MULTI-HULL SHIPS: designing.

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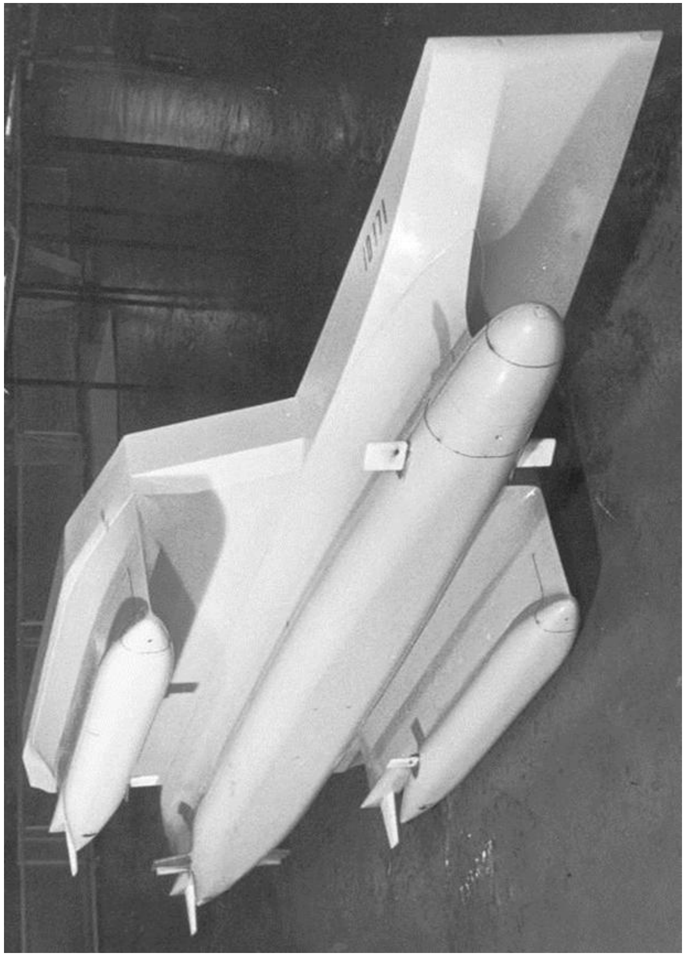
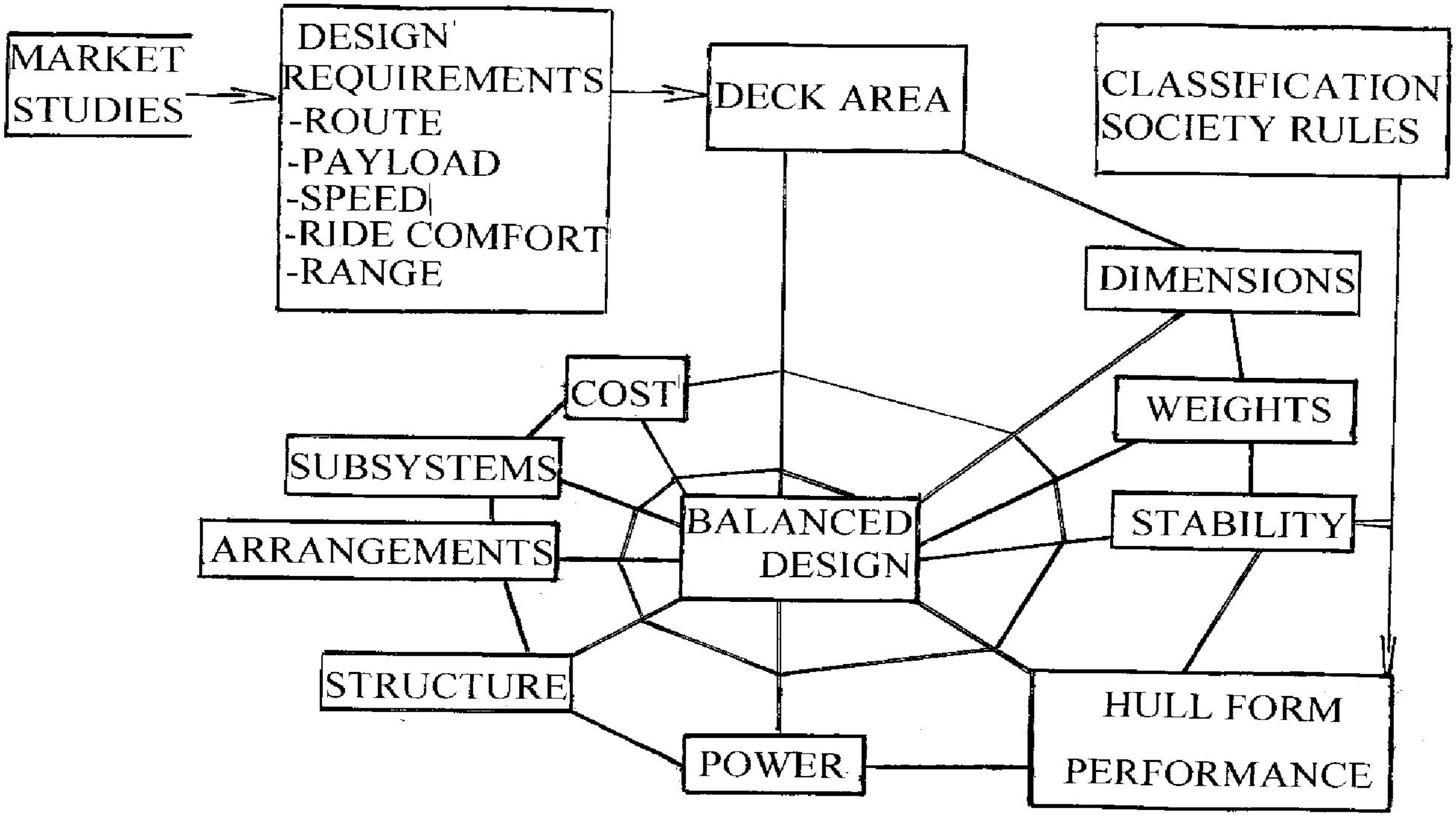


