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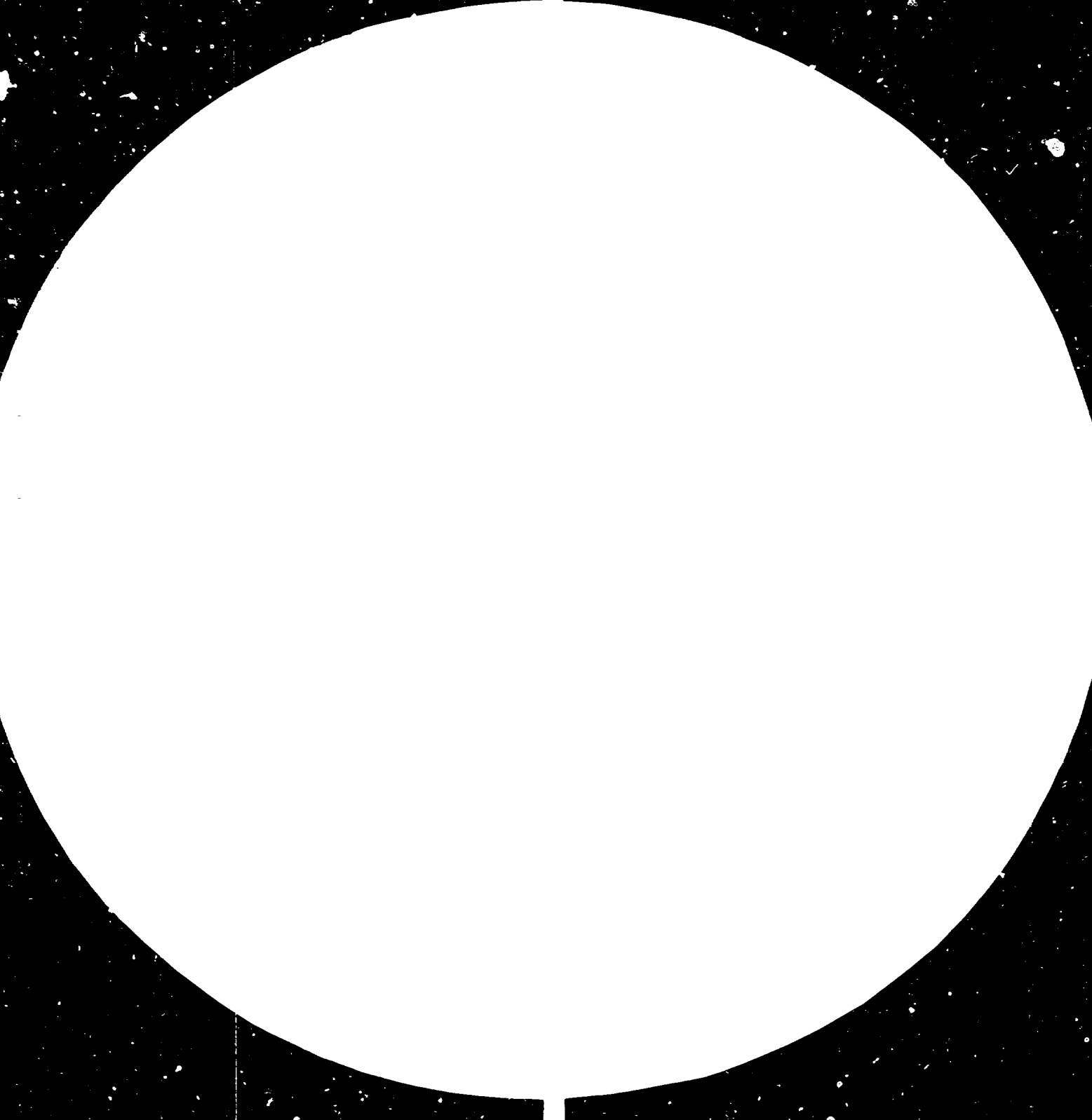

