PROGRAM SUBMITTAL

☒ New Program ☐ Revision to Program

Model No. ☐ 67 ☐ 97 ☒ 41C

Program Title PLANING BOAT POWER PREDICTION

No. of Steps/Lines 326 **Category No.** 921

Category Name SHIP STABILITY

Abstract — 50 Word Maximum This program predicts horsepower (EHP) requirements for planing craft over a selected range of speeds and LCG locations. It essentially automates the "Savitsky short form" procedure. Other output of interest during preliminary design includes trim angle, bare hull and appended resistance and a factor to predict porpoising.

Necessary Accessories: one memory module, printer

Name Edmund Glowacki

Company Bold Craft Engineering Corporation

Address 4163 Oxford Ave.

City Jacksonville **State/Country** Florida **Zip Code** 32210

Phone Number (904) 384-2209

If my program is accepted, my bonus choice is:

☐ FOUR PROGRAMS OR ☒ CREDIT FOR FOUR PROGRAMS*

* No partial credit will be given. Select all four programs at the same time.

Submittal Checklist: Please use the checklist below to insure submittal of all proper program documentation.

☒ Program Submittal ☒ Program Description II ☒ Program Listing(s) ☒ Registers, Status ...

☒ Program Description I ☒ User Instructions ☒ Magnetic Card(s) ☒ Keyboard, Card Labeling (optional)

Signature [signature] Date 10-27-81

PROGRAM DESCRIPTION I

Program Title PLANING BOAT POWER PREDICTION

Contributor's Name Edmund Glowacki

Address c/o Bold Craft Engineering Corp., 4163 Oxford Ave.

City Jacksonville **State/Country** Florida **Zip Code** 32210

Program Description, Equations, Variables This program predicts effective horsepower (EHP) requirements for planing craft over a selected range of speeds and longitudinal center of gravity (LCG) locations. It essentially automates the "Savitsky short form" procedure (Ref.1) where all forces of propulsion, lift, drag and weight are assumed to act through the vessel's center of gravity. This provides an excellent tool for preliminary design, when variables such as propeller shaft angle and position are not yet decided.

The program prompts for all inputs:

"CHINE BEAM=" B_{px} = maximum chine beam (feet)

"BOAT WEIGHT=" Δ = displacement (pounds)

"WATER DENS.=" ρ = water density at desired temperature ($lb\ sec^2/ft^4$) (see page 10)

(continued on next page)

Necessary Accessories one memory module, printer

Operating Limits and Warnings A zero (0.00) input for speed and/or LCG increment will cause the program to calculate the same condition over and over again.

Reference(s)

(1) Savitsky, Daniel, "Hydrodynamic Design of Planing Hulls", Marine Techonology(MT), The Society of Naval Architects and Marine Engineers (SNAME), New York, Oct. 1964; (2) Blount, D.L., and Fox, D.L., "Small Craft Power Prediction", MT, SNAME, NY, Jan. 1976

(continuation page)

Input Prompts cont'd

"DEADRISE=" β =deadrise angle at midchine length (degrees)

"KIN. VISC.=" ν = kinematic viscosity of water at desired temperature (ft^2/sec) (see page 11)

"LOW SPEED=" V_{KT}^{LO}= slow end of desired speed range (knots)

"HIGH SPEED=" V_{KT}^{HI} = fast end of desired speed range (knots)

"SPEED STEPS=" KT = desired increments through speed range (knots)

"AFTMOST LCG=" aftmost end of LCG range (feet from transom)

"FWDMOST LCG=" forward end of LCG range (feet from transom)

"LCG STEPS=" desired increments through LCG range (feet)

These quantities are calculated within the program but do not appear as printed output:

V = boat velocity (ft/sec) = $V_{KT} \times 1.689$

C_v = speed coefficient = $V/(g B_{px})^{1/2}$ ($g = 32.15\ ft/sec^2$)(Ref.1)

$C_{L\beta}$=lift coefficient for a surface with deadrise (Ref.1)

$$= \Delta \Big/ \frac{\rho}{2} V^2 B_{px}^2$$

C_{Lo}= lift coefficient for a surface with no deadrise (Ref.1)

$$= C_{L\beta} + 0.0065\ \beta\ C_{Lo}^{0.6}$$

V_m= mean velocity of water over planing surface with deadrise

$$= V \left\{ 1 - \frac{0.012\sqrt{\lambda} - 0.0065\,\beta(0.012\sqrt{\lambda}\ \tau^{1.1})^{0.6}}{\lambda \quad \cos\beta} \right\}^{1/2}$$ (Ref.1)

R_e= Reynolds number = $V \lambda B_{px} / \nu$ (Ref.2)

C_f= Schoenherr turbulent friction coefficient (ATTC line)

$$= \left\{ \frac{0.242}{\text{Log}_{10}(R_e C_f)} \right\}$$ (Ref.2)

(continuation page)

Printed output for each desired combination of LCG and speed includes several "by-products" of the EHP calculation which are of interest to the boat designer:

"**LCG= **" indicates LCG location (feet from transom)

"KT=" V_{KT} = boat speed (knots)

"LAM=" λ = mean wetted length-beam ratio (Ref.1)

$$= \frac{LCG}{B_{px}} \Big/ 0.75 \left\{ \frac{1}{5.21\left(\frac{C_v}{\lambda}\right)^2 + 2.39} \right\}$$

