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Report C-3311

PERFORMANCE OF HIGH-SPEED NAVAL SHIPS, PART II RESULTS OF RESISTANCE TESTS IN SMOOTH WATER ON NINE HULL FORMS (LCB/LCF EFFECT) (U)

NAVAL SHIP RESEARCH AND DEVELOPMENT CENTER

Washington, D.C. 20034

PERFORMANCE OF HIGH-SPEED NAVAL SHIPS, PART II RESULTS OF RESISTANCE TESTS IN SMOOTH WATER ON NINE HULL FORMS (LCB/LCF EFFECT) (U)

by

Marc P. Lasky

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DEPARTMENT OF HYDROMECHANICS

RESEARCH AND DEVELOPMENT REPORT

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November 1970 Report C-3311

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Naval Ship Research and Development Center
Washington, D.C. 20034

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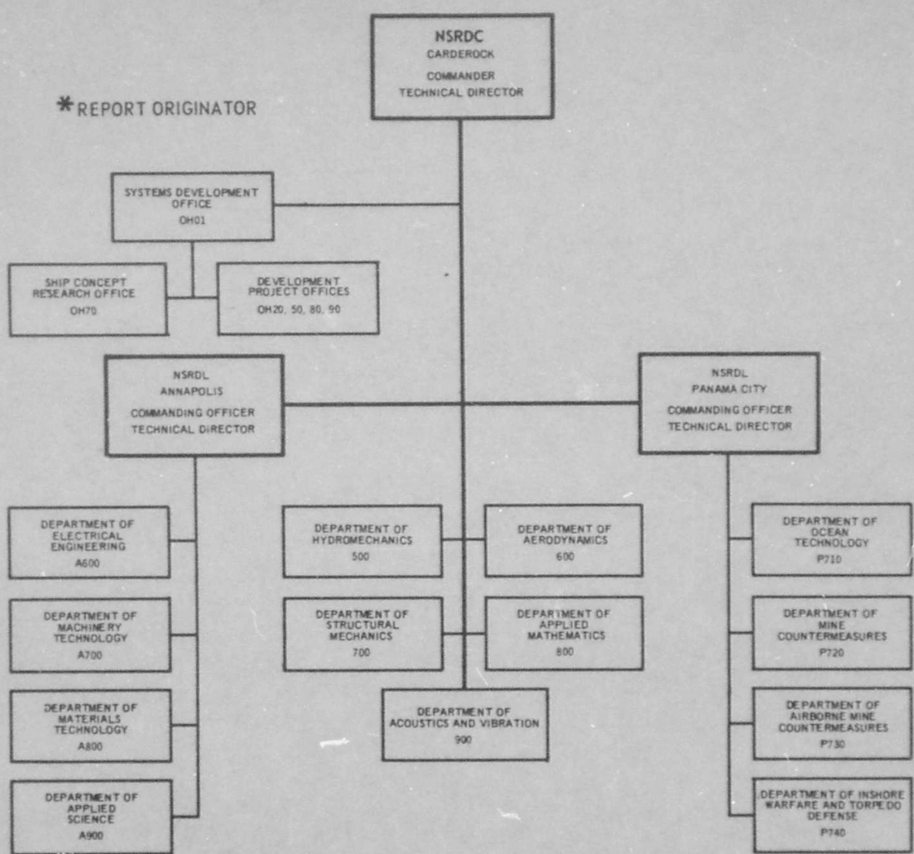

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DEPARTMENT OF THE NAVY

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ABSTRACT

(U) The effect of changing the relative locations of the longitudinal center of buoyancy (LCB) and the longitudinal center of flotation (LCF) on the resistance characteristics of high-speed naval ships was investigated. The results indicate that there was no direct relationship between the resistance and any one hull parameter except that of wetted surface. It was also found that at speed-length ratios greater than 1, the resistance characteristics of hulls with a transom and/or bulbous bow of moderate size (5-10 percent) had overall superiority over hull forms that did not have these features.

ADMINISTRATIVE INFORMATION

(U) This investigation was authorized under the NAVSHIPS Exploratory Development Applied Hydromechanics Program, Budget Project 20, FY69, as Problem 588-071-2 (LCB/LCF Studies) and funded under Subproject SF35 421 007, Task 1713.

INTRODUCTION

(U) The Naval Ship Engineering Center (NAVSEC) sponsored an experimental study to determine the effects of varying the longitudinal positions of the center of buoyancy (LCB) and the center of flotation (LCF) on the seaworthiness characteristics of high-speed naval ships. Part of this program included determination of the resistance characteristics of models in smooth water.

(U) The resistance results for the first four designs of the series, represented by Models 2, 4, 5, and 6, were originally forwarded in Reference 1.* A second series, represented by Models 1, 3, 7, and 8, was designed to explore ideas suggested by the first series of seaworthiness tests. After preliminary test results obtained with the second series had been evaluated, it was decided to repeat the resistance tests with all eight models to eliminate doubts regarding the accuracy of some of the test

*References are listed on page 27.

results. The results of the second series of tests were originally forwarded in Reference 2. Finally, a third series of tests were conducted using Models 5a, 9, and 9a; resistance characteristics for the third series were forwarded in Reference 3. A report on another aspect of Models 5a and 9a is in preparation. This report presents the combined results of the LCB/LCF series resistance tests (Models 1 through 9).

PROCEDURE

(U) Nine 10-foot models were constructed to a linear ratio of 48 according to plans furnished by the Concept Design Division of NAVSEC. All models had the same load waterline length, maximum beam, draft, displacement, block coefficient, prismatic coefficient, and maximum section coefficient. The wetted surface and many of the other coefficients varied for each model.*

(U) The resistance tests were performed in the NSRDC towing tanks. The initial phase of the testing program involved a determination as to whether turbulence stimulation would be required because of the large linear ratio. In other words, since the models were relatively small, it was felt that possibly the Reynolds Number would be too low to accurately predict the full-scale resistance characteristics from model tests. Models 1 and 3 were selected for this determination because past experience had indicated that forms with V-shaped bows would be the most troublesome from a scaling point of view. Resistance tests conducted on both models with and without sand strips indicated that turbulence stimulation was not necessary.

(U) Resistance measurements were obtained on the remaining models by using a girder-balance beam system. These data are considered to be repeatable to within ±1 percent. Sinkage and rise data were also obtained during the resistance tests by means of an electronic trim gage which operates on the Wheatstone Bridge principle. Measurements are considered to be accurate to within ±0.05 inch (model scale); they were repeatable in

*Model 9 also varied to some degree in the prismatic and maximum section coefficients.

subsequent "check tests" to within ±1 percent. Since very little is known about the correlation of these data and the sinkage and rise of full-scale ships, the accuracy of the predictions obtained is not actually known. But since it is the purpose of this study to find guidelines leading to an improved hull form, the important factor is repeatability of the data so that accurate comparisons can be made.

RESULTS

(U) Principal dimensions, hull coefficients, and abbreviated lines and body plans for these models are presented in Figures II-1 through II-9. Sectional area curves and profile photographs of the models are presented in Figures II-10 and II-11, respectively. As can be seen in the photographs, the numbers on the models do not correspond to the model numbers of the LCB/LCF series. The NSRDC designations indicated on the photographs will not be referred to as such; instead, the models are designated in this report as LCB/LCF Series Models 1-9. Figure I-2 of Reference 5 is reproduced as Figure II-12 of this report to show the relative locations of the LCF and LCB.

(U) The experimental results of the resistance tests were expanded to full-scale predictions for ships operating in smooth, deep, salt water having a temperature of 59 F. All friction calculations were computed using the International Towing Tank Conference (ITTC) Friction Formulation of 1957 in conjunction with a model-ship correlation allowance of 0.0004. The sinkage and rise data were also expanded to full-scale predictions. Individual curves of predicted effective horsepower (ehp), resistance data, and calm water trim characteristics for each model are given in References 2 and 3. The proper NSRDC model number can be found by using Figure II-11.

(U) The calm-water resistance characteristics are presented in three groups: the frictional resistance (Figures II-13 and II-14), the residual resistance (Figures II-15 and II-16), and finally the total resistance (Figures II-17 and II-18). The calm-water sinkage and rise data have also been separated into three groups. Figure II-19 presents histograms of the underway draft of the ship at the forward perpendicular (bow), after perpendicular (stern), and longitudinal center of flotation (LCF). Finally, the underway trimming characteristics are presented in Figures II-20 and II-21.

DISCUSSION

RESIDUAL RESISTANCE

(C) It is difficult to find any trends in the data as presented in Figure II-16. However, a histogram of the results indicates that models with bulbous bows generally tend to have higher residual resistance in the lower speed range and lower resistance in the higher speed range. The results also indicate that there may be a limit to the size of the bulb. For example, Model 9 which has a 25-percent bulb (this is considered quite large) had the least desirable residual characteristics of all the models at low speeds, and it also appeared to be one of the least desirable hull forms throughout the whole speed range.

TOTAL RESISTANCE

(C) For the most part, the hulls with transoms were inferior at low speeds and superior at high speeds from a resistance point of view. In order to choose an optimum hull, it is significant to point out the overall differences in ehp between the various hull forms tested. At the maximum speed ($V/\sqrt{L}$ = 1.8), the overall range of ehp was 7 percent for transom hulls and 8 percent for nontransom hulls. The total powering range showed a 17-percent maximum difference in ehp between all models tested at this speed. However, at the approximate cruising speed ($V/\sqrt{L}$ = 0.8), the maximum variation in ehp was 56 percent. Since the overall results indicate that there is little difference from a maximum power standpoint in the requirements of the various hull forms, the main concern would be the seaworthiness characteristics of these hulls. However, the cruising range requirements showed a wide variation of ehp and this could affect ship endurance if nuclear fuels are not used. Therefore, before an optimum design is chosen, careful consideration should be given to all operating modes of the hull forms.

TRIM

(C) The trim data indicate that there was little or no change in trim below a speed-length ratio of 1.0. However, as speed increased, all hull forms appeared to trim by the stern except Model 9 which trimmed by the bow. From a propulsion point of view, a trim by the stern has the advantage of better propeller immersion. With regard to resistance in smooth water, the results obtained herein indicate that changes in trim have little or no effect on the resistance characteristics. These results are also in agreement with those of Chapter 12 of Reference 6.