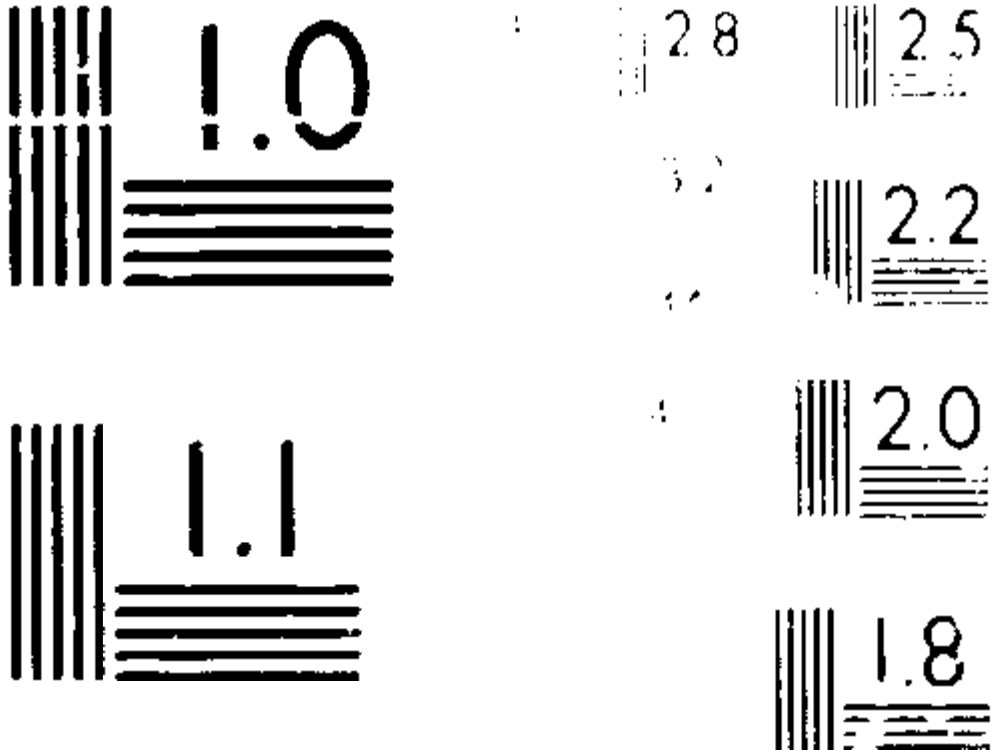
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MATERIALS AND PRODUCTION TECHNOLOGY FOR SMALL SHIPS

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1. INTRODUCTION

The analysis of considered subject requires an approach which may be called a system one. For this purpose a scheme of basic information-material relations for systems of ships operation, ships design and erection and ships repair is elaborated and presented /Fig.1/. On this scheme are given the basic couplings and conditions of different character, namely:

- social,
- economical,
- informational,
- energetical,
- material

On the basis of the analysis of this scheme following system dependencies may be distinguished:

- the development of the ships' operation system depends on the requirements and possibilities of the general economical system of the country into consideration,

- the development of the new ships building and existing fleet repair depends on the requirements or needs of the ships' operation system and on the possibilities of its management system,

- the possibilities of the management system depends on the development degree of the general economical system of the country into consideration,

- on the general economical system of the country considered and on its bases /among others on the ship owners and shipyards/ an influence have the general conditions i.e. world economy, other countries, international organisations, etc.