"PORP=" porpoising coefficient = $\sqrt{C_{L}/2}$ (Ref.1)

(to be used with graph on page 9)

"T=" τ = trim angle, average of centerline and chine (degrees)(Ref.1)

$$= C_{Lo}\left\{ 0.012\sqrt{\lambda} + \frac{0.0055\,\lambda^{5/2}}{C_v^2} \right\}^{1/1.1}$$

"RBH=" bare hull resistance (pounds) (Ref.1)

$$= \Delta \tan\tau + \frac{\rho V_m^2 \lambda B_{px}\,(C_f + 0.0004)}{2\cos\beta\cos\tau}$$

"FV=" F_∇ = volume Froude number = $V / \left(\frac{g^3\Delta}{\rho}\right)^{1/6}$

"APDRAG=" estimated appendage drag (pounds) (Ref.2)

$$= \text{RBH}\ (0.005\,F_\nabla^2 + 0.05\ )$$

"RTOT=" total drag (pounds) = RBH + APDRAG

"EHP=" effective horsepower = $\frac{RTOT \cdot V}{550}$ (Ref.1)

Of special interest of the terms listed above are C_{Lo}, C_f & λ. Notice that each of these terms appear on both sides of the equal sign in their respective equations. This feature precludes the use of simple algebra to solve the equations. A successive substitution routine was employed to obtain solutions. Levels of accuracy selected are to one more significant figure than is readily obtainable from design curves in the references, i.e. $C_{Lo} \pm E{-4}$, $C_f \pm E-6$ & $\lambda \pm E-4$ (lines 153,232 and 108 respectively, in the program listing). These limits can be changed to suit the operator. Each additional significant figure of accuracy

(continuation page)

desired required approximately six additional seconds of running time for each subroutine being modified, e.g. if the accuracy of λ and C_f are increased to $\pm$ E-5 and $\pm$ E-7 respectively, the entire EHP calculation can be expected to take about twelve seconds longer to run than it does without modification.

The American Towing Tank Conference (ATTC) standard roughness allowance of 0.0004 is added to C_f, the Schoenherr friction coefficient. This is identified in the program listing (line 248) and can be adjusted at the discression of the operator.

Advantages of the program over manual computation include increased speed and accuracy. This designer found it takes three to five minutes to manually produce one EHP calculation using the design charts in the references. Program running time is approximately one minute for each calculation. Perhaps the greatest advantage of the program lies in its ability to provide results over a user defined range of speeds and LCGs without the need for operator attendance once the initial input prompting is completed.

Other variables are held constant. These are quantities which are first chosen based on the designer's experience. One or more of these variables may be modified after the results of each program run is analyzed. After a rough hull layout is established, quantities such as chine beam and deadrise are fixed. Trim, porpoising or powering predictions may suggest changes. Boat weight is also relatively fixed for a given load condition, as structural and machinery weights are estimated from principal dimensions and performance requirements. Kinematic viscosity and density are fixed as properties of the water temperature and type, i.e. salt or fresh.

(continuation page)

The variable over which the designer still has control at this stage of modeling is the LCG location. Major weight items, particularily tanks and engines can be shifted to affect LCG. We are interested in how LCG movement will affect boat performance.

The ability to vary speed over a desired range allows output to be plotted in a familiar format, e.g. speed vs power, speed vs trim, etc.

Note here that if only one speed and/or LCG is desired the initial speed or LCG can simply be reinserted for the upper limit of the range and for the non-zero increment by pushing [R/S] when those prompts are displayed. If a zero (0.00) increment is inserted the program will loop infinitely, repeating the same condition over and over.

The program predicts effective horsepower (EHP). This is the towline power actually required to propell the boat without regard for losses in efficiency due to gear boxes, hull-propeller interaction, bearings, etc. The efficiencies of these and other elements are grouped together in what is called the propulsive coefficent η_D. For planing craft η_D varies from 0.50 to 0.55 (Ref.2). The amount of horsepower that must be installed (in terms of what manufactorers call the rated SHP of their engines) is obtained from the relationship $SHP = \frac{EHP}{\eta_D}$. The conservative use of 0.50 for η_D results in the requirement that generally twice the EHP be installed in order to achieve predicted performance.

This program is not intended to turn the man on the street into a planing boat designer. Rather, it provides the naval architect with fast, accurate predictions to help with engine selection and general arrangements during the early stages of design.

(CONTINUATION PAGE)

PRINTOUT FROM SAMPLE PROBLEM

CHINE BEAM= 14.50
BOAT WEIGHT= 50,000.00
WATER DENS.= 1.99
DEADRISE= 16.00
KIN. VISC.= 1.09E-5
LOW SPEED= 15.00
HIGH SPEED= 30.00
SPEED STEPS= 5.00
AFTMOST LCG= 18.00
FWDMOST LCG= 20.00
LCG STEPS= 1.00