CONCLUSION

(C) There does not appear to be any meaningful correlation of ehp with any one hull parameter except wetted surface which has a substantial effect on the low-speed resistance characteristics. According to Figures II-19 through II-21, (and supported by References 5 and 7) as the LCB and the LCF are moved farther apart, the ship exhibits more desirable trim characteristics. However, in order to move these parameters apart, the designer must increase the size of the transom and/or the bulbous bow. This, in turn, increases the wetted surface of the hull and results in greater ehp. Fortunately, the bulbous bow can reduce the residual resistance to some extent for speed-length ratios greater than 1.0. Further, at high speeds, the transom sterns exhibit overall superior characteristics.

(C) It appears from the data, that a compromise can be made between resistance characteristics at high and low speeds. Hull forms with both a transom and a bulbous bow of moderate size exhibit reasonably good characteristics throughout the speed range. The initial choice of hull form for all-around superior performance would appear to be Model 7. Models 1 and 3 represent hull forms that appear to be inferior throughout most of the speed range. The remaining hulls tend to exhibit both good and bad characteristics and the selection of one of them would depend on how much of any one characteristic the designer would be willing to scarifice.

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Appendages: Bare Hull

Dimensions	Ship	Model
Length (LWL) Ft	480	10.0
Length (LBP) Ft	480	10.0
Beam (B_x) Ft	48	1.00
Draft (H) Ft	16	0.333
Displ. in tons	5000 S.W.	0.044 F.W.
Wetted Surf. Sq. Ft	22,190	9.60
Design V in Kts.	39.44	5.69
LCB/LWL = 0.49 Aft of F.P.		
LCF/LWL = 0.48 Aft of F.P.		
WL Entrance Half Angle = 12°		
λ = 48.00	$V/\sqrt{L_{LWL}}$ = 1.80	
Ⓚ 5.57	Ⓟ = 1.76	
Lines: BuShips Body Plan PD5923 (Code 421)		
BuShips Profile & WL Endings PD5923		
(Code 421) Dated 7/14/65		

LWL Coefficients			
C_B	0.472	C_{WF}	0.74
C_P	0.580	C_{WA}	0.65
C_X	0.814	L_E/L	0.497
C_W	0.696	L_P/L	0
C_{PF}	0.60	L_R/L	0.503
C_{PA}	0.57	L/B_X	10.0
C_{PE}	0.60	B_X/H	3.0
C_{PR}	0.57	$\Delta/(.01L)^3$	45
C_{PV}	0.68	$S/\sqrt{\Delta L}$	14.3
C_{PVA}	0.70	f	0
C_{PVF}	0.71	t	1.50
LBP Coefficients			
C_B	0.473	L/B_X	10.0
C_P	0.585	$\Delta/(.01L)^3$	45

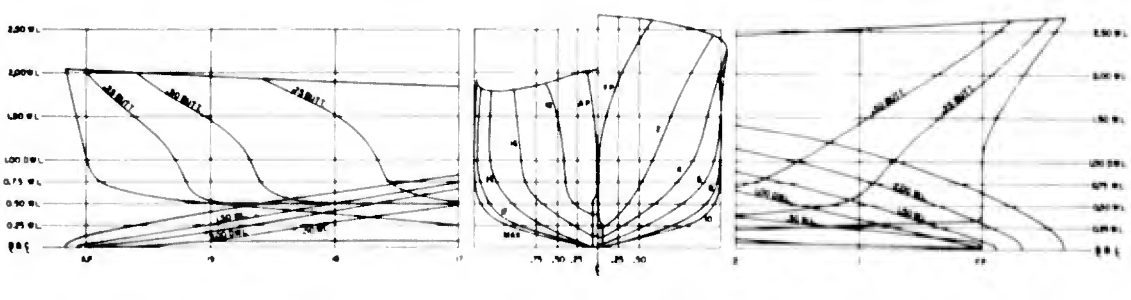

Figure II.1 - Ship and Model Data for a High-Speed Naval Ship - LCB/LCF Series Model 1 (U)

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Appendages: Bare Hull

Dimensions	Ship	Model
Length (LWL) Ft	480	10.0
Length (LWP) Ft	480	10.0
Beam (B_x) Ft	48	1.00
Draft (H) Ft	16	0.333
Displ. in tons	5000 S.W.	0.044 F.W.
Wetted Surf. Sq. Ft	23,350	10.13
Design V in Kts.	39.44	5.69
LCB/LWL = 0.52 Aft of F.P.		
LCF/LWL = 0.51 Aft of F.P.		
WL Entrance Half Angle = 9 1/2°		
λ = 48.0	$V/\sqrt{L_{LWL}}$ = 1.80	
Ⓚ = 5.57	Ⓟ = 1.76	
Lines: BuShips (Code 421) Sketches and Data Sheets Dtd 1/9/64		

LWL Coefficients			
C_B	0.472	C_{WF}	0.66
C_P	0.580	C_{WA}	0.72
C_X	0.814	L_E/L	0.545
C_W	0.688	L_P/L	0
C_{PF}	0.53	L_R/L	0.455
C_{PA}	0.64	L/B_X	10
C_{PE}	0.56	B_X/H	3
C_{PR}	0.60	$\Delta/(.01L)^3$	45
C_{PV}	0.68	$S/\sqrt{\Delta L}$	15.1
C_{PVA}	0.72	f	0
C_{PVF}	0.65	t	1.02

LBP Coefficients			
C_B	0.472	L/B_X	10
C_P	0.580	$\Delta/(.01L)^3$	45

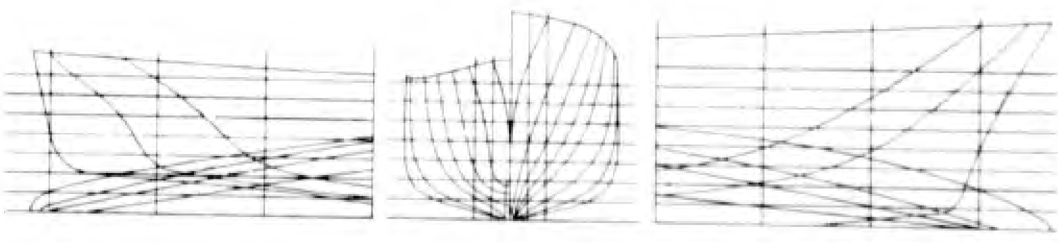

Figure II.2 - Ship and Model Data for a High-Speed Naval Ship - LCB/LCF Series Model 2 (U)

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Appendages: Bare Hull

Dimensions	Ship	Model
Length (LWL) Ft	480	10.0
Length (LBP) Ft	480	10.0
Beam (B_x) Ft	48	1.0
Draft (H) Ft	16	0.333
Displ. in tons	5000 S.W.	0.044 F.W.
Wetted Surf. Sq. Ft	23,330	10.1
Design V in Kts.	39.44	5.69
LCB/LWL = 0.55 Aft of F.P.		
LCF/LWL = 0.54 Aft of F.P.		
WL Entrance Half Angle = 7°		
λ = 48.00	$V/\sqrt{L_{LWL}}$ = 1.80	
Ⓚ = 5.57	Ⓟ = 1.76	
Lines: BuShips PD5925 & PD5926 (Code 421)		
Dated 8/27/65		

LWL Coefficients			
C_B	0.472	C_{WF}	0.59
C_P	0.580	C_{WA}	0.78
C_X	0.814	L_E/L	0.604
C_W	0.681	L_P/L	0
C_{PF}	0.50	L_R/L	0.396
C_{PA}	0.76	L/B_x	10.0
C_{PE}	0.55	B_x/H	3.0
C_{PR}	0.63	$\Delta/(.01L)^3$	45
C_{PV}	0.69	$S/\sqrt{\Delta L}$	15.0
C_{PVA}	0.73	f	0
C_{PVF}	0.63	t	0.91
LBP Coefficients			
C_B	0.469	L/B_x	10.0
C_P	0.582	$\Delta/(.01L)^3$	45

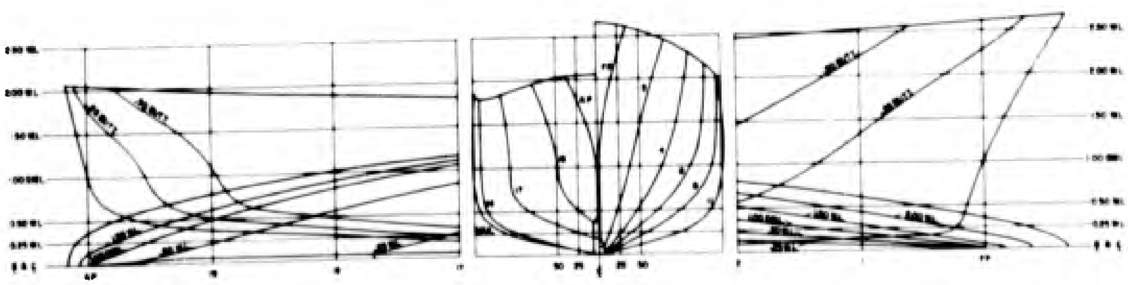

Figure II.3 - Ship and Model Data for a High-Speed Naval Ship - LCB/LCF Series Model 3 (U)

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Appendages: Bare Hull

Dimensions			LWL Coefficients			
	Ship	Model	C_B	0.472	C_{WF}	0.59
Length (LWL) Ft	480	10.0	C_P	0.580	C_{WA}	0.77
Length (LBP) Ft	480	10.0	[illegible]	0.814	L_E/L	0.50
Beam (B_x) Ft	48	1.00	C_W	0.682	L_P/L	0
Draft (H) Ft	16	0.333	C_{PF}	0.59	L_R/L	0.50
Displ. in tons	5000 S.W.	0.044 F.W.	C_{PA}	0.57	L/B_x	10
Wetted Surf. Sq. Ft	23,470	10.19	C_{PE}	0.59	B_x/H	3
Design V in Kts.	39.44	5.69	C_{PR}	0.57	$\Delta/(.01L)^3$	45
LCB/LWL = 0.49 Aft of F.P.			C_{PV}	0.69	$S/\sqrt{\Delta L}$	15.1
LCF/LWL = 0.54 Aft of F.P.			C_{PVA}	0.60	f	0.10
WL Entrance Half Angle = 6 1/2°			C_{PVF}	0.81	t	0.94
λ = 48.0	$V/\sqrt{L_{LWL}}$ = 1.80		LBP Coefficients			
Ⓚ = 5.57	Ⓟ = 1.76		C_B	0.472	L/B_x	10
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Sheets Dtd 1/9/64						