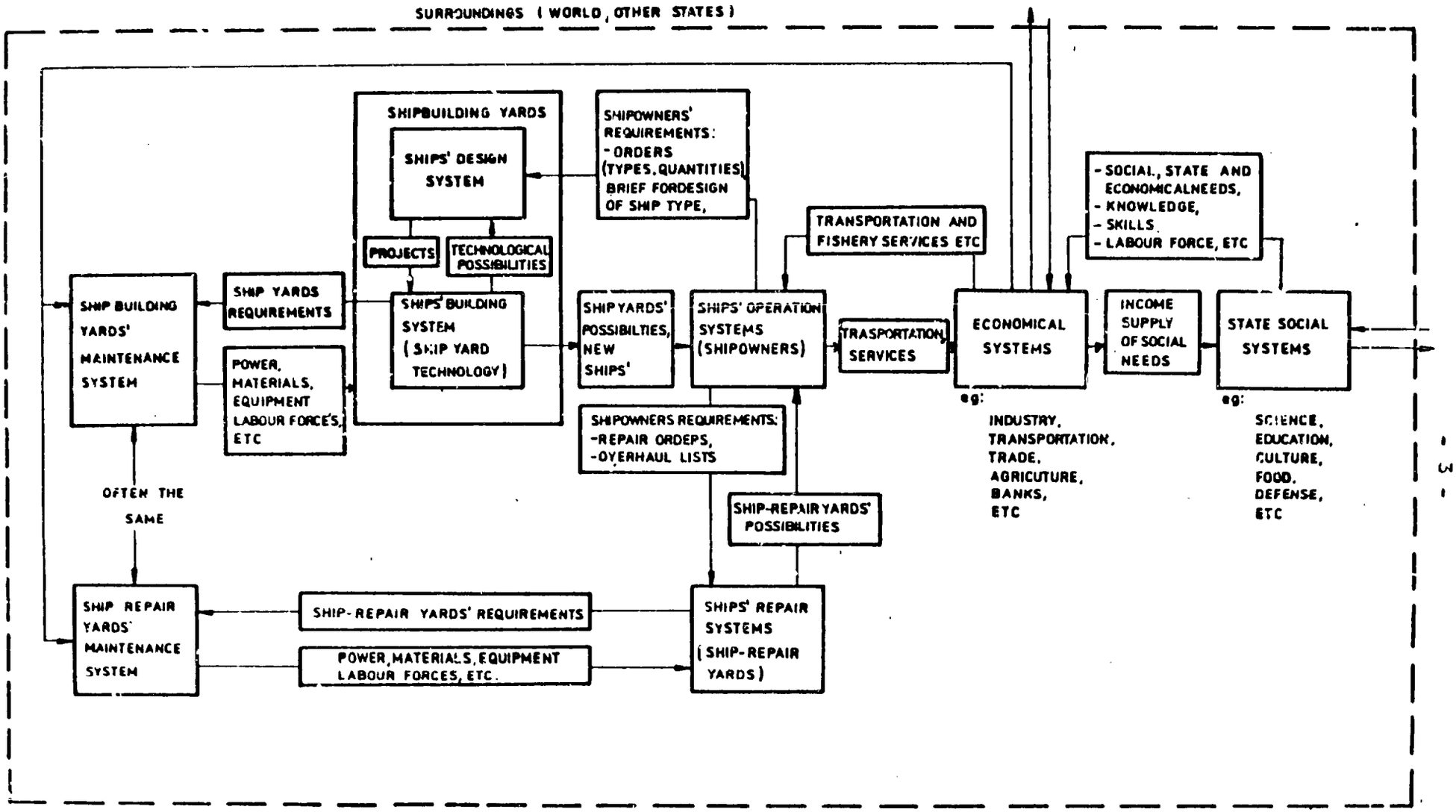

Fig 1. SCHEME OF BASIC RELATIONS FOR SHIPS' DESIGN, BUILDING, OPERATION AND REPAIR SYSTEMS.

Between the distinguished systems a number of feedbacks exists which have different action intensity and value in distinguished time intervals. Therefore the estimation of correct development relations of these systems is a considerably difficult problem.

2. GENERAL ASSUMPTIONS

On the basis of a system analysis the following general assumptions for the selection /recommendation/ of the technology and structural materials for the production of ships may be presented, namely:

1. The economical development of the considered countries differs in an essential way from the level of developed countries what means that the economy and industry of the first one is in an initial stage.