** LCG= 18.00 **	** LCG= 19.00 **	** LCG= 20.00 **
KT= 15.00	KT= 15.00	KT= 15.00
LAM= 2.76	LAM= 3.01	LAM= 3.25
PORP= 0.43	PORP= 0.43	PORP= 0.43
T= 5.24	T= 4.50	T= 3.89
RBH= 5,522.	RBH= 4,946.	RBH= 4,489.
FV= 1.47	FV= 1.47	FV= 1.47
APDRAG= 336.	APDRAG= 301.	APDRAG= 273.
RTOT= 5,857.	RTOT= 5,247.	RTOT= 4,762.
EHP= 270.	EHP= 242.	EHP= 219.
KT= 20.00	KT= 20.00	KT= 20.00
LAM= 2.29	LAM= 2.50	LAM= 2.72
PORP= 0.32	PORP= 0.32	PORP= 0.32
T= 5.95	T= 5.26	T= 4.64
RBH= 6,562.	RBH= 6,070.	RBH= 5,647.
FV= 1.96	FV= 1.96	FV= 1.96
APDRAG= 454.	APDRAG= 420.	APDRAG= 391.
RTOT= 7,017.	RTOT= 6,491.	RTOT= 6,038.
EHP= 431.	EHP= 399.	EHP= 371.
KT= 25.00	KT= 25.00	KT= 25.00
LAM= 2.03	LAM= 2.20	LAM= 2.37
PORP= 0.26	PORP= 0.26	PORP= 0.26
T= 5.61	T= 5.15	T= 4.71
RBH= 6,756.	RBH= 6,493.	RBH= 6,257.
FV= 2.45	FV= 2.45	FV= 2.45
APDRAG= 541.	APDRAG= 520.	APDRAG= 501.
RTOT= 7,297.	RTOT= 7,013.	RTOT= 6,758.
EHP= 560.	EHP= 538.	EHP= 519.
KT= 30.00	KT= 30.00	KT= 30.00
LAM= 1.90	LAM= 2.04	LAM= 2.19
PORP= 0.22	PORP= 0.22	PORP= 0.22
T= 4.87	T= 4.57	T= 4.28
RBH= 6,726.	RBH= 6,631.	RBH= 6,551.
FV= 2.94	FV= 2.94	FV= 2.94
APDRAG= 628.	APDRAG= 619.	APDRAG= 611.
RTOT= 7,354.	RTOT= 7,249.	RTOT= 7,163.
EHP= 678.	EHP= 668.	EHP= 660.

PROGRAM DESCRIPTION II

Sample Problem (Sketch if Desired)

Determine engine horsepower required and optimum LCG (between 18' and 20' fwd of the transom) for a 50' triple screw boat:

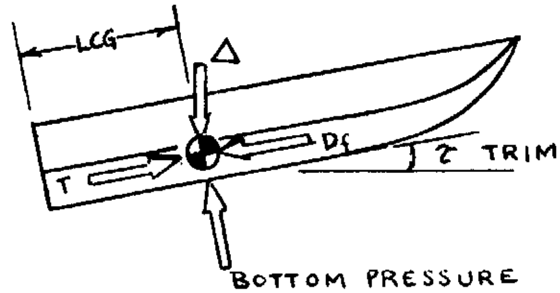
Δ = 50000#

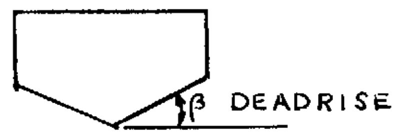
β = 16°

B_{Px} = 14.5'

