

COMPETITIVE AND SUSTAINABLE GROWTH (GROWTH) PROGRAMME



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**Innovative types of inland ships and their use on the river Rhine, its tributaries
and the adjacent canals.**

Four questions are to be answered:

1. What are the most promising innovations concerning ship technology innovations encountered on the river Rhine and its tributaries in terms of their economic potential for the inland waterway sector?
2. Which of these innovations have already been or are expected to be realised in a commercial setting?
3. Which of the most promising innovations have commercially not been successful to date?
4. Which policy recommendations can be given?

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Summary

The first chapter presents the ships most frequently operating on the river Rhine since the middle of the last century, starting with conventional motor ships and formations of barges up to river-sea-ships. The further development of these ship types as regards their operational efficiency is shown.

As to unconventional vehicles the physically basic conditions for the increase of the required engine power are explained in dependency of speed and water depth and therefore some fast ships are described, which at present still do not run on inland waterways.

The second chapter contains innovations and their goals, i.e. new types of ships, new loading and unloading systems as well as nautical and logistic programs. These innovations enable a fast and efficient waterborne cargo transport. – Ideas for unconventional fast ships are still on the drawing board; the shipping sector will pay attention to these developments but at the moment considers the risk to be too high to build and operate such vehicles.

The basic equipment of ships sailing on the Rhine is prescribed by the RheinSchUO (“Regulations for Navigation on the Rhine”) but however a lot of ships exceed these requirements. Modern computer hardware and software significantly influence the technical, nautical and logistic sequences of operation to the benefit of shippers and charterers.

Policy is asked to harmonize competitive conditions not by tax advantages but rather by load dependent tolls and by granting the same level means for maintenance and improvement of the waterways as it is already applied for landborne traffic modes.

Introduction

A presentation of the technical shipbuilding innovations can only be sensible if the ships at present predominantly operating on the river Rhine and its tributaries are introduced to show later on why innovations are necessary.

Until the middle of the last century numerous barge trains operating as towing units were running on the important European rivers apart from many self-propelled ships. The transport of goods on the waterways was versatile and reliable in terms of time.

Business segments lost to truck and train could possibly be gained back by the modern new ship types, pushing and coupling units, because these ships can transport various goods and in addition the existing waterways allow for much more waterborne traffic.

When designing and building a new ship several aspects have to be taken into consideration:

- what kind of goods shall be transported
- at which speed the vessel should operate on different waterway depths
- what are the envisaged operating areas?

These data are required for fixing the main technical characteristics of a ship. The identification of the general framework is especially crucial for inland vessels because depending on seasonal conditions varying water depths can be met on the natural waterways. Therefore, both the maximal loading draught and the maximal speed can often not be realized. During operation on canals (artificial waterways) however the lock dimensions determine the maximum size of the ships.

1. Ships operating on the River Rhine and its tributaries, new constructions and conversions

1.1 Conventional Ships

1.1.1 Self-propelled vessels

Subject to some of the above mentioned assumptions the *Zentralverein für Deutsche Binnenschifffahrt* (Central Association for German Inland Navigation) assigned self-propelled vessels to different classes in the middle of the last century [1]. This classification proved to be of significant importance for Inland Navigation within Germany. The following ships were included in this classification (dimensions: length x breadth x max. draught; net deadweight) (Figure 1).



Figure 1 Ship types of the Central Association for German Inland navigation

class Theodor Bayer

48 m x 5.05 m x 2.3 m; 370 t

class Oskar Teubert

53 m x 6.29 m x 2.5 m; 562 t

class Karl Vortisch

57 m x 7.04 m x 2.5 m; 605 t

class Gustav Koenigs
67 m x 8.2 m x 2.5 m; 930 t

class Johann Welker
80 m x 9.5 m x 2.5 m; 1290 t

Especially vessels of the last two types are sailing on the river Rhine and its tributaries even today. Many of these ships were extended and/or equipped with twin-screw-propulsion and ducted propellers (Figure 2) as to improve their loading capacity as well as the ship's speed.



Figure 2 Ducted propeller

Ship types like *Peniche* (Figure 3) or *Spits* also operating on the river Rhine and its tributaries are met now and then. But still quite a number of these small ships are on their way within the Netherlands and Belgium as feeder ships.

| | |
|--------------------|------------|
| Length: | L = 38.5 m |
| Breadth: | B = 5.0 m |
| Carrying capacity: | = 350 t |



Figure 3 Ship type „Peniche“

In the past decade the ship operators (shipping companies, private owners) wanted to have bigger and bigger ships and simultaneously demanded for a good power to speed ratio. This process was initiated – among other things - by rising oil prices as well.

Further development of self-propelled ships:

Since the foundation of the *Versuchsanstalt für Binnenschiffbau Duisburg* (VBD) in 1954 (today: *European Development Centre for Inland and Coastal Navigation*) a multitude of ship models were investigated at this institute with the target to improve the ship shapes for the operation on shallow water. The research project “**Inland Ship of the Future**” funded by the German Ministry of Education and Research (BMBF) in the eighties of the last century resulted in inland ship shapes (Figure 4) which have a power saving of 15 – 20 % compared to conventional ships [2].

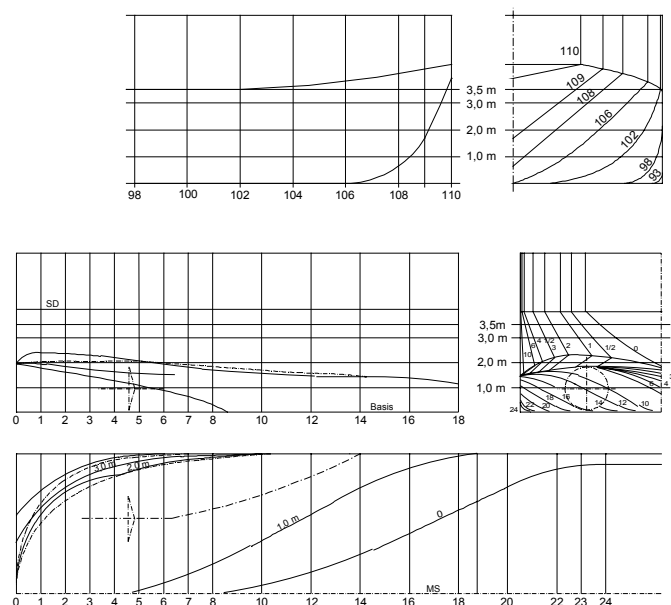


Figure 4 Example of the ship type „Inland ship of the future“, ship lines design

Depending on the operating area and the kind of goods the length of these ships varies between 80 m and 110 m. The shape of the fore ship can be selected from several variants – matching the particular conditions (waterway, kind of goods, ship’s speed etc.). The aft ship should be designed as a single or twin screw ship. The tanker “Alchemist Lausanne” (Figure 5) belongs to this class.



Figure 5 Tanker „Alchemist Lausanne“

On the river Rhine the trend to bigger ships continues to exist as the following examples show:

technical data of the motor ship "JOWI" (Figure 6):

| | |
|--------------------|----------------------|
| length | L = 135.00 m |
| breadth | B = 16.84 m |
| draught | T = 3.20 m |
| loading capacity | = 4600 t |
| container capacity | = 392 TEU (4 layers) |



Figure 6 Motor ship „JOWI“

technical data of the tanker "Compromis " (Figure 7)

| | |
|------------------|--------------|
| length | L = 135.00 m |
| breadth | B = 16.84 m |
| draught | T = 4.00 m |
| loading capacity | = 5710 t |



Figure 7 Tanker "Compromis"

Besides however, some smaller vessels like for example the containerships of the type "Neokemp" entered the market (Figure 8) with the dimensions:

| | | |
|------------------|------------|-----------|
| length | L | = 63.00 m |
| breadth | B | = 7.00 m |
| maximal draught | T_{\max} | = 2.8 m |
| loading capacity | | = 870 t |



Figure 8 Motor ship type „Neokemp“

The last mentioned ship has a continuous cargo hold, the bridge at the fore ship and it can carry 32 TEU in 2 layers one upon the other [3].

1.1.2 Barge Trains

The formations which at present operate on the river Rhine are almost exclusively pushing units. There are no more towing trains to be found here. A **pushed train** consists of a push boat with one or more barges; a **coupling train** is composed of a pushing motor ship with barges coupled laterally and / or in front.

1.1.2.1 Barges

Already in 1970, standards and recommendations for the building of barges were published by the Nautical-Technical-Commission of the International Association for Navigation on the river Rhine [4] in order to simplify the arrangement of formations with nearly the same type of barges.

