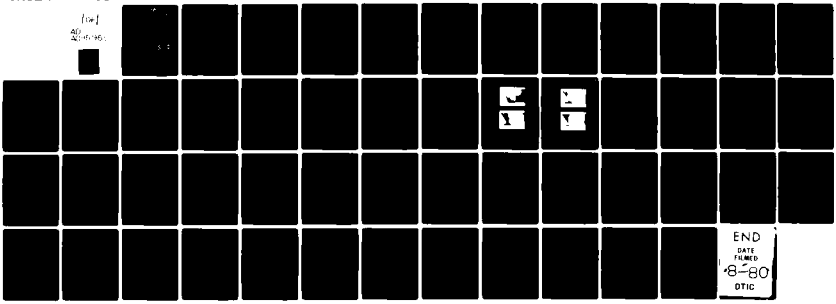
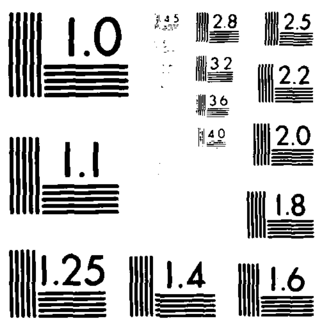
AD-A085 965 DAVID W TAYLOR NAVAL SHIP RESEARCH AND DEVELOPMENT CE--ETC F/G 13/10
EVALUATION OF BULBOUS BOWS DERIVED FROM WAVE SPECTRA ANALYSIS O--ETC(U)
JUN 80 S C FISHER
UNCLASSIFIED DTNSRDC/SPD-0049-13 NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

LEVEL II

DAVID W. TAYLOR NAVAL SHIP RESEARCH AND DEVELOPMENT CENTER

Bethesda, Md. 20084

(2)

(6)

EVALUATION OF BULBOUS BOWS DERIVED FROM WAVE SPECTRA ANALYSIS ON THE LSD 41 (MODEL 5367)

by

(10) Steven C. Fisher

APPROVED FOR PUBLIC RELEASE: DISTRIBUTION UNLIMITED

(9) Final rept.,

SHIP PERFORMANCE DEPARTMENT REPORT

(11) JUN[redacted]80

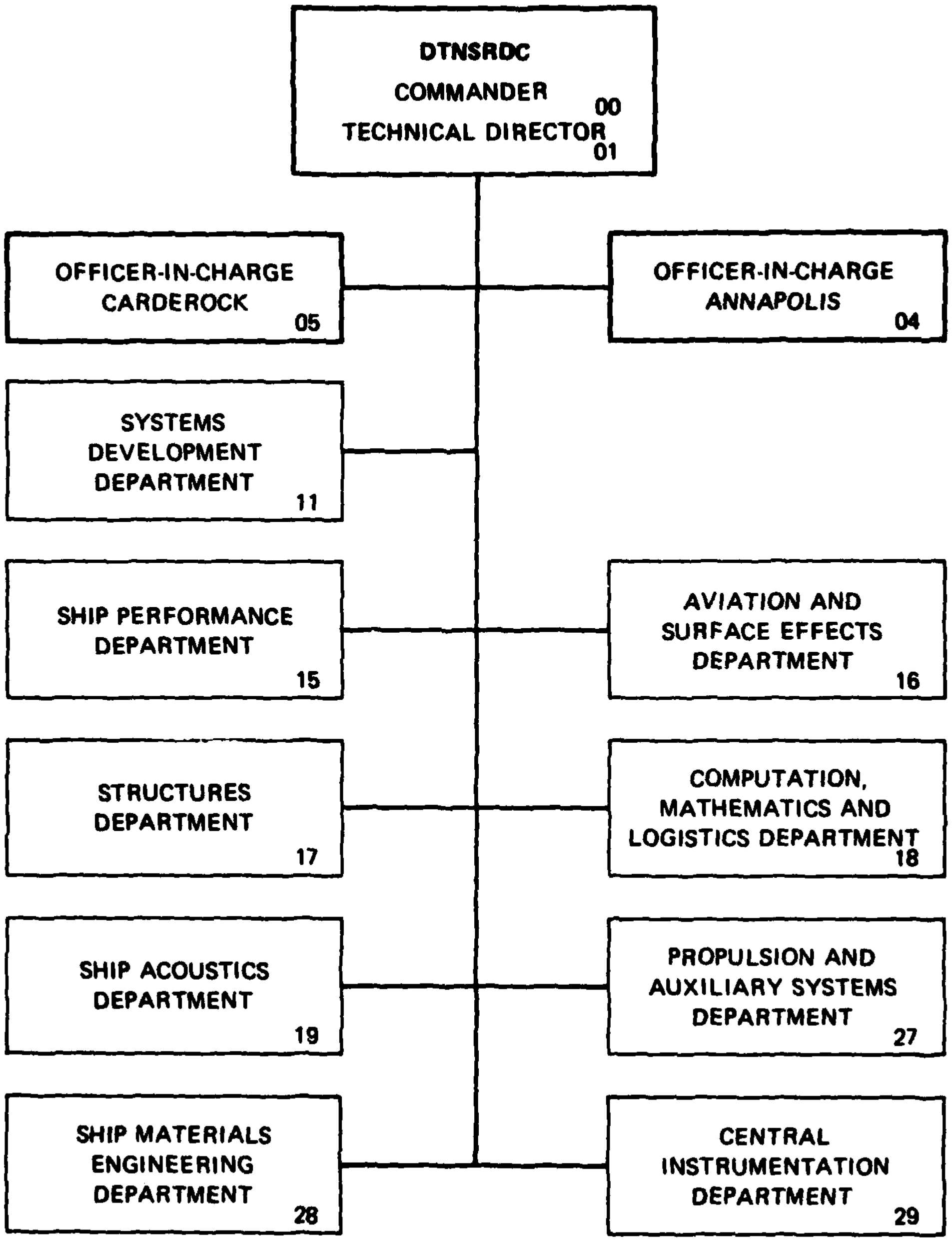
(12) 51

(14) DTNSRDC/SPD-0049-13

DTNSRDC/SPD-0049-13

EVALUATION OF BULBOUS BOWS DERIVED FROM WAVE SPECTRA ANALYSIS ON THE LSD-41 (MODEL 5367)

MAJOR DTNSRDC ORGANIZATIONAL COMPONENTS



UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER DTNSRDC/SPD-0049-13	2. GOVT ACCESSION NO. AD-A085 965	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Evaluation of Bulbous Bows Derived From Wave Spectra Analysis on the LSD 41 (Model 5367)		5. TYPE OF REPORT & PERIOD COVERED Final 6. PERFORMING ORG. REPORT NUMBER DTNSRDC/SPD-0049-13
7. AUTHOR(s) Steven C. Fisher		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS David W. Taylor Naval Ship R&D Center Ship Performance Department Bethesda, MD 20084		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS WR81520 Work Unit 1524-652
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Sea Systems Command (NAVSEA) Code 3213 Washington, DC 20362.		12. REPORT DATE JUNE 1980 13. NUMBER OF PAGES viii+38
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

APPROVED FOR PUBLIC RELEASE: DISTRIBUTION UNLIMITED

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Bulbous Bows
Wavemaking Resistance
Wave Spectra
Longitudinal Wavecuts
LSD-41

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Bulbous bows were designed for LSD 41 Model 5367 using a theoretical approach developed by Sharma which uses data from longitudinal wavecut experiments. The performances of the bulbs are compared to that of the original design bulb. The results indicate that the wavecut bulbs have the same or lower resistance at higher speeds than the original bulb for the model.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-LF-014-6601

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF FIGURES (Continued)

LIST OF FIGURES (Continued)

LIST OF TABLES

NOTATION

A_o	Cross sectional area of a bulb at the forward perpendicular
C_R	Residuary resistance coefficient, $R_R/\frac{1}{2}\rho SV^2$
C_R'	Modified residuary resistance coefficient nondimensionalized using the wetted surface of the ship without a bulb
C_W	Wave resistance coefficient calculated from the wave pattern, $R_W/\frac{1}{2}\rho SV^2$
E	Wave spectra amplitude
F, G	Sine and cosine components of the wave spectra, where F and G are defined as $G(u) + i\,F(u) = G\,(\sec\theta\tan\theta) + i\,F\,(\sec\theta\tan\theta) =$ $\frac{4\cos\theta\sin\theta}{k_o\,(1+\sin^2\theta)}\, e^{ik_o y\sec\theta\tan\theta}\int_{-\infty}^{\infty} dx\,\zeta(x)\,e^{ik_o x\sec\theta}$
g	Acceleration due to gravity
k_o	Wave number, g/V^2
L	Ship length
P	Relative bulb size ($A_{o_{new}}/A_{o_{old}}$)
P_E	Effective power
Q	Relative bulb position (bulb length change/L)
R_R	Residuary resistance
R_W	Wave resistance
s	$\sec\theta$
S	Wetted surface
u	$\sec\theta\tan\theta$
V	Speed, m/s
x	Longitudinal distance from the forward perpendicular of the model to the wave probe

NOTATION (CONTINUED

y	Transverse distance from the model centerline to the wave probe
η	Bulb influence factor, $C_{W_{bulb}}/C_{W_{no\ bulb}}$
θ	Angle in the x-y plane between the x-axis and the direction of wave propagation
ζ	Nondimensional waveheight (waveheight $\cdot$ k_o)
ρ	Density

ENGLISH/SI EQUIVALENTS

ENGLISH	SI
1 inch	25.400 millimetres [0.0254 m (metres]
1 foot	0.3048 m (metres)
1 foot per second	0.3048 m/sec (metres per second)
1 knot	0.5144 m/sec (metres per second)
1 pound (force)	4.4480 N (Newtons)
1 degree (angle)	0.01745 rad (radians)
1 horsepower	0.7457 kW (kilowatts)
1 long ton	1.016 tonnes, 1.016 metric tons, or 1016 kilograms

ABSTRACT

Bulbous bows were designed for LSD 41 (Model 5367) using a theoretical approach developed by Sharma which uses data from longitudinal wavecut experiments. The performances of the bulbs are compared to that of the original design bulb. The results indicate that the wavecut bulbs have the same or lower resistance at higher speeds than the original bulb for the model.

ADMINISTRATIVE INFORMATION

This work was performed at the David W. Taylor Naval Ship R&D Center (DTNSRDC), Bethesda, Maryland 20084. The project was funded under Naval Sea Systems Command (NAVSEA 3213), Work Request Number 81538 and performed under Ship Performance Department Work Unit Number 1524-652.

INTRODUCTION

As one phase of the design development of the LSD 41, a study was undertaken to design suitable bulbs using a combined experimental and theoretical approach. The bulbs were to be built and compared with the conventionally-designed bulb.

The method used in designing the bulbs was developed by Sharma[1]. It assumes that the wave spectra of the hull and of the bulb itself can be linearly superimposed. The wave spectra are derived from wave height data obtained from longitudinal wavecut experiments. A more detailed explanation of the method is given by Reed[2].

The longitudinal wavecut experiments were performed on Model 5367 representing the design configuration of the LSD 41. The first series of wavecuts, performed in December 1978, was used to design the wavecut bulbs for the model. The model was run at three speeds, with and without the bulb initially designed by NAVSEA 3213 for the model. A later series of resistance and longitudinal wavecut experiments was performed in March 1979, using various bulbs, including the bulbs designed using Sharma'a method.

The results of the analysis of the longitudinal wavecuts are given in terms of the bulb influence factor and the relative bulb size and location. The bulb influence factor, η, is the ratio of the wave-

[1]References are listed on page 10

making resistance of the model with a bulb to the wavemaking resistance of the bulbless hull. The relative bulb size, P, is the ratio of the new bulb cross sectional area to the old bulb cross sectional area at the forward perpendicular. The relative bulb location, Q, is the forward or aft shift in position of the new bulb relative to the old bulb, non-dimensionalized by the ship length. Bulb size refers to the cross sectional area of the bulb at the forward perpendicular.

Within this report, a number of comparisons are made, and the reliability of the bulb design method is examined. The results of the towed resistance experiments are compared to the wave resistance calculated from the wave pattern. The data from the December 1978 wavecut experiments are compared with the data from the March 1979 wavecut experiments to examine repeatability.

EXPERIMENTAL ARRANGEMENT

The ship model used in this experiment was Model 5367, representing the LSD 41. The model was constructed of wood to a scale ratio of 21.251. The principal dimensions of Model 5367 and the LSD 41 are given in Table 1. The model had a large cutout at the bow, extending from station 2¼ forward. The cutouts simplified changes from one bulb (or bow) to another.

Three bulbs, shown in Figures 1 and 2, were used during the resistance and wavecut experiments. The elliptical bulb was the bulb originally designed for the model. The long and short circular bulbs were designed using data from the wavecut experiments with the model fitted with the elliptical bulb. The long circular bulb was the optimum bulb at V_S = 8.32 m/s (16.16 knots), while the short circular bulb was the optimum bulb at V_S = 11.40 m/s (22.14 knots) for the same bulb size. The long circular bulb was a 1.84 m (6.05 ft) extension, at the ship scale, of the short circular bulb, lengthened by adding a parallel section to the bulb at the forward perpendicular. Model 5367 represented the LSD 41 without a bulb; Models 5367-1, 5367-2, and 5367-3 represented the LSD 41 fitted with the elliptical, short and long circular bulbs, respectively.

The model was towed during the wave cut experiments and was fully appended, with shafts, struts, rudders, and fairings; and without propellers. All of the experiments were performed at a model displacement of 1630 kilograms (3600 pounds) which corresponded to a ship displacement of 16,121 t (15,867 tons), and at an even keel. The model drafts did not depend appreciably upon which bulb was used because the differences in bulb volume were relatively small.

Longitudinal wavecuts were taken during both series of experiments using a resistance wire wave probe to measure wave height. The signals from the wire wave probe were digitized and stored on magnetic tape for later analysis, using a package of computer programs[2] which were written at the University of Michigan under the direction of S. D. Sharma.

DISCUSSION

PREDICTIONS

The method that was used to design the improved bulbs for Model 5367 (LSD 41) assumes that the bulb wave spectra are linear, and can be superimposed over a bulbless hull wave spectra. By altering the phase and amplitude of the bulb spectra a different bulb size and length can be simulated. The wavemaking resistance calculated from the altered wave spectra is used to compare different bulb sizes and lengths.

The longitudinal wavecut experiments were conducted at three speeds, corresponding to 8.32 m/s (16.16 knots), 10.45 m/s (20.31 knots), and 11.40 m/s (22.14 knots), full scale. The wave spectra calculated from the data taken during the longitudinal wavecut experiments are shown in Figures 3 to 16. The plots include the sine and cosine components of the wave spectra, F and G, and the wave spectra amplitude, E. The wave spectra of the model with and without the original bulb, and with the bulbs designed using Sharma's method are included. The contour plots of the bulb size, P, versus the relative bulb location Q, as a function of the bulb influence factor η , are shown in Figures 17 to 27. The contour plots can be used to demonstrate the effects of changing bulb size or length on the wavemaking resistance. It should be noted that all of the wavecut data for the model without a bulb are from the December 1978 wavecut experiments.

The contour plots for Model 5367 with the elliptical bulb from the December 1978 wavecut experiments were used to define the size and position of the wavecut bulbs for the model. The size and position of the long circular bulb were based on the optimum bulb at V_S = 8.32 m/s (16.16 knots), while the position of the short circular bulb was based on the best bulb at V_S = 11.40 m/s (22.14 knots) with the same bulb size as the long circular bulb. The long circular bulb was 0.7%L longer than the elliptical bulb, and had a 40% larger cross section. The short circular bulb was 0.3%L shorter than the elliptical bulb, and also had a 40% larger cross section. A circular cross section was chosen because the top of an elliptical bulb with the required cross sectional area would have been too close to the free surface.

The results of, and predictions from, the wave spectra analysis of the wavecuts of Model 5367 fitted with the three bulbs are shown in Table 2. The predictions based on the results from the December 1978 wavecut experiments at V_S = 8.32 m/s (16.16 knots) indicate that η will decrease from 0.47 with the elliptical bulb to 0.38 with the long circular bulb, and increase to 0.49 with the short circular bulb. The predictions based on the results from the March 1979 wavecut experiments indicate that η will decrease from 0.45 with the elliptical bulb to 0.40 with the long circular bulb, and increase to 0.80 with the short circular bulb. The values of η calculated from the wave spectra for the long and short circular bulbs are 0.76 and 0.78, respectively, larger than most of the predicted values.

Since there were no experiments with the elliptical bulb at V_S = 10.45 m/s (20.31 knots) in December 1978, there are no corresponding predictions. The predictions based on the results from the wavecut experiments in March 1979 at V_S = 10.45 m/s (20.31 knots) indicate η will decrease from 0.54 with the elliptical bulb to 0.34 with the long circular bulb, and increase to 0.58 with the short circular bulb. The values of η calculated from the wave spectra for the long and short circular bulbs are 0.44 and 0.54, respectively, which are close to the predicted values.