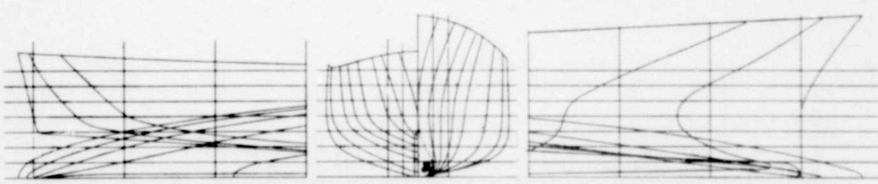

Figure II.4 - Ship and Model Data for a High-Speed Naval Ship - LCB/LCF Series Model 4 (U)

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Appendages: Bare Hull

Dimensions			LWL Coefficients			
	Ship	Model	C_B	0.472	C_{WF}	0.57
Length (LWL) Ft	480	10.0	C_P	0.580	C_{WA}	0.89
Length (LBP) Ft	480	10.0	C_X	0.814	L_E/L	0.558
Beam (B_x) Ft	48	1.00	C_W	0.714	L_P/L	0
Draft (H) Ft	16	0.333	C_{PF}	0.54	L_R/L	0.442
Displ. in tons	5000 S.W.	0.044 F.W.	C_{PA}	0.64	L/B_x	10
Wetted Surf. Sq. Ft	24,110	10.46	C_{PE}	0.57	B_x/H	3
Design V in Kts.	39.44	5.69	C_{PR}	0.58	$\Delta/(.01L)^3$	45
LCB/LWL = 0.52 Aft of F.P.			C_{PV}	0.66	$S/\sqrt{\Delta L}$	15.6
LCF/LWL = 0.57 Aft of F.P.			C_{PVA}	0.59	f	0.05
WL Entrance Half Angle =			C_{PVF}	0.76	t	0.75
λ = 48.0	$V/\sqrt{L_{LWL}}$ = 1.80		LBP Coefficients			
Ⓚ = 5.57	Ⓟ = 1.76		C_B	0.472	L/B_x	10
Lines: BuShips (Code 421) Sketches and Data			C_P	0.580	$\Delta/(.01L)^3$	45
Sheets Dtd 2/3/64						

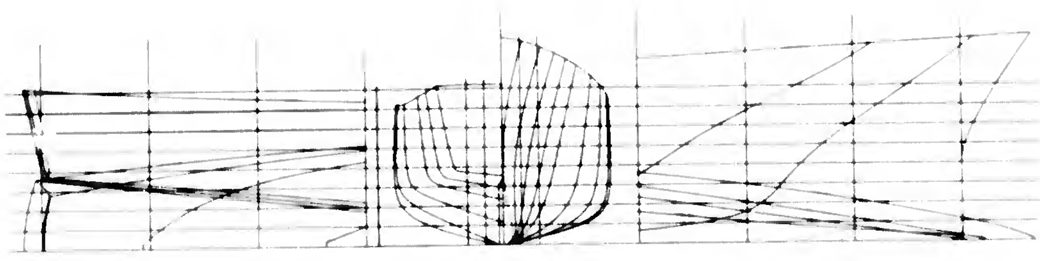

Figure II.5 - Ship and Model Data for a High-Speed Naval Ship - LCB/LCF Series Model 5 (U)

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Appendages: Bare Hull

Dimensions			LWL Coefficients			
	Ship	Model	C_B	0.472	C_{WF}	0.54
Length (LWL) Ft	480	10.0	C_P	0.580	C_{WA}	1.02
Length (LWP) Ft	480	10.0	C_X	0.814	L_E/L	0.565
Beam (B_x) Ft	48	1.00	C_W	0.735	L_P/L	0
Draft (H) Ft	16	0.333	C_{PF}	0.49	L_R/L	0.435
Displ. in tons	5000 S.W.	0.044 F.W.	C_{PA}	0.73	L/B_x	10
Wetted Surf. Sq. Ft	24,560	10.66	C_{PE}	0.53	B_x/H	3
Design V in Kts.	39.44	5.69	C_{PR}	0.65	$\Delta/(.01L)^3$	45
LCB/LWL = 0.55 Aft of F.P.			C_{PV}	0.64	$S/\sqrt{\Delta L}$	15.8
LCF/LWL = 0.60 Aft of F.P.			C_{PVA}	0.58	f	0
WL Entrance Half Angle = 6°			C_{PVF}	0.75	t	0.76
λ = 48.0	$V/\sqrt{L_{LWL}}$ = 1.80		LBP Coefficients			
Ⓚ = 5.57	Ⓟ = 1.76		C_B	0.472	L/B_x	10
Lines: BuShips (Code 421) Sketched and Data Sheet Dtd 1/21/64			C_P	0.580	$\Delta/(.01L)^3$	45

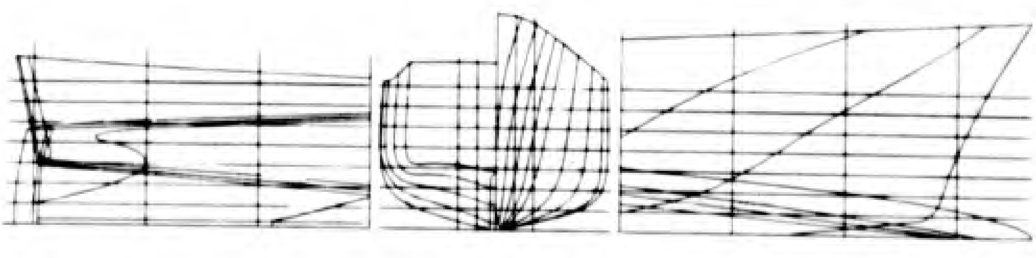

Figure II.6 - Ship and Model Data for a High-Speed Naval Ship - LCB/LCF Series Model 6 (U)

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Appendages: Bare Hull

Dimensions			LWL Coefficients			
	Ship	Model	C_B	0.472	C_{WF}	0.53
Length (LWL) Ft	480	10.0	C_P	0.580	C_{WA}	0.97
Length (LBP) Ft	480	10.0	C_X	0.814	L_E/L	0.553
Beam (B_x) Ft	48	1.00	C_W	0.721	L_P/L	0
Draft (H) Ft	16	0.333	C_{PF}	0.60	L_R/L	0.447
Displ. in tons	5000 S.W.	0.044 F.W.	C_{PA}	0.59	L/B_x	10.0
Wetted Surf. Sq. Ft	24,650	10.7	C_{PE}	0.62	B_x/H	3.0
Desigh V in Kts.	39.44	5.69	C_{PR}	0.53	$\Delta/(.01L)^3$	45
LCB/LWL = 0.49 Aft of F.P.			C_{PV}	0.65	$S/\sqrt{\Delta L}$	15.9
LCF/LWL = 0.60 Aft of F.P.			C_{PVA}	0.83	f	0.13
WL Entrance Half Angle = 6°			C_{PVF}	0.92	t	1.39
λ = 48.00	$V/\sqrt{L_{LWL}}$ = 1.80		LBP Coefficients			
Ⓚ = 5.57	Ⓟ = 1.76		C_B	0.469	L/B_X	10.0
Lines: BuShips PD5921 (Code 421)			C_P	0.580	$\Delta/(.01L)^3$	45
Dated 8/9/65						

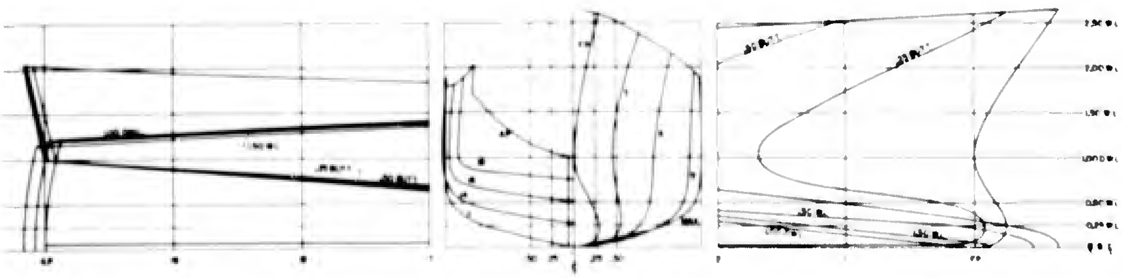

Figure II.7 - Ship and Model Data for a High-Speed Naval Ship - LCB/LCF Series Model 7 (U)

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Appendages: Bare Hull

Dimensions			LWL Coefficients			
	Ship	Model	C_B	0.472	C_{WF}	0.49
Length (LWL) Ft	480	10.0	C_P	0.580	C_{WA}	1.11
Length (LWP) Ft	480	10.0	C_X	0.814	L_E/L	0.578
Beam (B_x) Ft	48	1.00	C_W	0.714	L_P/L	0
Draft (H) Ft	16	0.333	C_{PF}	0.54	L_R/L	0.422
Displ. in tons	5000 S.W.	0.044 F.W.	C_{PA}	0.67	L/B_x	10.0
Wetted Surf. Sq. Ft	25,320	11.0	C_{PE}	0.57	B_x/H	3.0
Design V in Kts.	39.44	5.69	C_{PR}	0.57	$\Delta/(.01L)^3$	45
LCB/LWL = 0.52 Aft of F.P.			C_{PV}	0.64	$S/\sqrt{\Delta L}$	16.3
LCF/LWL = 0.63 Aft of F.P.			C_{PVA}	0.81	f	0.09
WL Entrance Half Angle = 4°			C_{PVF}	0.96	t	1.60
λ = 48.00	$V/\sqrt{L_{LWL}}$ = 1.80		LBP Coefficients			
Ⓚ = 5.57	Ⓟ = 1.76		C_B	0.460	L/B_x	10.0
Lines: BuShips Body Plan PD5919 (Code 421)			C_P	0.570	$\Delta/(.01L)^3$	45
BuShips Profile & WL Endings PD5920						
(Code 421) Dated 6/24/65						