The barge type "EUROPE I" with the dimensions:

| | | | |
|------------------|------------------|---|---------|
| length | L | = | 70.00 m |
| breadth | B | = | 9.50 m |
| max. draught | T _{max} | = | 3.2 m |
| loading capacity | | = | 1680 t |

can only be found here and there on the river Rhine. On the canals and tributaries of the river Rhine however, it is still used.

On a large scale, the barge type "EUROPE II" has generally been accepted. It is built as type II, II a and II b. The types II and II a (Figure 9) have a so called pontoon bow. The differences between these variations consist in different draughts and consequently different loading capacity. Their dimensions are:

| | length [m] | breadth [m] | moulded depth [m] | max. draught [m] | loading capacity [t] | container capacity [TEU] |
|------------|---------------|----------------|-------------------------|------------------------|----------------------------|-----------------------------------|
| Europa II | 76.50 | 11.40 | 3.50 | 3.40 | 2340 | about 160 or 170 ¹⁾ |
| Europa IIa | 76.50 | 11.40 | 4.00 | 3.90 | 2710 | about 160 or 170 ¹⁾ |

1) with adjusted cargo holds

Table 1: Dimensions of the EUROPA II variants

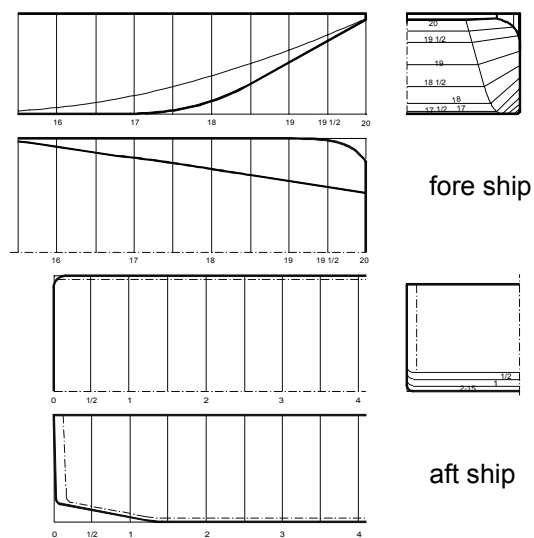


Figure 9 Barge type „Europe II a“, ship lines (pontoon bow)

The type II b is characterized by a wedged frame bow (Figure 10). It is built with a moulded depth of 3.5 m as of 4 m as well. The deadweight increases with a wedged frame bow and the resistance against water drops. It is recommendable to use such a bow especially in case of small waves (approximately seaway 2). For an employment of inland barges in more heavy seaway a V-frame bow will be preferred (Figure 11).

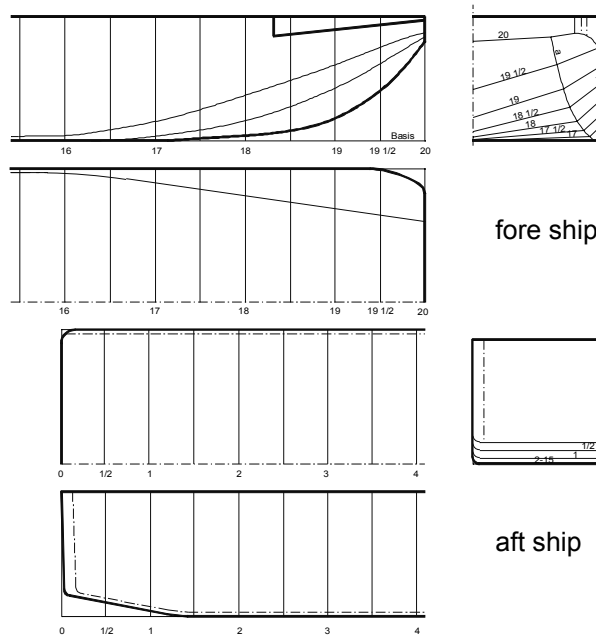


Figure 10 Barge type „Europe II b“, ship lines (wedged shape)

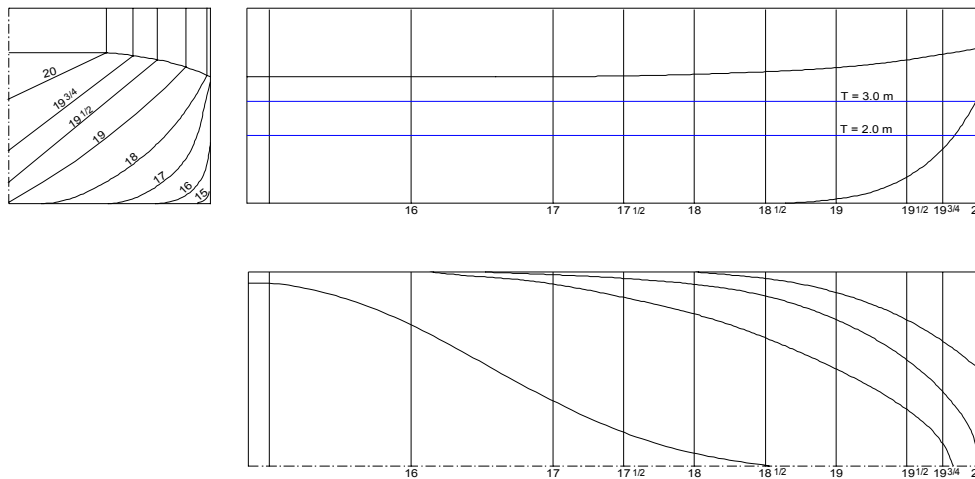


Figure 11 V-shaped bow

For the operation on a lower water depth (e.g. upper Rhine, Elbe) the type EUROPE II c with wedged frame bow has been developed. It differs from the above called types by the lower moulded depth, but it can be combined without any problem with the other types within a train. Its main dimensions are

| | length [m] | breadth [m] | moulded depth [m] | max. draught [m] | loading capacity [t] | container capacity [TEU] |
|-----------|------------|-------------|-------------------|------------------|----------------------|--------------------------|
| Europa II | 76.50 | 11.40 | 2.65 | 2.50 | 1830 | about 160 or 170 |

Table 2: Dimensions of the barge Europa II c

Figure 12 shows formations of pushing and coupling units sailing on the river Rhine.

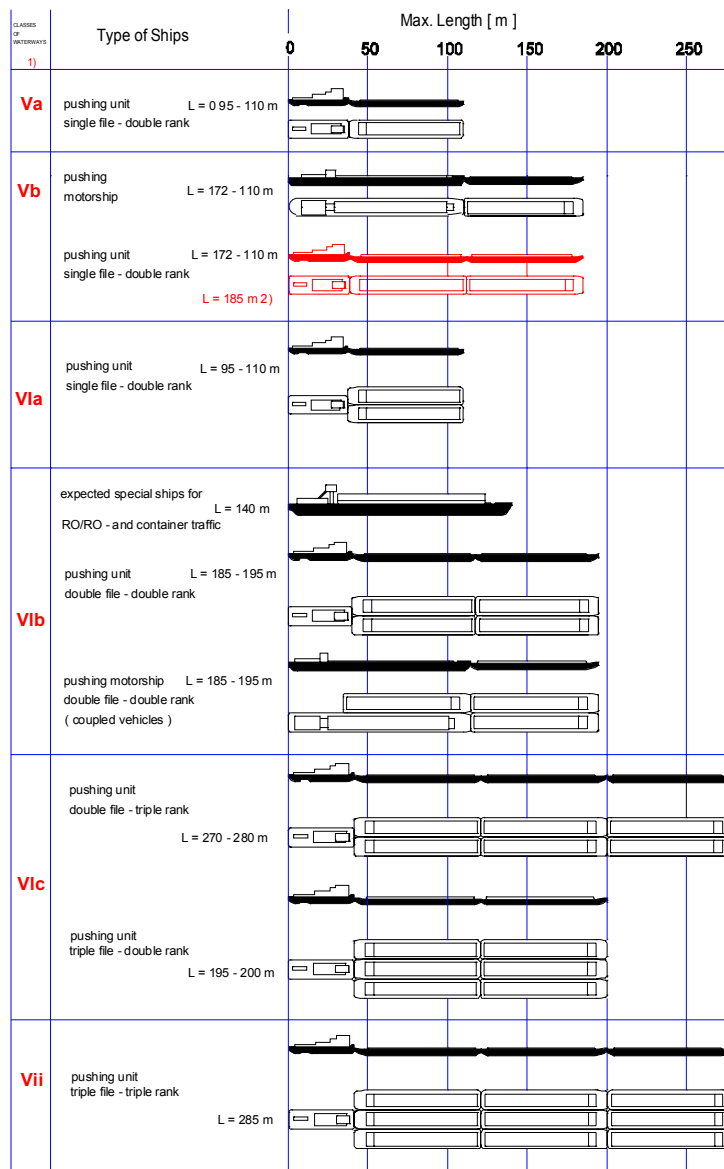


Figure 12 Possible arrangements of pushing and coupling trains operating on the river Rhine

On this river pushed trains do normally transport liquid cargo as an exception only since coupling trains are more effective in action (Figure 13). Bulk cargo – mainly ore and coal – are transported on the lower Rhine predominantly with pushboat-barge formations consisting of four or six units.