At V_S = 11.40 m/s (22.14 knots), the predictions from the December 1978 wavecut experiments indicate that η will decrease from 0.69 with the elliptical bulb to 0.68 and 0.62 with the long and short circular bulbs, respectively. The predictions from the March 1979 wavecut experiments indicate that η will decrease from 0.63 with the elliptical bulb to 0.44 with the long circular bulb, and increase to 0.64 with the short circular bulb. The values of η calculated from the wave spectra for the long and short circular bulbs are 0.53 and 0.57, relatively close to the average of the predicted values.

The values of η measured for the wavecut bulbs are usually within $\pm$ 0.10 of the predicted values. An examination of the contour plots for bulbs F and G indicate that the new bulbs are much closer to the optimum size and length than the original bulb.

Since the resistance experiments were conducted both with and without the original and wave cut bulbs, a comparison can be made with the trends of a modified residuary resistance coefficient, C_R', and η. C_R' differs from C_R in that the wetted surface of the ship without a bulb, instead of the wetted surface of a given bow configuration, is used in the non-dimensionalization of the residuary resistance. This means that differences in C_R' will only reflect the changes in the residuary resistance, and not include the effects due to changes in wetted surface.

The results of the resistance experiments for Model 5367 are presented in Table 3. Note that by definition, η is equal to 1.0 for a model without a bulb, and that the C_R' values are multiplied by 10^3. At V_S = 8.23 m/s (16.16 knots), the results show an increase in C_R' from 0.936 with the elliptical bulb to 0.956 with the long and 1.055 with the short circular bulbs. These values agree with the trends in η. The C_R' value for the model without a bulb is 0.997, lower than the corresponding C_R' value for the short circular bulb. However, the short circular bulb had a value of η less than 1.0, which implies the circular bulb has a lower wavemaking resistance than the hull without a bulb. At 10.45 m/s (20.31 knots), the results show a decrease in C_R' from 1.160 with the elliptical bulb to 1.108 with the long circular bulb, and little difference with the short circular bulb, 1.162. The C_R' value of the model without a bulb was 1.284. All of these values of C_R' follow the trends in η. At V_S = 11.40 m/s (22.14 knots), there is a decrease in C_R' from 1.345 with the elliptical bulb to 1.241 and 1.329 with the long and short circular bulbs, respectively. The value of C_R' for the model without a bulb is 1.485. Again, these values of C_R' follow the trends in η.

Generally, the C_R' values agree with the trends indicated by the values of η. However, the amount of change in C_R' may be much smaller than that in η. One reason for this is that the wavemaking resistance calculated from the wave spectra gives only the resistance due to generating the wave system measured at the wave probe, while C_R' includes other resistance components such as those due to form drag, local waves, and wavebreaking.

A change in bulb size or length can have a positive effect on the wave system at a distance from the model; but may have a negative effect on the other components of residuary resistance.

The ratio of the effective power from the towed resistance experiments for the LSD 41 with a given bulb to the effective power without a bulb, ($P_{E_{bulb}}/P_{E_{no\ bulb}}$) plotted against speed, is shown in Figure 28. It should be noted that for towed resistance experiments, the experimental accuracy is ± 1½ percent. The accuracy of wavecut resistance experiments has not been thoroughly determined; however, it is probably no better than the accuracy of the towed resistance experiments.

Above 7.7 m/s (15 knots), the long circular bulb is either the best performing bulb, or differs from the best performing bow configuration by an amount within the experimental accuracy. The short circular bulb is the poorest performing bow configuration at the lower speeds. However, above 9.6 m/s (18.6 knots) the differences between the resistance performances of the model fitted with the short circular bulb and with the elliptical bulb are within the experimental accuracy. The resistance performance of the model with the short circular bulb improved relative to that with the elliptical bulb and without a bulb as the speed increased. This is not surprising since the short circular bulb was optimized for the higher speeds.

REPEATABILITY

The results from the two sets of longitudinal wavecut experiments can be used to examine the repeatability of this theoretical experimental bulb design method. The optimum bulb location and size, determined from the contour plots, are the basis of the comparison between the original and the repeated experiments.

A comparison of the contour plots for Model 5367 with the elliptical bulb showed that at V_S = 8.32 m/s (16.16 knots), the optimum bulb from the March 1979 experiments (Figure 19) was 0.6%L (ΔQ = 0.006) forward of and 16% smaller than the optimum bulb from the December 1978 experiments

(Figure 17). At V_S = 11.40 m/s (22.14 knots), the optimum bulb from the March 1979 experiments (Figure 21) was 1.6%L (ΔQ = 0.016) forward of and the same size as the optimum bulb predicted from the December 1978 wavecut experiments (Figure 18).

The comparison of the contour plots for Model 5367 with the elliptical bulb from the December 1978 and March 1979 wavecut experiments indicates that there are noticeable differences in the optimum bulb size and/or position between the repeated experiments. An examination of the plots of the wave spectra reveals that the spectra amplitude showed good repeatability, but the phase did not. The phase differences can explain the differences in the longitudinal position of the optimum bulb, and the differences in optimum bulb size, since the amplitude spectra showed good repeatability.

One possible cause of the differences in the phase of the wave spectra is insufficient accuracy in the measurements of the distances between the model and the wave probe. An error of a few centimeters in one of the measurements can noticeably alter the phase of the wave spectra. Since the amplitude of the wave spectra is not affected by changes in the phasing, the wave resistance calculated from the spectra does not change. If the errors in the measurements are consistent for the model with and without a bulb, the bulb spectra amplitude will be correct, but the phase will be wrong. It should be noted that the contour plots will not be effected by errors in the measurements, since the error in the phase of the bulb spectra will be compensated by the error in the phase of the hull spectra. However, if the errors in the measurements are not consistent between the model with and without a bulb, both the phase and the amplitude of the bulb spectra will change, and the contour plots will be completely altered.

Another explanation for the differences seen in the contour plots between the December 1978 and March 1979 experiments is insufficient accuracy in the calibration constant for the wave probe. The wave probe was calibrated only once, at the beginning of the experiments, and the calibration was not repeated. If the calibration changed during the experiments, the amplitude of the wave spectra of the bulb itself will be incorrect and the contour plots will be inaccurate.

A further comparison can be made with the long and short circular bulbs, since the long circular bulb is a lengthened version of the short circular bulb. Ideally, the contour plots of the short and long circular bulbs should have the same shape and size (at the same speed), but the abscissa values for the long circular bulb should be shifted to the right by $\Delta Q = 0.01$, the amount of the bulb length change.

The corresponding contour plots for the two circular bulbs had the same shape and size at $V_S = 8.32$ m/s (16.16 knots) and 10.45 m/s (20.31 knots). However, the change in Q between the bulbs was different from that which was expected. At 8.32 m/s (16.16 knots), there was a change in Q of 0.001 in the expected direction to give an effective ΔQ of 0.009. At 10.45 m/s (20.31 knots), there was a change in Q of 0.004 in the expected direction to give an effective ΔQ of 0.006.

The contour plots of the two circular bulbs at 11.40 m/s (22.14 knots) did not have the same size and showed large differences in the optimum bulb position. Since the optimum bulb predicted from the contour plots from the long circular bulb and the elliptical bulb had similar values of η and A_o, the differences between the contour plots of the circular bulbs is most likely due to inaccuracies in the short circular bulb data.

Except at 11.40 m/s (22.14 knots), the contour plots of the long and short circular bulbs agree in shape and size, but show changes in bulb positions which are different from that which is expected. This indicates that this method can give good information on bulb size, but not as good information on the fore and aft bulb location. This is supported by previous experience with Sharma's method on other models.

CONCLUSIONS

Linear superposition of the bulb and hull wave spectra can become a useful tool in estimating the change in bulb size and position that may improve the resistance performance of a ship. Further evaluation is needed to determine if the inconsistent results are due to experimental measurement errors or a fault of the method used. The method is not qualitative since only the wavemaking resistance is optimized, while the effects of the changes on the other components of the residuary resistance are not accounted for. It should be noted that the predictions of changes in bulb size seem to be better than the predictions of the change in the bulb longitudinal position. This is supported by previous experience with this method.

The model fitted with the long circular bulb has the same or lower resistance than the model fitted with the elliptical bulb, the short circular bulb, and without a bulb above 7.7 m/s (15 knots). The model fitted with the long circular bulb has the same or lower resistance than the model with the elliptical bulb and without a bulb above 9.6 m/s (18.6 knots).

For future longitudinal wavecut experiments, more care should be taken in measuring the distances between the model and the wave probe, and in calibrating the wave probe. The wave probe calibration should be repeated, and calibrations should be taken during the experiments and after the wave cut experiments are completed.

REFERENCES

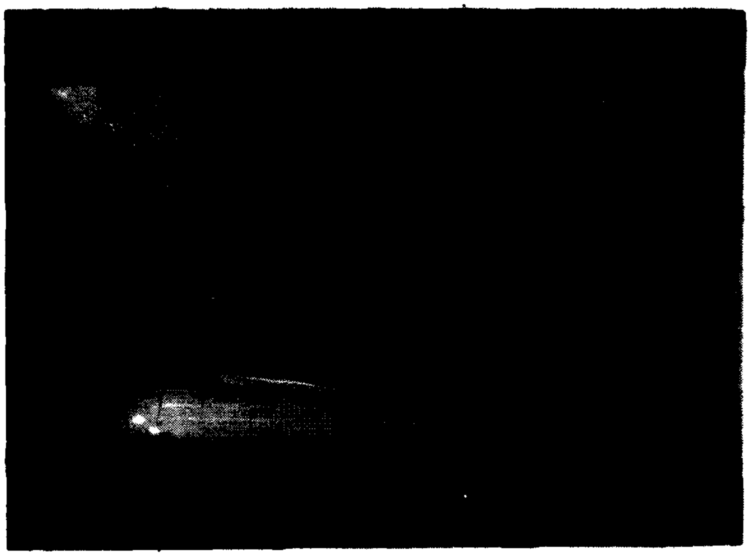
1. Sharma, S. D., "An Attempted Application of Wave Analysis Technique to Achieve Bow-Wave Reduction," Sixth ONR Symposium on Naval Hydrodynamics, pp. 731-73 (1966).

2. Reed, A. M., "Documentation for a Series of Computer Programs for Analyzing Longitudinal Wave Cuts and Designing Bow Bulbs," DTNSRDC/SPD-0820-01 (Jun 1979).

Model 5367 With No Bulb (PSD 3968-1-80)

Model 5367 With the Elliptical Bulb (PSD 3970-1-80)

Figure 1 - Model 5367 (LSD 41) With No Bulb and the Elliptical Bulb



Model 5367 With the Long Circular Bulb (PSD 3971-1-80)

Model 5367 With the Short Circular Bulb (PSD 3972-1-80)

Figure 2 - Model 5367 (LSD 41) With the Long Circular Bulb and the Short Circular Bulb

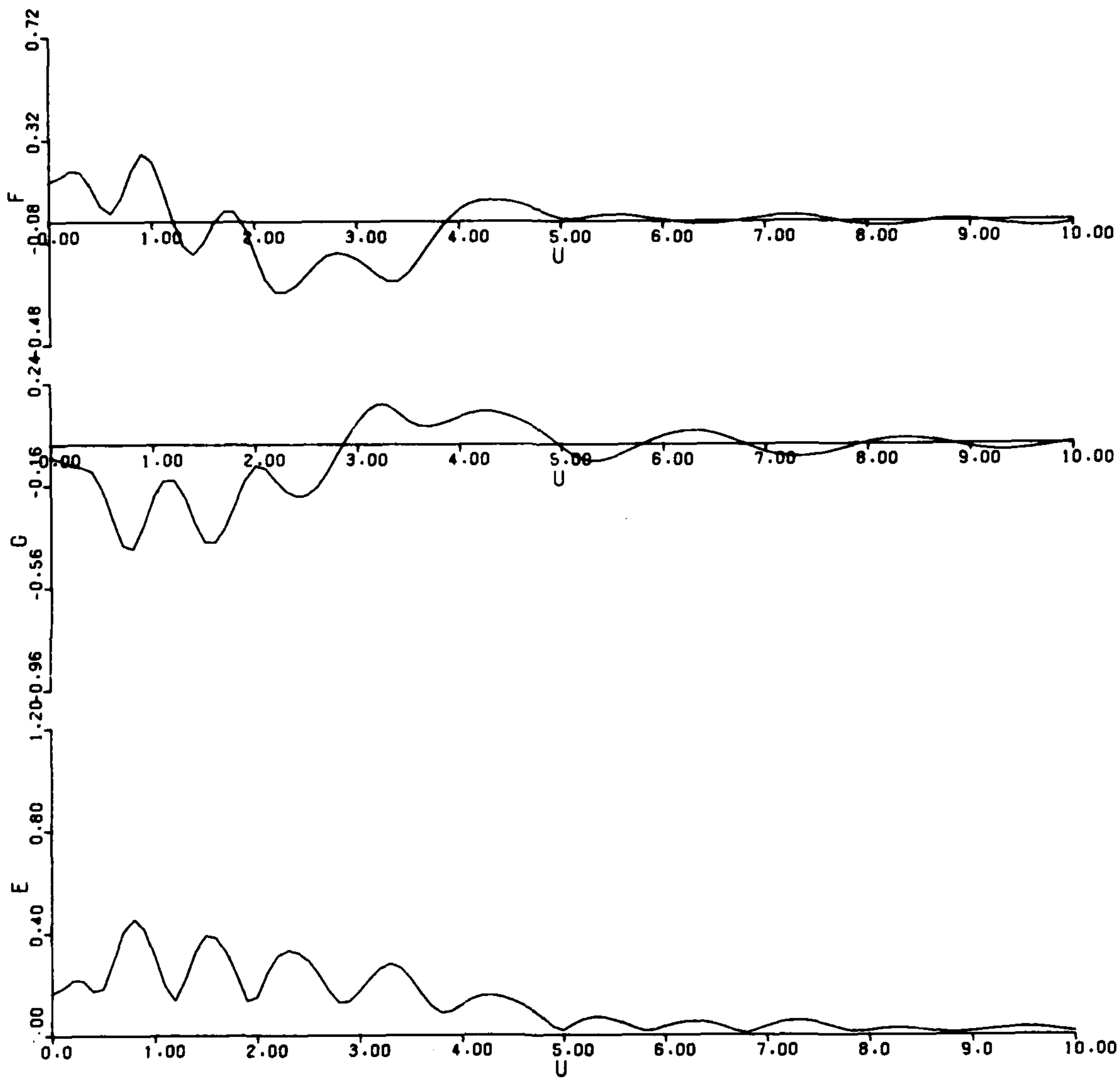


Figure 3 - Wave Spectra of LSD 41 (Model 5367) Without a Bulb at V_s = 8.32 m/s (16.16 knots) from the December 1978 Wavecut Experiments

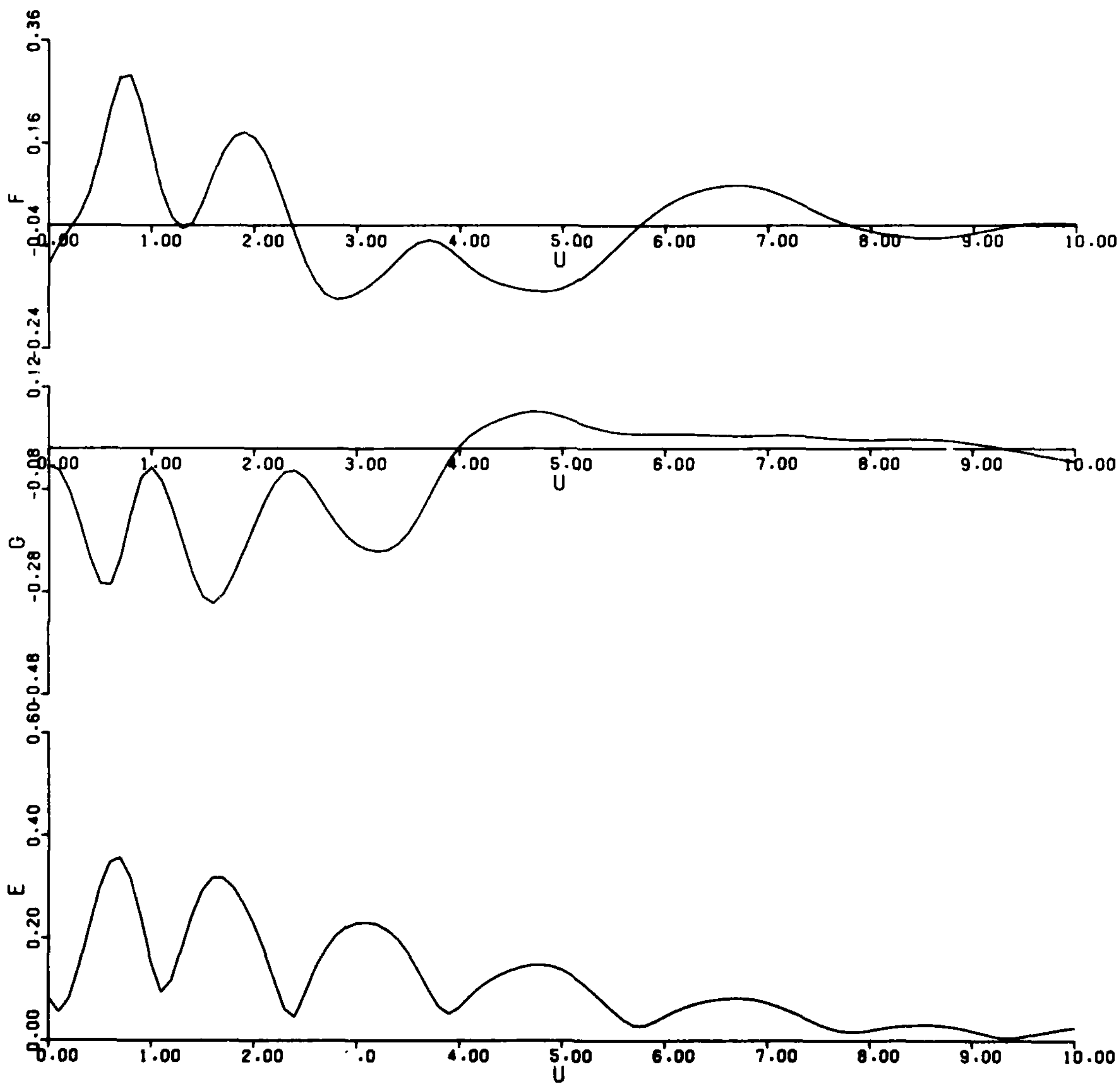


Figure 4 - Wave Spectra of LSD 41 (Model 5367) Without a Bulb at V_s = 10.45 m/s (20.31 knots) from the December 1978 Wavecut Experiments