As a rule, a new multi-hull ship has nothing near enough prototype as a base of dimension selection. It means, the technical characteristics of a new ship must be estimated by the direct calculations.
Besides, wide possible ranges of dimension correlations is the reason of variant designing of multi-hulls.
Multi-hull ships are most economically effective as so named “capacity carriers”, i.e. are intended for transporting of any light cargoes with big needed area deck or inner volume of the ship (as passengers, wheeled vehicles, light containers, science laboratories, weapon systems). Than, the needed area of decks is the first needed initial demand for selection of dimensions.

7.1. Specific algorithm of designing, [1].

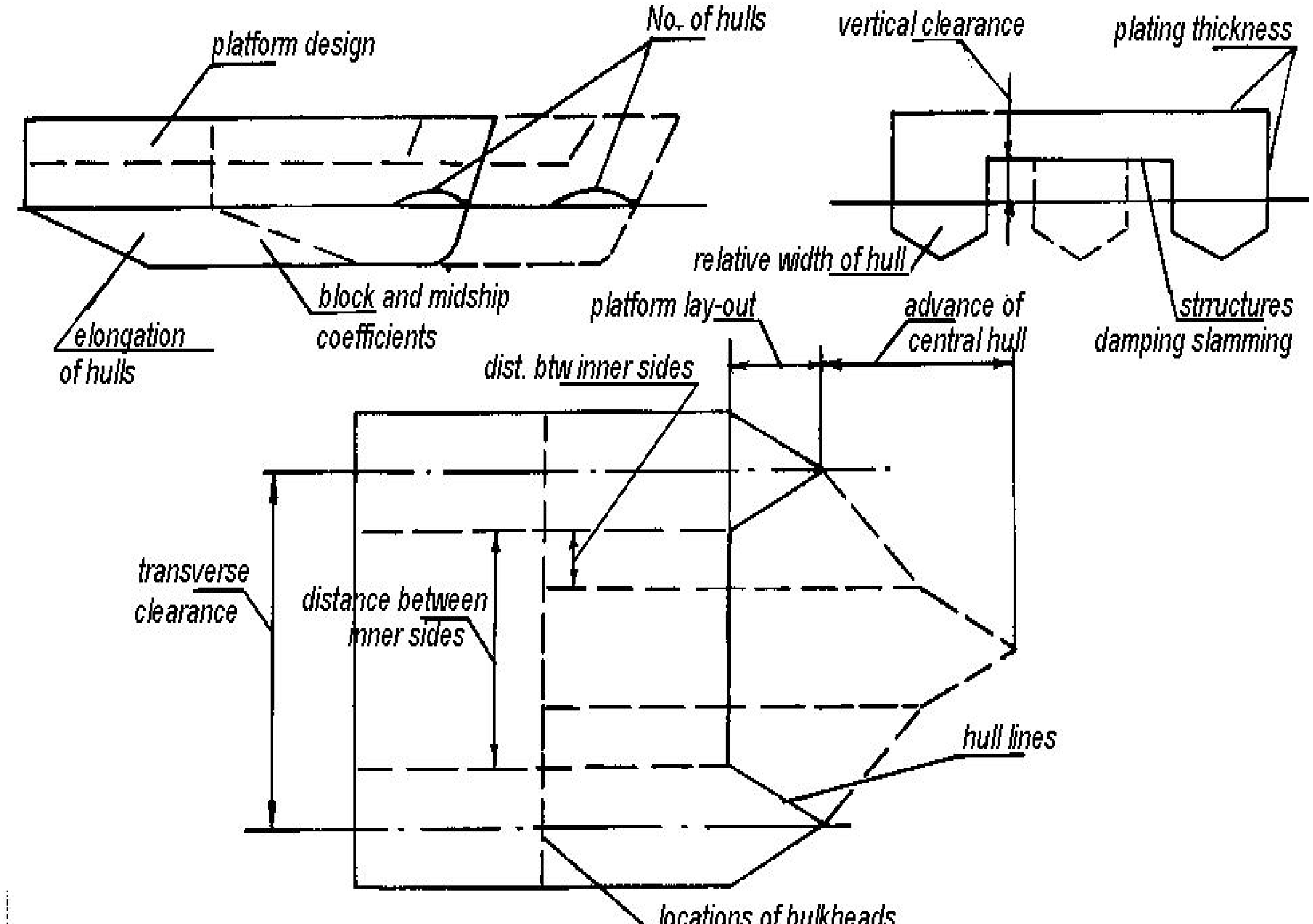


Necessary initial data, [1], [2]:

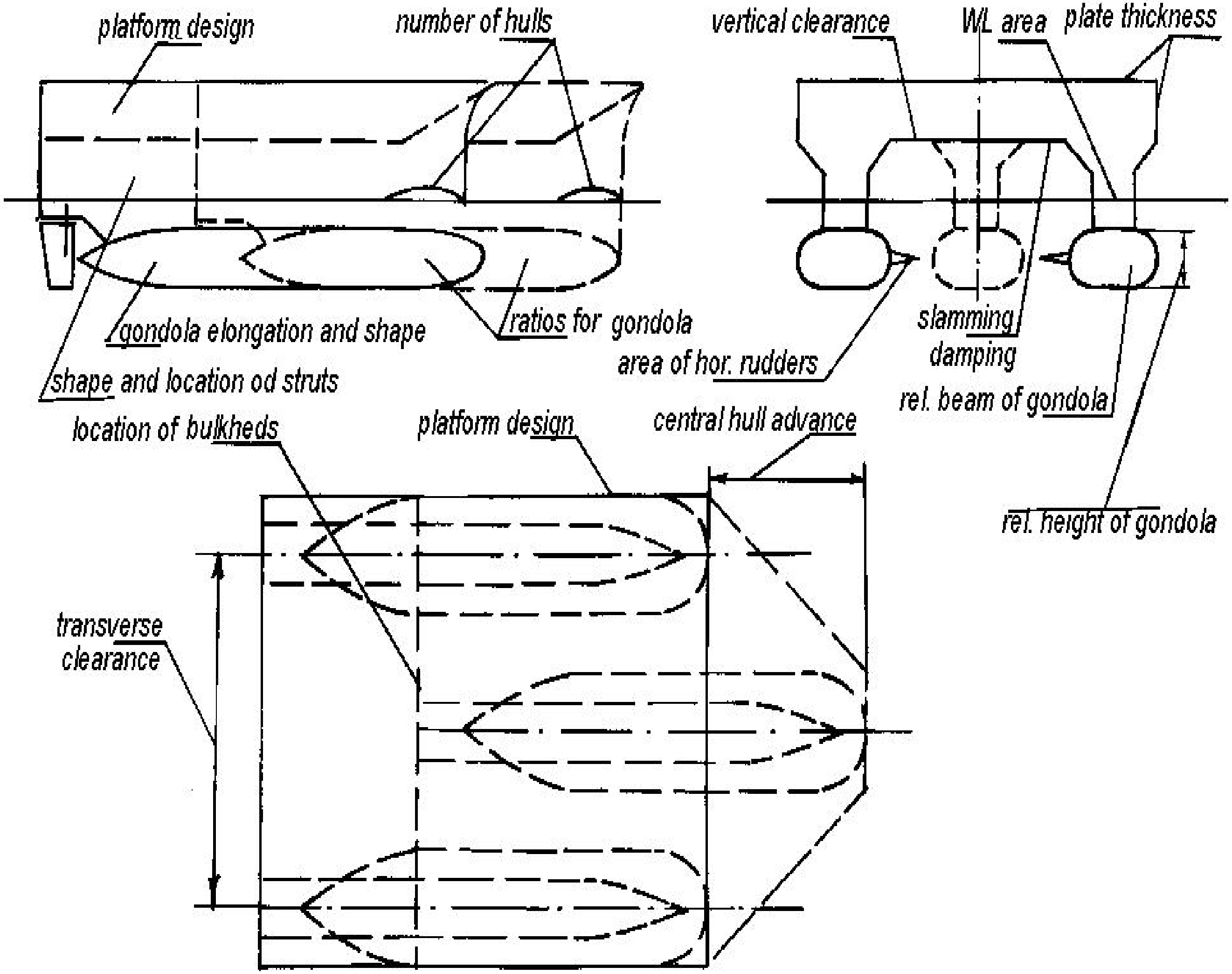
- Deck area;
- Payload;
- Maximal draft;
- Desired type of main engine;
- Possible restrictions of overall dimensions from building or repairing point of view;
- Weather conditions;
- Desired standards of seakeeping.