Figure 13 Coupling unit of tank motor ship and tank barge

1.1.3 Push boats:

Basically, there is a differentiation between long range pushboats, canal pushboats and harbour pushboats. At nearly all these vehicles the propulsion equipment consists of screws with nozzles, i.e. the propellers are ducted.

Long range pushboats (Figure 14) run on the lower and the middle Rhine. They are twin- and triple-screw pushers with a total engine power of $P_D = 1440 \text{ kW}$ to 4500 kW .



Figure 14 Long range pushboat

The dimensions are

| | | |
|---------|-----|-------------|
| length | L = | 30 – 35 m |
| breadth | B = | 14 – 15 m |
| draught | T = | 2.6 – 2.7 m |

Canal push boats, mostly twinscrew boats, are working on the tributaries and the adjacent canals and have an engine power of $P_D = 2 \times 300 \text{ kW}$.

Their dimensions are

| | | |
|---------|-----|-----------|
| length | L = | 15 ÷ 25 m |
| breadth | B ≤ | 11 m |
| draught | T = | 1.5 ÷ 2 m |

Harbour pushboats shall shift one or more barges within the harbours to the different wharves, possibly also to the Rhine roads. Mostly, these boats are smaller and equipped with lower but sufficient engine power in order to push single barges upstream on the Rhine. Dimensions:

| | | | |
|---------|-----|---------|---|
| length | L = | 11 ÷ 20 | m |
| breadth | B = | 11 | m |
| draught | T = | 1.5 ÷ 2 | m |

A newbuilding of pushboats is not in sight at present, existing long range boats are overhauled and modernised.

1.1.4 River-sea-ships

Ships for the throughout traffic from inland waterways to maritime waterways and vice versa are no novelty. Basically, it must be distinguished between inland going sea ships (Figure 15) and seagoing inland ships (Figure 16). The first are sea ships whose draught allows sailing also on inland waterways. At sea they must be able to resist a heavy seaway (Baltic Sea, North Sea, Biscay etc.). The last are inland ships where the equipment, the strength, the stability and the freeboard allow the operation on maritime waterways up to a certain seaway status. On rivers and partly also on canals the traffic routes go far into the hinterland if possible. The dimensions of these ships are also determined either by the "Rheinschiffahrts-Polizei-Verordnung" (Police Regulations for Navigation on the Rhine) [5], the "Binnenschiffahrts-Straßenordnung" (Inland Waterways Regulations) [6] (which considers the dimensions of the locks) or by the operating range of the dockside cranes.



Figure 15 inland going sea ship MS „Twistede“



Figure 16 Seagoing inland ship

1.1.4.1 Inland going sea-ships

Basically, this type of ship derives from coastal vessels. Such ships have a loading capacity of between 400 t and 2000 ÷ 5000 t. The main dimensions of the smaller vehicles are approximately

| | | |
|--------------------|-----|--------|
| length | L = | 45 m |
| breadth | B = | 7 m |
| draught | T = | 2.5 m |
| container capacity | = | 24 TEU |

The majority of these ships do only have a certificate for “home-trade”

The main dimensions of the bigger ships are quite different

| | | |
|--------------------|-----|---------------|
| length | L = | 80 ÷ 90 m |
| breadth | B = | 10.5 ÷ 11.5 m |
| draught | T = | 3.5 ÷ 4.5 m |
| air draught | = | 6 ÷ 9 m |
| container capacity | = | 81 – 160 TEU |

or

| | | |
|--------------------|-----|---------------|
| length | L = | 100 ÷ 120 m |
| breadth | B = | 12 ÷ 16 m |
| draught | T = | 4.5 ÷ 5.5 m |
| container capacity | = | 176 – 260 TEU |

Most of these ships have the license for “coastal trade” or “unlimited area of navigation”.

1.1.4.2 Seagoing inland-ships

They should at least be able to withstand a seaway force 3 ÷ 4 corresponding to wind force of Beaufort 4 ÷ 5 (medium size wave height $\zeta_w \approx 2$ m). Strength and stability in the seaway are to be considered very high. According to the area of navigation and the occurring seaways the required freeboard might have a lower height than determined by the International Assignment of Freeboard. At the same time the stability of the ships in seaway as well as the arising seaway have to be taken into consideration possibly resulting in a limitation of the operating area. The dimensions of such a ship could be:

| | | |
|-----------------------|-----|---------------|
| length | L = | 80 ÷ 110 m |
| breadth | B = | 11.45 m |
| draught | T = | 2.5 m |
| max. loading capacity | ≈ | 1600 t |
| container capacity | ≈ | 125 – 210 TEU |

Mostly such ships hold the license for „home-trade“, but some seagoing inland ships exist with the license for „unlimited area of navigation“.

1.1.4.3 Seagoing pushing trains

Such trains, as operating on the Russian rivers, do not run on the river Rhine. Because of the required limited draught of the sea barges during sailing on shallow water there appear some stability problems in seaway. The barges having a small breadth and a high centre of gravity run the risk of having a low stability and therefore of capsizing. Compensating the low draught by widening the barges, a higher loading capacity is

gained of course but at the same time a high initial stability is achieved which can lead to heavy motions in seaway and thus to damages of the load. – The problem of the coupling between the push boat and the barge should be solved as some publications show, for example [7].

1.2 Unconventional Ships

These ships in general refer to fast vehicles which don't have the shape of a hull as the usual displacement ship. Usually, they are not able to transport bulk or liquid cargo in large quantities. Unconventional ships are running at a higher speed than the classical cargo and passenger vessels [8]. Some hydrodynamic explanations being necessary for the further understanding can be found hereinafter.

At constant propulsion power the speed of a ship sailing on a restricted water depth is influenced just by the water depth or at constant speed by the propulsion power, respectively (Figure 17). When operating on a restricted water depth quite a similar phenomenon arises like the speed of sound within aviation. That is the so-called back-wave velocity or critical speed

$$V_{krit} = \sqrt{g \cdot h}$$

with

g = constant of gravitation

h = water depth

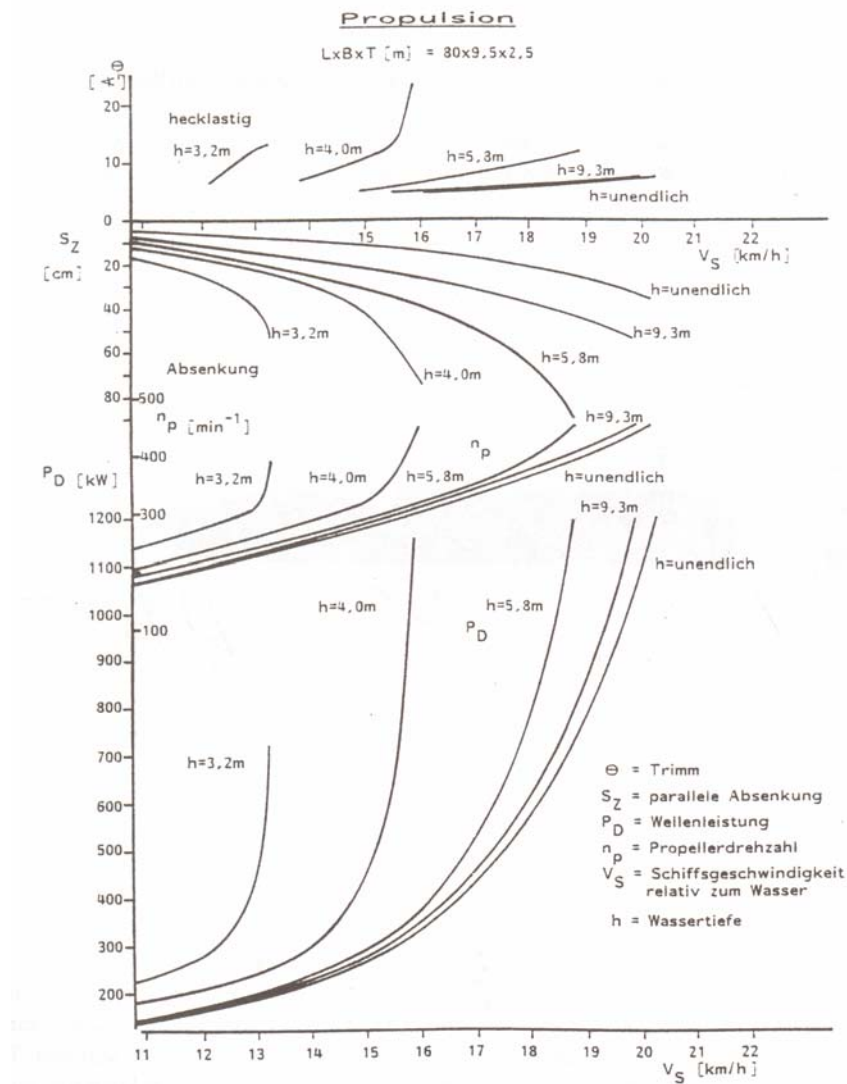
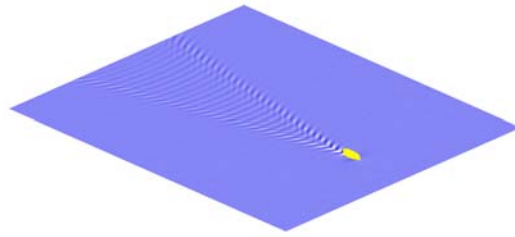