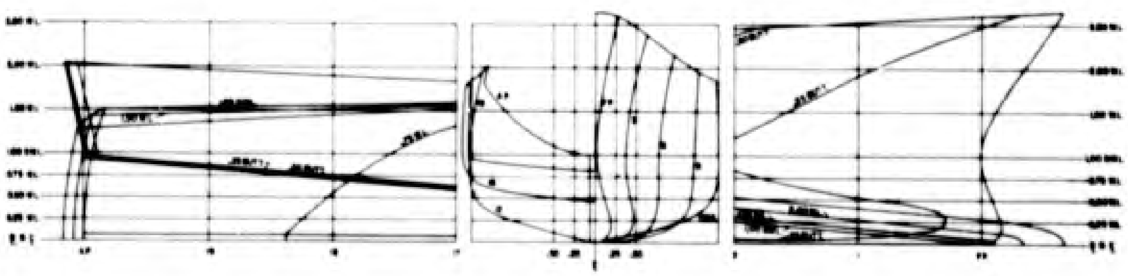

Figure II.8 - Ship and Model Data for a High-Speed Naval Ship - LCB/LCF Series Model 8 (U)

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Appendages: Bare Hull

Dimensions			LWL Coefficients			
	Ship	Model	C_B	0.472	C_{WF}	0.46
Length (LWL) Ft	480	10.0	C_P	0.571	C_{WA}	1.10
Length (LBP) Ft	480	10.0	C_X	0.825	L_E/L	0.526
Beam (B_x) Ft	48	1.00	C_W	0.747	L_P/L	0
Draft (H) Ft	16	0.333	C_{PF}	0.64	L_R/L	0.474
Displ. in tons	5000 S.W.	0.044 F.W.	C_{PA}	0.52	L/B_x	10.0
Wetted Surf. Sq. Ft	28,210	12.25	C_{PE}	0.65	B_x/H	3.00
Design V in Kts.	39.44	5.69	C_{PR}	0.48	$\Delta/(.01L)^3$	45.0
LCB/LWL = 0.46 Aft of F.P.			C_{PY}	0.63	$S/\sqrt{\Delta L}$	18.2
LCF/LWL = 0.63 Aft of F.P.			C_{PVA}	0.78	f	0.25
WL Entrance Half Angle = 4.7°			C_{PVF}	0.19	t	1.03
λ = 48.0	$V/\sqrt{L_{LWL}}$ = 1.80		LBP Coefficients			
Ⓚ = 5.57	Ⓟ = 1.76		C_B	0.472	L/B_x	10.00
Lines: Bow & Stern, Lines & Body (Ref: NAVSEC)			C_p	0.571	$\Delta/(.01L)^3$	45
P.D. #6217-15 10/12/67						

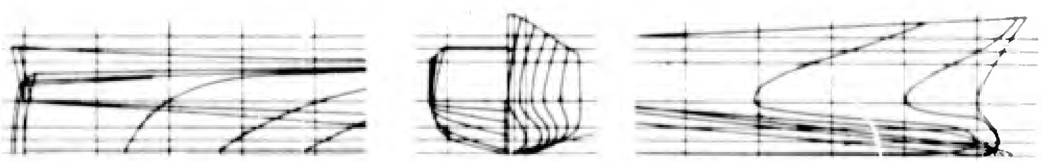


Figure II.9 - Ship and Model Data for a High-Speed Naval Ship - LCB/LCF Series Model 9 (U)

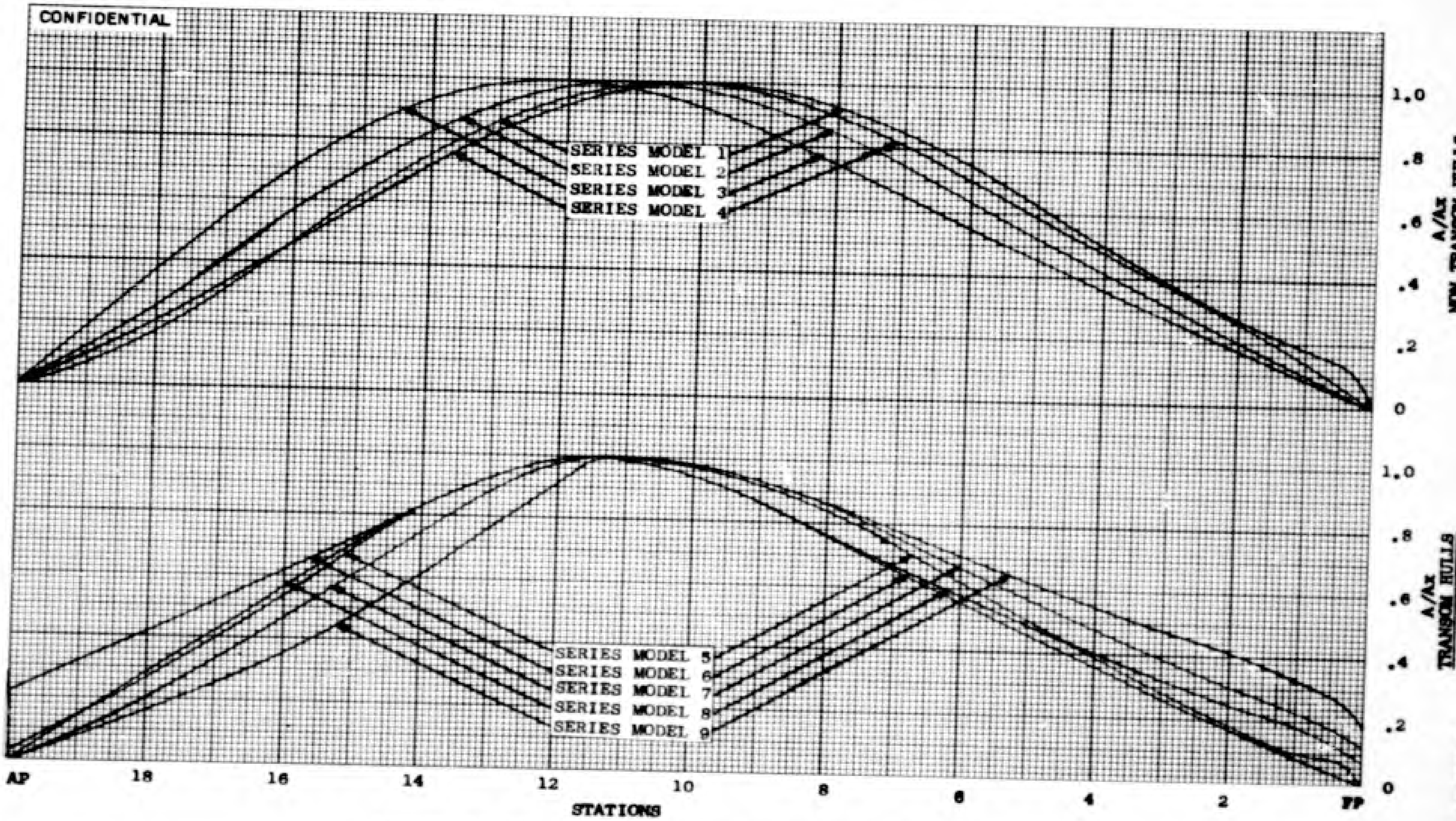


Figure II.10 - Section Area Curves (A/A_x) of the LCB/LCF Hull Forms (U)

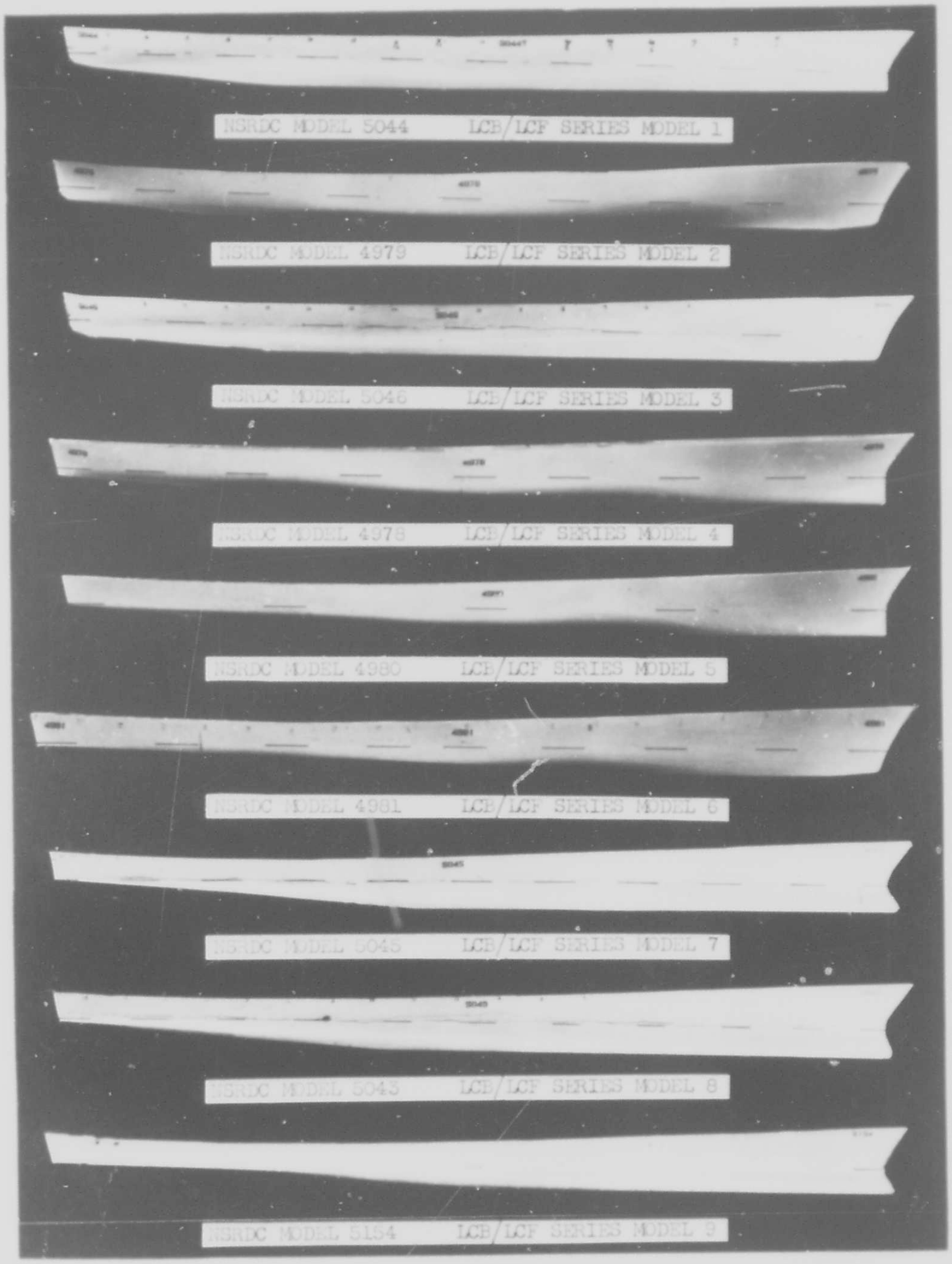


Figure II.11 - Profiles and Model Designations of the LCB/LCF Hull Forms (U)