assume seawater @ 70° F

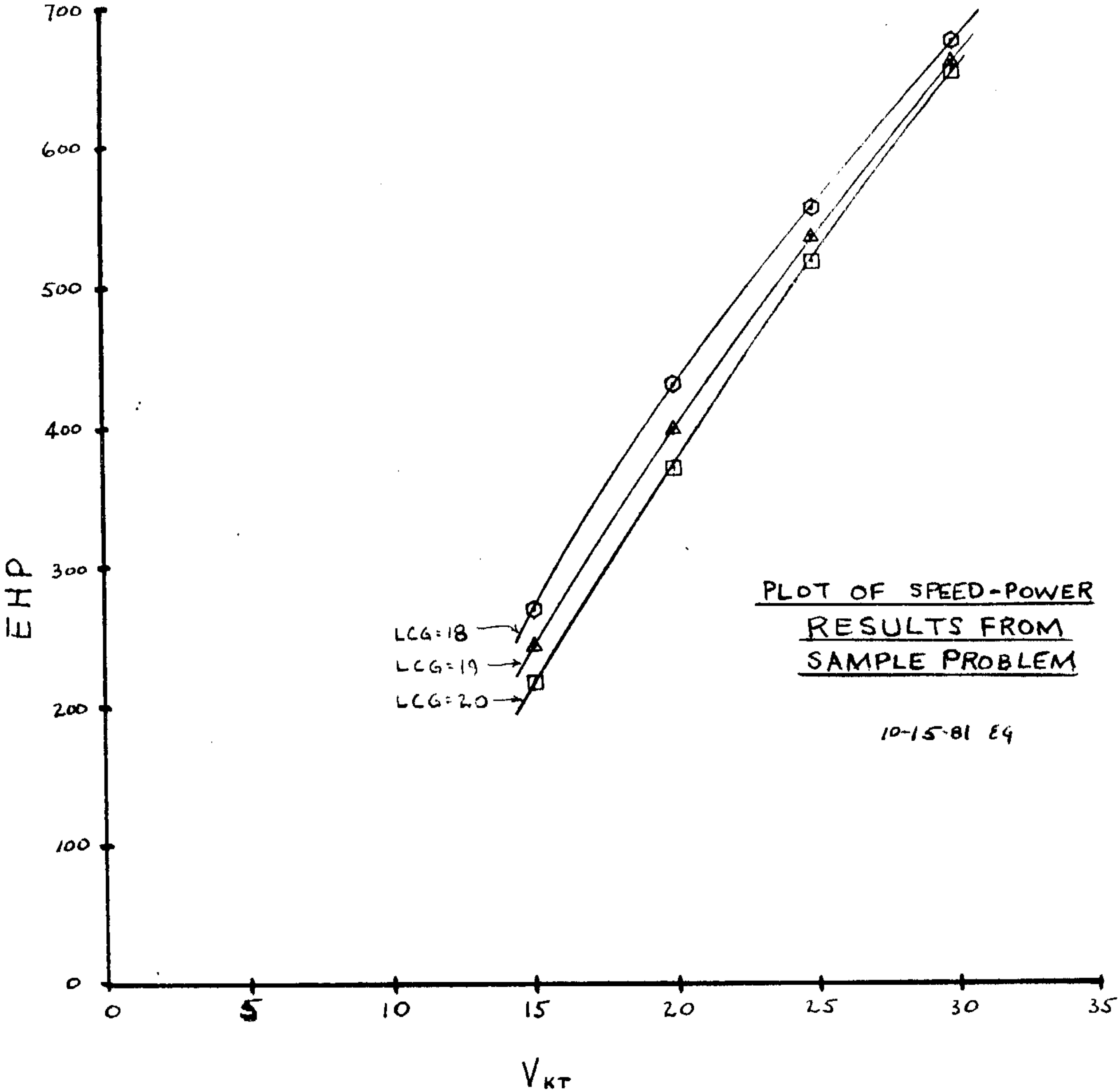
top speed = 30 kt

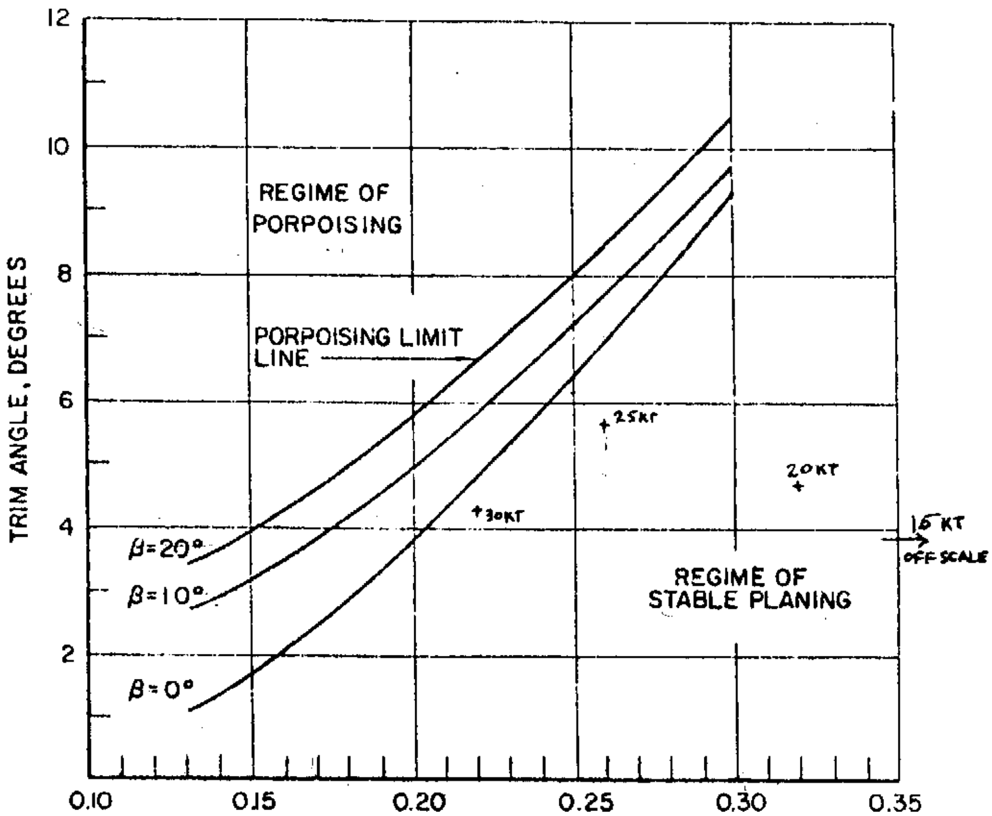




SOLUTION:

Input	Function	Display	Comments
	[USER]		set USER mode
	[XEQ] SIZE 022		establish R00 through R21
	read program cards, 1-7		"PBPP" ready in [LN]
	[LN]	CHINE BEAM =	B_{Px} = 14.5'
14.5	[R/S]	BOAT WEIGHT =	Δ = 50000#
50000	[R/S]	WATER DENS.=	ρ = 1.9876 (page 10)
1.9876	[R/S]	DEADRISE =	β = 16°
16	[R/S]	KIN. VISC.	ν = 1.088 x 10^{-5} (page 11)
1.088 [EEX] 5 [CHS]	[R/S]	LOW SPEED =	use 15 kt
15	[R/S]	HIGH SPEED =	30 kt
30	[R/S]	SPEED STEPS =	use 5 kt increments
5	[R/S]	AFTMOST LCG =	18' fwd of transom
18	[R/S]	FWDMOST LCG =	20' fwd of transom
20	[R/S]	LCG STEPS =	use 1' increments
1	[R/S]		Program will run automatically thru 12 combinations of speed and LCG. Output is shown on page 7. Plots of EHP vs speed are prepared on page 8 to help select optimum LCG.
			Optimum LCG location for minimum smooth water resistance is at 20' fwd of transom.
			$SHP = \frac{EHP}{\eta_D} = \frac{660}{0.5} = 1320$ hp total
			1320 hp / three shafts implies each engine should provide 440 hp.
			Running time for data input and 12 cases was 10 min, 20 sec.