Systematic calculations of zero approximated dimensions and economy characteristics of various ship types must be carried out previously for ship type selection.

Some recommendations for designing of ships with traditional hull shape, [2].



Some recommendations for SWA ship designing, [2].



“Award” comparison of some SWA ship characteristics. (The best option has the smallest sum of points.), [2]

Ship type	Trisec	Duplus	One outrigger	Two outriggers	Tricore
Sea-keeping	1	3	3	4	2
Relative area of decks	1	1	4	3	2
Relative structural weight	4	3	1	2	5
SUM	6	7	8	9	9

Zero and first approximation of a SWA ship designing, [1].

№	Step	Formula	Notes
1	Relative beam variation	B_{OA}=K1*L	K1= 0.2-0.4 for duplus; K1=0.3-0.5 for trisec; K1 = 0.3-0.5 for SWA outrigger ship
2	Overall length, m	L_{OA} = {(1.1+v_E)*w_P/ [(1+N1)*h_D*K1]}$^{0.5}$ for SWATH; L_{OA}=[2*(1.1+v_E)*w_P/ (1+N1)*h_D*K1(1+l_A)]$^{0.5}$ for outrigger ship; L_{OA}= {0.7*(1.1+v_E)*w_P/ [(1+N1)*h_D*K1]}$^{0.5}$ – for tricore	If there is a restriction of length, it must be taken into account at that step.
3	Overall beam, m	B_{OA}= K1*L_{OA}	If there is a restriction of overall beam, it must be taken into account at that step.
4	Definition of the weight of above-water platform metal structure,t	W_{PS} =(1.1+v_E)*w_P*q_{WP}	
5	Total weight of platform, W_P, t	W_P = W_{PS} + P	
6	Ship displacement at zero approximation, W_0, t	W_0 = W_P/ w_P	Volume dispacement V_0 = W_0 / 1.025, cu m.

7	Zero approximation value of water-plane area, S_{WP}, sq m	$S_{WP} = a_{WP}*(V_0)^{2/3}$	The bigger value of a_{WP} means more convenient arrangement and simple ensuring of strength, but worse seakeeping. Recommended value is 1.0 for zero approximation.
8	Design draft selection.	d	If there is the design draft restriction, the maximal permissible draft must be stated; if not, the design draft can be selected equal to design height of wave of 3-% exceedance.
9	Gondola height definition, h_g, m	$h_g = 0.6*d$	The relative height of the gondola can be 50-65% of design draft, the recommended value is 60 %.
10	Gondola block coefficient selection, C_{BG}	$C_{BG} \approx 0.65$	The value corresponds to gondola aspect ratio L/D = 7, i.e. it is a minimal value for real aspect ratios.
11	Strut volume definition, V_{ST}, cu m	$V_{ST} = S_{WP}*(d-h_g)$	The vertical boards of struts are supposed.