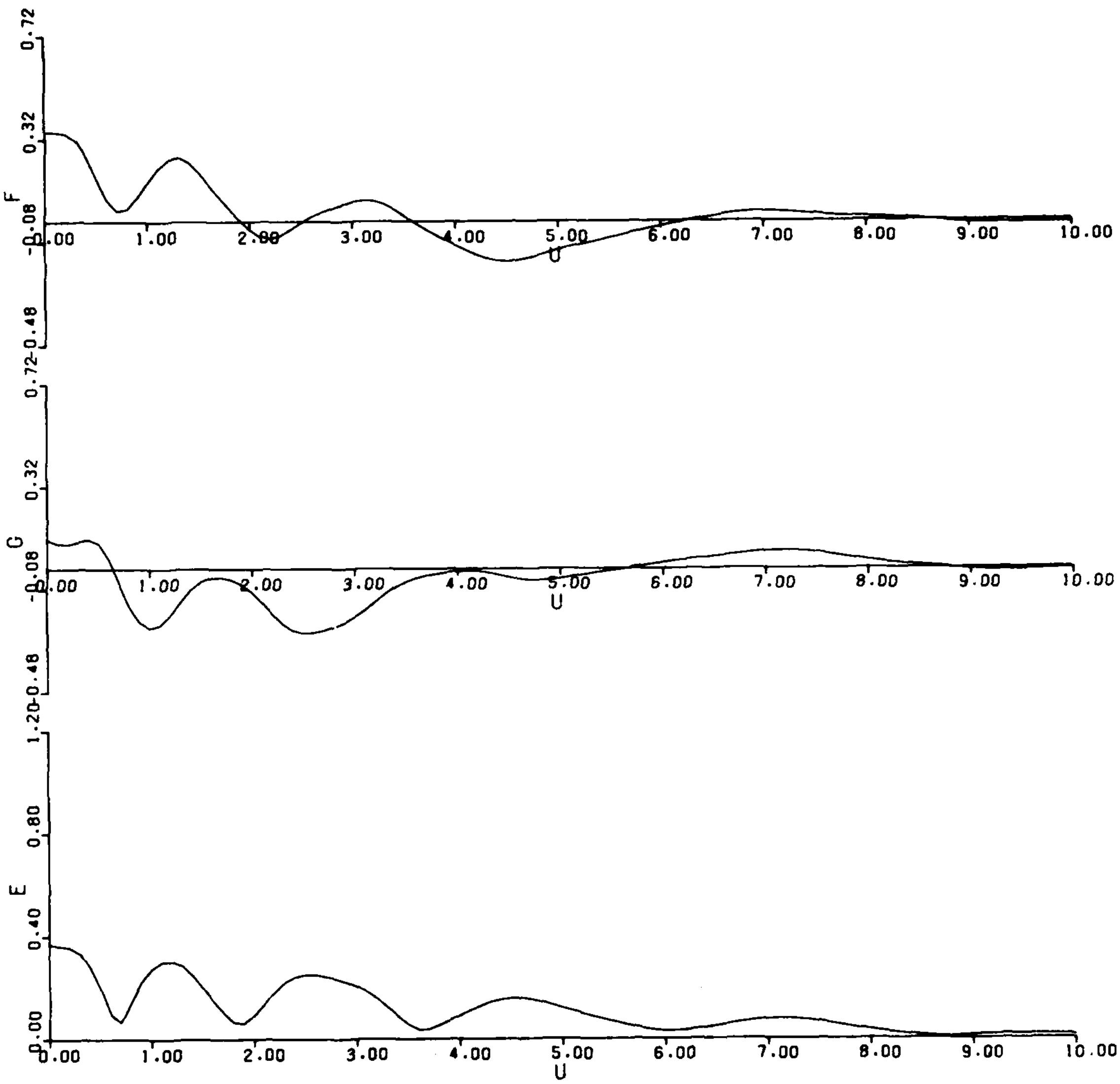


Figure 5 - Wave Spectra of LSD 41 (Model 5367) Without a Bulb at V_s = 11.40 m/s (22.14 knots) from the December 1978 Wavecut Experiments

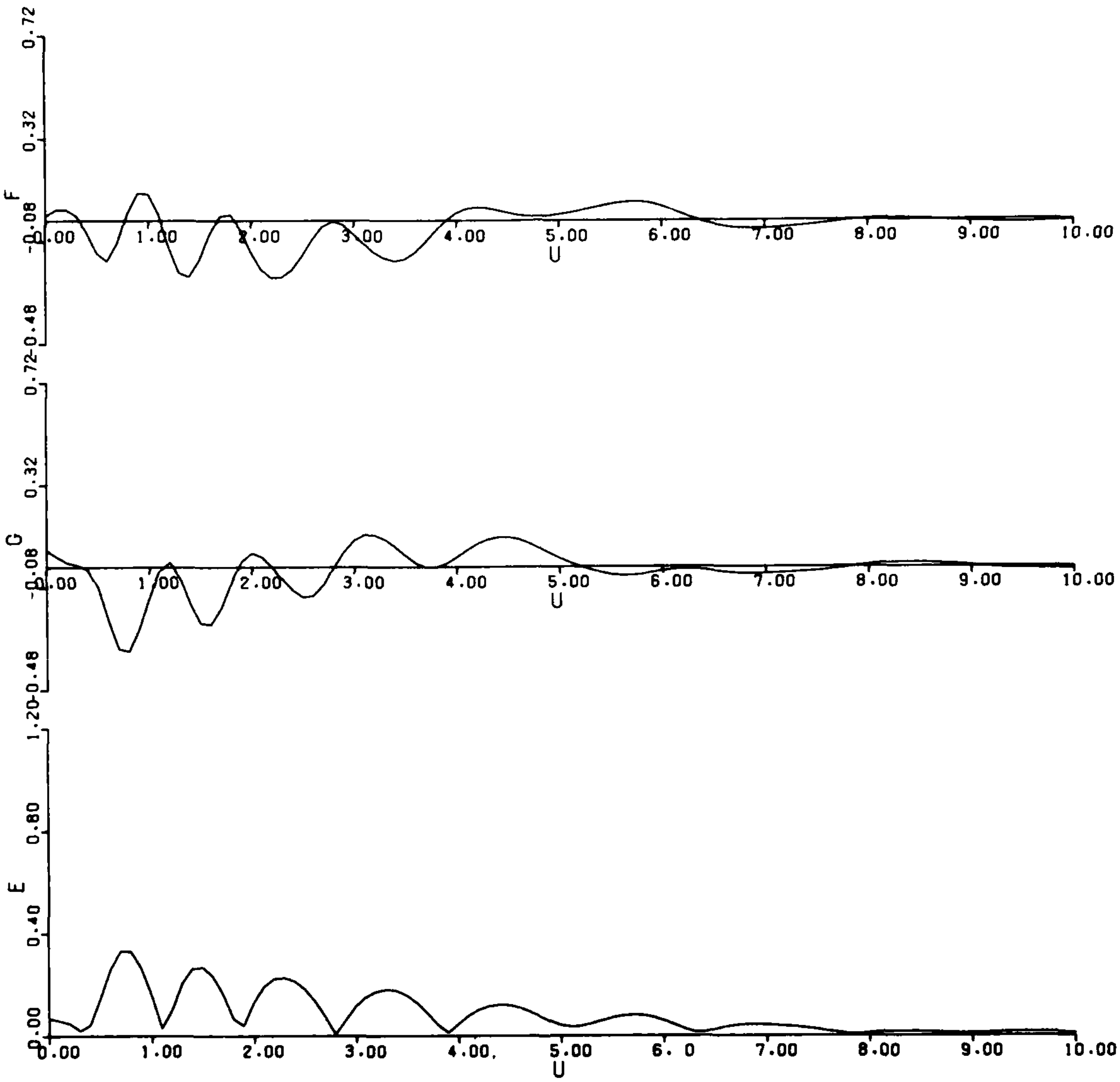


Figure 6 - Wave Spectra of LSD 41 (Model 5367) With the Elliptical Bulb at V_s = 8.32 m/s (16.16 knots) from the December 1978 Wavecut Experiments

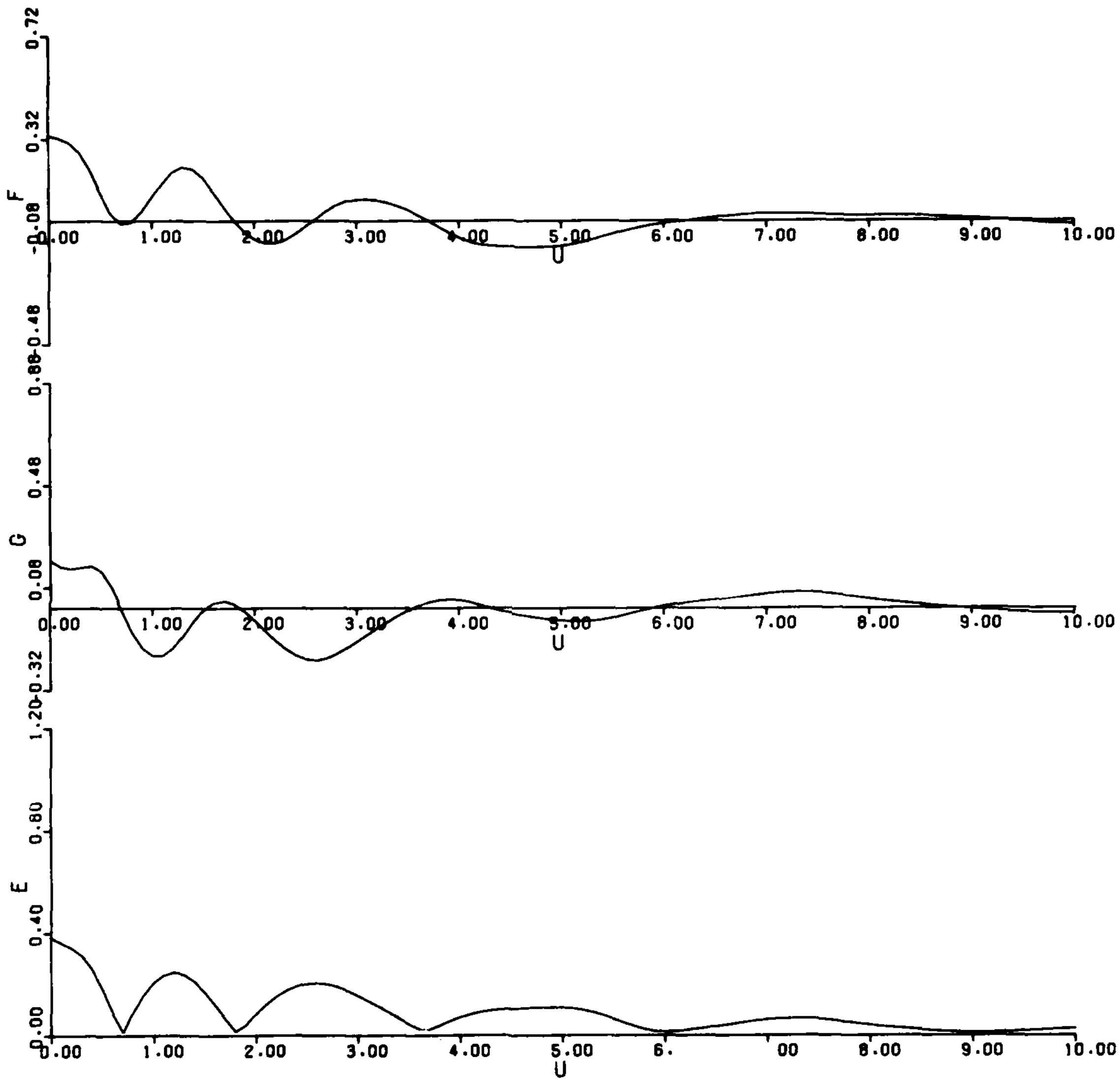


Figure 7 - Wave Spectra of LSD 41 (Model 5367) With the Elliptical Bulb at V_s = 11.40 m/s (22.14 knots) from the December 1978 Wavecut Experiments

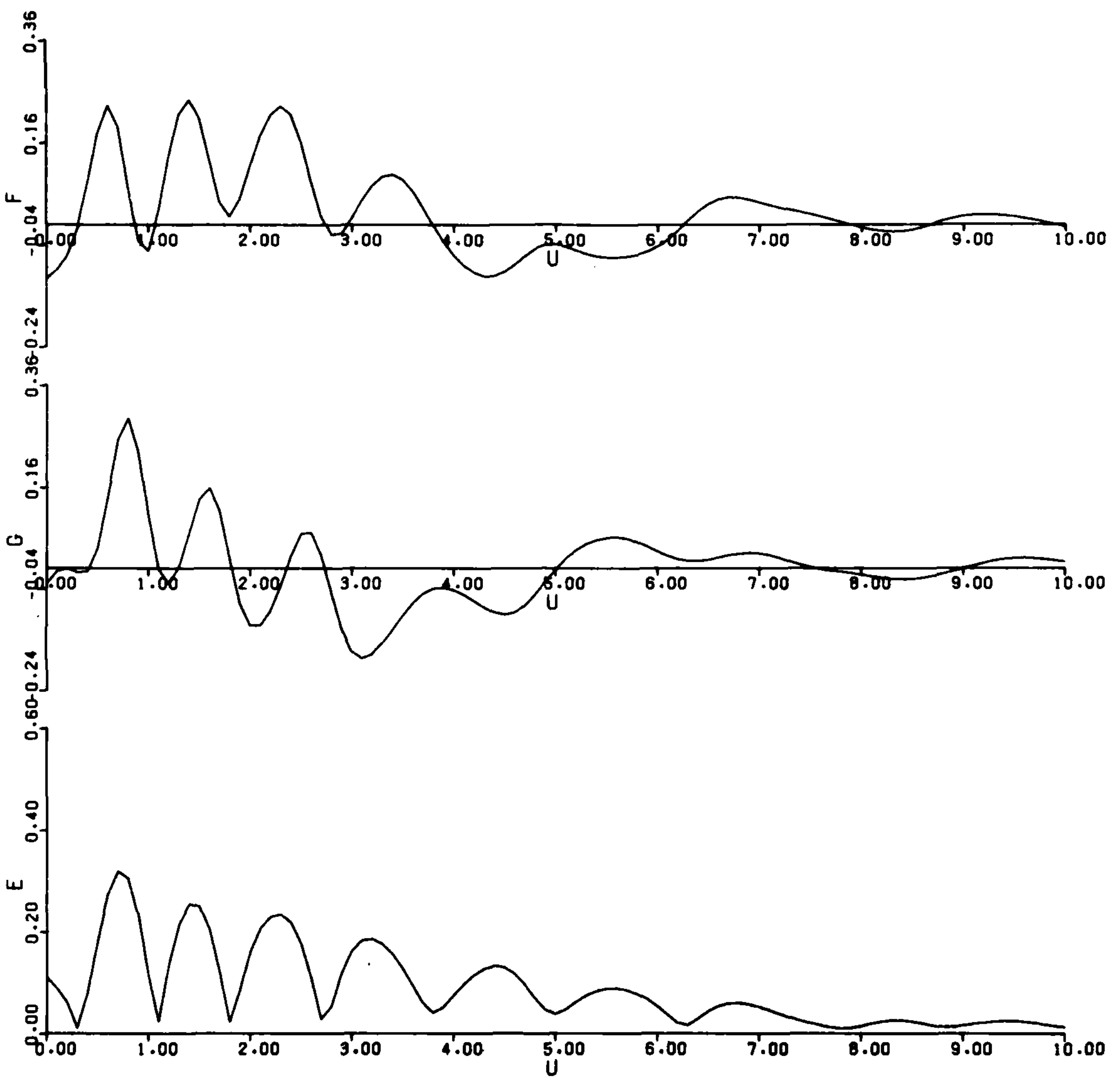


Figure 8 - Wave Spectra of LSD 41 (Model 5367) With the Elliptical Bulb at V_s = 8.32 m/s (16.16 knots) from the March 1979 Wavecut Experiments