2. The present stage of development of the social and economical systems of these countries is already generating certain requirements on the development of utilization systems of the ships /requirements of the fishing fleet - the food problem, requirements of the transportation services by sea and rivers means, requirements of technical and navigational services of harbours, the necessity of protection of the own economical zone, etc/.

3. The demand of new ships for the developing countries results from the following reasons:

- the shipping industry has a local range /service of own harbours and local waterways/ as well as a near range /neighbor countries/,

- the fishery is operating in the area of the own economical zone,

- the development of harbours, navigational aids and the sailing safety as well as the protection of the coast requires a large number of technical and outer boundary protection /coast quard/ ships,

- the number of harbours is considerably low, they are small and technicaly undeveloped /among other the need of ship-repair yards, sufficient amount of reloading equipment, covered cold stores/,

- the production possibilities of the existing yards /if any/ are unsufficient whilst the production technology is outdated.

4. The introduction of the assumptions presented in point 3 allows to determine a number of ships typed, which should be built in the considered countries, namely:

- fishing boats operating from beaches and local harbours,

- fishing vessels operating from harbours on the shore fisheries,

- cargo vessels of cabotage and river navigation,

- cargo-passenger ships, passenger, ships and ferries serving the local traffic and connections between large harbours having ocean going navigation,

- work vessels serving small harbours, navigation safety and protection of boundaries of the country considered.

5. The introduction of the assumptions according to the point 4 allows to determine the range of dimensions /length/ of ships into consideration, namely:

- fishing boats	3.5 to 10.0 m
- fishing vessels	10.0 to 25.0 m
- cargo vessels, cargo-passangers and passanger vessels, ferries	15.0 to 40.0 m
- work vessels and coast guard vessels	5.0 to 25.0 m

6. To assure a full and fast fullfilment of the demands of the ships operation systems on new ships in the countries into consideration as well as to reach a situation in which the whole shipbuilding would be the essential factor influencing the general development, it is necessary:

- to ensure a sufficient production scale and to introduce a serial production allowing to decrease the production costs,

- to base the ship production on local materials, local labour forces, simple and easy to learn technology,

- to choose technical simple designs and structures of ships characterized by a large operation reliability and small repair requirements,

- to determine the import of materials, equipment and outfit for ships building on a level which is justified by the development of the own industry and payment possibilities of the foreign trade,

- to connect the production activities of the shipayrd with the repair of the existing fleet; an efficient technical service is the basic economical condition of functioning of the ships operation systems.

3. MATERIALS AND TECHNOLOGIES FOR BUILDING OF SMALL SHIPS

In the production of large ships as the main material steel is applied. For small ships a difference exists, namely, the application of many other materials and technologies take place. At the time being in the production of small ships following basic materials for the hull are in use:

a/ wood - required are sorts of high strength and durability whilst the quality of timber has to be the highest,

b/ waterproof plywood - its quality depends on the kind of glue and sort of wood used whilst application concerns small boats,

c/ coldmoulded wooden shell plating glued from many layers of facing boards /possible due to the introduction of modern glues as Kaskofen or West Epoxy System/,

d/ ship steels, weldable, of normal or increased strength,

e/ light aluminium alloys e.g. duraluminium in many different alloy sorts and strength improvements,

f/ polyester-fiberglass laminates being the products of the modern chemistry; this materials are introduced mainly in high economical developed countries,

g/ ferrocement, material which, notwithstanding of its advantages, is not commonly used whilst the production technology is not wide known.

The comparison of the above mentioned materials from the point of view of their physical and maintenance properties is presented in Tab.1 called "Comparison of physical and maintenace properties of hull material". This comparison does not include

the prices because they differ considerably for the above listed materials in different countries. Here the relativity of the assumed criterions and estimations, included in the above comparison, has to be stressed. These were determined by the expert method.

For the further considerations of the selection problem of materials and technologies for building of small ships it is necessary to compare the structures of the basic hull types and the connected materials and technology requirements.

The comparison is presented in the two following tables:

Tab.2. "Comparison of small ships hull structures".