Figure 17 Power-speed diagram of a ship sailing on different water depths

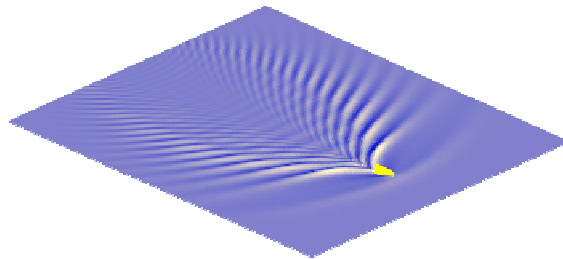
By forming the quotient

$$\frac{V}{\sqrt{g \cdot h}} = F_{nh}$$

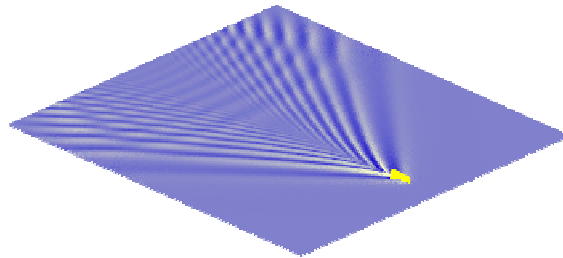
derives the so called *Depth Froude Number* F_{nh} (comparable approximately to the aerodynamical Mach Number) which shows the alteration of the ship's resistance as a result of the changing wave generation on a restricted water depth (Figure 18). The critical speed is reached at $F_{nh} = 1$. The following table illustrates its dependence on the water depth.



Wave pattern at a subcritical speed ($F_{nh} = 0.7$)



Wave pattern at the critical speed ($F_{nh} = 1.0$)



Wave pattern at a supercritical speed ($F_{nh} = 1.5$)

Figure 18 Changing of the wave pattern generated by a vehicle running at different speeds ($0.7 \leq F_{nh} \leq 1.2$) on constant water depth

| h [m] | $V_{crit.} (\Delta F_{nh} = 1)$ | |
|----------|---------------------------------|------|
| | [km/h] | [kn] |
| 60 | 87.3 | 47.2 |
| 30 | 61.8 | 33.3 |
| 20 | 50.4 | 27.2 |
| 10 | 35.7 | 19.3 |
| 5 | 25.2 | 13.6 |
| 3 | 19.5 | 10.5 |
| 2 | 15.9 | 8.6 |

km/h = kilometre per hour

kn = knots = sea miles per hour (1 sea mile = 1,852 kilometre)

Table 3: Dependence of the critical speed on the water depth

With decreasing water depth the achievable maximal speed for displacement ships declines. Although at present not only passenger ships but also fast container ships are in parts sailing at a speed corresponding to a depth Froude number of $F_{nh} = 0.8 \div 0.85$, a further rise of speed is economically irresponsible because of an excessively high engine power to be installed and a considerable impact on the environment caused by the generated waves. Displacement ships ever should run at subcritical speed range ($F_{nh} < 1$). The supercritical speed range ($F_{nh} > 1$) is reserved to the fast ships being suited for it due to their underwater shape combined with a lower generation of waves. When passing from the subcritical into the supercritical range, the transition of the transcritical range ($0.9 \leq F_{nh} \leq 1.1$) should take place very quickly because of the stability of motion.

(< smaller than; > larger than; \leq smaller than or equal)

1.2.1 Fast displacement ships (ships running in subcritical speed range)

1.2.1.1 Monohull ships

At present no “unconventional” monohull freighters exist on the river Rhine, which run within the subcritical speed range. In chapter 1.1 ship types have been introduced which are able, on account of their equipment and consideration of their different operating

areas, to transport all kinds of bulk cargo and if necessary even sensitive and perishable goods.

1.2.1.2 Multihull ships

An example for an unconventional displacement ship is the so called **semi-catamaran** (Figure 19), sailing at speeds within the high subcritical range. It is conceivable that the semi-catamaran can drive at a speed equivalent to $F_{nh} = 0.85$. A good manoeuvrability and stop ability can be obtained as well as a lower wave generation and an acceptable power-to-speed ratio.

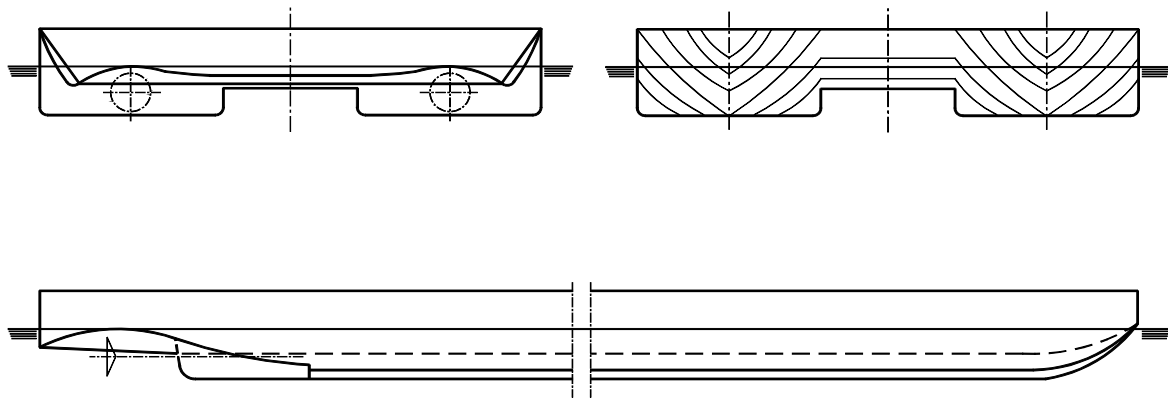


Figure 19 Semi-catamaran, drawing lines

Compared to a conventional monohull cargo vessel the semi-catamaran has clear advantages concerning deck cargo because of its construction ($B_{tot} = 11.45 - 22.9$ m). Both side hulls are connected by a flat middle hull with a lower draught, which is completely available for deck load. Unlike single hull ships, the stability of such a catamaran allows for container stowage in several layers.

On the river Rhine semi-catamarans have not been accepted till now.

1.2.2 Fast vehicles (ships running within the supercritical range)

Fast ships are able to run within the supercritical speed range on account of their shape. Therefore, they should either be so called “planing ships” (Figure 20) or “semi-planing ships” whereby their design could be of mono hull or multi hull type. Hydrofoil boats do also belong to this group (Figure 21), likewise air-cushion vehicles, air-cushion-catamaran-vehicles (Figure 22), wing in ground effect vehicles (Figure 23) etc.

All these vehicles are not only used for passenger transport but can also carry high quality goods on the waterways at higher speeds than have been applied till now. - Regarding the operation of such vehicles it has to be avoided to just transfer fast deep sea ships to inland water-ways, because hydrodynamic conditions claim other ship shapes for shallow water than for deep water.