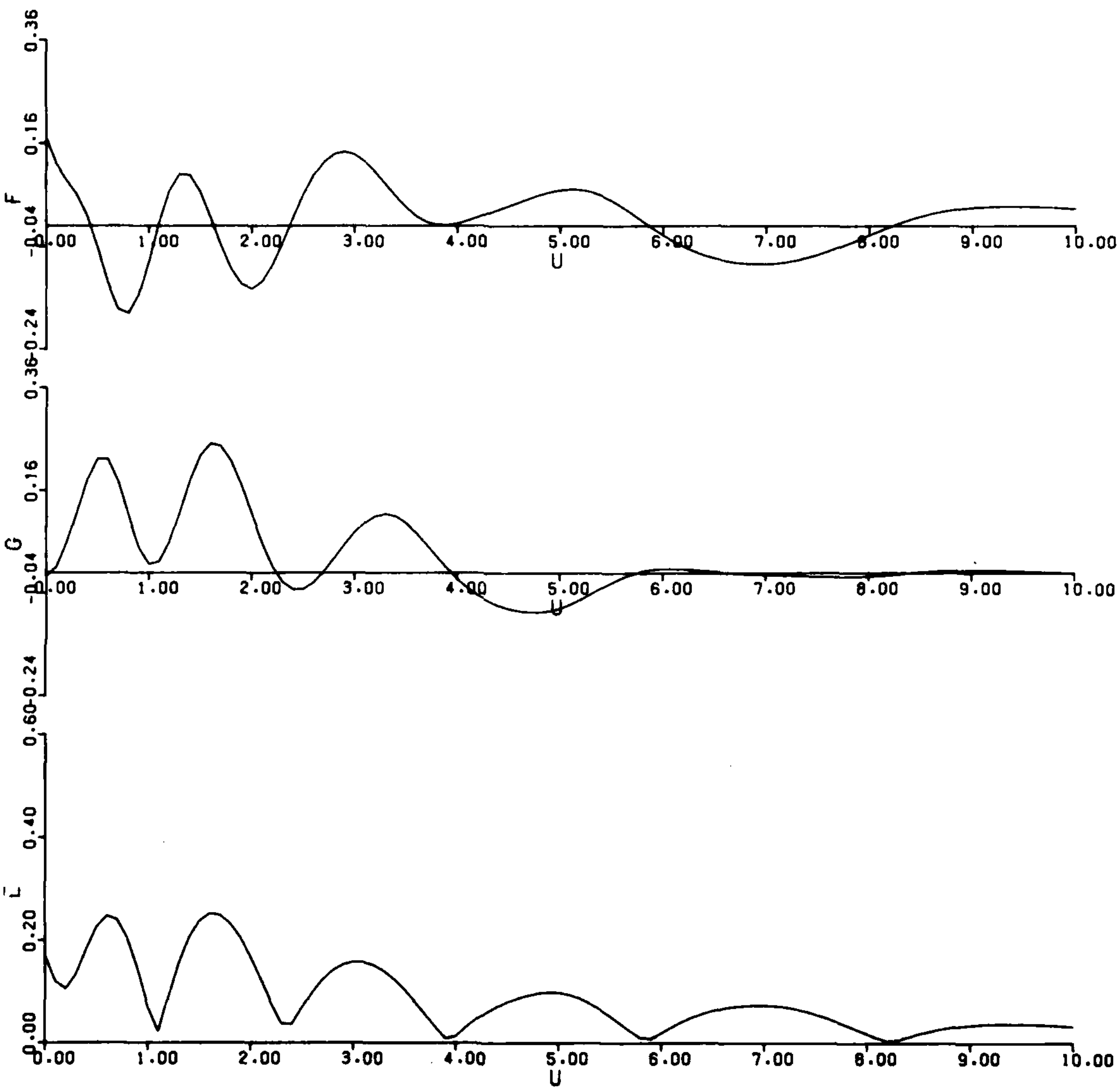


Figure 9 - Wave Spectra of LSD 41 (Model 5367) With the Elliptical Bulb at V_s = 10.45 m/s (20.31 knots) from the March 1979 Wavecut Experiments

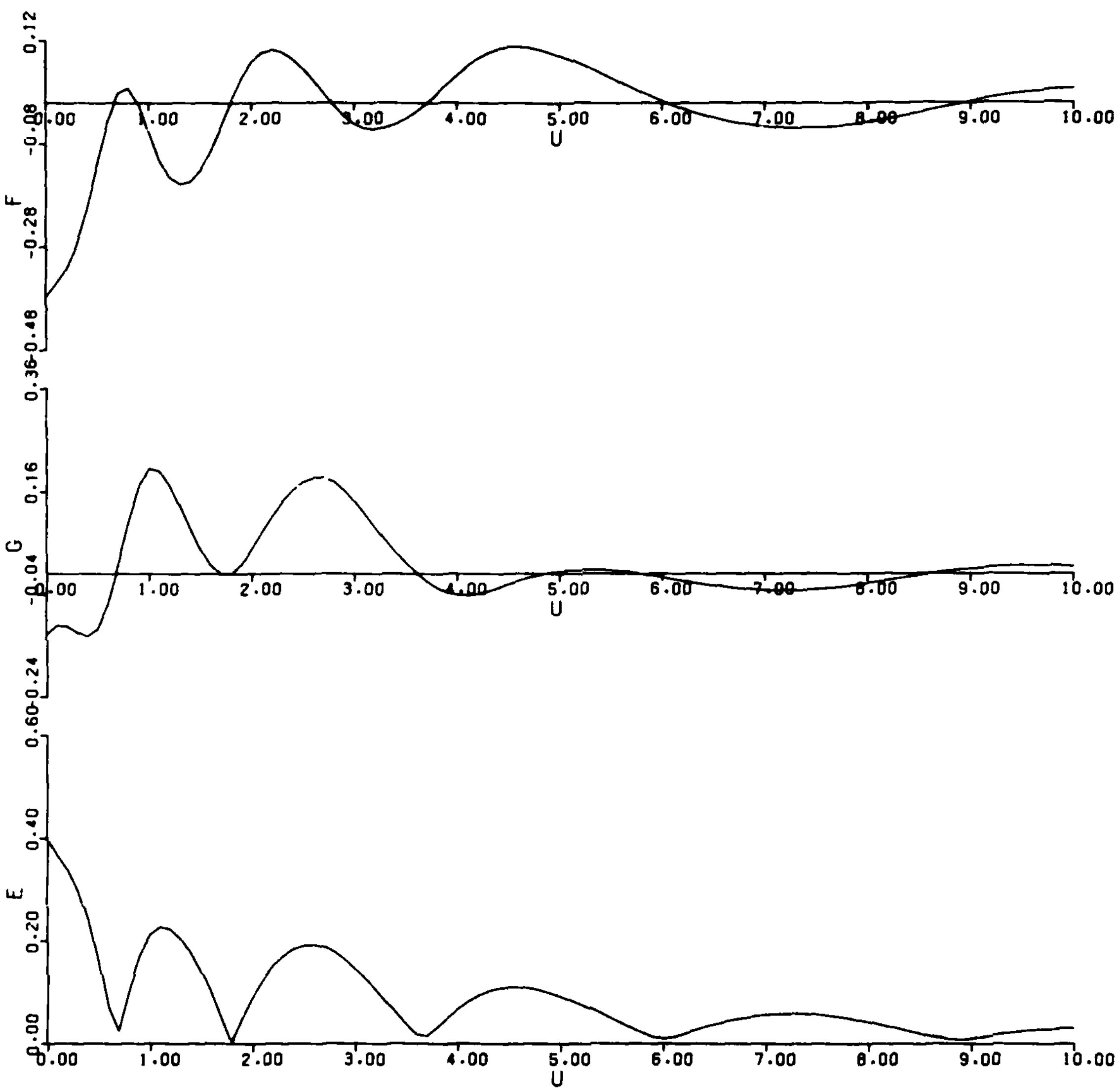


Figure 10 - Wave Spectra of LSD 41 (Model 5367) With the Elliptical Bulb at V_s = 11.40 m/s (22.14 knots) from the March 1979 Wavecut Experiments

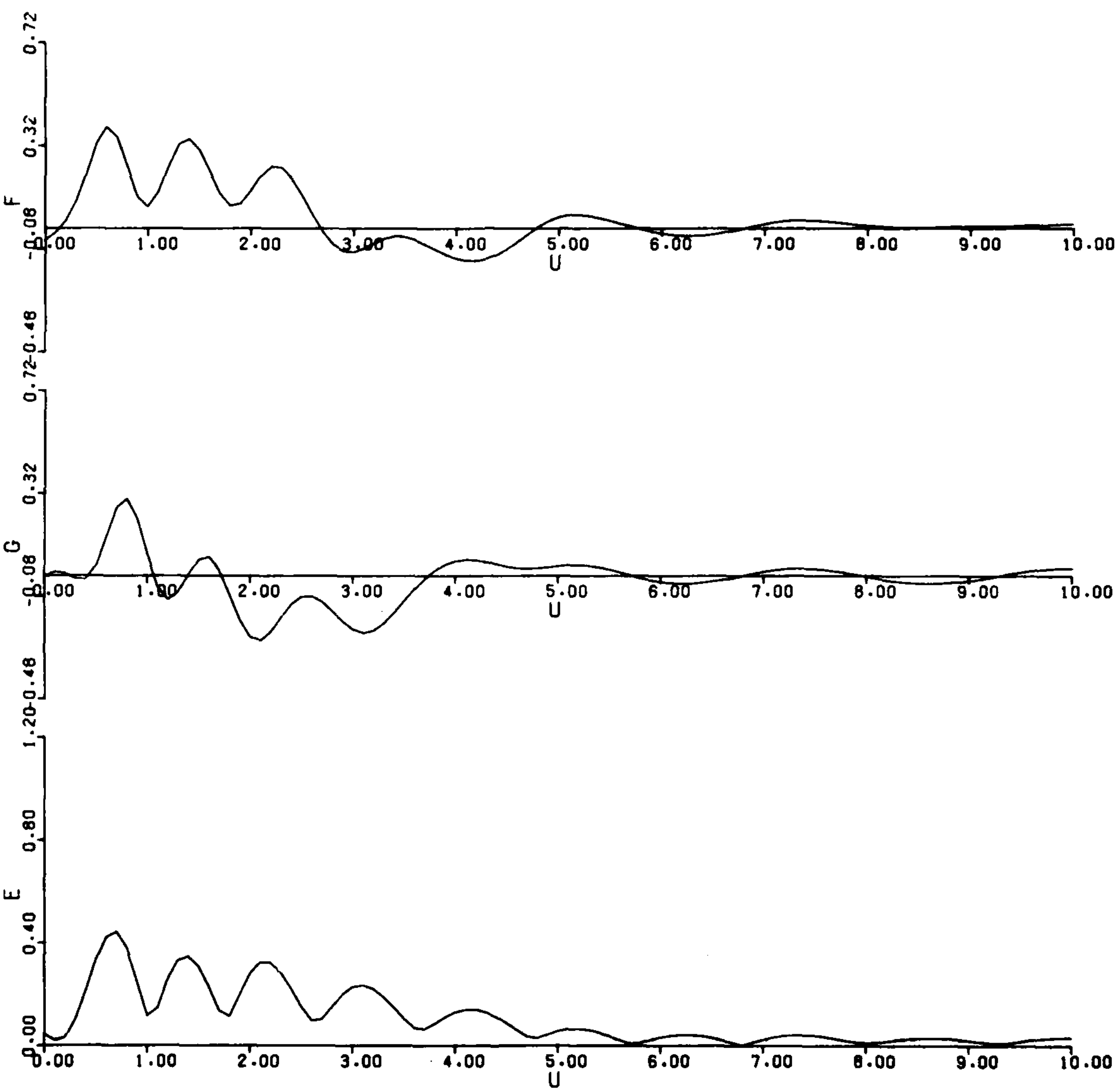


Figure 11 - Wave Spectra of LSD 41 (Model 5367) With the Short Circular Bulb at V_s = 8.32 m/s (16.16 knots) from the March 1979 Wavecut Experiments

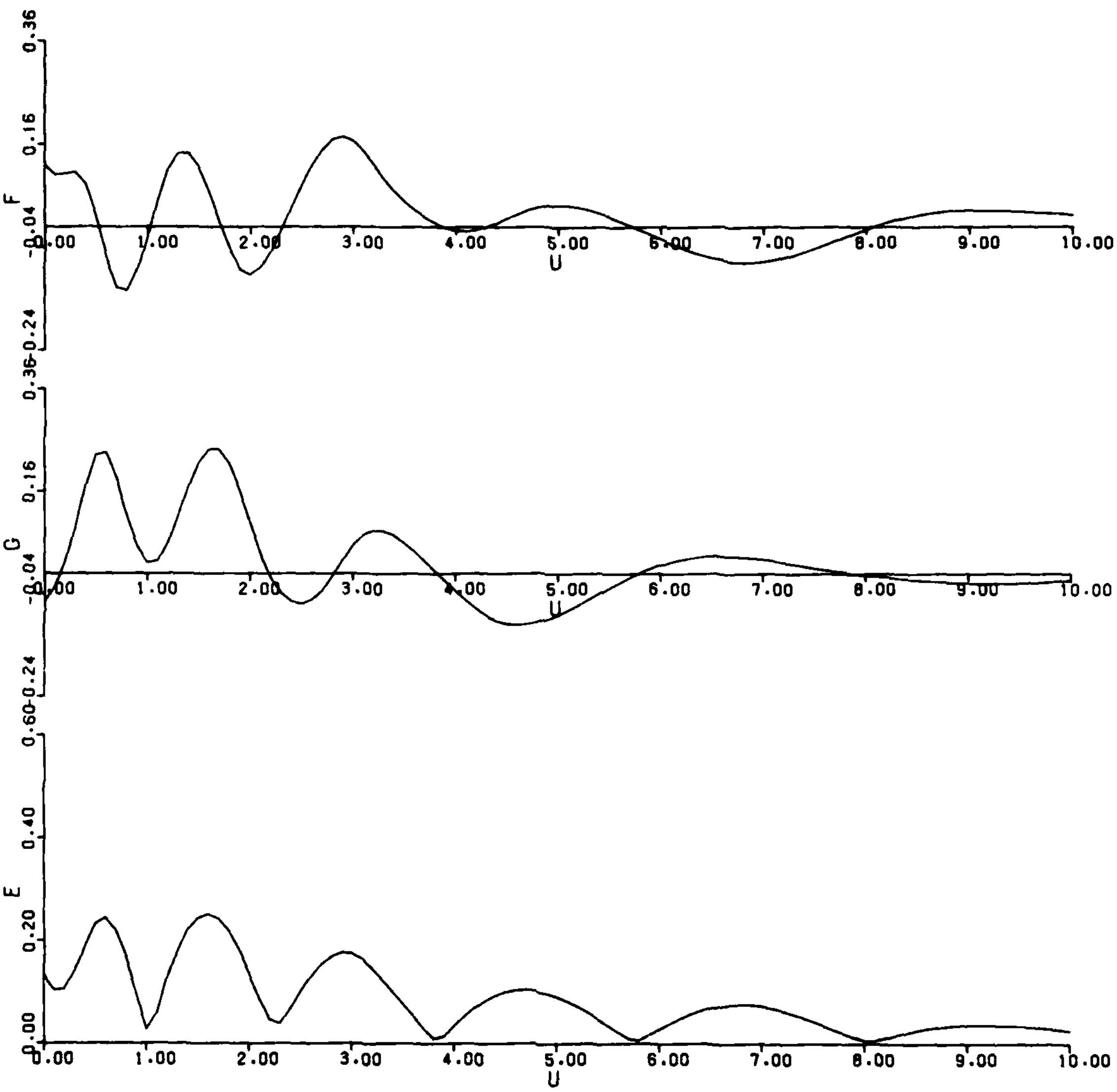


Figure 12 - Wave Spectra of LSD 41 (Model 5367) With the Short Circular Bulb at V_s = 10.45 m/s (20.31 knots) from the March 1979 Wavecut Experiments