Tab.3. "Comparison of technological requirements for building of small ships".

In the analyses the ship launching and transfering arrangements are neglected. The technical characteristics of these arrangements are more or less independent on the hull material. Analogically as in Tab.1 also in Tab.2 and Tab.3 the relativety of assumed criterions and estimations has to be stressed, mainly because of lack of exact technical data. The extensive description presented in the above tables seems to characterize sufficiently the basic hull structures and erection technologies.

Table No. 1. COMPARISION OF PHYSICAL AND MAINTENANCE PROPERTIES OF HULL MATERIALS

No	Feature / Material of hull	Mass density $\frac{G}{m^3}$	Tensile strength MPa	Characteristic smell xx	Heat conductivity $\frac{W}{/m.k/}$	Vibration dumping and sound absorption	Appearance	Material's resistance on: Sea environment	marine fauna	mechanical damage /local/	fire	Repair of shell plating	Maintenance of hull
1.	Timber	0,47-0,7	60-100 x	pleasant	very low 0,14-04	good	very good	good	bad	good	bad	often complicated, high skilled workers required	difficult and expensive
2.	Plywood shell plating	0,4-0,8	30-50 x	pleasant	very low 0,2-0,3	good	good	worse than timber	bad	good	bad	enough easy, average skilled workers required	difficult and expensive, durability worser than timber
3.	Cold moulded shell plating /several facing boards glued diagonal/	0,6-0,8	40-80 x	pleasant	very low 0,2-0,3	good	very good	better than timber	better than timber	better than timber	bad	easy, low skilled workers required	easier and less expansive than timber
4.	steel	7,85	370-520	without smell	High 58	bad	good	bad	complete	good	good	easy, average skilled workers required	easy and expensive
5.	Aluminium alloy	2,5-2,9	160-335	without smell	very high 175	bad	good	very good	complete	worser than steel	enough good	not easy, high skilled workers required	easy and not expensive by high requirements of electrolytic protection
6.	Polyester-Fibreglass laminate	1,6-1,9	80-270	unpleasant	very low 0,12-0,25	enough good	very good	very good	complete	bad	bad	easy, low skilled workers required	easy and cheap
7.	Ferrocement	2,3-2,5		without smell	low 7	enough good	enough good	good	complete	bad	very good	easy, low skilled workers required	easy and cheap

x For items 1, 2, 3 bonding strength

x x After painting smell is also connected with sort of paints

Table No. 2 COMPARISION OF SMALL SHIP'S HULL STRUCTURES

No.	Type of hull construction	Shell plating	Framing and fastening	Inside spaces and insulations	Main technological requirements	Optimum range of hull's overall length /m/
1	2	3	4	5	6	7
1.	wood, traditional	- carvel planking - clinker planking - strip planking - diagonal and longitudinal planking /bigger ship's/	- wood - cooper alloy boat rivets - anticorrosive protected steel bolts and ferrules - antirust fastennings /alloys of metals/ - waterproof glues	- wood - zinc coated steel sheets - non-ferrous metals sheets - cork	- woodworking machines - steam-bonding equipment for planks and ribs - cold-gluing moulds for framing	- less than 20
2.	plywood /sharpie forme/	- waterproof plywood	as item 1	as item 1	- woodworking machines - cold-gluing moulds for framing	less than 10
3.	composite	- as item 1	- wood - steel sections - as item 1	as item 1	as item 1 and cutting, bending, welding and galvanizing equipment for steel framings	10 - 30
4.	coldmoulded	- several facing boards glued diagonal	as item 1	as item 1	as item 2 and a hull mould or a special construction of hull framing	less than 20
5.	coldmoulded - composite	- as item 4	as item 3	as iter 1	as item 4 and equipment for steel framings as item 3	15 - 35
6.	steel	- plates	- sections - stiffenors - brackets - welding	as item 1 and - steel plates, - plastics	- woodworking machines - cutting, bonding, welding and galvanizing equipment for steel, - jigs and welding positioners /in a serial production/	more than 10
7.	aluminium alloy	- plates	- sections-stiffners - brackets - welding - riveting	- wood - plastics - aluminium alloy sheets	- woodworking machines - cutting, bonding, welding and riveting equipment for al. alloy - jigs and welding positioners /in a serial production/	4 - 30