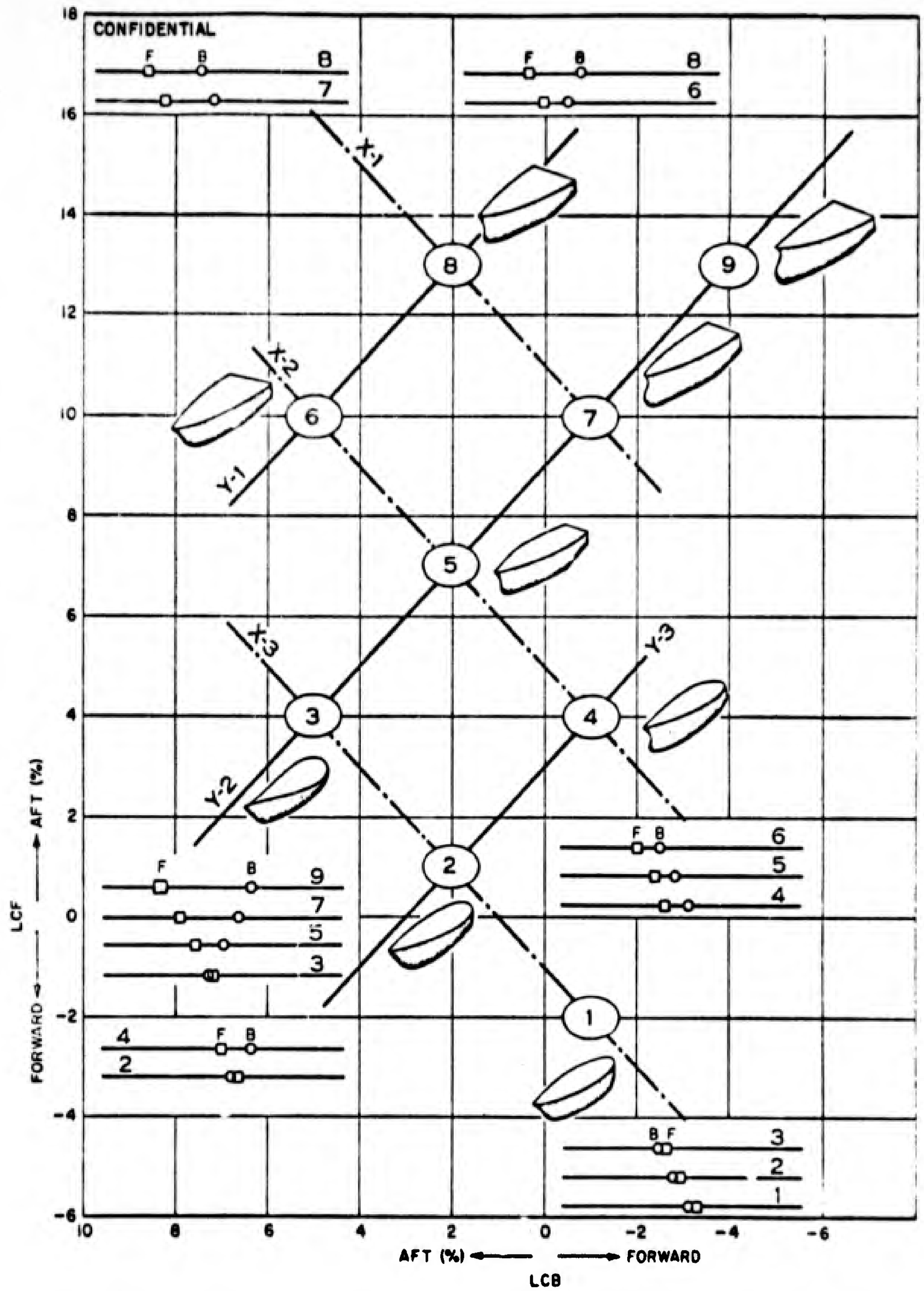


Figure II.12 - Comparison of the Relative Locations of the LCF and LCB for the Nine Models Tested (U)

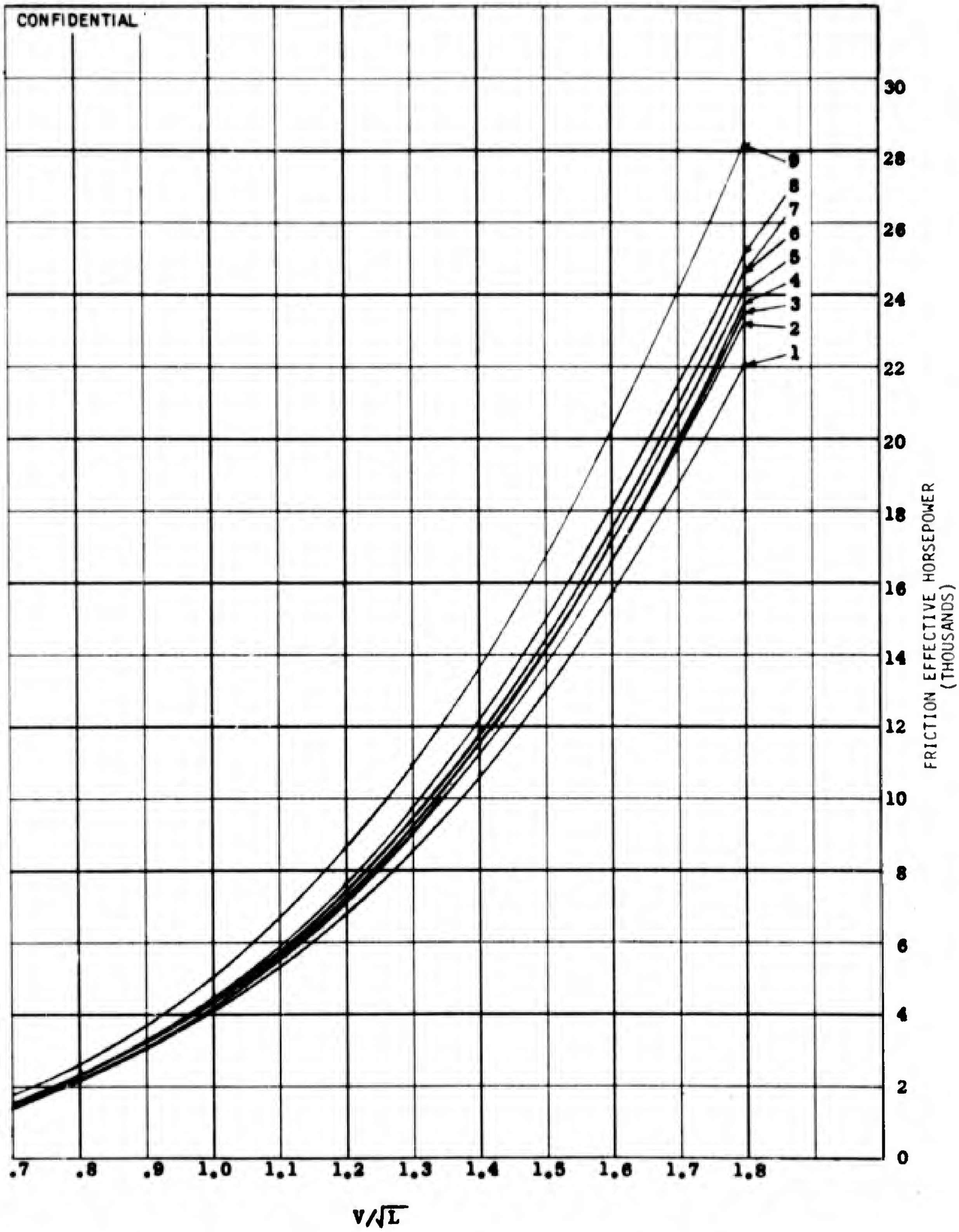


Figure II.13 - Curves of Predicted Frictional Effective Horsepower for the LCB/LCF Hull Forms (U)