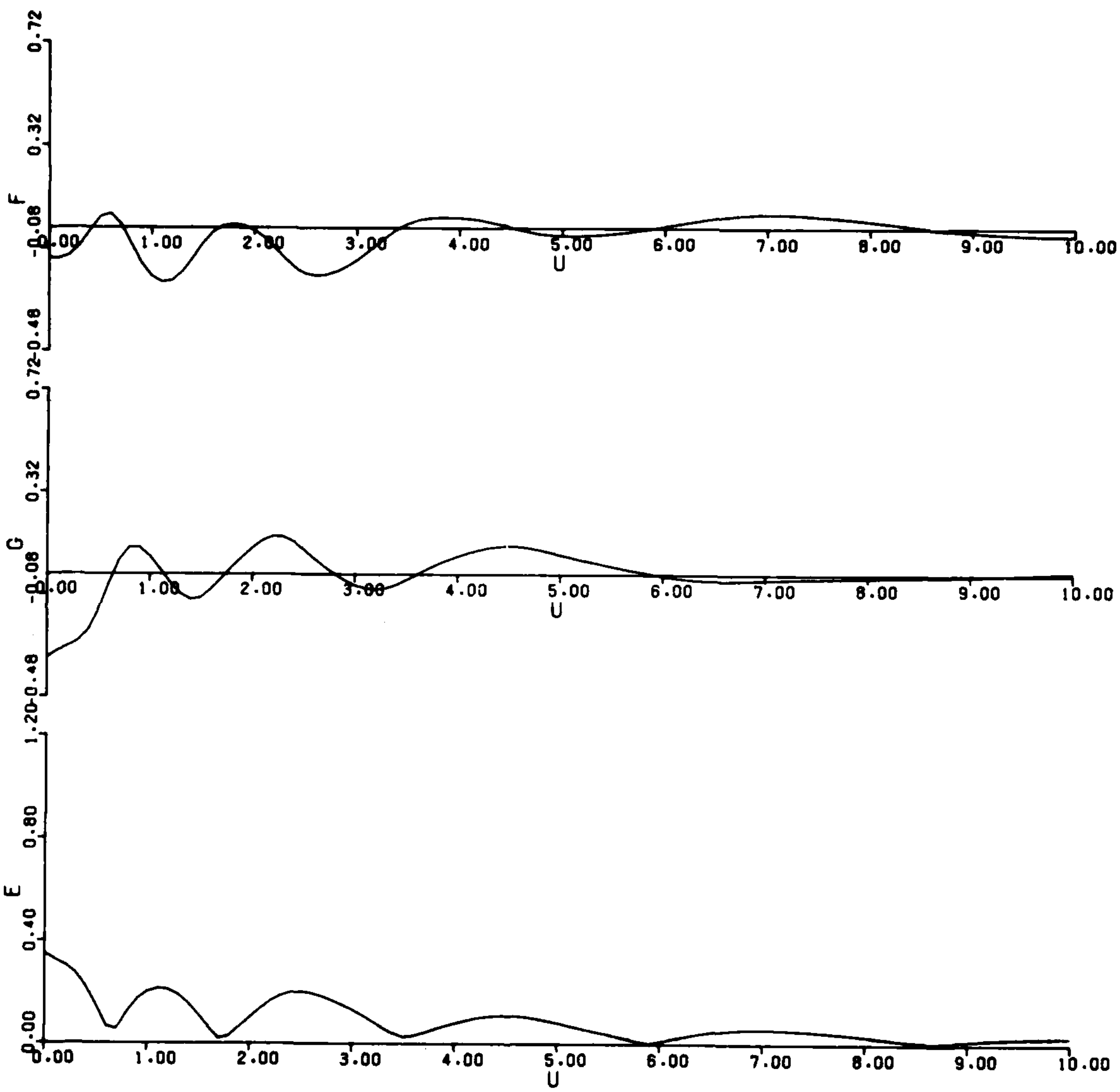


Figure 13 - Wave Spectra of LSD 41 (Model 5367) With the Short Circular Bulb at V_s = 11.40 m/s (22.14 knots) from the March 1979 Wavecut Experiments

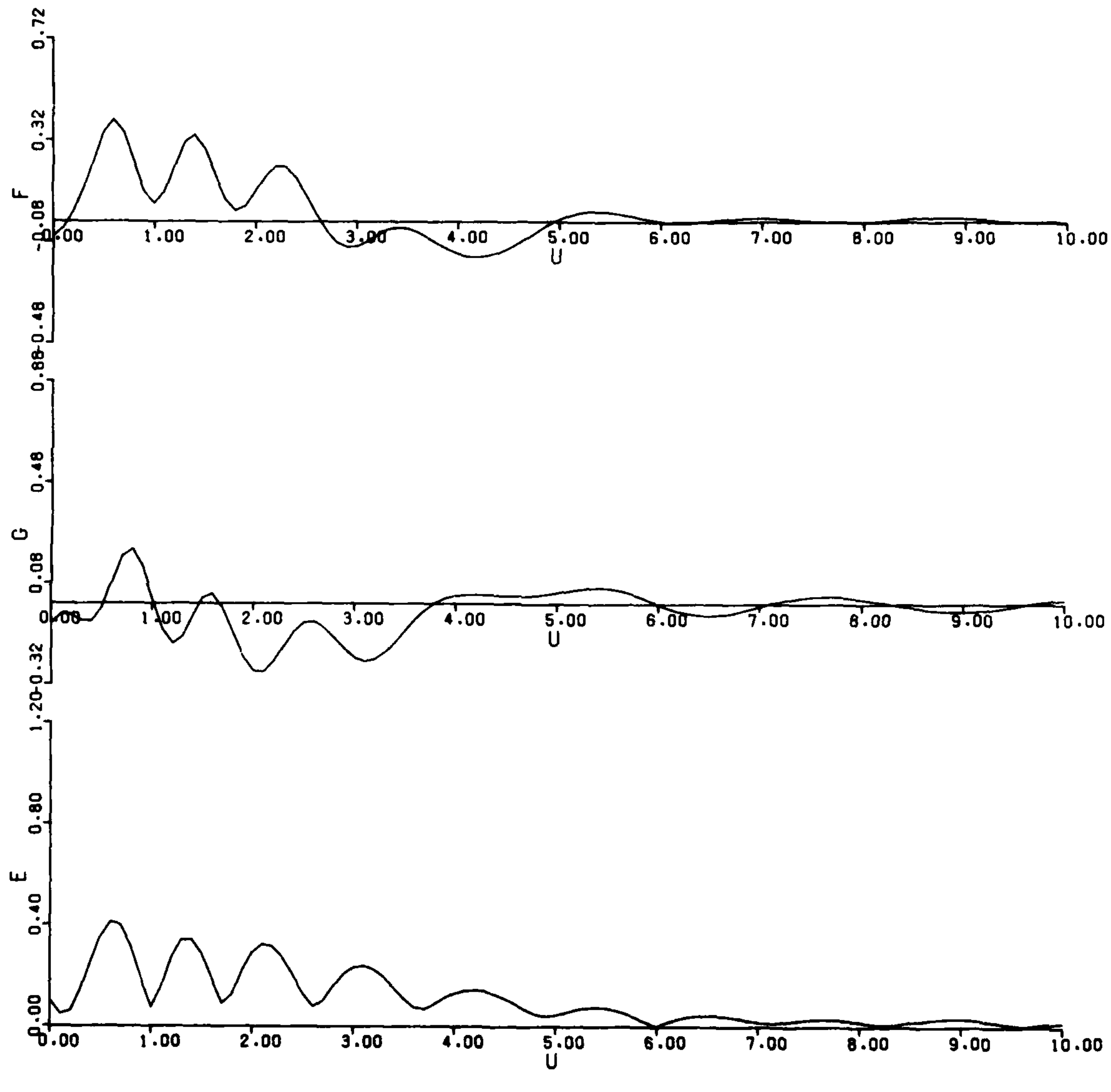


Figure 14 - Wave Spectra of LSD 41 (Model 5367) With the Long Circular Bulb at V_s = 8.32 m/s (16.16 knots) from the March 1979 Wavecut Experiments

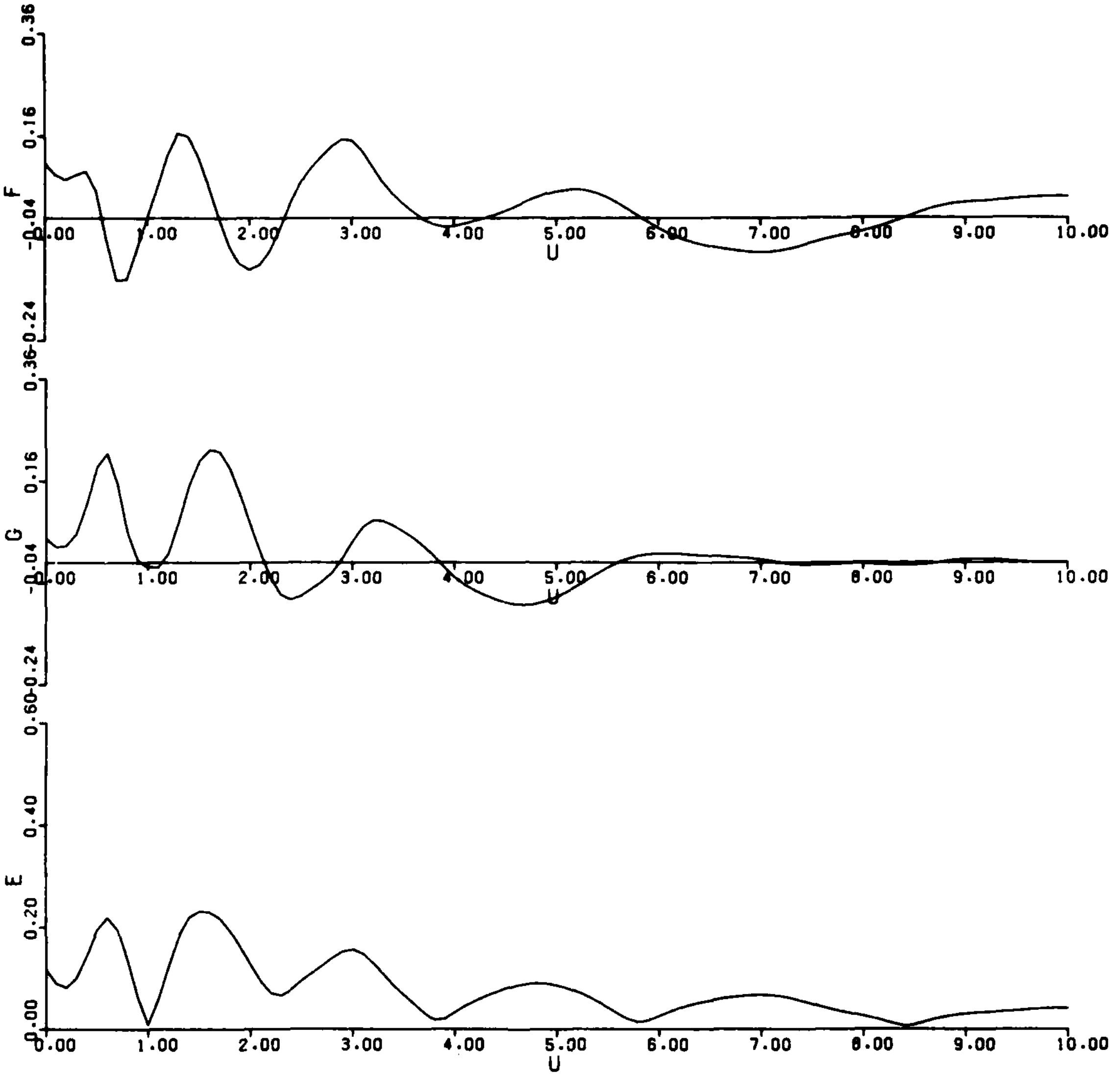


Figure 15 - Wave Spectra of LSD 41 (Model 5367) With the Long Circular Bulb at V_s = 10.45 m/s (20.31 knots) from the March 1979 Wavecut Experiments

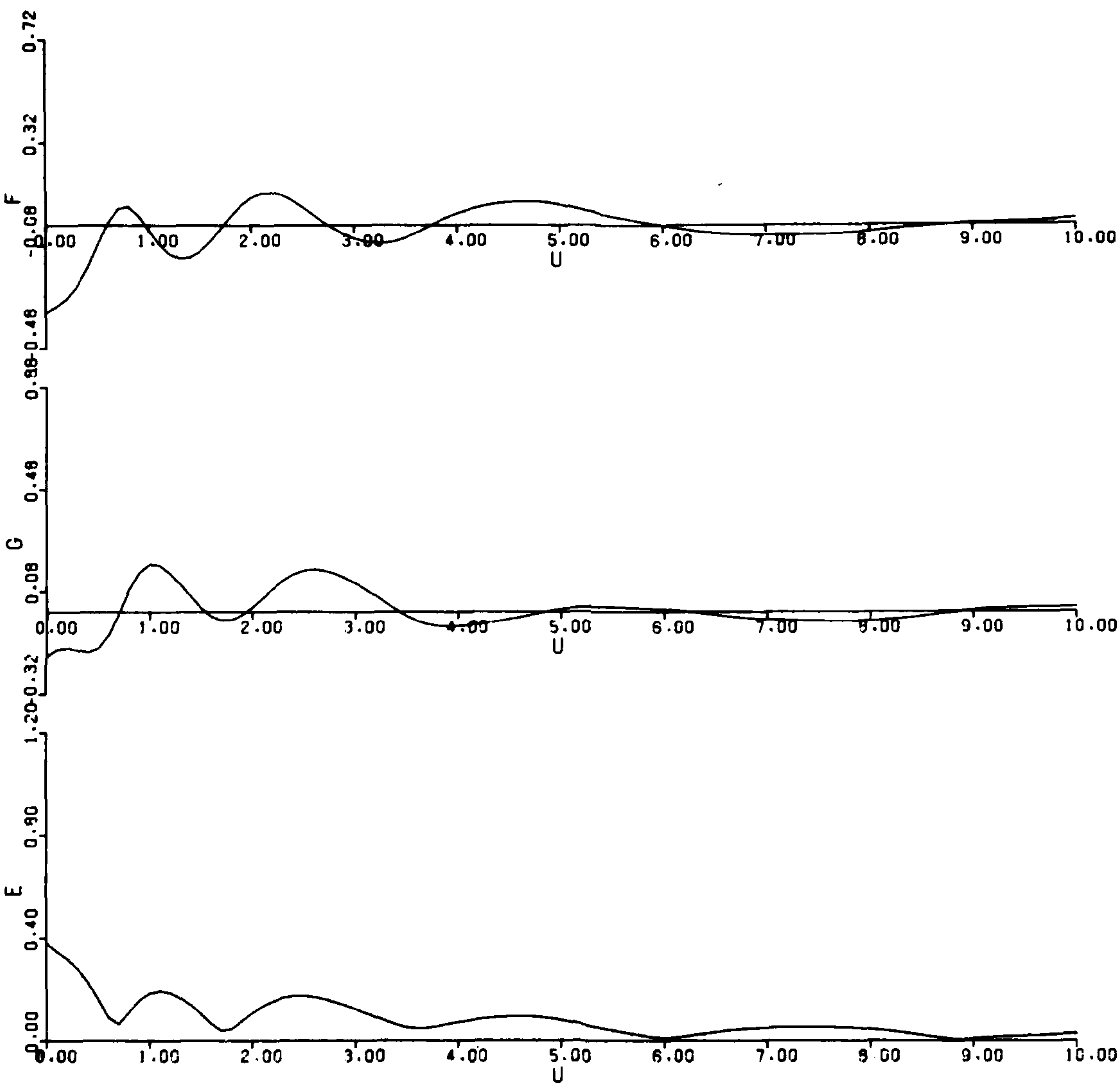


Figure 16 - Wave Spectra of LSD 41 (Model 5367) With the Long Circular Bulb at V_s = 11.40 m/s (22.14 knots) from the March 1979 Wavecut Experiments