1	2	3	4	5	6	7
8.	polyester-fiberglass laminate /single skin/	- several fiberglass mats and cloths bonded by polyester resin	- laminated as a skin with using of plastic foams or balsa /eventual/	- laminate - plastics - wood - anti-rust metal sheets	- moulds for hull, deck and inside compartments - laminating positioners /in serial production/ - resin mixers - equipment for building inside spaces	less than 35
9.	polester-fiberglass /sandwich/	- as item 8 and - inner and outside skin filled with plastic foam or balsa	as item 8	as item 8	- moulds for outside and inner skin or for one skin - moulds for deck and inside compartments - and as item 8	less than 35
10.	ferrocement	- wire frame covered by cement mortar	- steel sections and brackets - reinforcement covered by cement mortar - welding for steel constructions	as item 6	- cutting, bending and welding equipment for steel - concret mixer - a special construction of hull framing - equipment for building inside spaces	15 - 40

Table No.3 COMPARISION OF TECHNOLOGICAL REQUIREMENTS FOR BUILDING OF SMALL SHIPS

No of type	Materials for the hull	Materials for inside spaces and insulations	Paint's consumption	Electric energy consumption	Technical gases consumption	Machines and tools	Transportation units and cranes x	Assembling moulds		Workers	
								individual production	serial production	individual production	serial production
1.	- wooden boards - wooden beams - metal fastening materials - waterproof glue	- wood boards - anticorrosive protected metal sheets - cork - metal fastening materials	high	medium	not necessary	- woodworking machines - hand tools - steam-bending equipment, - cold-gluing moulds for framing	necessary for bigger ships	not necessary	existing for framing	very high skilled	very high skilled
2.	- waterproof plywood sheets - and as item 1	- plywood - and as item 1	high	low	not necessary	- as item 1	- as item 1	not necessary	existing for framing	average skilled	average skilled
3.	- as item 1 - steel sections and plates	- as item 2	high	medium	low	- as item 1 - cutting bending, welding and galvanizing equipment for steel framing	- as item 1	not necessary	existing for framing	high skilled	average skilled
4.	- wooden facing boards - and as item 1	- as item 2	high	low	not necessary	- as item 1	- as item 1	existing and necessary	existing and necessary	average skilled	unskilled

						vanishing equipment for steel framings					
4.	- wooden facing boards - and as item 1	- as item 2	high	low	not necessary	- as item 1	- as item 3	existing and necessary	existing and necessary	average skilled	unskilled
5.	- as items 3 and 4	- as item 2	high	medium	low	- as item 3	- as item 1	as item 4	as item 4	average skilled	unskilled
6.	- steel sections and plates	- steel plates - and as item 2	high	high	high	- cutting, bending welding and galvanizing equipment for steel - hand tools - woodworking machines	as a rule necessary	not necessary	existing and necessary	high skilled	average skilled
7.	- aluminium alloy plates and sections	- wood boards, - plywood sheets - plastics - aluminium alloy sheets and fastenings	low	high	high /argon/	-cutting, bending and welding equipment and riveting for al.alloy - woodworking machines, - hand tools	- as item 1	not necessary	existing and necessary	high skilled	average skilled
8.	- fiberglass mats and cloths - polyester resin - plastic foam - balsa	- as raw materials - and as item 2	very low	low	not necessary	- resin mixers, - hand tools - woodworking machines - fan installations	- as item 1	existing, necessary	existing and necessary	average skilled	unskilled