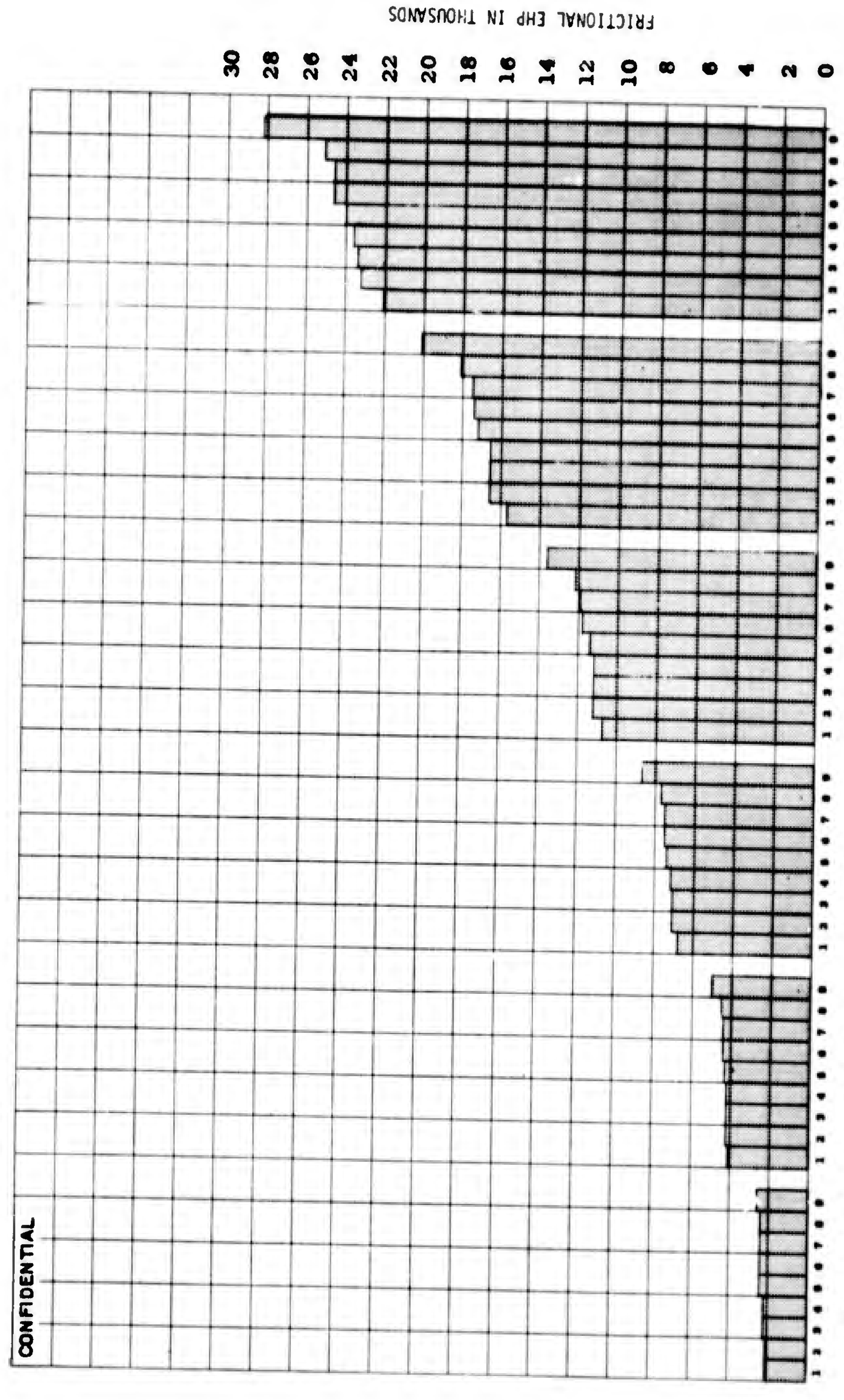


Figure II.14 - Comparison of the Predicted Frictional Effective Horsepower of the LCB/LCF Hull Forms at Even Speed-Length Ratios (U)

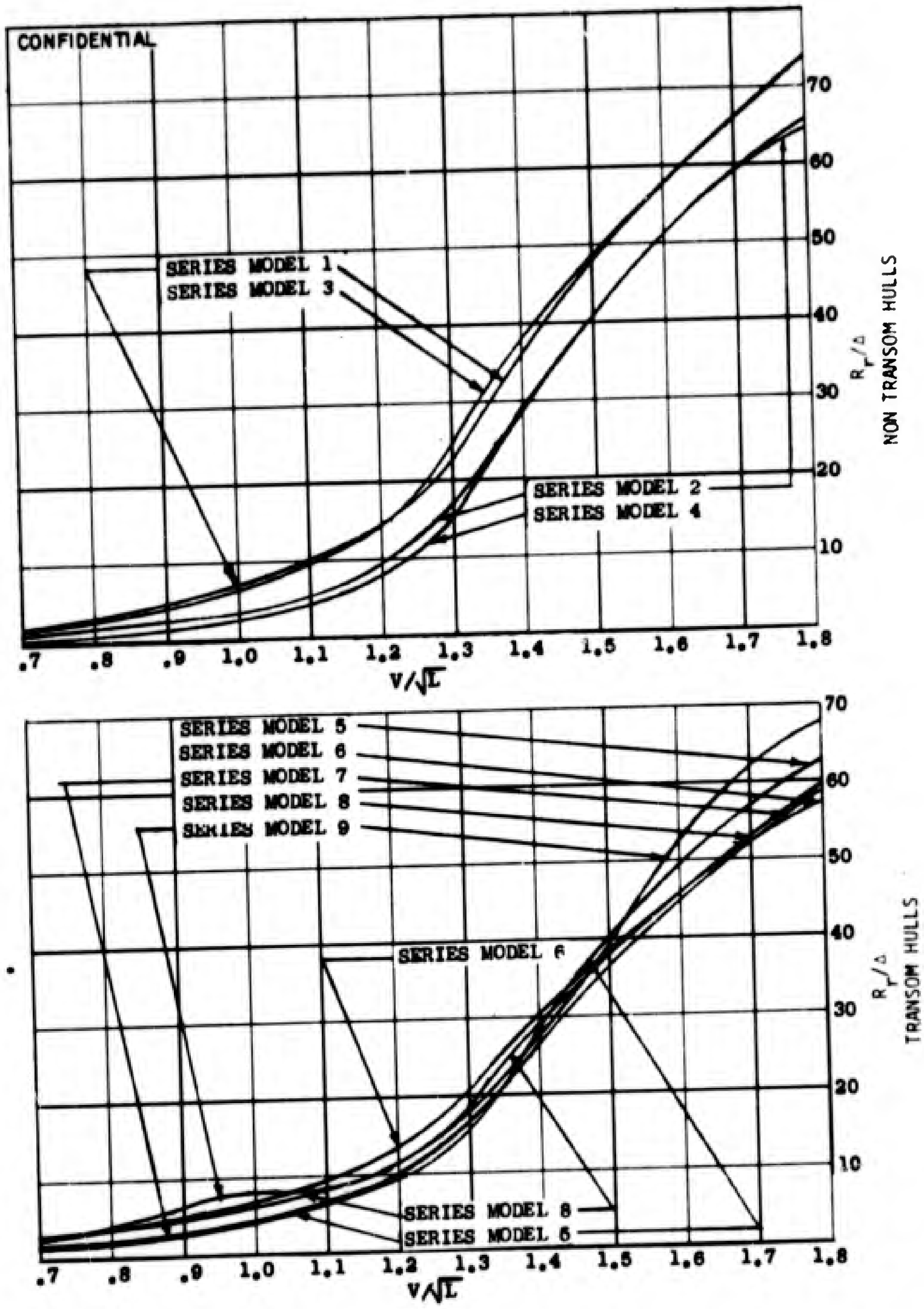


Figure II.15 - Curves of the Predicted Residual Resistance Characteristics for LCB/LCF Hull Forms (U)

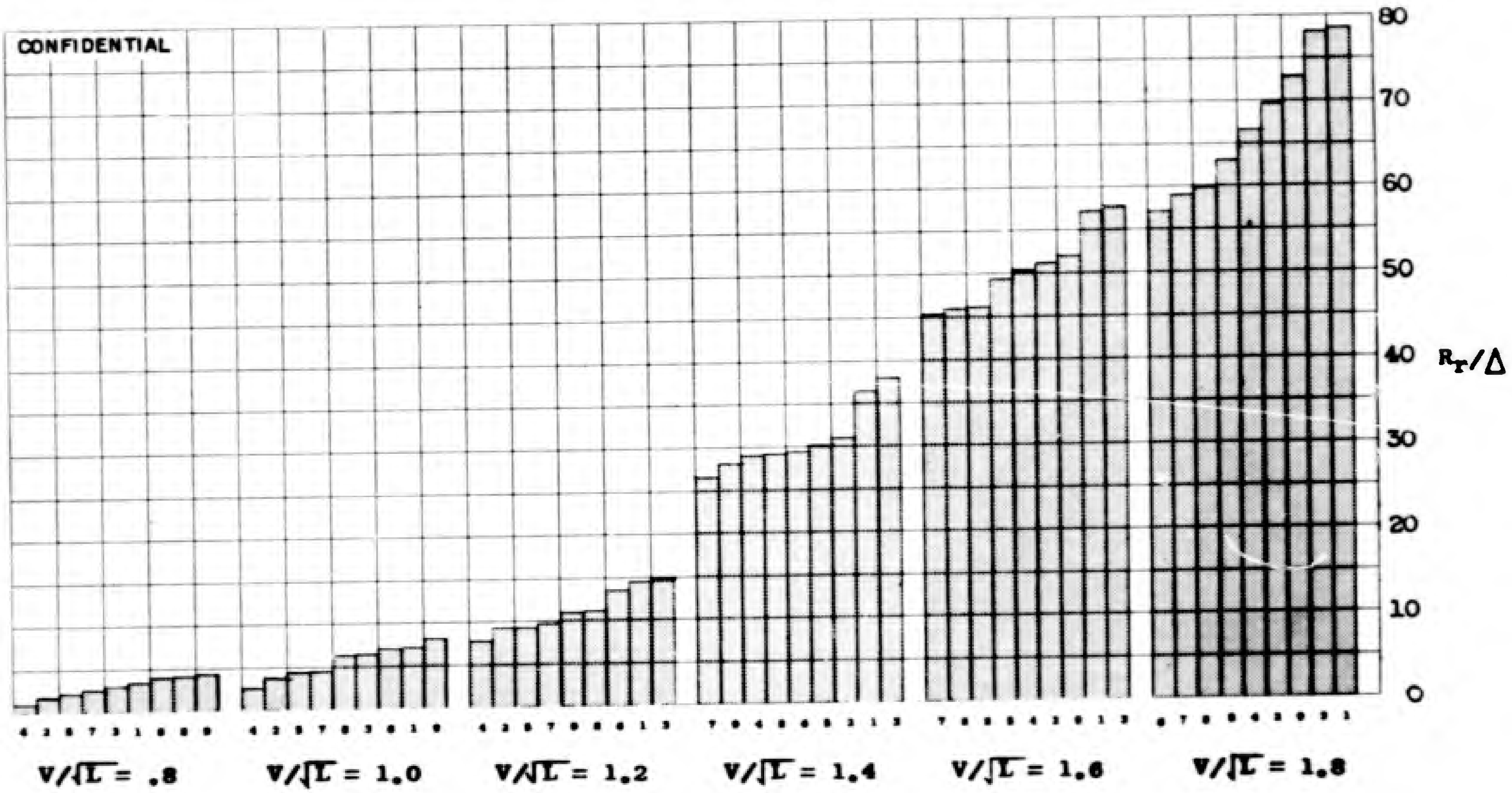


Figure II.16 - Comparison of the Predicted Residual Resistance Characteristics of the LCB/LCF Hull Forms at Even Speed-Length Ratios (U)