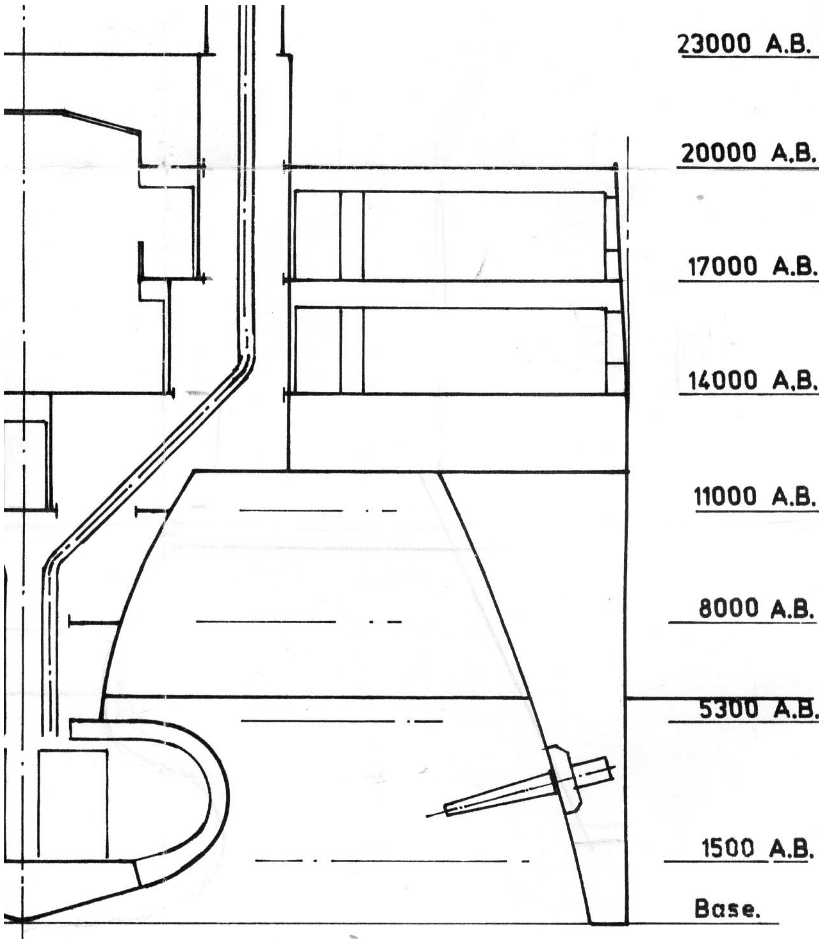
12	Gondola volume, cu m	$V_G = V_0 - V_{ST}$	For outrigger ship, V_0 ,must be decreased previously at 10% - relative volume displacement of outriggers.
13	Gondola beam, m	$B_G = V_G / (N_I * L_{OA} * h_g * C_{BG})$	The minimal value of a gondola beam is equal to its height; the recommended relative beam is about doubling of the gondola height; if the beam is bigger, than 3-4 height, than ship draft and gondola height can be increased.
14.	A hull wetted area estimation, sq m	$S_{WI} = L_I * (2.14 * h_g + 0.8d + 2B_G - B_{ST})$	Approximate data, with some error to safety side.
15	Vertical clearance selection, m	h_V	In dependence from a hull length, see "MHS-seakeeping"
16	Above-water area of struts, sq m	$S_{SA} = 2 \Sigma L_I * h_V$	Not average, but recommended value is preferable one.
17	Platform plating area, sq m	$S_{PP} = 2 * L_{OA} * (B_{OA} + 2 * N1 * h_D)$	Two inner longitudinal bulkheads are added too.