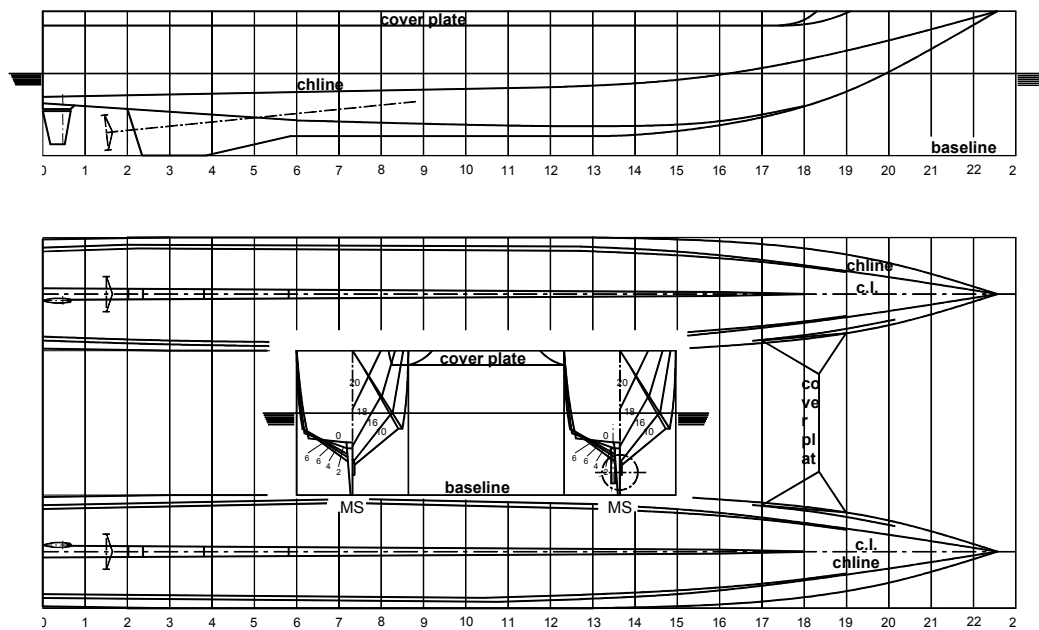


Figure 20 Body plan of a planing craft (catamaran)



Figure 21 Hydrofoil craft

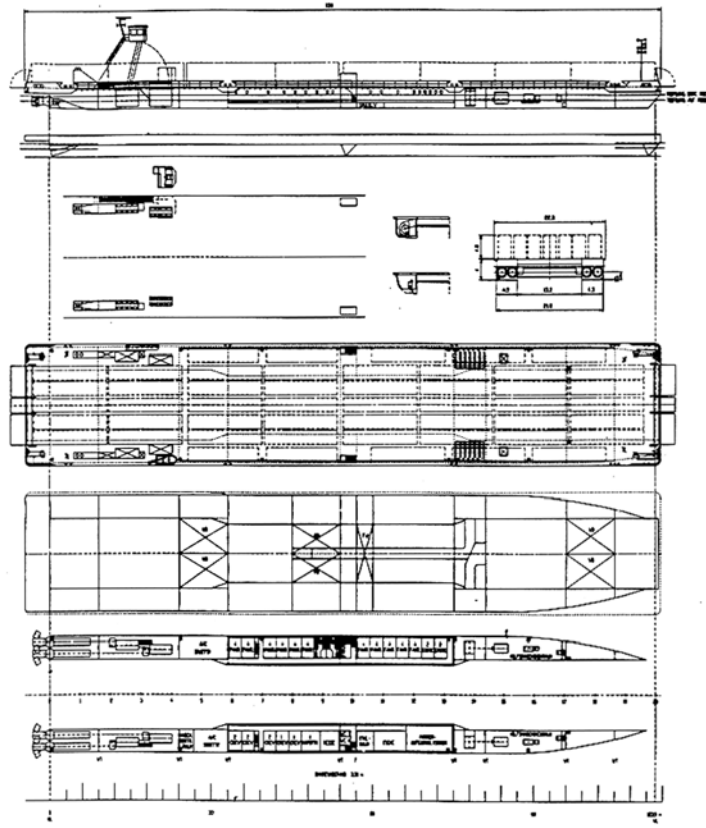


Figure 22 Body plan of an air cushion vehicle



Figure 23 Wing in ground effect vehicle

1.2.2.1 Monohull ships

Till now the existing ships running within the supercritical range only meet authority tasks (water police, fire brigade) as well as passenger transport or private yachting (Figure 24). At present such vehicles are not in action as cargo ships.



Figure 24 Vehicle running in the supercritical speed range

1.2.2.2 Multihull ships

To date no catamarans, trimarans, air cushion vehicles, air cushion catamarans, hydrofoil boats etc. are applied as cargo ships on the river Rhine.

1.3 Equipment and facilities of ships

The required equipment and facilities for ships running on the river Rhine is laid down within the “Rheinschiffsuntersuchungsordnung” (RheinSchUO) (Testing Regulations for Vessels on the Rhine) [9] of the Central Commission for Navigation on the Rhine as follows:

- chapter 6 control device
- chapter 7 wheelhouse
- chapter 8 propulsion engine
- chapter 9 electrical installations
- chapter 10 equipment

- chapter 11 safety in the field of work
- chapter 12 living rooms
- chapter 13 heating system, cooking equipment and refrigerating plants operating with fuel
- chapter 14 liquid gas plant for household purposes
- chapter 16 special rules for vehicles determined to be part of a pushing train or a coupling train
- chapter 19 special rules for canal peniches
- chapter 20 special rules for sea-going ships
- chapter 22a special rules for vehicles with a length of more than 110 meters

All these rules have to be fulfilled by all ships operating on the river Rhine and its tributaries.

1.4 Telematics

All ships, operating on the river Rhine, are normally equipped with a radio-telephone for the exchange of news and the predominant number of ships has a radar system too. Both facilities are necessary for the traffic safety.

2. Realized, planned or expected Innovations

The preceding chapter deals with the ship types today predominantly operating on the river Rhine and its tributaries, their dimensions, their cargo capacity and container capacity, respectively, without claiming to give a complete overall view.

Discussions and interviews with private ship owners and representatives of shipping companies in Germany and the Netherlands have shown that characteristics of newbuildings and conversions of existing vessels are strongly influenced or even determined by the cargo to be transported – dependent on its state of aggregation, its quality and quantity. Still available shipping companies concentrate more often on special purpose ships, preferring long-term contracts and point to point traffic, while private ship owners mostly but not solely stick to the so called all-round vessels, which are qualified for the transport of various kinds of goods also on the tributaries.

Common innovative targets connected with new ships or new ship types are at hand in case shipping companies, private ship owners and charterers join to conclude a long-term contract particularly concerning specialized ships, in order to decrease the risk of a newbuilding for the individual party concerned. The same applies to other fields of interest within inland navigation and its participants. i.e. changes within the framework of conditions for waterborne transport (improvement and maintenance of the waterways), improvements of navigational equipment and solving of logistic problems are desirable goals to be realized. There are also real concepts with regard to improved ships and their equipment, like for instance the loading and unloading systems in the ports. However, depending on the cargo to be transported ship owners largely differentiate between these proposals. Owners of tank ships (chemical tankers, oil tankers, gas tankers) have other ideas than owners of dry-cargo vessels, whereby it has to be furthermore kept in mind what kind of dry cargo ship is referred to either bulker and container ship, or allrounder and special ship etc. In order to improve the survey the following chapter has been subdivided.

The decision of a private owner or a shipping company to put on a single motor ship, coupling or pushing trains for forthcoming transports depends to a large extent on their comprehensive economical and technical experience and the resulting business philosophy.

During the design and building of new ship types the yards should attach importance to a light-weight construction in order to minimize the draught. Safety, in this case the strength of the ships, must not be jeopardized. To increase the strength, swedged walls for example could be used as double hull for a tanker.

2.1 Dry-cargo Vessels

2.1.1 Motorships (self-propelled vessels)

Based on the shapes of the BdZ in the nineties of the last century a **cargo motor ship** has been developed by the VBD [10], which on account of her dimensions

| | |
|--------------------|---------------------|
| length | $L = 82 \text{ m}$ |
| breadth | $B = 9,5 \text{ m}$ |
| draught | $T = 2.5 \text{ m}$ |
| loading capacity | $= 1300 \text{ t}$ |
| container capacity | $= 77 \text{ TEU}$ |

is qualified for operating on the **tributaries and canals** (Figure 25).