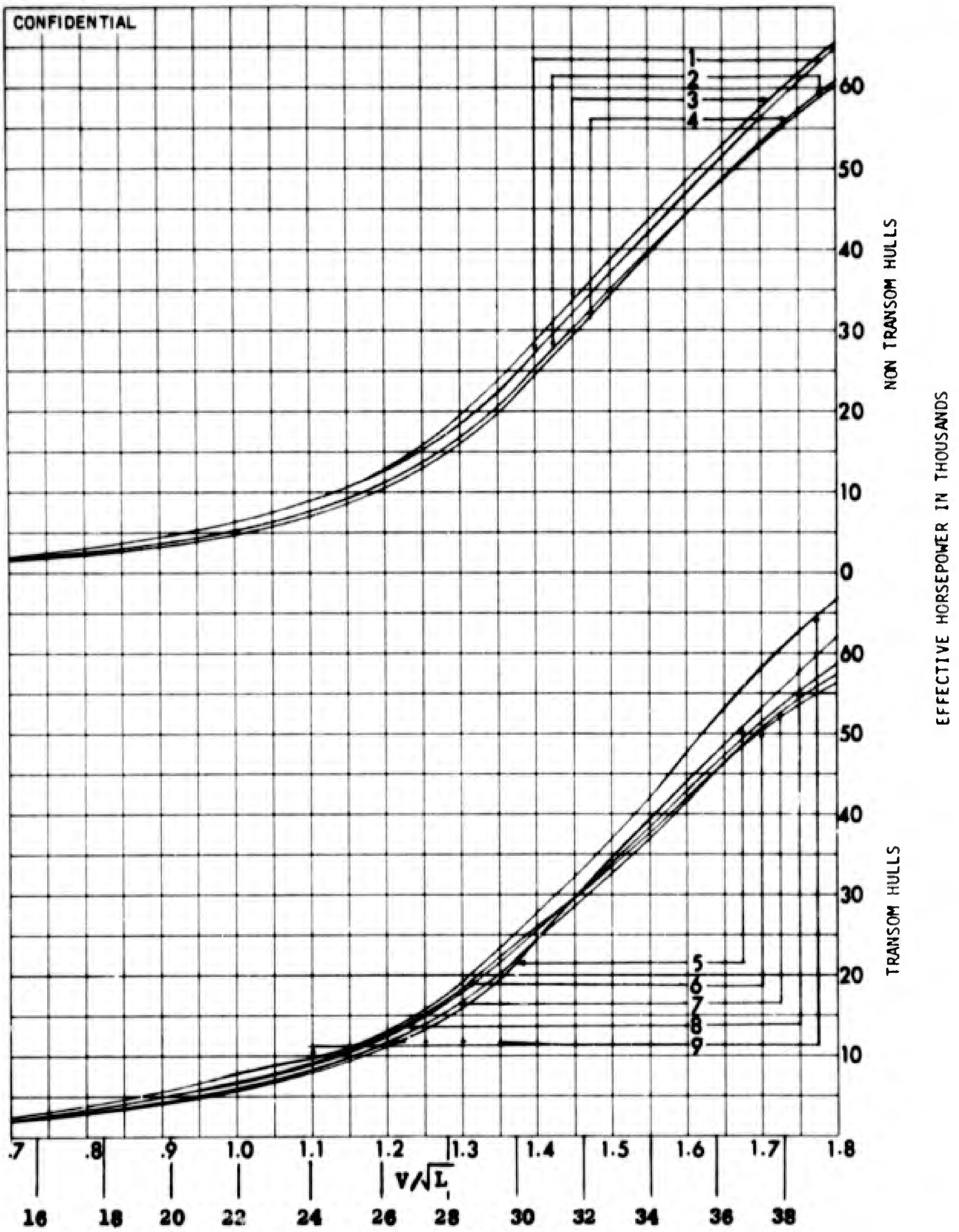


Figure II.17 - Curves of Predicted Total Effective Horsepower for LCB/LCF Hull Forms (U)

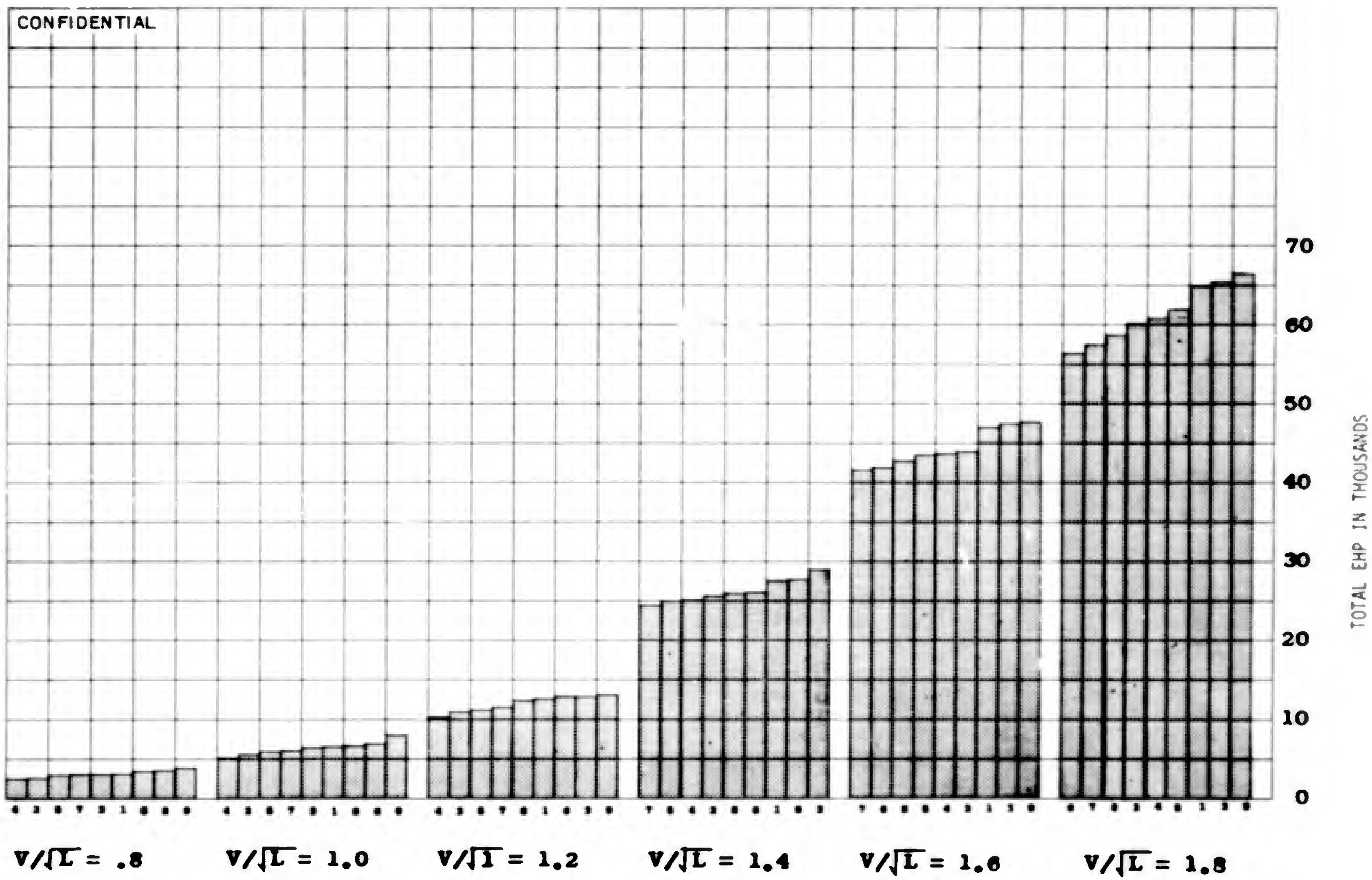


Figure II.18 - Comparison of the Predicted Total Effective Horsepower of the LCB/LCF Hull Forms at Even Speed-Length Ratios (U)