1	2	3	4	5	6
9.	- as item 8	- as item 8	very low	low	not necessary
10.	- stool sections and plates - stool net - cement - sand - water	- as raw material - and as item 2	low	low	low

x does not concern launching equipment

7	8	9	10	11	12
- as item 8	- as item 1	existing and necessary	existing and necessary	average skilled	unskilled
- cutting, bending and welding equipment - hand tools - concretemixer - woodworking machines	- as item 1	not necessary	existing and necessary	average skilled	unskilled

4. SELECTION CRITERIONS OF MATERIALS AND TECHNOLOGY FOR SMALL SHIPS HULL BUILDING

The selection of the optimum material and technology for building of small ships can be made when taking into consideration a number of oriterions from which a certain amount concerns the limited possibilities of the maintenance system of the yard /see Fig.1/. The developed countries which have a very strong economy and a developed industry have no prob_ems to maintain the shipyard industry. In the case of certain shortages they can import raw materials, equipment, technology and also labour force. It may be stated that in the developed countries the development of several industry domains is particularly deprndent on the possibilities of their maintenance systems. Therefore the above presented kinds of criterions are very important.

On the basis of many designs and literature studies the following list of criterions is prepared, which should be taken into consideration during the selection of material and technology for building of small ships hulls, namely:

a/ Structural usability of materials from the point of view of ships' size and type.

b/ Operational properties of material for given climatic conditions appearing during water transport.

c/ Cheapness and accessibility of materials on the local market.

d/ Accessibility of imported materials.

e/ Sale possibility of the produced units and the possibility of introduction of serial production.

f/ Usability of the material for serial production.

g/ Kind and scope of necessary technological process.

h/ Energy consumption during production.

i/ Consumption of technical gasses.

j/ Labour consumption during production.

k/ Qualification requirements for workers and accessibility of labour forces.

l/ Type, number and costs of necessary machines and production equipment.

m/ Elimination possibilities of high skilled works.

n/ Eliminations possibilities of heavy works harmful for health of workers.

o/ Investment costs of shipyard building /erection/ together with costs of shipyard starting and staff education.

p/ Operational costs of the shipyard.

q/ Tradition of the local boatbuilding and existing ship building.

r/ Shipyard location possibilities.

s/ Civil engineering and installation works possibilities of the designed shipyard.

t/ Scope and kind of repair services performed next to new production.

u/ Export possibilities of ships to neighbor countries.

Analysing the above list one may observe that:

- the optimization analysis of the selection of materials and technologies for shipbuilding has to be made from the point of view of many criterions,

- in actual conditions the several criterions have the character of limits, which are changing with time,

- a part of the pr(ented criterions can't be quantitatively expressed and requires a subjective estimation.

Taking the above into consideration it may be stated that the estimation of the way of selection of materials and technologies for shipbuilding in a considered country is very difficult and requires for each case a separate analysis and feasibility study.

5. RECOMMENDATIONS

On the basis of the presented considerations it may be stated that it is impossible to determine such a recommendations in the field of selection of materials and technologies for building of ships which could be the optimum for all countries. However, following recommendations may be presented:

Type No.1 - technicaly outdated, too expensive in execution, not suitable for serial production - should not be recommended in governmental programmes.

Type No.2 - limited application mainly for small size vessels - can be recommended only in specific conditions.

Type No.3 - can be recommended for production of large size vessels when the requisition is small and con old climatic zones /lack of shipworms - toredo/.

Type No.4 - is particularly recommended for production of small and middle size ships for all countries rich in wood.

Type No.5 - can be recommended for big size ships in all countries rich in wood.

Type No.6 - can be recommended for production of middle and large ships particularly in countries which have no wood.

Type No.7 - because of very high technological and operational requirements it is not recommended for ships production in developing countries.

Type No.8 and 9 - because of their advantages they are recommended particularly for production of small and middle size ships for countries which in the balance of foreign trade can allow for a large import.

Type No.10 - particularly recommended for building of all types of ships in countries which have no wood and which have small import possibilities.

Finally the authors like to state that the presented suggestions and analyses are of course open for critical discussion, which would be highly appreciated.