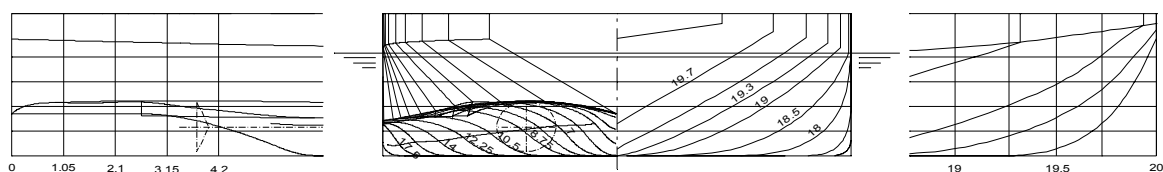


Figure 25 Lines drawing of a ship for the river Rhine and its tributaries

Especially, for the transport of containers also on low water level a dedicated **shallow water ship** has been designed by the shipyard Roßlau and the VBD (Figure 26)

| | |
|------------------|-------------------------------------|
| Length | $L = 110 \text{ m}$ |
| Breadth | $B = 11.4 \text{ m}$ |
| Max. draught | $T_{\max} = 2 \text{ m}$ |
| Light draught | $T_{\text{light}} = 0.65 \text{ m}$ |
| Loading capacity | $= 1690 \text{ t}$ |

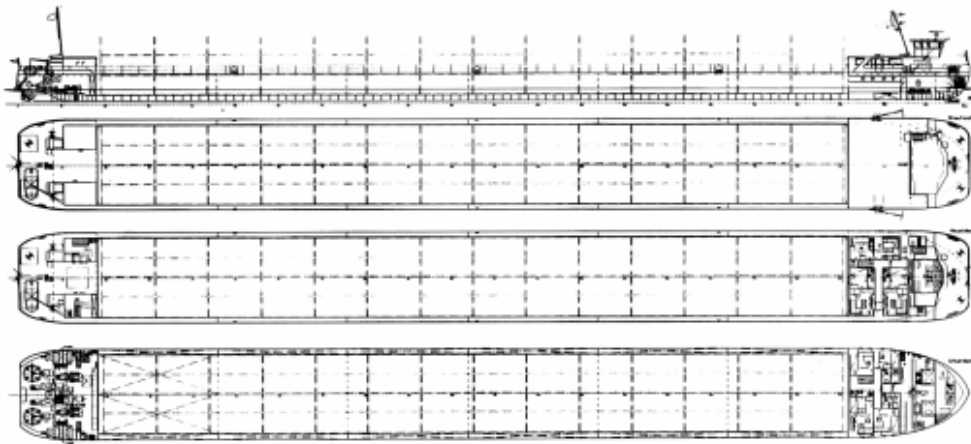


Figure 26 Motor ship for shallow water

This ship is able to transport twenty TEUs when other vessels are no longer able to run due to their draught [11].

Some considerations are under discussion to build a future **super-container-ship** for operation on the river Rhine with a capacity of 640 TEU. The dimensions could be about 135 meters x 20 meters. Such **big ships** will be equipped with cell guides to facilitate transshipment of cargo, containers and swap bodies, which are better suited for storing pallets than the ISO-container.

A proposal of the VBD aims at carrying a **mixed cargo**. This would mean that bulk cargo (solid or liquid) is stowed within the cargo holds and containers or swap bodies will be stacked on a supporting frame above the bulk cargo (Figure 27). Thus, container transport by inland vessels will be of interest to areas with a low container volume. The combination of heavy bulk cargo and lightweight containers offers the possibility to largely utilize the capacity of the ship regarding both her deadweight and her cargo

capacity. In addition, this vessel is able to far more economically operate on canals with lower air clearance – because of its higher draught [12].

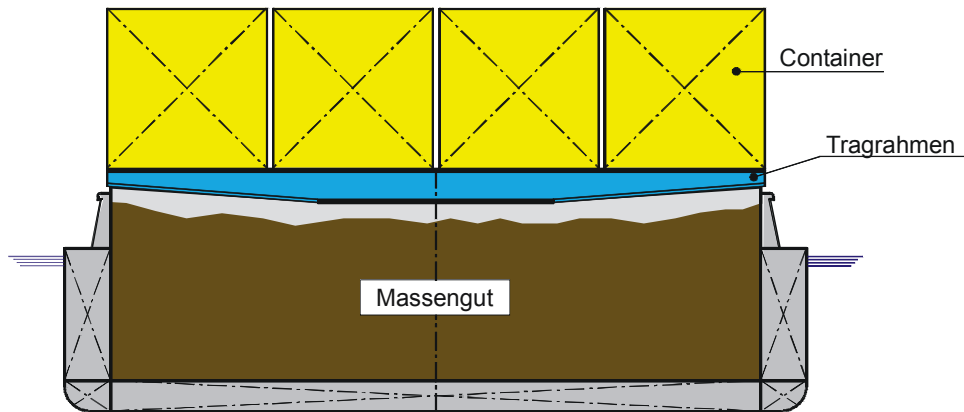


Figure 27 Ship for mixed Cargo (cross-section)

A further innovative proposal is the so called **inland ship particularly suitable to operate on shallow water** (Figure 28). This vessel is to represent a competitive ship type being able to run on the river Rhine as well as on the river Elbe. It has a fixed minimal breadth of 9 meters and a maximal breadth of 12.6 meters. Buoyancy bodies with built in excess pressure mounted within the wing passage effect this flexibility. These bodies are moved by hydraulic cylinders. The draught of a ship can be lowered with the help of these technical features without changing the cargo quantity [13].

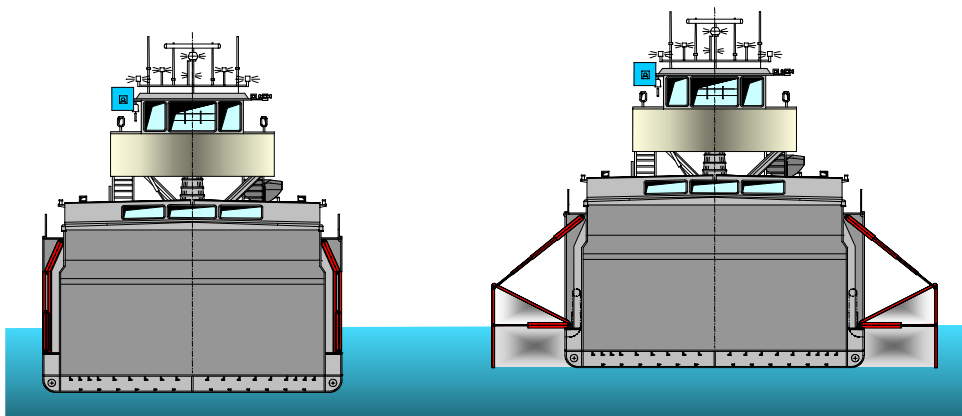


Figure 28 Inland ship especially suitable to operate on shallow water (cross-sections)

For the transport of bananas from Antwerp / Belgium to the Ruhr-region / Germany the building of a **refrigerated cargo vessel** is planned with the dimensions

$$L \times B \times T = 135 \text{ m} \times 11.4 \text{ m} \times 2.5 \text{ m}.$$

About 2000 pallets shall be transported with containers stacked in 3 layers.

On the drawing board there are already plans for **super ships** consisting of two bodies coupled together in a streamlined single form with the dimensions

$L \times B = 180 \text{ m} \times 15 \text{ m}$. Moreover, super large ships ($L \times B = 170 \div 190 \text{ m} \times 20 \div 25 \text{ m}$), designed as **double-end-ships** (Janus-head) are going to be considered. Here propulsion units will be installed at both ends, so that a turning manoeuvre in restricted water is not necessary any more. – Such ships could be built only if vessels with a greater length than 135 meters will be allowed to operate on the Rhine.

It must be added that a flour (tank) ship has already in 2002 been put into service (Figure 29). This ship is designed for the waterborne transport of flour and has the dimensions

| | | |
|--------------|------------------|----------|
| Length | L | = 86 m |
| Breadth | B | = 11.4 m |
| Max. draught | T _{max} | = 2.85 m |
| Deadweight | | = 1452 t |



Figure 29 Flour (tank) ship

The future belongs also to the so called pallet-ships. These ships must have a special load- and unload-system. The pallets are not stowed in containers or swap-bodies but with the help of rolling floors / rolling stages, so that a multilayer loading is possible within cell guides. Cargo handling times drop in comparison to the present situation by applying this new technique.

The last two ship types require adequate loading facilities ashore.

