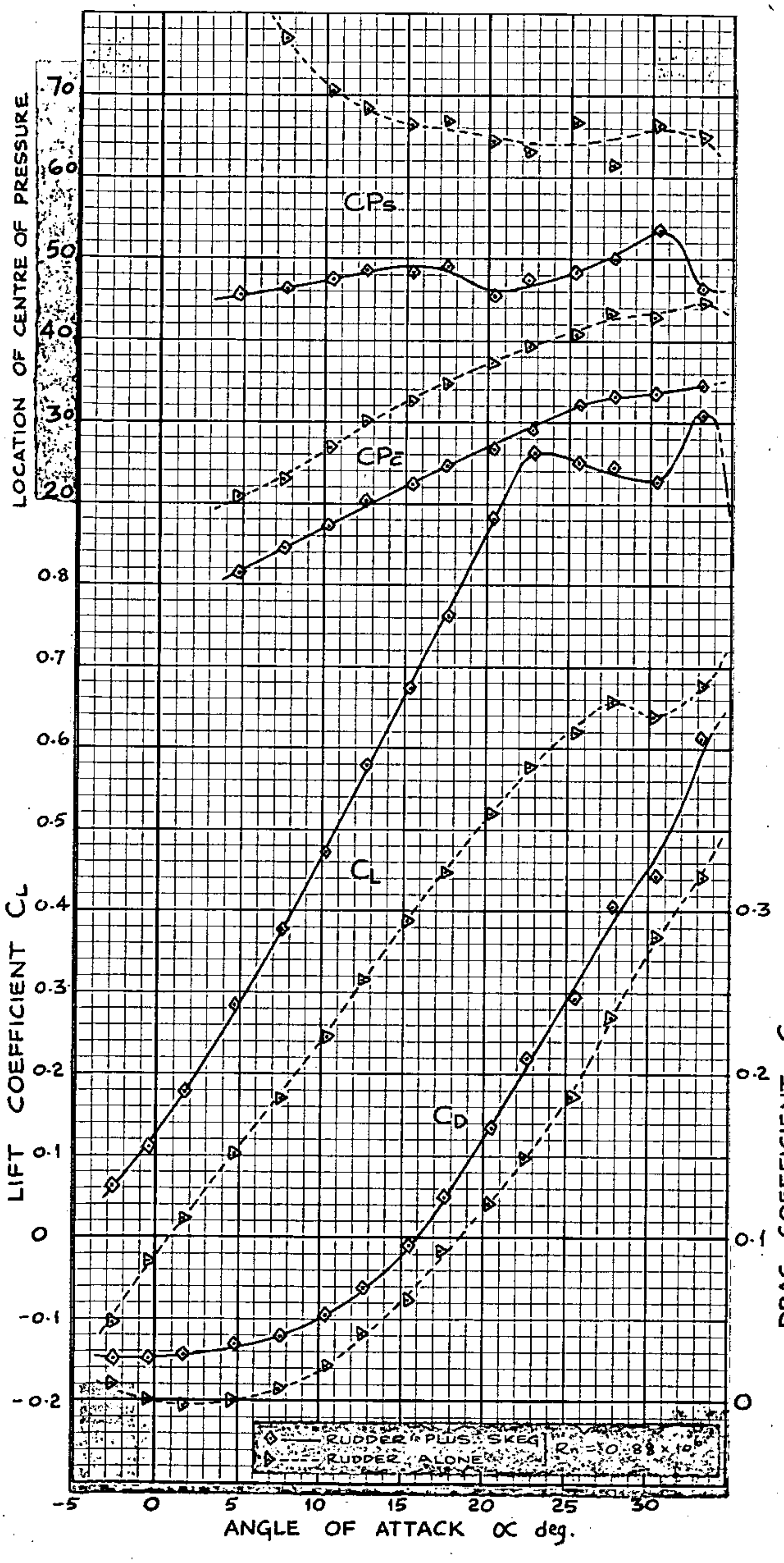
SKEG ANGLE $\beta = +4.75°$

Fig. 9e LIFT, DRAG AND CENTRE OF PRESSURE CHARACTERISTICS FOR SKEG RUDDER No. 3



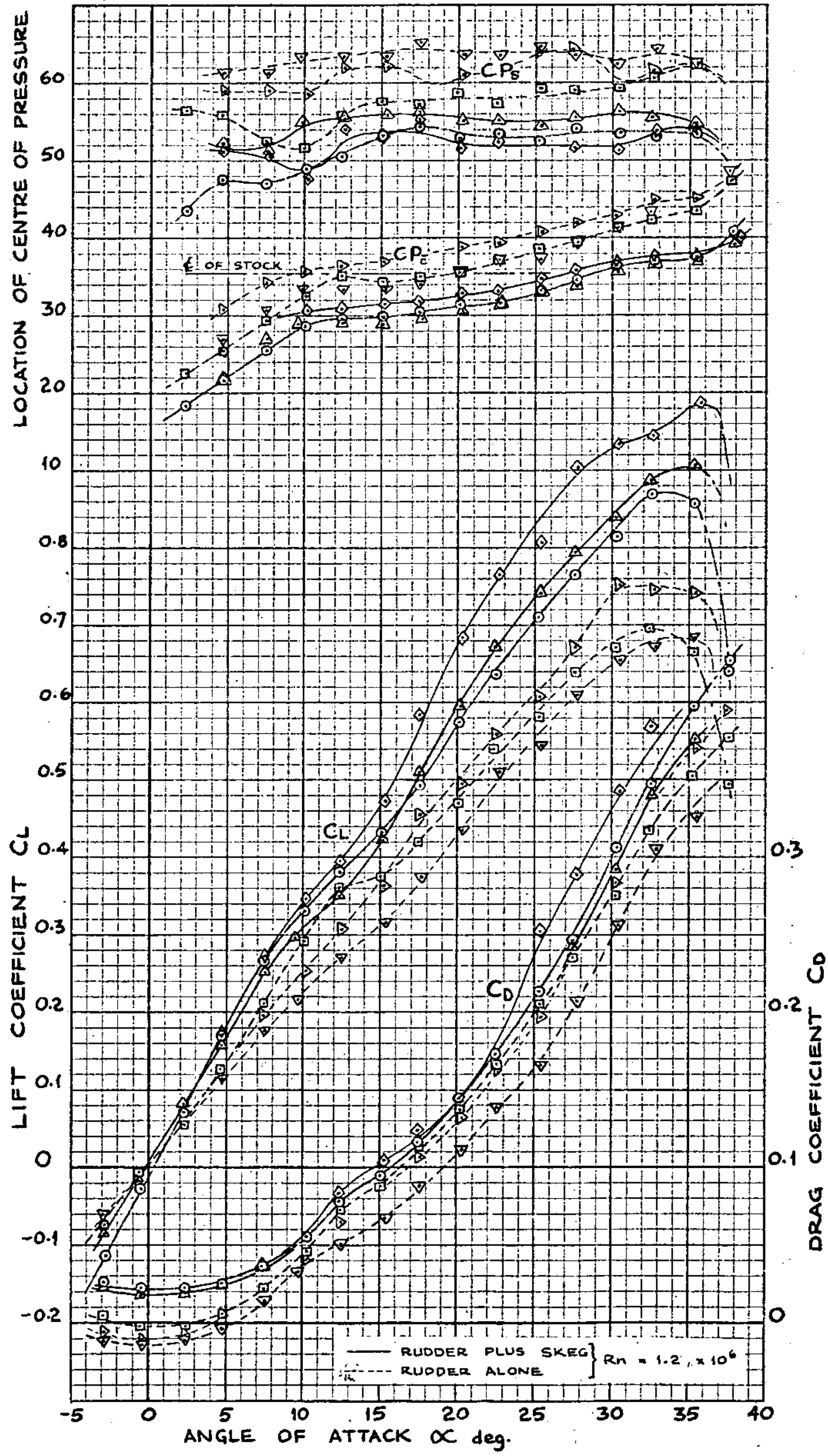
SKEG ANGLE $\beta = +9.75°$

Fig. 9f LIFT, DRAG AND CENTRE OF PRESSURE CHARACTERISTICS FOR SKEG RUDDER No.3



SKEG ANGLE $\beta = +14.75^{\circ}$

Fig. 98 LIFT, DRAG AND CENTRE OF PRESSURE CHARACTERISTICS FOR SKEG RUDDER No.3



⊙ ⊡ RUDDER No. 1
△ ▽ " " 2
◇ ▷ " " 3

SKEG ANGLE $\beta = -0.25°$

Fig. 10 COMPARISON BETWEEN RUDDER Nos. 1, 2 and 3