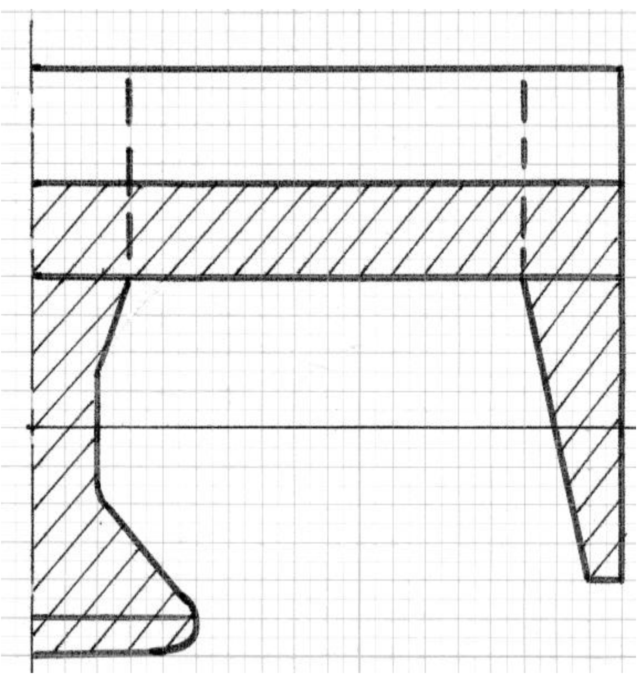
18	Number of lateral bulkheads	$N_B = L_{OA} / (h_V + 0.3*d)$	Some bulkheads can be not water-tight ones, i.e. can be changed by lateral frames.
19	Area of a bulkhead, sq m	$s_B = B_{OA}*N1*2.5 + K*h_V*B_{ST} + K*0.47*B_G*d$	K = 2 for SWATH; K=1 for main hull of outrigger SWA ship
20	Total area of lateral bulkheads, sq m	$S_{LB} = N_B*s_B$	With some error to safety side (it was supposed, all bulkheads have dimensions, as at ship middle).
21	Total area of structure plating, sq m	$\Sigma S = \Sigma S_{WI} + S_{SA} + S_{PP} + S_{LB}$	
22	Average thickness, mm	t_{AV}	Accordingly to MHS-strength
23	Plating weight, t	$W_P = 0.001*\Sigma S*t_{AV}*q$	For steel q = 7.85 t/cub.m; for light alloy q=4 t/cub. m
24	Equipped hull weight, t	$W_H = W_P*q_1*q_2$	For displacement 1,000 t, q_1 = 1.6; for displacement 10,000 r, q_1=1.6; usually q_2 = 1.25, for technical ships, q_2=1.5.
25	Installed power, P_F,and economy speed power, P_E, definition	As a function of displacement, length, wetted area.	Accordingly to MHS-performance

26	**Selection of corresponded engine and its weight**	$W_E=P_F*q_F$	**Approximately weight of: diesels – q_E = 1.5*3 kgf/kWt, gas turbines-q_F=2*1.5 kgf/kWt. The recommended method is the engine selection from the corresponded cataloques.**
27	**Fuel supply definition for needed range R**	$W_F = P_E*q_F*R/v_E$ **for economy speed** v_E, **or** $W_F = P_E*q_F*R/v_S$ **for full speed** v_S	**Approximately outlay q_F (including lubricating oil) of high-speed diesels is 0.235 kgf/(kWt*hour), for gas turbines – 0.3 kgf/(kWt*hour)**
28	**Empty ship weight, t**	$W_0=1.25*(W_H+W_E)$	**The coefficient 1.25 is a correction for ship system weight taken into account**
29	**Full displacement, t**	$W = W_0 + W_F + P$	**The first approximation**
30	**Definition of inner volume structure center, m**		**By the data on inner volume part arrangement**
31	**Definition of ship mass center height, m**	Z_G	**By the data on hull structure, power plant, payload, fuel supply weights and placement relative the base plane.**
32	**Design heeling moment, tm**	M_{heel}	**The design cases depends from the ship specificity:: -bow wind heel for a slow-and middle-speed ship; -circulation for a fast ship; -passenger accumulation on a board (for small passenger ships).**