700
600
500
400
300
200
100
0
EHP
0
5
10
15
20
25
30
35
VKT
LCG=18
LCG=19
LCG=20
PLOT OF SPEED-POWER
RESULTS FROM
SAMPLE PROBLEM
10-15-81 EG



"PORP" = $\sqrt{C_L/2}$

Porpoising limits for prismatic planing hulls

(Reproduced from Ref.1 with permission of D. Savitsky)

1. Locate porpoising factor (PORP) on the lower axis.
2. Locate predicted trim angle (T) on the left side, vertical axis.
3. Interpolate appropriate "PORPOISING LIMIT LINE" for the charactoristic deadrise angle (β) of the boat.
4. If the intersection of PORP and T lies below the limit line, the craft is stable.

Points for the sample problem (with LCG=20') are shown plotted. The sample craft appears stable through 30 knots.

Table of Density of Water

These values were adopted by the American Towing Tank Conference in 1942.
The fifth significant figures are doubtful.

Density of Fresh Water ρ lb × sec²/ft⁴	Temperature degree F	Density of Sea Water ρ_s lb × sec²/ft⁴	Density of Fresh Water ρ lb × sec²/ft⁴	Temperature degree F	Density of Sea Water ρ_s lb × sec²/ft⁴
1.9399	32	1.9947	1.9381	61	1.9901
1.9399	33	1.9946	1.9379	62	1.9898
1.9400	34	1.9946	1.9377	63	1.9895
1.9400	35	1.9945	1.9375	64	1.9893
1.9401	36	1.9944	1.9373	65	1.9890
1.9401	37	1.9943	1.9371	66	1.9888
1.9401	38	1.9942	1.9369	67	1.9885
1.9401	39	1.9941	1.9367	68	1.9882
1.9401	40	1.9940	1.9365	69	1.9879
1.9401	41	1.9939	1.9362	70	1.9876
1.9401	42	1.9937	1.9360	71	1.9873
1.9401	43	1.9936	1.9358	72	1.9870
1.9400	44	1.9934	1.9355	73	1.9867
1.9400	45	1.9933	1.9352	74	1.9864
1.9399	46	1.9931	1.9350	75	1.9861
1.9398	47	1.9930	1.9347	76	1.9858
1.9398	48	1.9928	1.9344	77	1.9854
1.9397	49	1.9926	1.9342	78	1.9851
1.9396	50	1.9924	1.9339	79	1.9848
1.9395	51	1.9923	1.9336	80	1.9844
1.9394	52	1.9921	1.9333	81	1.9841
1.9393	53	1.9919	1.9330	82	1.9837
1.9392	54	1.9917	1.9327	83	1.9834
1.9390	55	1.9914	1.9324	84	1.9830
1.9389	56	1.9912	1.9321	85	1.9827
1.9387	57	1.9910	1.9317	86	1.9823
1.9386	58	1.9908			
1.9384	59	1.9905			
1.9383	60	1.9903			

Table of Kinematic Viscosity of Water

These values were adopted by the American Towing Tank Conference in 1942. The fifth significant figures are doubtful.

$\times 10^{-5}$

Kinematic Viscosity of Fresh Water $\nu \times 10^5$ ft²/sec	Temperature degree F	Kinematic Viscosity of Sea Water $\nu_s \times 10^5$ ft²/sec	Kinematic Viscosity of Fresh Water $\nu \times 10^5$ ft²/sec	Temperature degree F	Kinematic Viscosity of Sea Water $\nu_s \times 10^5$ ft²/sec
1.9291	32		1.1937	61	1.2470
1.8922	33		1.1769	62	1.2303
1.8565	34		1.1605	63	1.2139
1.8219	35		1.1444	64	1.1979
1.7883	36		1.1287	65	1.1822
1.7558	37		1.1133	66	1.1669
1.7242	38		1.0983	67	1.1519
1.6935	39		1.0836	68	1.1372
1.6638	40		1.0692	69	1.1229
1.6349	41	1.6846	1.0552	70	1.1088
1.6068	42	1.6568	1.0414	71	1.0951
1.5795	43	1.6298	1.0279	72	1.0816
1.5530	44	1.6035	1.0147	73	1.0684
1.5272	45	1.5780	1.0018	74	1.0554
1.5021	46	1.5531	0.98918	75	1.0427
1.4776	47	1.5289	0.97680	76	1.0303
1.4538	48	1.5053	0.96466	77	1.0181
1.4306	49	1.4823	0.95276	78	1.0062
1.4080	50	1.4599	0.94111	79	0.99447
1.3860	51	1.4381	0.92969	80	0.98299
1.3646	52	1.4168	0.91850	81	0.97172
1.3437	53	1.3961	0.90752	82	0.96067
1.3233	54	1.3758	0.89676	83	0.94982
1.3034	55	1.3561	0.88621	84	0.93917
1.2840	56	1.3368	0.87586	85	0.92873
1.2651	57	1.3180	0.86570	86	0.91847
1.2466	58	1.2996			
1.2285	59	1.2817			
1.2109	60	1.2641			