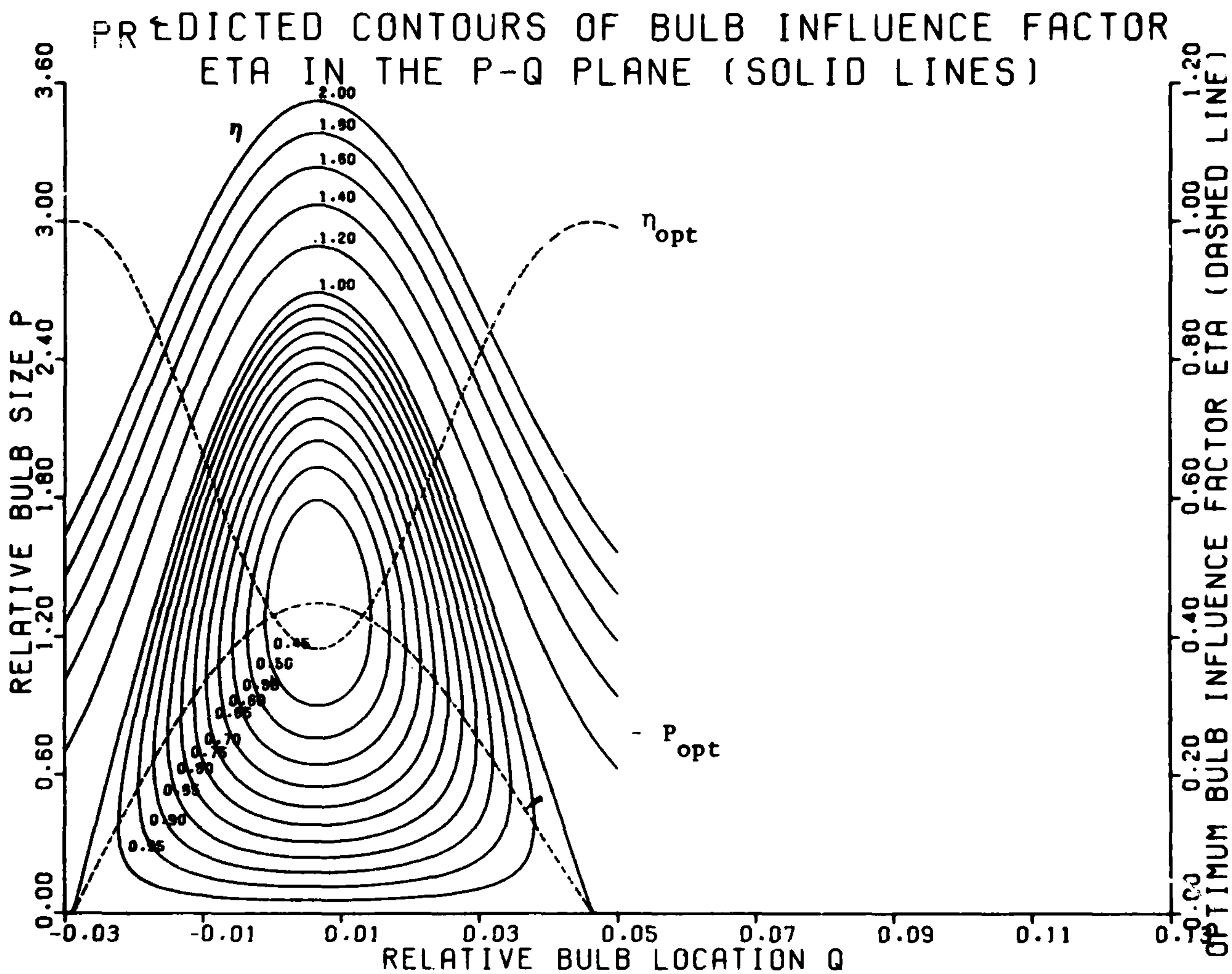


Figure 17 - Predicted Contours of η for LSD 41 (Model 5367) With the Elliptical Bulb at V_s = 8.32 m/s (16.16 knots) from the December 1978 Wavecut Experiments

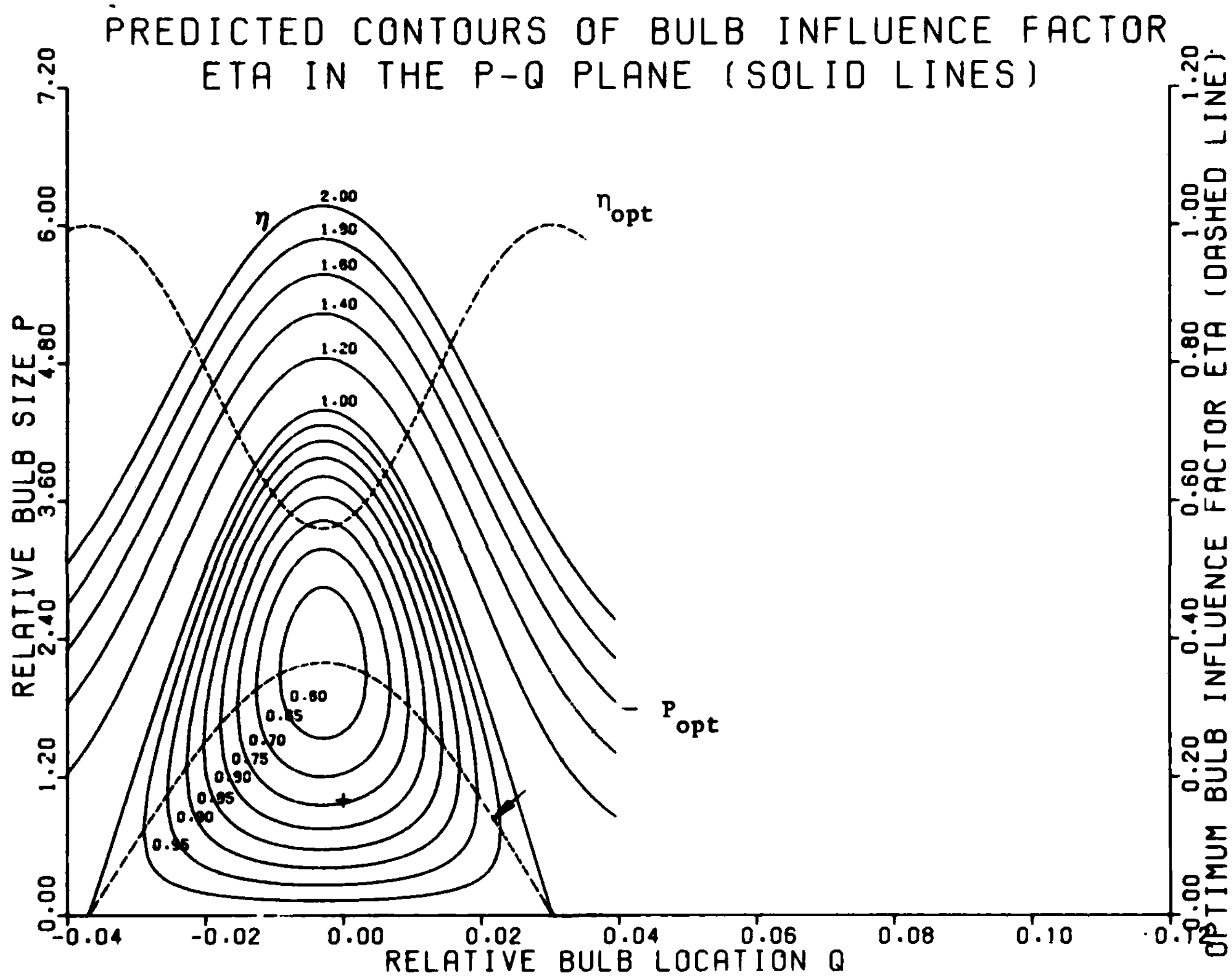


Figure 18 - Predicted Contours of η for LSD 41 (Model 5367) With the Elliptical Bulb at V_s = 11.40 m/s (22.14 knots) from the December 1978 Wavecut Experiments

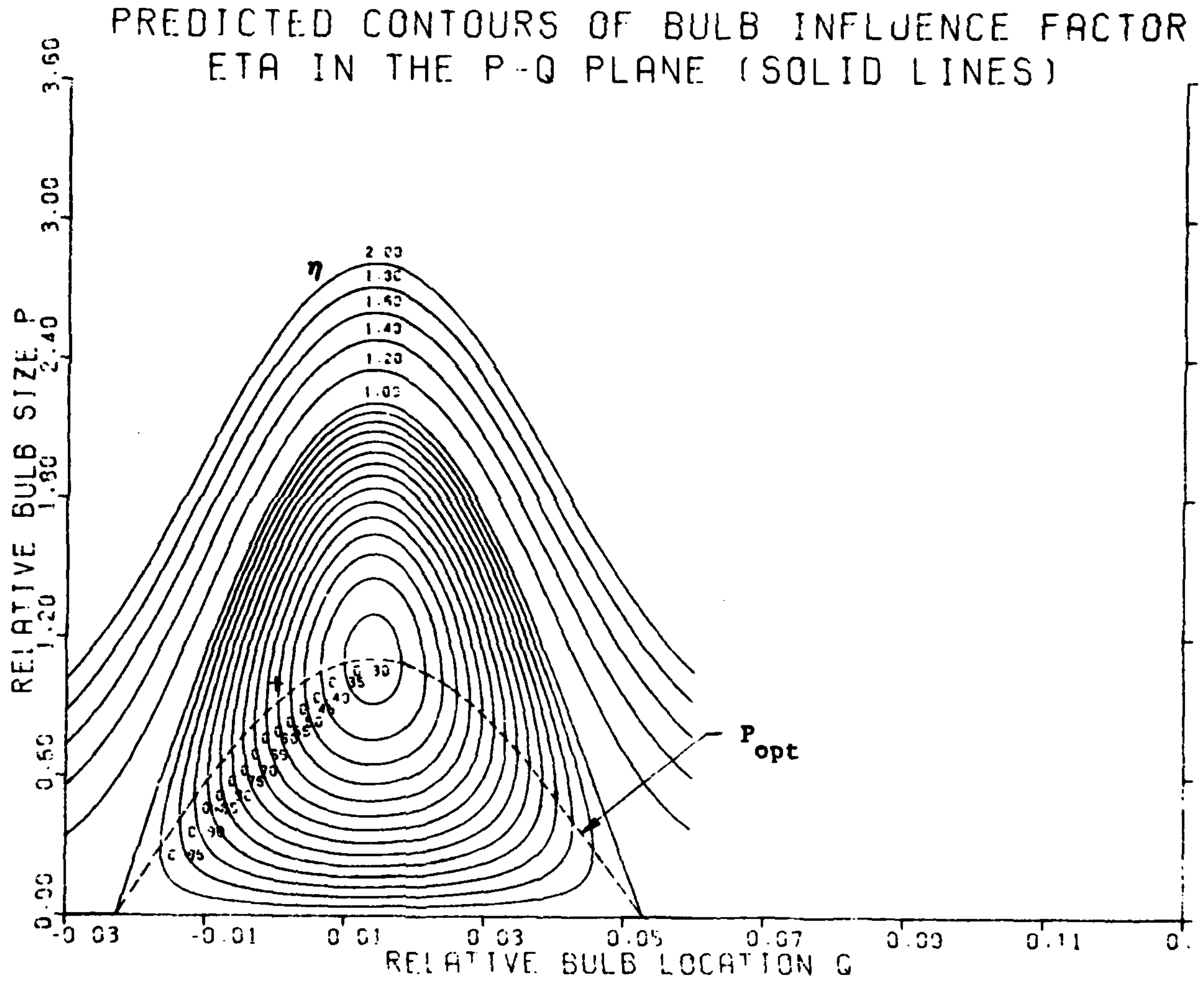


Figure 19 - Predicted Contours of η for LSD 41 (Model 5367) With the Elliptical Bulb at V_s = 8.32 m/s (16.16 knots) from the March 1979 Wavecut Experiments

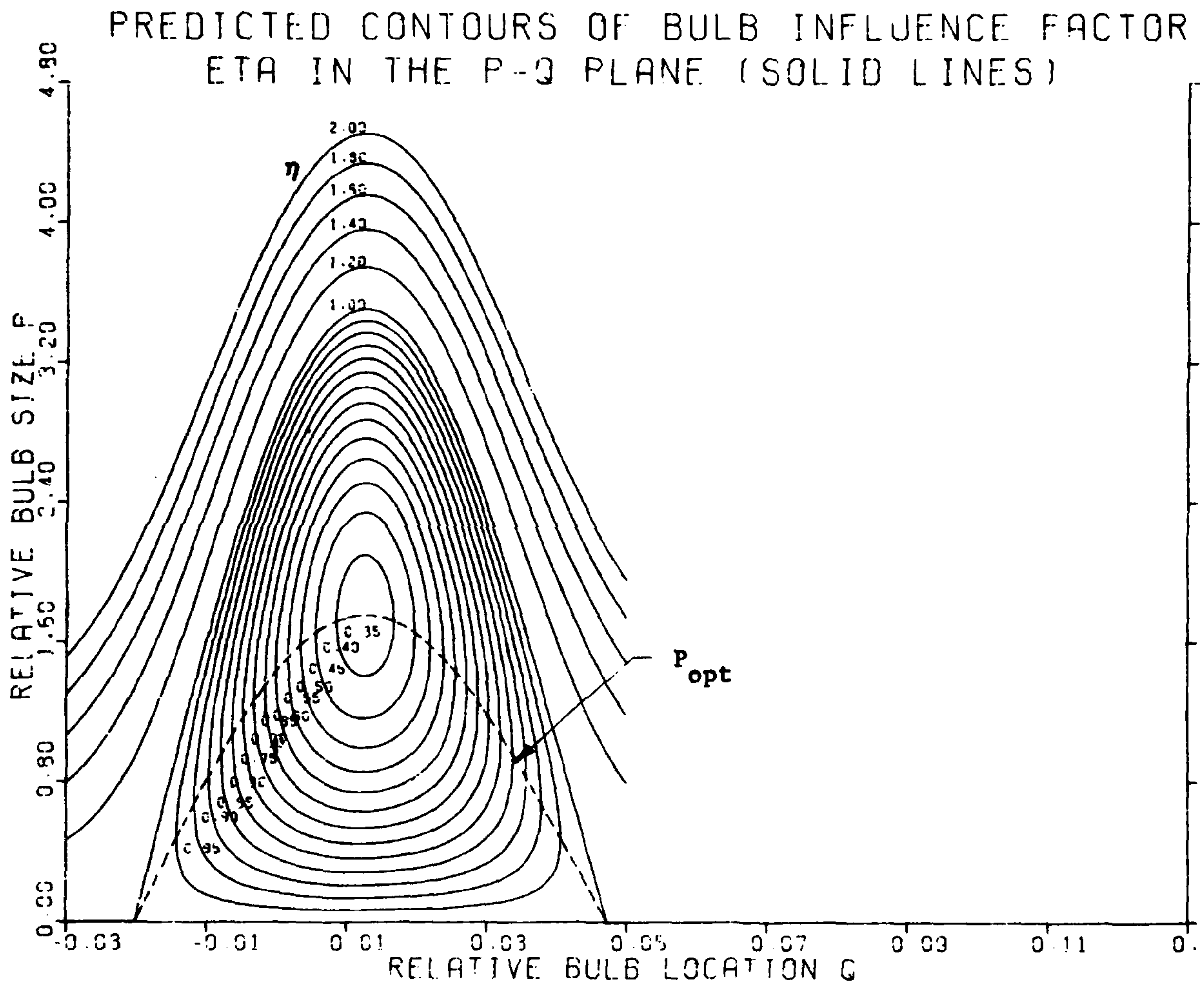


Figure 20 - Predicted Contours of η for LSD 41 (Model 5367) With the Elliptical Bulb at V_S = 10.45 m/s (20.31 knots) from the March 1979 Wavecut Experiments

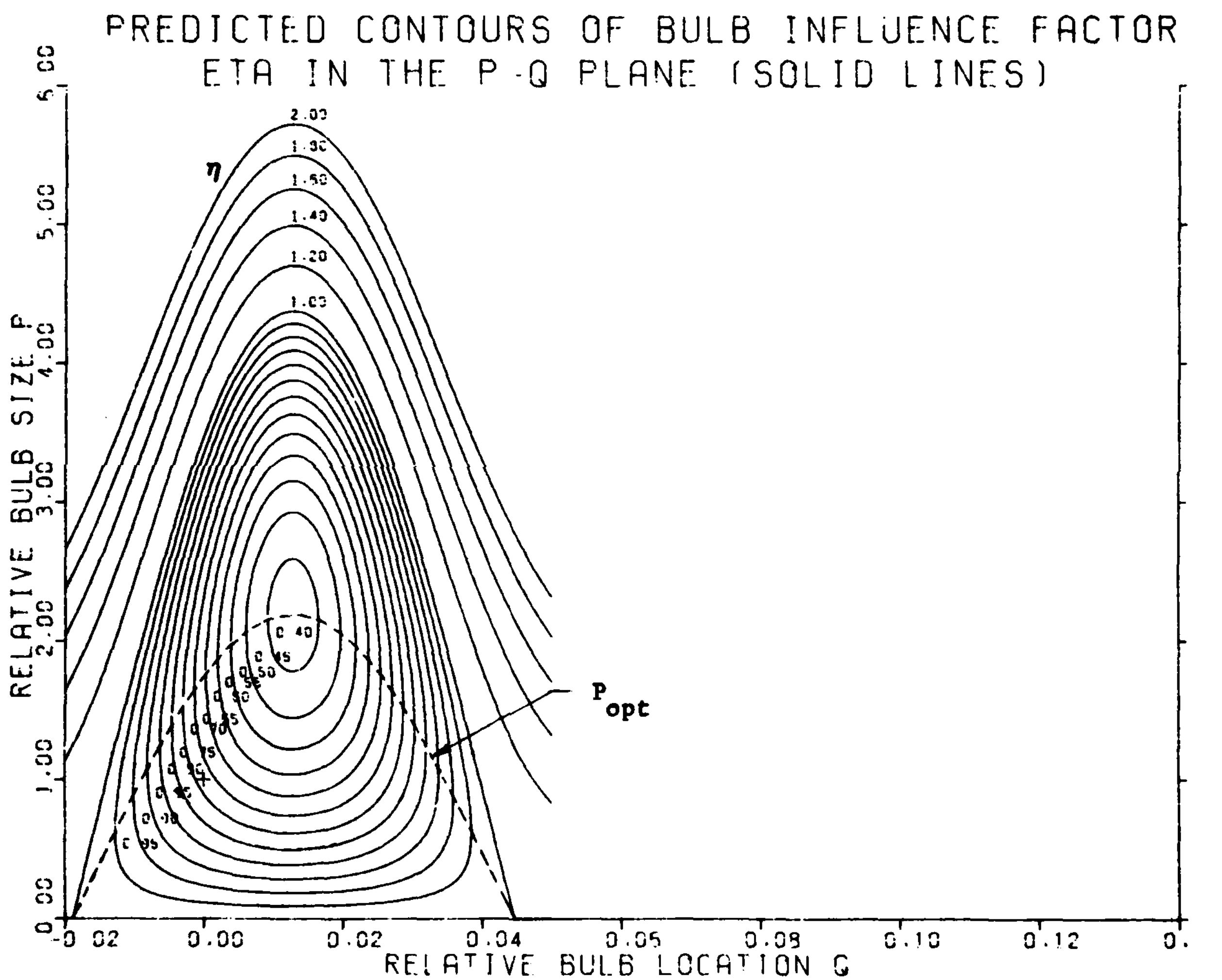


Figure 21 - Predicted Contours of η for LSD 41 (Model 5367) With the Elliptical Bulb at V_s = 11.40 m/s (22.14 knots) from the March 1979 Wavecut Experiments