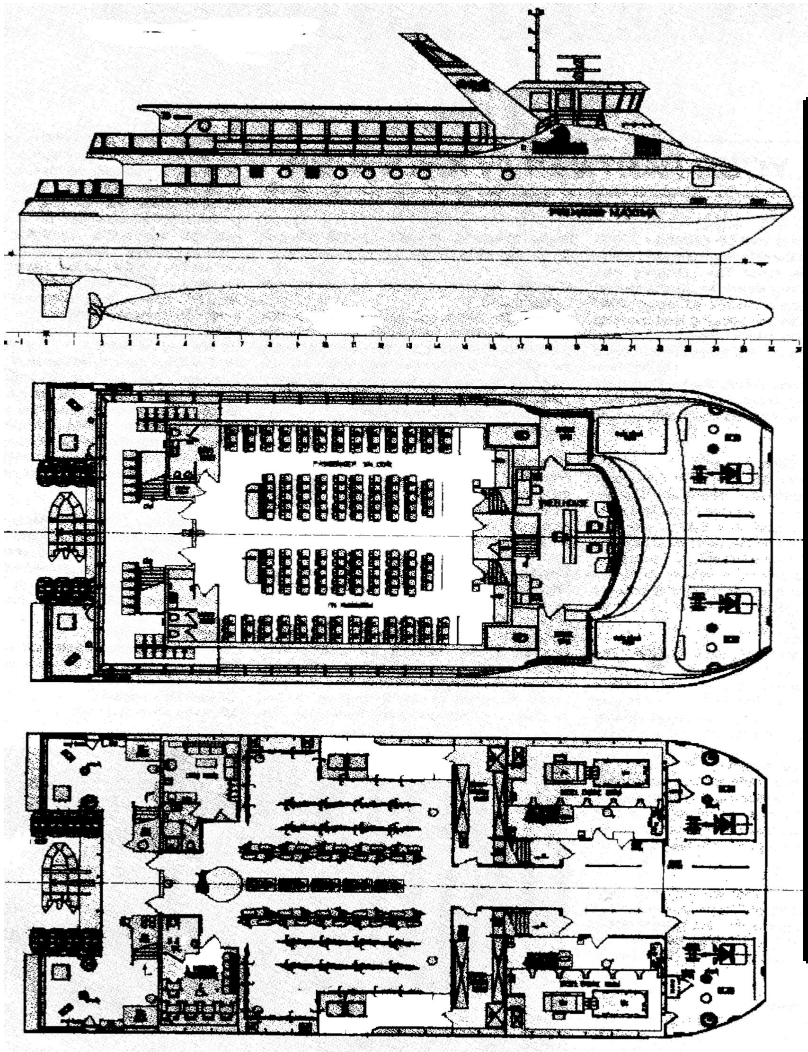
33	Needed initial lateral metacenrtic height, m	$GM = M_{heel} / (W*\alpha)$	Permissible angle of heel α = 10 degrees for passenger and trade ships; α = 15 degrees for a combat ship.
34	Needed lateral metacentric radius, m	$BM = GM + Z_G - 0.5h_G$	
35	Needed area of side hull water-plane, sq m	$A_S \approx 4*BM*W/B_{OA}^2$	If the area is too big, the corresponded options of overall beam are not permissible ones.
36	Calculation of longitudinal metacenrtic height, m	Usual formulas.	The longitudinal metacentric height must be bigger, than lateral one, at two times, as minimum.
37	Estimation of ship motions		According to MHS-seakeeping
38	Estimation of ship operability coefficient		The same
39	Selection of permissible options		According to the needed levels of seakeeping.

Worse (left, 6,000 t, propulsive coefficient 0.65) and better (right, 4,500 t, propulsive coefficient 0.75) options of passenger SWA ship with outriggers. [3].