USER INSTRUCTIONS

SIZE: (HP-41C) 022

STEP	INSTRUCTIONS	INPUT	FUNCTION	DISPLAY
1.	set [USER] mode; read in program		"PBPP" [LN]	
2.	call PBPP		[LN]	CHINE BEAM =
3.	input max. chine beam (ft.)	B_{PX}	[R/S]	BOAT WEIGHT=
4.	input vessel displacement (lb.)	Δ	[R/S]	WATER DENS.=
5.	input water density ($lb\ sec^2/ft^4$)	ρ	[R/S]	DEADRISE =
6.	input deadrise angle at midchine length (deg.)	β	[R/S]	KIN. VISC. =
7.	input kinematic viscosity (ft^2/sec)	ν	[R/S]	LOW SPEED =
8.	input slow end of desired speed range (kt.)	V_{KT} LO	[R/S]	HIGH SPEED =
9.	input fast end of desired speed range (kt.)	V_{KT} HI	[R/S]	SPEED STEPS=
10.	input positive, non-zero speed increment desired	V_{KT} INCR.	[R/S]	AFTMOST LCG=
11.	input aftmost LCG desired (ft. from transom)	LCG_{AFT}	[R/S]	FWDMOST LCG=
12.	input foreward-most LCG desired (ft. from transom)	LCG_{FWD}	[R/S]	LCG STEPS =
13.	input positive, non-zero LCG increment desired	LCG INCR.	[R/S]	

For next run, repeat 2. thru 13.

If only one speed is desired, input it for "LOW SPEED=" and press [R/S] three times.

-similarly-

If only one LCG is desired, input it for "AFTMOST LCG=" and press [R/S] three times.

PROGRAM LISTING

☐ 67 ☐ 97 ☒ 41C

STEP/LINE	KEY ENTRY	KEY CODE (67/97 only)	COMMENTS
01	◆LBL "PBPP"		
02	"CHINE BEAM="		
03	PROMPT		
04	STO 00		store B_{px} in R00
05	"⊢ "		
06	ARCL X		
07	PRA		
08	"BOAT WEIGHT="		
09	PROMPT		
10	STO 01		store Δ in R01
11	"⊢ "		
12	ARCL X		
13	PRA		
14	"WATER DENS.="		
15	PROMPT		
16	STO 02		store ρ in R02
17	"⊢ "		
18	ARCL X		
19	PRA		
20	"DEADRISE="		
21	PROMPT		
22	STO 03		store β in R03
23	"⊢ "		
24	ARCL X		
25	PRA		
26	"KIN. VISC.="		
27	PROMPT		
28	STO 04		store ν in R04
29	"⊢ "		
30	ARCL X		
31	PRA		
32	"LOW SPEED="		
33	PROMPT		
34	STO 18		store 1^{st} V_{kt} in R18
35	STO 05		store V_{kt}^{Lo} in R05
36	"⊢ "		
37	ARCL X		
38	PRA		
39	"HIGH SPEED="		
40	PROMPT		

STEP/LINE	KEY ENTRY	KEY CODE (67/97 only)	COMMENTS
41	STO 06		store V_{kt}^{Hi} in R06
42	"⊢ "		
43	ARCL X		
44	PRA		
45	"SPEED STEPS="		
46	PROMPT		
47	STO 07		store speed incr. in R07
48	"⊢ "		
49	ARCL X		
50	PRA		
51	"AFTMOST LCG="		
52	PROMPT		
53	STO 08		store LCG_{Aft} in R08
54	"⊢ "		
55	ARCL X		
56	PRA		
57	"FWDMOST LCG="		
58	PROMPT		
59	STO 09		store LCG_{Fwd} in R09
60	"⊢ "		
61	ARCL X		
62	PRA		
63	"LCG STEPS="		
64	PROMPT		
65	STO 10		store LCG_{incr} in R10
66	"⊢ "		
67	ARCL X		
68	PRA		
69	ADV		
70	◆LBL 99		
71	" ** LCG= "		print LCG for the range of speeds to follow (lines 71–74)
72	ARCL 08		
73	"⊢ **"		
74	PRA		
75	◆LBL 98		
76	RCL 18		display/print speed for EHP calculation (lines 76–79)
77	"KT= "		
78	ARCL X		
79	AVIEW		
80	1.689		
81	*		V
82	STO 17		store V in R17
83	32.15		"g"
84	RCL 00		

Note: Refer to "HP-41C OWNER'S HANDBOOK AND PROGRAMMING GUIDE" for specific information on keystrokes. The Function Index is found at the very back of the Handbook. Refer to Appendix E in 67 or 97 "OWNER'S HANDBOOK AND PROGRAMMING GUIDE" for exact keystrokes.