2.1.2 Barges

Model tests with large barges were already carried out in the nineties of the last century [14]. Resulting from the existing loading and unloading facilities along the Rhine stretch the following convenient dimensions for barges revealed:

| | |
|--------------------|---------------------|
| length | L = 100 m |
| breadth | B = 14 m |
| draught | = 4 m |
| load capacity | = 4550 t |
| container capacity | = 260 TEU (4layers) |

resp.

| | |
|--------------------|-----------|
| length | L = 95 m |
| breadth | B = 16 m |
| draught | T = 4 m |
| load capacity | = 4995 t |
| container capacity | = 240 TEU |

At present the building of **large barges** for bulk cargo is planned with the dimensions $L \times B \times T = 100 \div 110 \text{ m} \times 11.4 \div 12.5 \text{ m} \times 3.5 \div 4.5 \text{ m}$ and a maximal deadweight capacity of 4500 t which can transport up to 18000 t in trains of four barges. The operation of even larger barges will be taken into consideration with possible

dimensions $L \times B \times T = 100 \div 110 \text{ m} \times 22.9 \div 25 \text{ m} \times 4 \div 5 \text{ m}$. A continuous volume of bulk cargo, especially on the lower Rhine, is the precondition for building these barges.

2.1.3 River-sea-ships

The building of fast **car transporters** is envisaged for the throughout traffic from the river Rhine via the North Sea to Great Britain, to avoid the expensive transfer (inland ship – sea-going ship and vice versa) in the ports of the North Sea coast. Both displacement ships and unconventional vessels will be taken into consideration.

There are additional plans to build a limited number of larger **seagoing inland ships** with the main dimensions $L \times B \times T = 135 \text{ m} \times 14 \div 15 \text{ m} \times 3 \text{ m}$ and a container capacity of about 300 TEU. Attention has to be paid to reduce the high initial stability for these ships caused of the relative great breadth, leading to strong movements in seaway.

2.2 Ships for liquid cargo (tank ships)

Basically, the ADNR-regulations have to be observed for tankers of any kind; in addition there have to be considered for

- building rules - gas tank ships type G
- building rules - chemical tank ships type C
- building rules - normal tank ships type N

Further details are given in [15].

Future new buildings will only be of double hull type. Initial ideas and suggestions, respectively, are also given on part of the charterers. At present some tankers are under construction with the length $L = 86 \div 110$ meters and a breadth $B = 11.45$ meters. These vessels can sail on the river Rhine, all tributaries and on the Rhine-Main-Danube-Canal. If necessary, e.g. in case of larger cargo volumes, they could be enlarged to a length of 110 m or 135 m without significant difficulties. Even then they will be able to operate on the RMD-Canal. Today many tank ships have a length of 86 meters dependent of the manning scale (article 23.10 of the Regulations for Navigation

on the Rhine). When sailing on the tributaries and canals a maximal length of 110 meters is stipulated due to the unchanged lock dimensions.

In the middle of 2003 a new specialized twin-screw tanker for gas and chemical goods has been put into service. Its main dimensions are:

$$L \times B \times T = 110 \text{ m} \times 11.45 \text{ m} \times 2.8 \text{ m}; \text{ loading capacity} = 2800 \text{ m}^3.$$

Due to its special shape and an increased displacement an additional loading capacity of 500 m^3 could be gained at simultaneously reducing the required engine power. This double-hull ship has additional cargo tanks and thus can be practically called a “triple hull” ship.

A further newbuilding is a chemical tanker (type C) with the dimensions $L \times B \times T = 86 \text{ m} \times 10.4 \text{ m} \times 2.8 \text{ m}$; loading capacity = $1500 \div 1600 \text{ t}$. It operates on the Belgian waterways, all Rhine tributaries and - at a lower draught - also on the upper Rhine.

Tank ships for operation on the Rhine have been designed with a length $L = 135$ meters and a breadth $B = 20$ meters, which are being built now and will be in the near future. Their deadweight is – dependent of the draught – between 6000 t and 8000 t . Because of their breadth such ships are not suitable for action on the Rhine tributaries and the surrounding canals.

Within the next years a large number of tank ships will be required. Unfortunately, there is a lack of required yard capacity, so that existing ships have to be overhauled. For this reason mono hull type ships will still run on inland waterways in the foreseeable future. Their safety should be improved by built in loading tanks (container).

2.3 Unconventional Ships

Some engineering consultancies and shipbuilding research institutes will think about the design of **small, fast, shallow water vessels** for sailing on the Rhine (speed on the Rhine against land $V_L = 30 \div 60 \text{ km/h}$) but also for the throughout traffic inland waterway \leftrightarrow maritime waterway, which are able to carry 30 to 40 containers or a corresponding number of lorries or motor cars. The last mentioned vessels must be able to withstand at least a seaway with strength of 3 to 4. The risk - referring to the speed-power-ratio, to

the quality and to the quantity of transported goods and thus to the efficiency of the vessels – should be much more negligible for such ships sailing in different waters, than the operation of bigger ships with a deadweight three or four times as high.

Of course there are considerations to put into service faster and bigger ships like Ro-Ro-vessels (Figure 30) with a carrying capacity of about 1500 t (about 36 trailers and motor vehicles or 50 semi-trailers). This would be an **air-cushion supported catamaran** ($V_L \approx 30$ km/h), which can successfully operate at long distances, e.g. on the river Danube. It should have the following approximate dimensions

| | |
|---------------------------|---------------------|
| length | $L = 135$ m |
| breadth | $B \geq 20$ m |
| min. draught (on cushion) | $T_{\min} \leq 2$ m |



Figure 30 Fast RoRo vehicle (surface effect ship)

Investigations of the VBD have shown that vessels, which can run within the supercritical speed range, possess an excellent manoeuvrability and stop ability. But further research work has to be done with different ship shapes on different water depths in order to minimize both the engine power and the wave generation when passing the transcritical speed range.

The development and testing of **wing-in-ground-effect vehicles** for an economically justified engine power is worldwide going on [16]. These vessels can operate everywhere, where big water areas are available (Baltic Sea, North Sea, Black Ocean, great lakes or river tributaries/ mouths). They are looked upon as waterborne and land surface vehicles and not as air vehicles because they run / float just above the water level or the surface of the earth. The driver doesn't need a pilot license. Future developed and built wing-in-ground-effect vehicles will be planned with a capacity of 80 passengers including luggage or the corresponding weight of cargo.

2.4 Facilities and equipment, Engine output und propulsion

Technical innovations for inland navigation do not only refer to new ship types but also to the facilities and equipment on board of ships and within ports. Completions and innovations of the standard equipment (see chapter I.3) of course will be taken into consideration when planning a newbuilding. Also here the ideas and requests of ship owners and charterers but above all the kind of cargo to be transported will influence the ship type. Besides, there are concepts and improvements relating to all types of ships. Some of these possible or requested improvements will be listed hereinafter:

- air condition plants on all explosion-safe tankships
- cellular rack for stacked swap bodies
- high rise stores for pallets
- roll stages for faster and better loading of pallets
- crosswise loading of goods with simultaneous operation of several loading devices (fork lift truck)
- utilization of new sources of energy, like solar cells or fuel cells in combination with electro-motors for driving auxiliary engines or if possible also the main engine(s)
- driving of auxiliary engines and smaller main engines by nitrogen motors [17]
- application of the SCR-catalyst (Selective Catalytic Reduction) [18] for the reduction of nitric oxides as part of the exhaust gas and with simultaneous reduction of gas oil consumption
- application of ducted propellers for inland cargo ships to reduce the propeller thrust load

- application of Z-drives with contra-rotating-propellers to improve the efficiency of rudder-propellers
- JAFO-Linear-Jet [19] as propulsion for fast inland ships
- application of slow running surface piercing propellers [20]
- separated engine rooms of twin-screw ships for safety reasons, e.g. to guarantee the operation of the ship in case of fire in engine room or flooding
- anti-blocking system enabling a reliable steering of the ship having multiple rudder arrangement in case that one rudder blade is blocked
- improvement of the ship's strength by new construction elements (swedged longitudinal and transverse structures)
- and others

Possible improvements and changes within the ports:

- installation of high capacity container bridges and other loading and unloading devices to reduce cargo-handling times
- lengthening of some quays for the berthing of large motor ships

The aforementioned examples only represent numerous intended or planned innovations. But they show that there are yet lots of possibilities to raise the attractiveness of cargo transport by inland ships, to improve its effectiveness and to support the ecological benefits.

2.5 Telematics

Because the telematics get more and more involved in inland navigation not only on nautical-technical but also on logistical fields this topic is treated separately within this chapter.