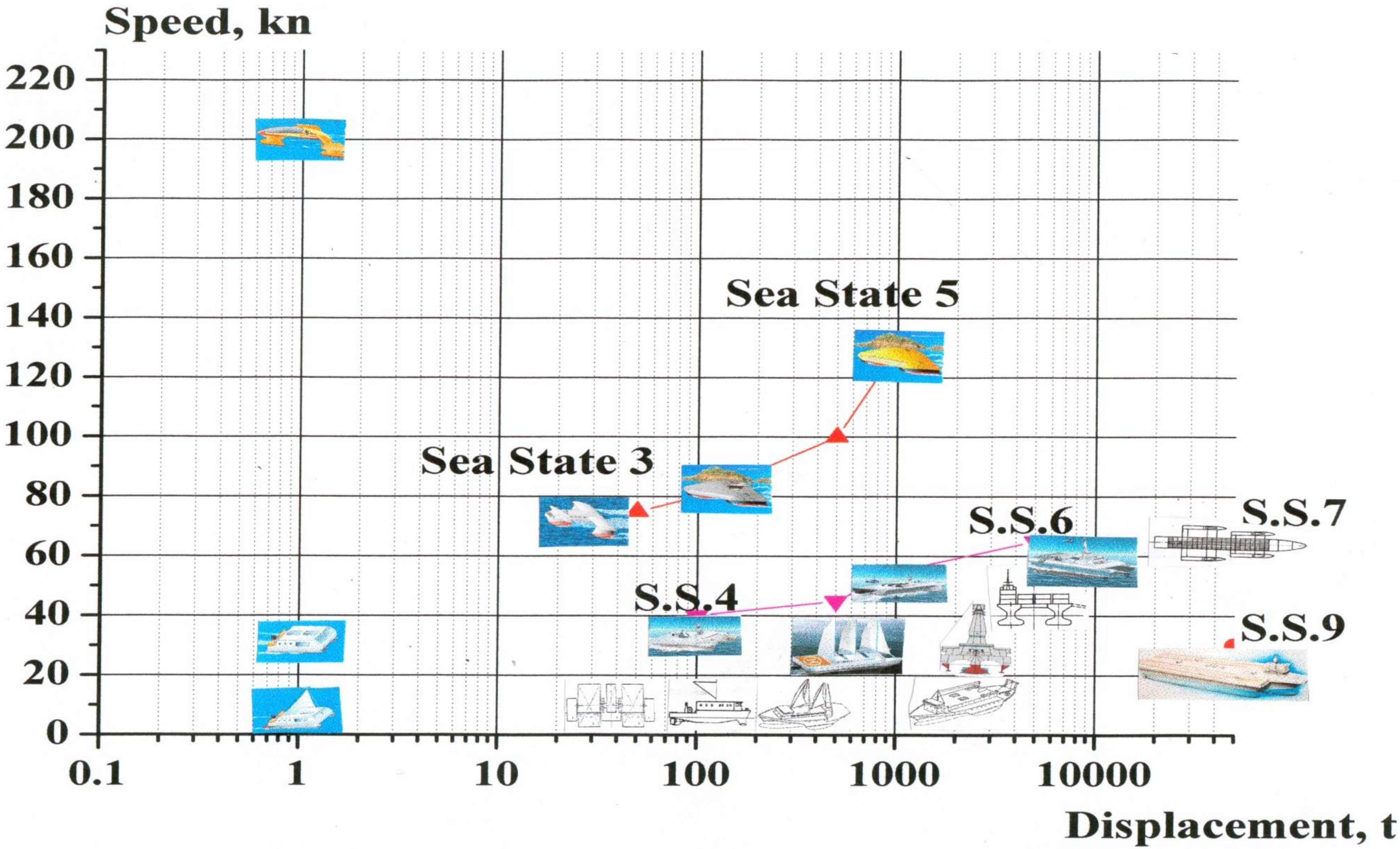
The built ship is not a better option, [1].



Ship options

Dimensions	Built ship	Design
L_{OA}* B_{OA}, m	37.7*17.3	34.5*17.3
Design draft, d, m	4.2	3.5
Displacement, D, t	Abt. 420	Abt. 250
Passengers, pers.	181	181
Fuel+ballast, cu m	22+29	22 + 0
Power, kWt	2 x 1560	2 x 1560
Design speed, kn	16.6	23.5

Some ship options were proposed by Victor Dubrovsky, [2].



General advantages of proposed multi-hull vessels, [2].

Concept, applications	Displ,t	Speed knots	Advantages
"Wave-piercing" trimaran (WPT) with air-born unloading, racing craft	1-2	200-250	Self-stabilized, enhanced seaworthiness
WPT as passenger, patrol, combat ship	20-1,000	75-150	Super-fast, enhanced seaworthiness
"Semi-planing" SWA ship, (SP SWATH) as passenger, naval, rescue craft, as fast container-carrier	15 – 5,000	30-65	Highest possible speed for SWA ships, high seakeeping, high safety
Outrigger SWA ship as naval, passenger, ro-ro, container-carrier	100-30,000	10-70	Least expensive, high seakeeping, safety and performance
Triple-hull SWA ship as passenger, naval craft, ferry	500-60,000	15-40	High seakeeping, high safety and performance
Small catamarans and trimarans as fishery, passenger, research, tugs	20 – 200	8 – 15	Low cost and high safety, universal river platform

REFERENCES

1. Dubrovsky V., Matveev K., Sutulo S., , “Small Water-plane Area Ships”, Backbone Publishing Co., 2004, ISBN-13978-09742019-3-1, Hoboken, USA,256 p.

2. Dubrovsky V., Lyakhovitsky A., “Multi Hull Ships”, ISBN 0-9644311-2-2, 2001, Backbone Publishing Co., Fair Lawn, USA, 495 p

3. Dubrovsky V., “Ships With Outriggers”, 2004, ISBN 0-9742019-0-1, Backbone Publishing Co., Fair Lawn ,USA, 88 p.