PROGRAM LISTING

☐ 67 ☐ 97 ☒ 41C

STEP/LINE	KEY ENTRY	KEY CODE (67/97 only)	COMMENTS
85	*		
86	SQRT		compute C_v
87	/		
88	STO 19		store C_v in R19
89	♦LBL 01		
90	X↑2		
91	5.21		
92	*		
93	2.39		
94	+		
95	1/X		
96	CHS		compute λ_i
97	.75		
98	+		
99	RCL 08		
100	RCL 00		
101	/		
102	X<>Y		this loop determines λ
103	/		
104	STO 20		λ_i
105	RCL 16		λ_{i-1}
106	-		$\delta\lambda$
107	ABS		
108	1 E-4		
109	X>Y?		
110	GTO 02		
111	RCL 19		
112	RCL 20		
113	STO 16		
114	/		
115	GTO 01		
116	♦LBL 02		
117	"LAM= "		
118	ARCL 20		display/print λ
119	AVIEW		
120	RCL 01		
121	2		
122	*		
123	RCL 02		
124	/		
125	RCL 17		compute $C_{L\beta}$
126	RCL 00		
127	*		
128	X↑2		
129	/		
130	STO 21		store $C_{L\beta}$ in R21
131	2		
132	/		compute PORP
133	SQRT		
134	"PORP= "		
135	ARCL X		display/print PORP
136	AVIEW		
137	RCL 03		
138	.0065		0.0065 β is first guess at C_{Lo}
139	*		
140	STO 16		store it in R16
141	♦LBL 03		
142	STO 11		
143	.6		
144	Y↑X		
145	RCL 16		compute C_{Lo_i}
146	*		
147	RCL 21		
148	+		
149	STO 15		C_{Lo_i}; this loop determines C_{Lo}
150	RCL 11		$C_{Lo_{i-1}}$
151	-		δC_{Lo}
152	ABS		
153	1 E-4		
154	X>Y?		
155	GTO 04		
156	RCL 15		
157	GTO 03		
158	♦LBL 04		
159	RCL 20		
160	SQRT		
161	STO 16		
162	5		
163	Y↑X		
164	.0055		
165	*		
166	RCL 19		
167	X↑2		
168	/		compute τ
169	RCL 16		
170	.012		
171	*		
172	+		
173	RCL 11		
174	X<>Y		
175	/		
176	1.1		
177	1/X		
178	Y↑X		
179	STO 12		store τ in R12
180	"T= "		
181	ARCL X		display/print τ
182	AVIEW		

Note: Refer to "HP-41C OWNER'S HANDBOOK AND PROGRAMMING GUIDE" for specific information on keystrokes. The Function Index is found at the very back of the Handbook. Refer to Appendix E in 67 or 97 "OWNER'S HANDBOOK AND PROGRAMMING GUIDE" for exact keystrokes.

PROGRAM LISTING

☐ 67 ☐ 97 ☒ 41C

STEP/LINE	KEY ENTRY	KEY CODE (67/97 only)	COMMENTS
183	1.1		
184	Y↑X		
185	RCL 20		
186	SQRT		
187	*		
188	.012		
189	*		
190	STO 16		
191	.6		
192	Y↑X		
193	RCL 03		
194	*		
195	.0065		compute V_m
196	*		
197	CHS		
198	RCL 16		
199	+		
200	RCL 12		
201	COS		
202	/		
203	RCL 20		
204	/		
205	CHS		
206	1		
207	+		
208	SQRT		
209	RCL 17		
210	*		
211	STO 13		store V_m in R13
212	RCL 00		
213	*		
214	RCL 20		
215	*		compute R_e
216	RCL 04		
217	/		
218	STO 14		store R_e in R14
219	.002		first guess at C_f
220	♦LBL 05		
221	STO 16		
222	*		
223	LOG		
224	.242		compute C_{f_i}
225	X<>Y		
226	/		
227	X↑2		
228	STO 15		C_{fi}
229	RCL 16		C_{fi-1}; this loop determines C_f
230	-		δC_f
231	ABS		

STEP/LINE	KEY ENTRY	KEY CODE (67/97 only)	COMMENTS
232	1 E-6		
233	X>Y?		
234	GTO 06		
235	RCL 14		
236	RCL 15		
237	GTO 05		
238	♦LBL 06		
239	RCL 02		
240	RCL 20		
241	*		
242	RCL 13		
243	RCL 00		
244	*		
245	X↑2		
246	*		
247	RCL 15		C_f
248	.0004		ATTC roughness
249	+		
250	*		
251	RCL 03		compute RBH
252	COS		
253	2		
254	*		
255	/		
256	RCL 12		
257	COS		
258	/		
259	RCL 12		
260	TAN		
261	RCL 01		
262	*		
263	+		
264	FIX 0		
265	"RBH= "		
266	ARCL X		display/print RBH
267	AVIEW		
268	RCL 01		
269	32.15		
270	X↑2		
271	*		
272	RCL 02		
273	/		compute F_∇
274	6		
275	1/X		
276	Y↑X		
277	RCL 17		
278	X<>Y		
279	/		
280	FIX 2		