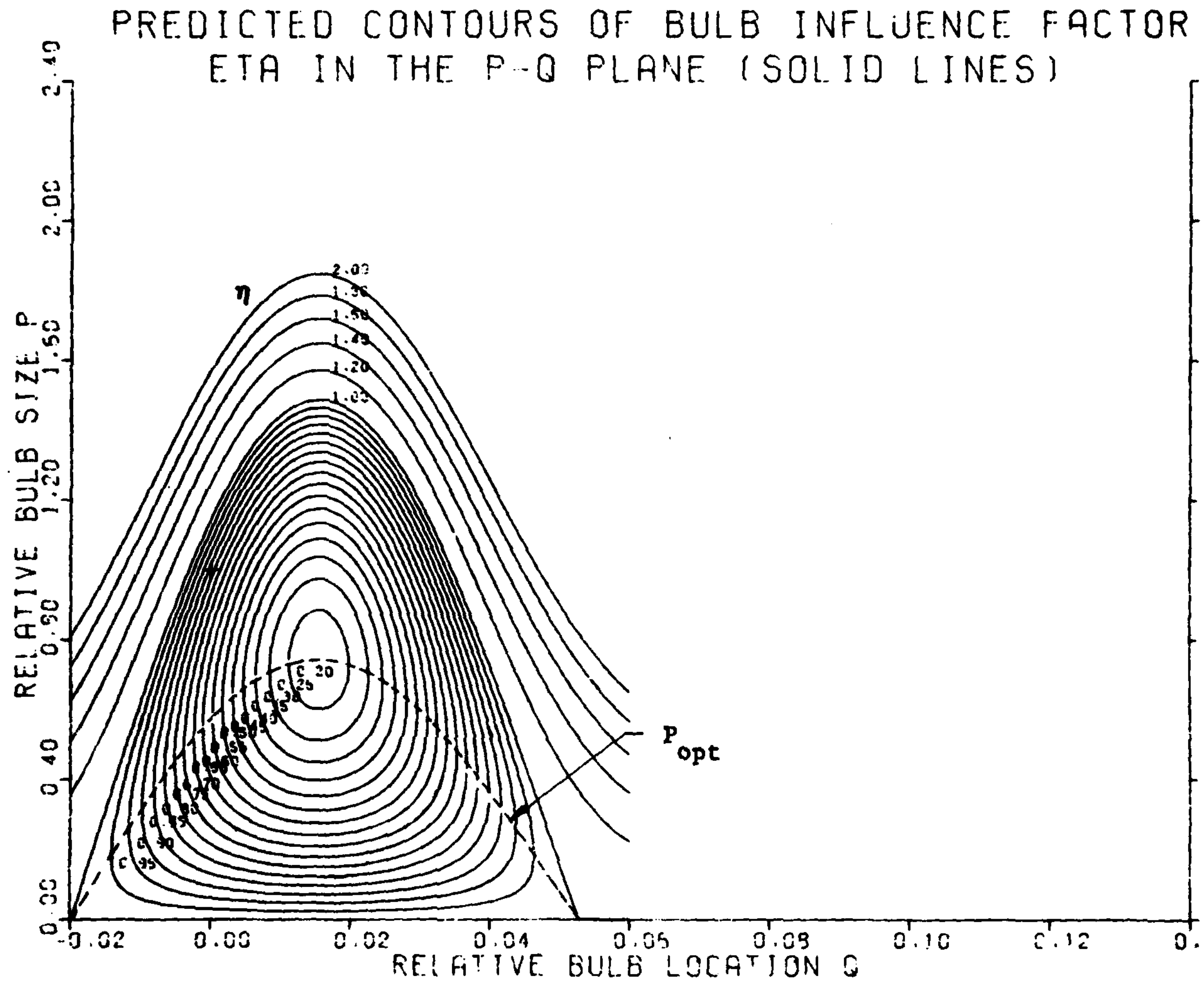


Figure 22 - Predicted Contours of η for LSD 41 (Model 5367) With the Short Circular Bulb at V_s = 8.32 m/s (16.16 knots) from the March 1979 Wavecut Experiments

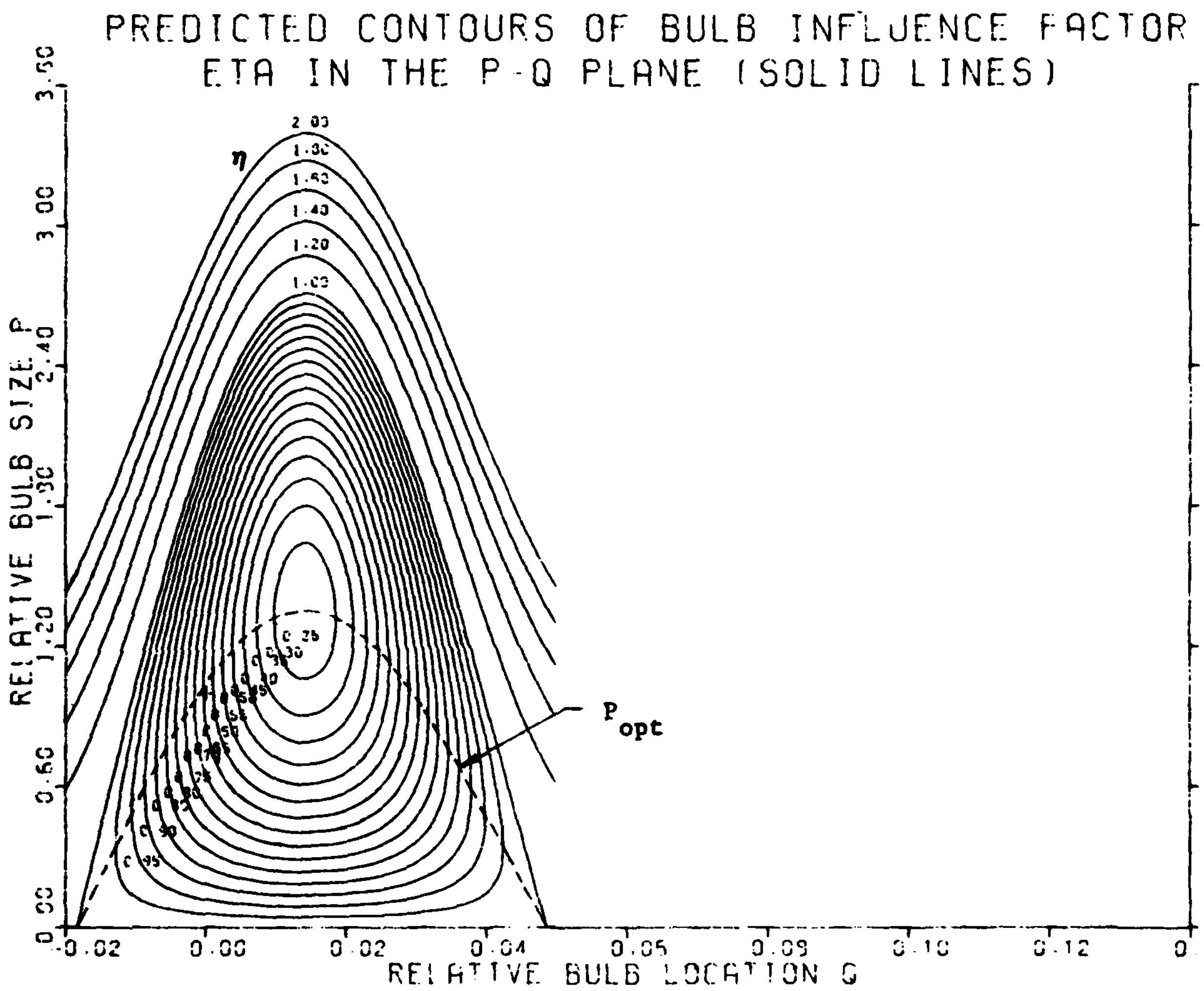


Figure 23 - Predicted Contours of η for LSD 41 (Model 5367) With the Short Circular Bulb at V_s = 10.45 m/s (20.31 knots) from the March 1979 Wavecut Experiments

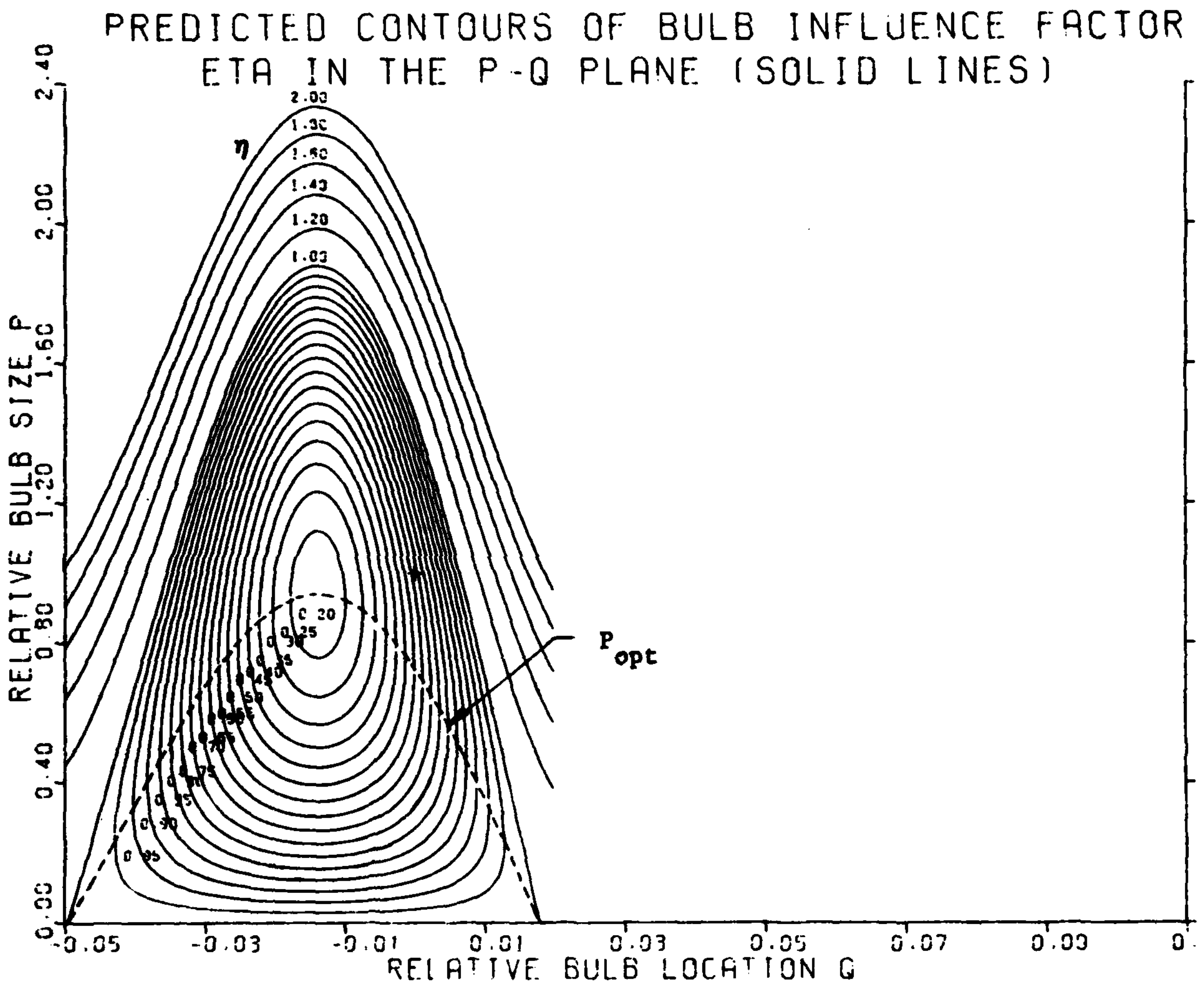


Figure 24 - Predicted Contours of η for LSD 41 (Model 5367) With the Short Circular Bulb at V_s = 11.40 m/s (22.14 knots) from the March 1979 Wavecut Experiments

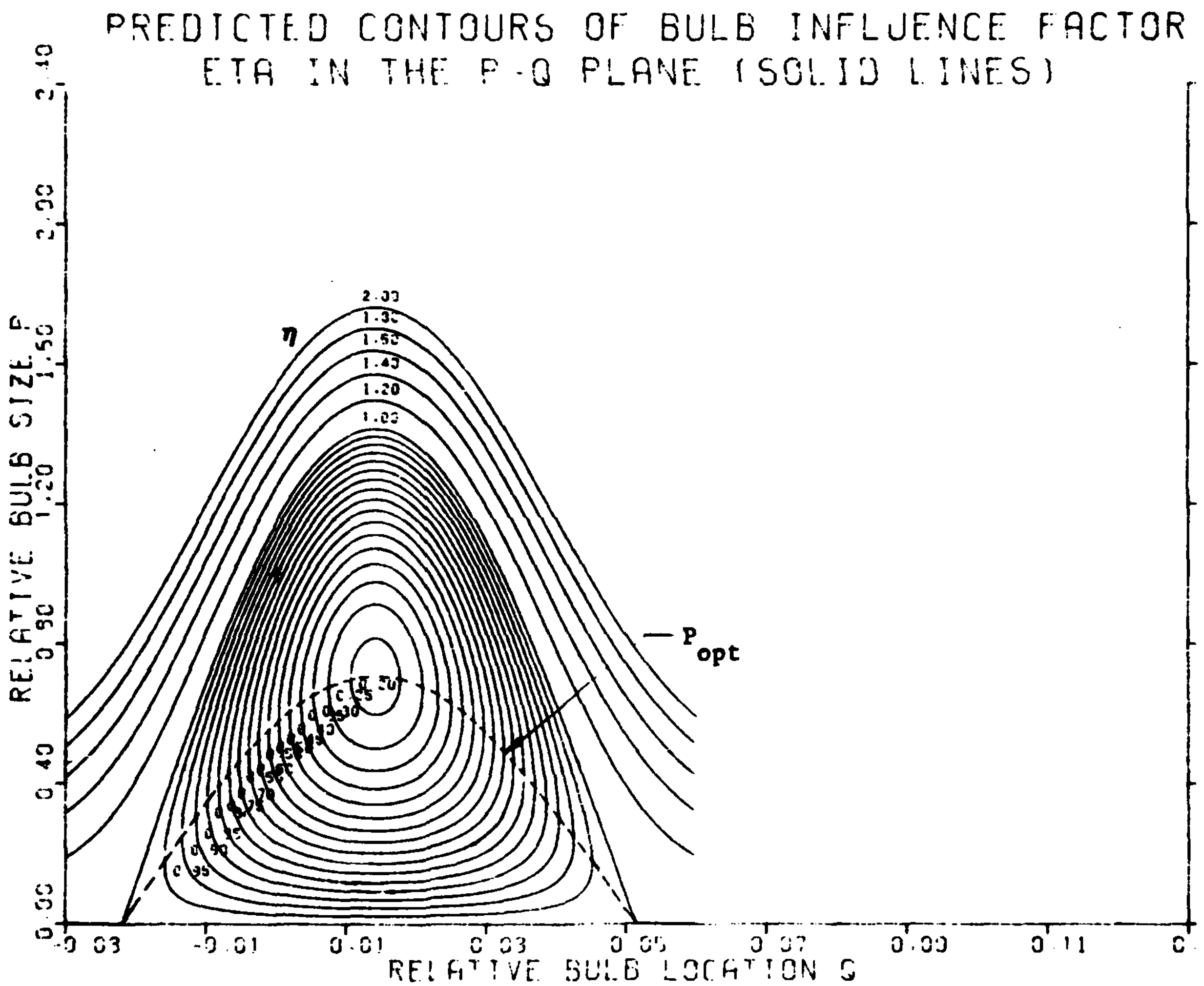


Figure 25 - Predicted Contours of η for LSD 41 (Model 5367) With the Long Circular Bulb at V_s = 8.32 m/s (16.16 knots) from the March 1979 Wavecut Experiments