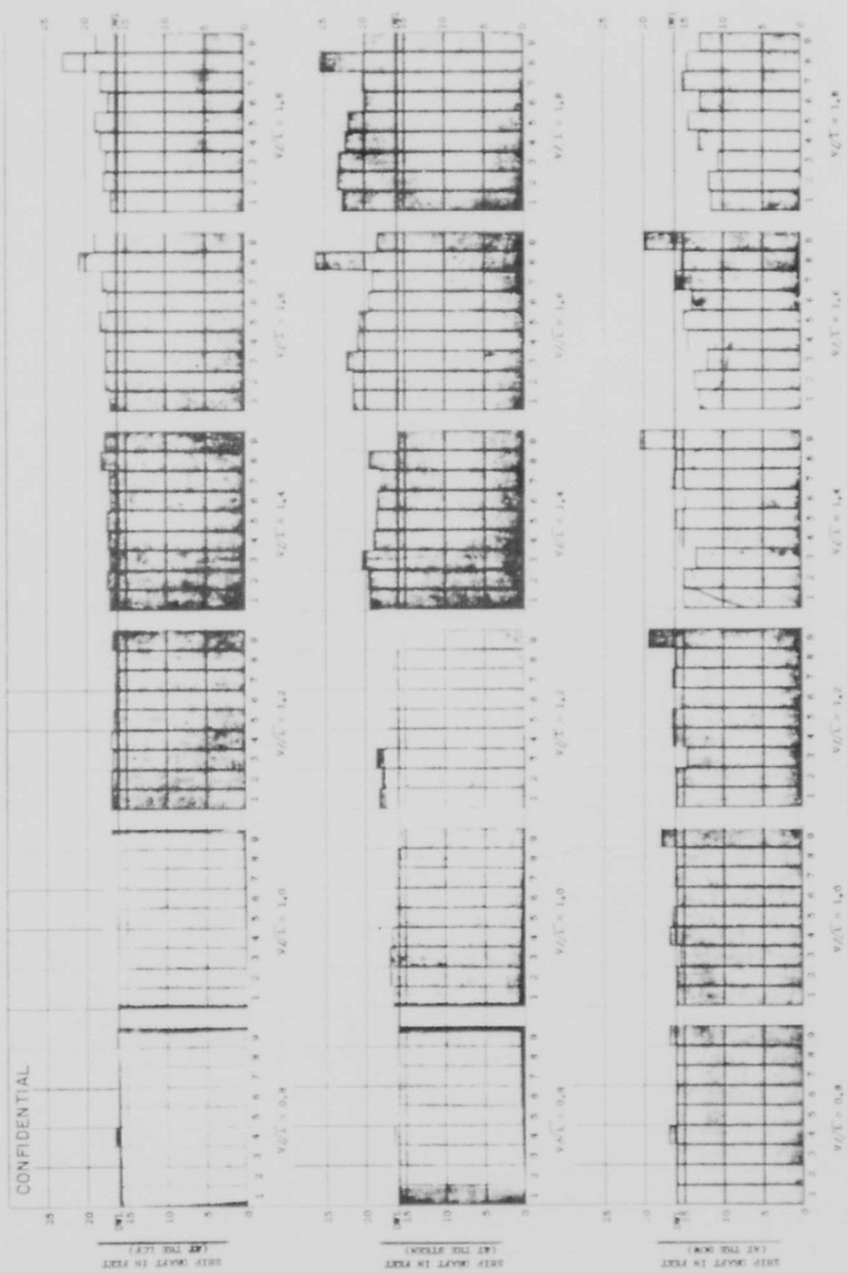
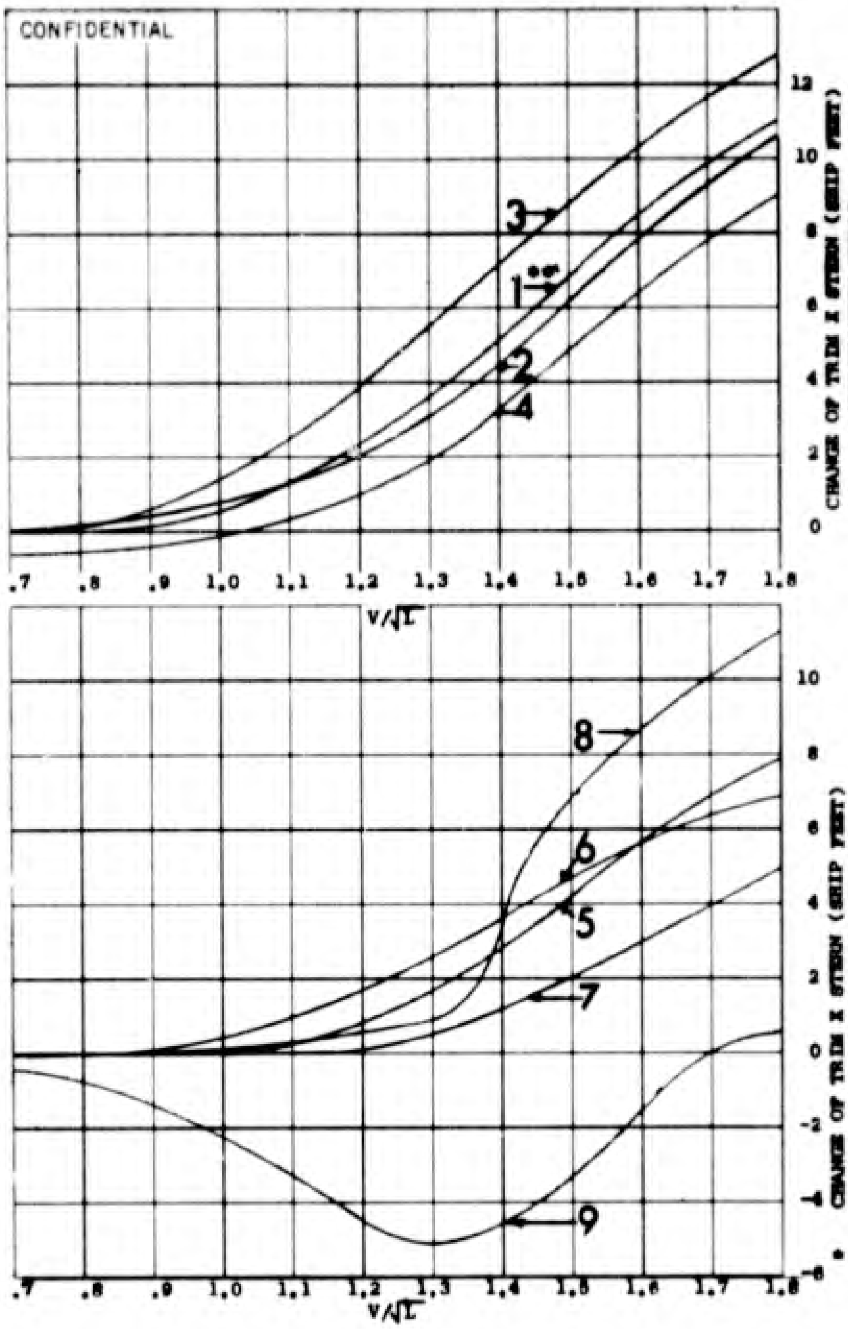


Figure II.19 - Comparison of the Predicted Underway Draft of the LCB/LCF Hull Forms at Bow, Stern, and Longitudibal Center of Buoyancy (U)



*NEGATIVE SIGN INDICATES A TRIM BY THE BOW

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Figure II.20 - Curves of Predicted Change of Trim by the Stern for LCB/LCF Hull Forms (U)

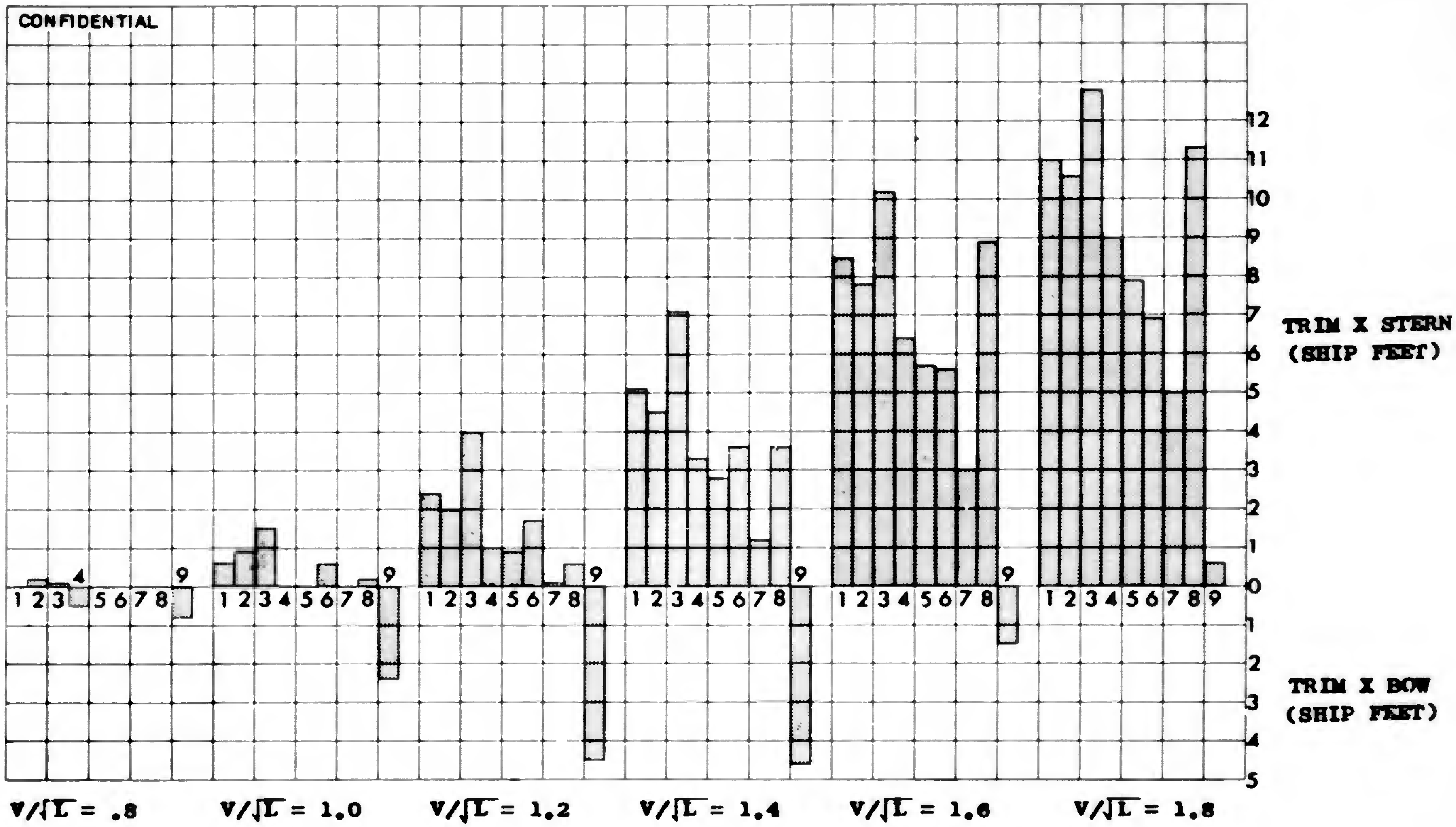

Figure II.21 - Comparison of the Change of Trim by the Stern of the L[illegible]/LCF Hull Forms at Even Speed-Length Ratios (U)

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13. ABSTRACT

(U) The effect of changing the relative locations of the longitudinal center of buoyancy (LCB) and the longitudinal center of flotation (LCF) on the resistance characteristics of high-speed naval ships was investigated. The results indicate that there was no direct relationship between the resistance and any one hull parameter except that of wetted surface. It was also found that at speed-length ratios greater than 1, the resistance characteristics of hulls with a transom and/or bulbous bow of moderate size (5-10 percent) had overall superiority over hull forms that did not have these features.

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Longitudinal center of flotation (LCF)						
Resistance Characteristics						
Bulbous Bow						
Transom						

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