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PROGRAM LISTING

☐ 67 ☐ 97 ☒ 41C

STEP/LINE	KEY ENTRY	KEY CODE (67/97 only)	COMMENTS
281	"FV= "		display/print F_∇
282	ARCL X		
283	AVIEW		
284	X↑2		compute APDRAG
285	.005		
286	*		
287	.05		
288	+		
289	X<>Y		
290	*		
291	FIX 0		
292	"APDRAG= "		display/print APDRAG
293	ARCL X		
294	AVIEW		
295	LASTX		compute RTOT
296	+		
297	"RTOT= "		display/print RTOT
298	ARCL X		
299	AVIEW		
300	RCL 17		compute EHP
301	*		
302	550		
303	/		
304	"EHP= "		display/print EHP
305	ARCL X		
306	AVIEW		
307	ADV		
308	FIX 2		increment speed
309	RCL 07		
310	RCL 18		
311	+		
312	STO 18		store V_{NEW} in R18
313	RCL 06		recall speed limit
314	X<>Y		If new speed is ≤ speed limit, proceed to LBL 98. If new speed is speed limit, reset LOW SPEED into current speed register R18 and increment LCG.
315	X<=Y?		
316	GTO 98		
317	RCL 05		
318	STO 18		
319	RCL 10		Increment LCG and test to assure it is ≤ FWDMOST LCG. If it is greater than FWDMOST LCG, program stops.
320	ST+ 08		
321	RCL 08		
322	RCL 09		
323	X<Y?		
324	STOP		
325	GTO 99		
326	END		

STEP/LINE	KEY ENTRY	KEY CODE (67/97 only)	COMMENTS
51			
60			
70			
80			
00			

REGISTERS, STATUS, FLAGS, ASSIGNMENTS

DATA REGISTERS

00	B_{PX}		
01	Δ		
02	ρ		
03	β		
04	μ		
05	LOW SPEED		
06	HIGH SPEED		
07	SPEED STEPS		
08	AFTMOST LCG		
09	FWDMOST LCG		
10	LCG STEPS		
11	C_{Lo}		
12	τ		
13	V_m		
14	R_e		
15	C_{Lo}, C_f		
16	various		
17	ν		
18	current speed		
19	C_v		
20	λ		
21	$C_{L\beta}$		

STATUS

SIZE 022 TOT. REG. 121 USER MODE ON X OFF

ENG ___ FIX 2 SCI ___

DEG X RAD ___ GRAD ___

FLAGS

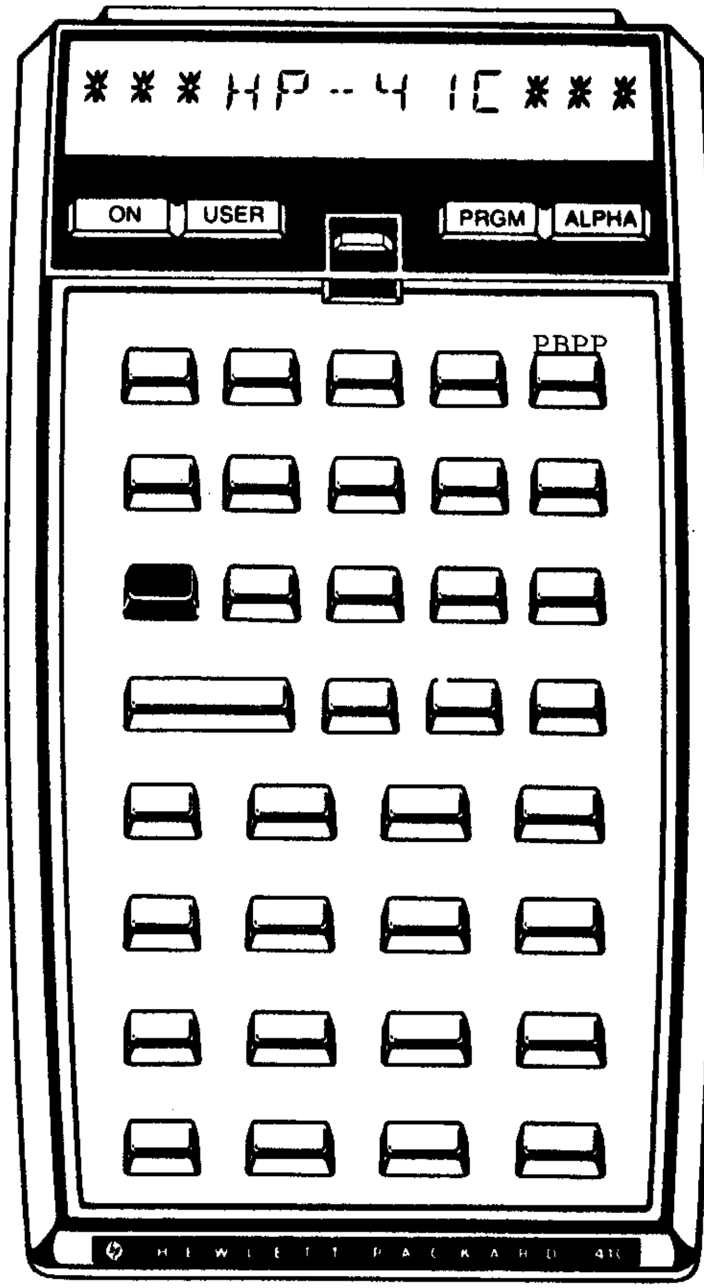
#	INIT S/C	SET INDICATES	CLEAR INDICATES

ASSIGNMENTS

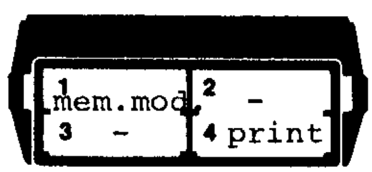
FUNCTION	KEY	FUNCTION	KEY
PBPP	LN		

KEYBOARD CARD LABELING

KEYBOARD



SYSTEM CONFIGURATION



CARD