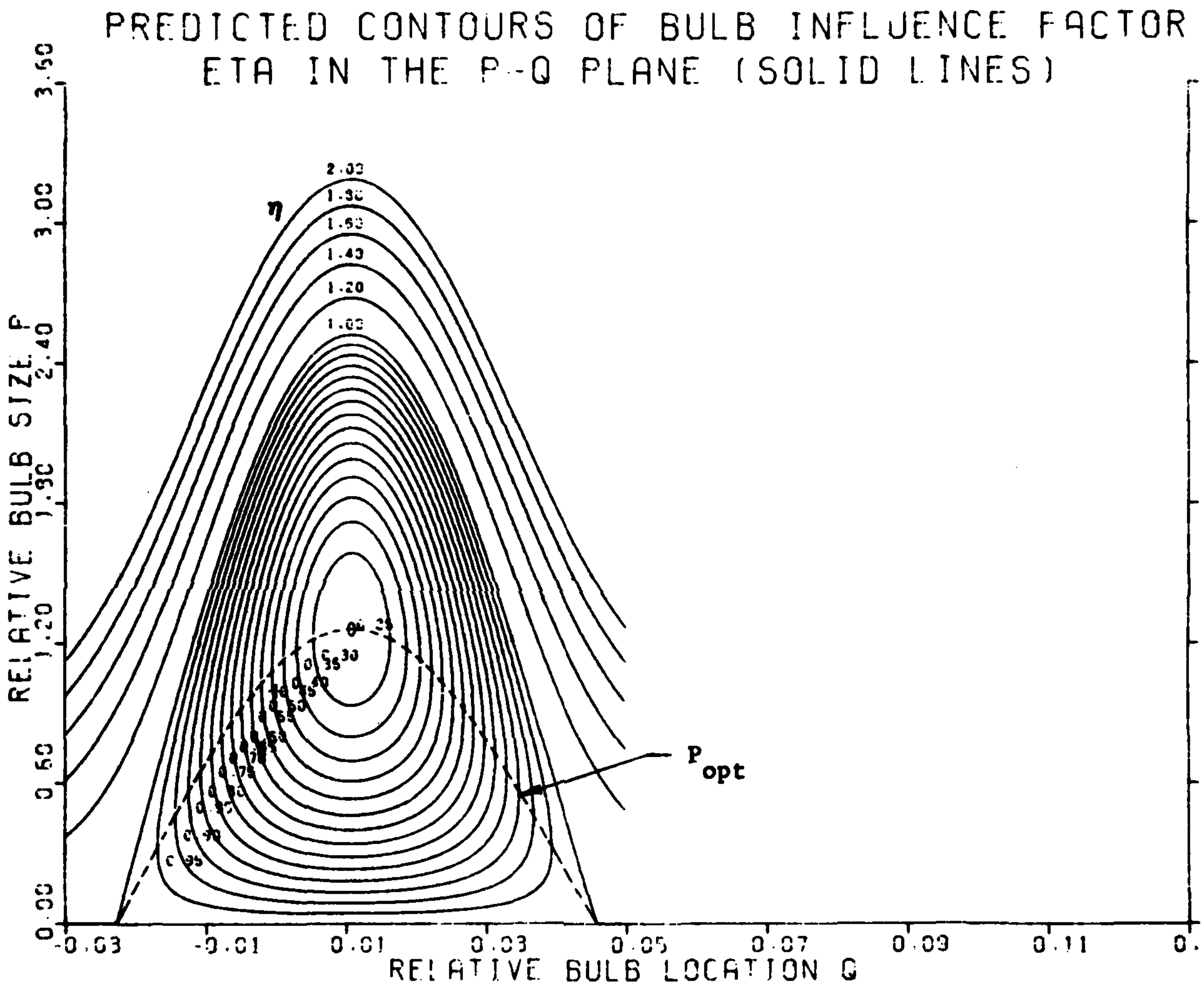


Figure 26 - Predicted Contours of η for LSD 41 (Model 5367) With the Long Circular Bulb at V_s = 10.45 m/s (20.31 knots) from the March 1979 Wavecut Experiments

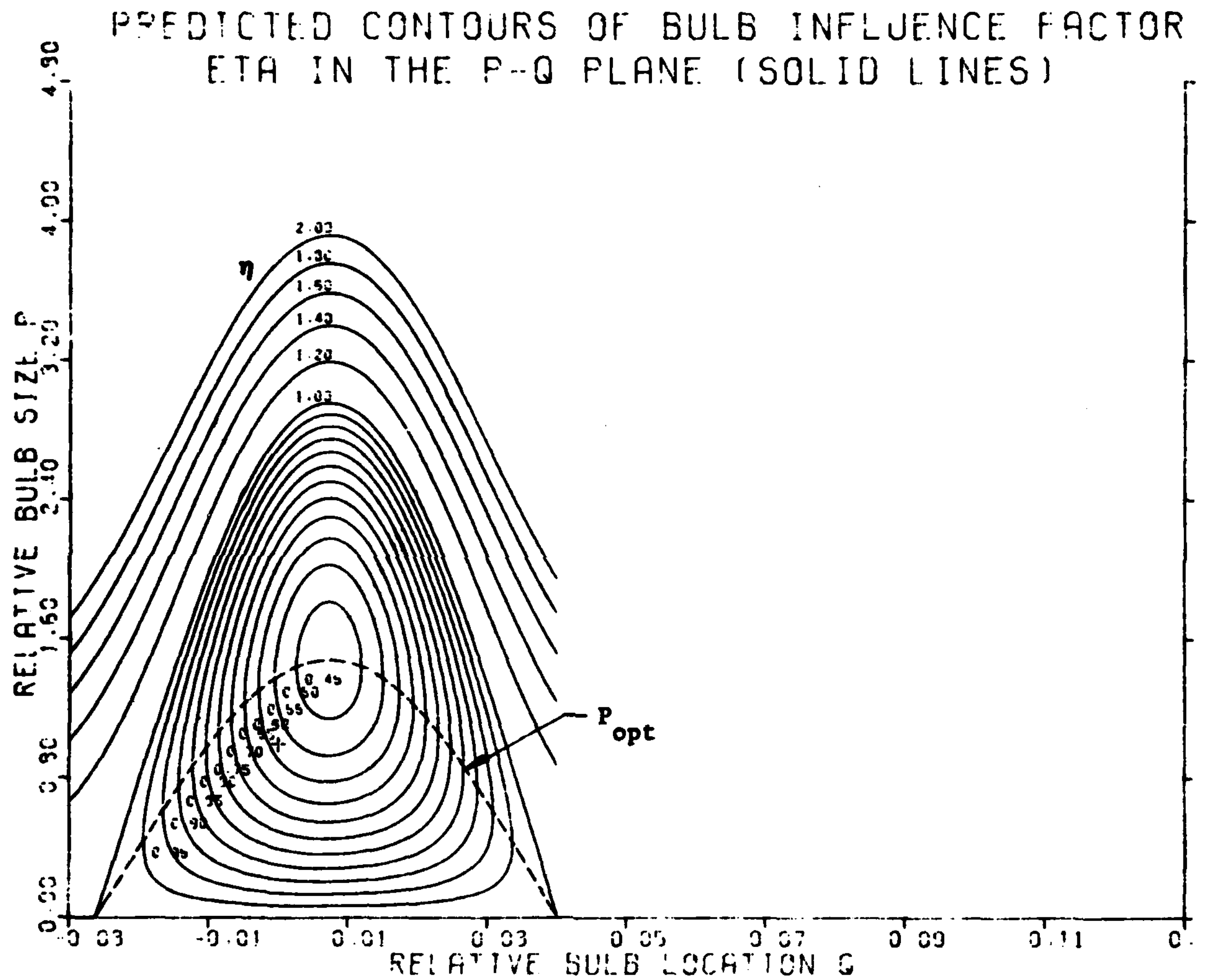


Figure 27 - Predicted Contours of η for LSD 41 (Model 5367) With the Long Circular Bulb at V_s = 11.40 m/s (22.14 knots) from the March 1979 Wavecut Experiments

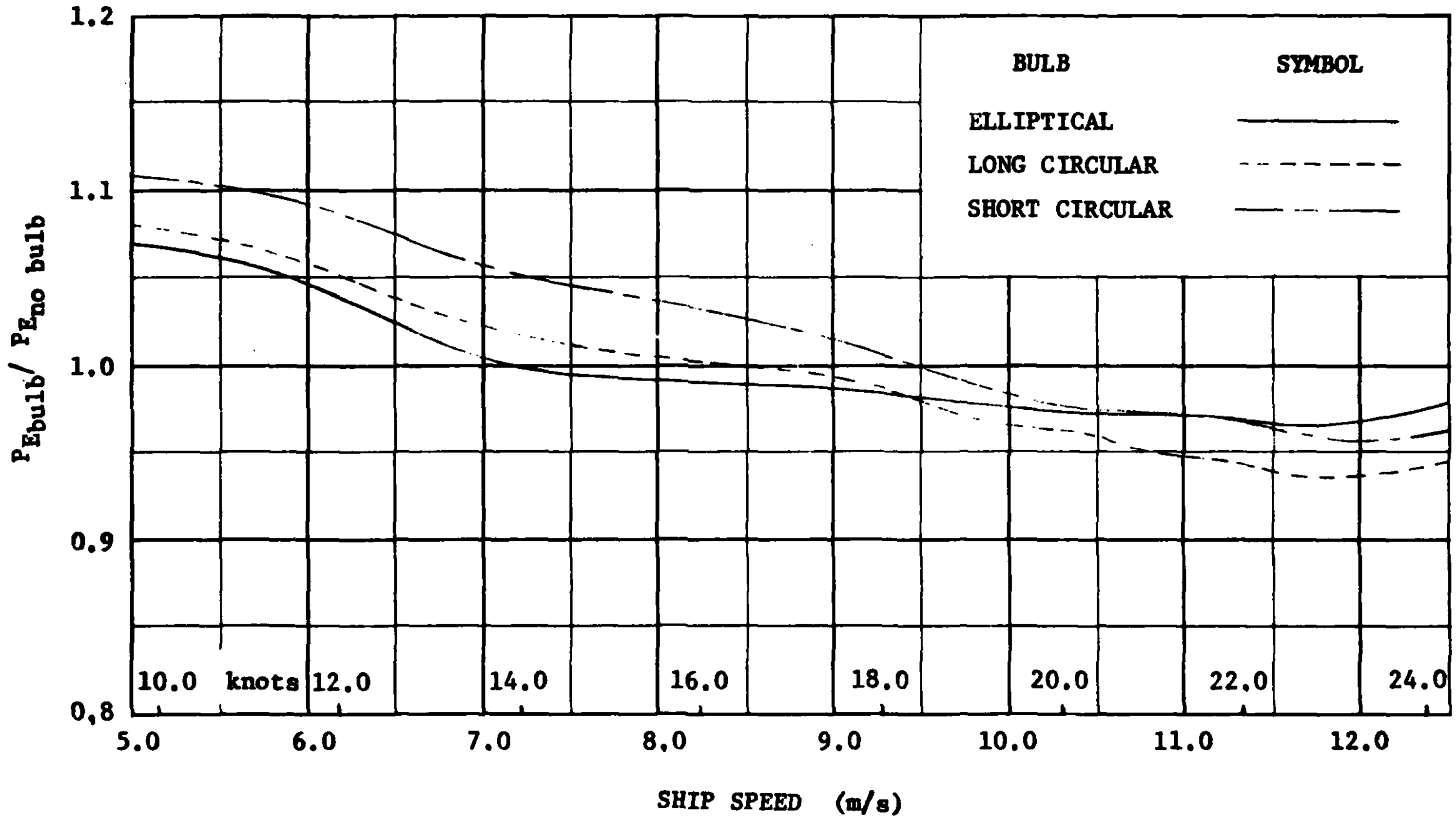


Figure 28 - Effective Power Ratios for LSD 41 with Various Bulbs

TABLE 1

PRINCIPAL DIMENSIONS OF LSD 41 AND MODEL 5367

	SHIP		MODEL	
LENGTH	176.8 m	580.0 ft	8.32 m	27.29 ft
DRAFT	6.0 m	19.6 ft	0.281 m	0.92 ft
DISPLACEMENT	16121 t	15867 tons	1.63 t	1.61 tons
WETTED SURFACE				
NO BULB	4740 m^2	51020 ft^2	10.50 m^2	112.97 ft^2
ELLIPTICAL BULB	4815 m^2	51826 ft^2	10.66 m^2	114.76 ft^2
SHORT CIRCULAR BULB	4819 m^2	51871 ft^2	10.67 m^2	114.86 ft^2
LONG CIRCULAR BULB	4845 m^2	52156 ft^2	10.73 m^2	115.49 ft^2
BULB CHARACTERISTICS				
BULB LENGTH (Beyond the Forward Perpendicular)				
ELLIPTICAL BULB	3.01 m	9.9 ft	0.141 m	0.46 ft
SHORT CIRCULAR BULB	2.65 m	8.7 ft	0.125 m	0.41 ft
LONG CIRCULAR BULB	5.13 m	16.8 ft	0.241 m	0.79 ft
BULB SIZE (A_o)				
ELLIPTICAL BULB	11.53 m^2	124.1 ft^2	0.026 m^2	0.27 ft^2
SHORT CIRCULAR BULB	16.15 m^2	173.8 ft^2	0.036 m^2	0.38 ft^2
LONG CIRCULAR BULB	16.15 m^2	173.8 ft^2	0.036 m^2	0.38 ft^2

SCALE RATIO = 21.251

TABLE 2

MEASURED AND PREDICTED VALUES OF η FOR MODEL 5367 (LSD 41) BASED ON DATA FROM WAVECUT EXPERIMENTS

	ELLIPTICAL BULB		SHORT CIRCULAR BULB			LONG CIRCULAR BULB		
V_s	Dec 1978 η	Mar 1979 η	Dec 1978 Predicted η	Mar 1979 Predicted η	Actual η	Dec 1978 Predicted η	Mar 1979 Predicted η	Actual η
8.32 m/s (16.16 knots)	0.47	0.45	0.49	0.80	0.78	0.38	0.40	0.76
10.45 m/s (20.31 knots)	-	0.54	-	0.58	0.54	-	0.34	0.44
11.40 m/s (22.14 knots)	0.69	0.63	0.62	0.64	0.57	0.68	0.44	0.53

TABLE 3

VALUES OF THE RESIDUARY AND WAVEMAKING RESISTANCE COEFFICIENTS FOR LSD 41 (MODEL 5367)

V_s = 8.32 m/s (16.16 knots)

BULB USED	C_W $\times10^{-3}$	C'_R $\times10^{-3}$	$\frac{C'_{R_{bulb}}}{C'_{R_{no\ bulb}}}$	η
None*	0.179	0.997	1.000	1.00
Elliptical Bulb*	0.081	0.936	0.939	0.47
Elliptical Bulb	0.082	0.936	0.939	0.45
Short Circular Bulb	0.137	1.055	1.058	0.78
Long Circular Bulb	0.133	0.956	0.959	0.76

V_s = 10.45 m/s (20.31 knots)

BULB USED	C_W $\times10^{-3}$	C'_R $\times10^{-3}$	$\frac{C'_{R_{bulb}}}{C'_{R_{no\ bulb}}}$	η
None*	0.324	1.284	1.000	1.00
Elliptical Bulb	0.180	1.160	0.903	0.54
Short Circular Bulb	0.170	1.162	0.905	0.54
Long Circular Bulb	0.138	1.108	0.863	0.44

V_s = 11.40 m/s (22.14 knots)

BULB USED	C_W $\times10^{-3}$	C'_R $\times10^{-3}$	$\frac{C'_{R_{bulb}}}{C'_{R_{no\ bulb}}}$	η
None*	0.438	1.485	1.000	1.00
Elliptical Bulb*	0.300	1.345	0.906	0.69
Elliptical Bulb	0.269	1.345	0.906	0.63
Short Circular Bulb	0.246	1.329	0.895	0.57
Long Circular Bulb	0.224	1.241	0.836	0.53

*Data taken during the December 1978 experiments

DTNSRDC ISSUES THREE TYPES OF REPORTS

1. DTNSRDC REPORTS, A FORMAL SERIES, CONTAIN INFORMATION OF PERMANENT TECHNICAL VALUE. THEY CARRY A CONSECUTIVE NUMERICAL IDENTIFICATION REGARDLESS OF THEIR CLASSIFICATION OR THE ORIGINATING DEPARTMENT.

2. DEPARTMENTAL REPORTS, A SEMIFORMAL SERIES, CONTAIN INFORMATION OF A PRELIMINARY, TEMPORARY, OR PROPRIETARY NATURE OR OF LIMITED INTEREST OR SIGNIFICANCE. THEY CARRY A DEPARTMENTAL ALPHANUMERICAL IDENTIFICATION.

3. TECHNICAL MEMORANDA, AN INFORMAL SERIES, CONTAIN TECHNICAL DOCUMENTATION OF LIMITED USE AND INTEREST. THEY ARE PRIMARILY WORKING PAPERS INTENDED FOR INTERNAL USE. THEY CARRY AN IDENTIFYING NUMBER WHICH INDICATES THEIR TYPE AND THE NUMERICAL CODE OF THE ORIGINATING DEPARTMENT. ANY DISTRIBUTION OUTSIDE DTNSRDC MUST BE APPROVED BY THE HEAD OF THE ORIGINATING DEPARTMENT ON A CASE-BY-CASE BASIS.

FILMED

8