Basic requirement to be met for a comprehensive utilization of the advantages telematics offer for inland navigation is to provide all ships with a computer. Also on the

river Rhine this aim is not attained. Today Swiss ships are obviously better equipped (92.9 % have computers) than Belgian ships (83.3 %), Dutch (81.6 %), German (58 %) and French (33.3 %) ships. The same applies to the use of the Internet on board of the vessels: Swiss = 71.4 %, Dutch = 50.6 %, Belgian = 40.5 %, French = 33.3 %, German = 26.8 %. The numbers are increasing since the last inquiry of June 2003 [21].

The use of a board-computer can cover the nautical, technical and/or logistical area if the system comprises different programs, e.g. given in [22]. In the following some of these programs are exemplary listed:

- * **ELWIS** (Electronical Waterway-Information-System); all kind of nautical information will be provided like water level, lock information, traffic information for waterways etc.; all news for inland navigation can be recalled dependent on the present trip
- * **BICS** (Binnenvaart Informatie en Communicatie Systeem) [23]; with this system voyages of (inland) ships can be announced either at the data-processing and follow-up system for navigation on the main waterways of the Netherlands (IVS 90) or at a regional data-processing system (RIVS).
- * **ARGO** /Advanced River Navigation = electronic channel-information system; it is an information project of the German waterway- and navigation administration; an electronic river map will be superposed with the radar display and supplied with extended depth information. ARGO exists in two kinds of modes: navigation mode and information mode
- * **COPIT** (Computer in der Partikulierschiffahrt in integrierten Transportketten, computer for independent ship owners operating within integrated transport chains); this project is an open modular information system for the conception of transport by inland navigation. By exchange of information and data inland ships will be tied up in the transport chain. With the help of an optimised telematic information system with other partners participating in the transport (forwarding, dispatcher, charterer, harbours) the utilized carrying capacity can be improved by shifting of transports of goods and unloaded voyages can be reduced.

- * **ISS-Bord** (Integrierte Software Schifffahrt, integrated software for shipping) supports the skipper at his administrative tasks around the transport by ship. By electronic exchange of information with the managing clerk at the agency, association or shipping company the shipmaster can receive orders of the control station, transmit current positions of the ship, deliver reports of the voyage etc.

Results of application are for example:

- fuel saving, effective sailing in dependence of the loading draught and waterway conditions
- higher safety achieved by the installation of an intelligent device, a speed-dependent bow steering gear (combination of an active and an passive rudder)
- application of an automatic drive and steering system (autopilot)
- managing of contracts and orders, evaluation of the vessel tonnage, recording of voyages
- but above all the integration of the waterborne cargo transport into complete transport chains by fast extensive information among charterers, managing clerks and shipmasters.

3. Unsuccessful Innovations

From an economic point of view unsuccessful innovations do not appear within inland navigation. If newbuildings should not match the foreseen requirements regarding the transport of particular goods on determined waterways, up to now there has always been a possibility to more successful operate such ships in another market segment. The latest example for such a development refers to the ships of the type "Neokemp" which do not carry out their feeder service on the river Rhine, as originally intended, but now operate on smaller Dutch and Belgium waterways with good results, underlined by additional planned newbuildings.

4. Political Recommendations

The classification of the European waterways (Figure 31) is given (see [24]). Maintenance and improvement of waterways however have to be pursued on a far larger scale than in the past and in addition following European standards in order to ensure a traffic relief on the roads. This is in general what European inland navigation claims on politicians. Closely connected with this is the improvement of the infrastructure along the waterways as it can be seen for instance along the river Rhine.













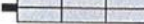
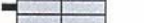
| Graphisches Symbol auf der Karte | Klasse der Binnenwasserstraße | MOTORSCHIFFE UND SCHLEPPKÄHNE | | | | | SCHUBVERBÄNDE | | | | Brückendurchfahrts-höhe | |
|---|-------------------------------|---------------------------------------|-------------|--------------|----------------|---------------|--|--------------------|-------------------|----------------|-------------------------|-----------------------|
| | | Typ des Schiffes: Allgemeine Merkmale | | | | | Art des Schubverbandes: Allgemeine Merkmale | | | | | |
| | | Bezeichnung | Länge L (m) | Breite B (m) | Tiefgang d (m) | Tonnage T (t) | Formation | Länge L (m) | Breite B (m) | Tiefgang d (m) | Tonnage T (t) | |
|  | I | Penische Westlich der Elbe | 38,5 | 5,05 | 1,8-2,2 | 250-400 | | | | | | 4,0 |
| | | Gross Finow Östlich der Elbe | 41 | 4,7 | 1,4 | 180 | | | | | | 3,0 |
|  | II | Kempenaar Westlich der Elbe | 50-55 | 6,6 | 2,5 | 400-650 | | | | | | 4,0-5,0 |
| | | BM-500 Östlich der Elbe | 57 | 7,5-9,0 | 1,6 | 500-630 | | | | | | 3,0 |
|  | III | Gustav Koenigs Westlich der Elbe | 67-80 | 8,2 | 2,5 | 650-1000 | | | | | | 4,0-5,0 |
| | | Östlich der Elbe | 67-70 | 8,2-9,0 | 1,6-2,0 | 470-700 | | 118-132 | 8,2-9,0 | 1,6-2,0 | 1000-1200 | 4,0 |
|  | IV | Johann Welker | 80-85 | 9,5 | 2,5 | 1000-1500 |  | 85 | 9,5 | 2,5-2,8 | 1250-1450 | 5,25 od. 7,0 |
|  | Va | Große Rheinschiffe | 95-110 | 11,4 | 2,5-2,8 | 1500-3000 |  | 95-110 | 11,4 | 2,5-4,5 | 1600-3000 | 5,25 od. 7,00 od. 9,1 |
|  | Vb | | | | | |  | 172-185 | 11,4 | 2,5-4,5 | 3200-6000 | |
|  | Vla | | | | | |  | 95-110 | 22,8 | 2,5-4,5 | 3200-6000 | 7,0 od. 9,1 |
| | Vlb | | 140 | 15 | 3,9 | |  | 185-195 | 22,8 | 2,5-4,5 | 6400-12000 | |
| | Vlc | | | | | |   | 270-280 195-200 | 22,8 33,0-34,2 | 2,5-4,5 | 9600-18000 | 9,1 |

Figure 31 Classification System of the European Waterways

Several examples for the expectations on part of inland navigation shall call on politicians to take actions:

- The **harmonizing the competitive conditions** between road, railway and waterway should be initiated to shift cargo transport from the congested roads to the waterways with a high level of free capacities. On part of inland navigation tax privileges are not addressed but rather burden dependent charges for the road-bound cargo traffic.
- When planning new **distribution centres** inland waterways should more intensely be taken into consideration (already on the drawing board). Small feeder ships are able to transport the cargo/containers from the ports along the tributaries and canals to (from) the distribution centres. In doing so the existing logistic is used for the transshipment of both cargo and containers to larger inland vessels on the Rhine or Rhine river-sea ships to achieve a better capacity utilization of those ships. Governmental subsidies are not only to enable the improvement of infrastructure but also be granted as knock-on finances for pilot projects
- Funds for the **maintenance and improvement of waterways** have to be increased.
- The **working time of the personnel ashore** in harbours and locks are to be adapted to the requirements of the skipper also covering services at the weekends and on public holidays. On the one hand this would cause changed working times for the concerned personnel ashore and on the other raise the attractiveness of inland navigation for charterers and forwarders.
- Harmonisation of the **financial subsidies for new shipbuildings** within the member states of the European Union.

- **Changing of the manning scale:** With the help of a better education and improved engine control procedures and new nautical techniques it should be possible to reduce the crew for single motor ships – independent of the ship's size – to two persons (1 navigator, 1 boatswain / technician).

- Avoidance of so-called **settlement measures for market structure.** The scrapping action in Germany has not really been advantageous. With the hold-up of new ship buildings technical innovations could not have been realized to a satisfactory extent. The neighbour countries profited from their national actions up to 1990.

- Support of **modernization and innovation actions** not only for new ship buildings but also for older ships to up-date their technical standard comprising the ship's shape and the equipment.

- Support of **research and development.** Due to the necessary interactive co-operation among the research institutes of inland shipbuilding and navigation as well as hydraulic engineering within the field of inland navigation investments do not only cover the improvement of single vehicles but - on account of the complicated framework in general - also the whole traffic on inland waterways. Such basic conditions are e.g.
 - influence of the restricted water depth and fairway width on the operation of ships,
 - change of the waterway boundaries (river or canal bed, bank, embankment) by operating ships,
 - different flow rates of the rivers at different water levels,
 - mutual influence of passing-by ships on confined waterway stretches.
 - high manoeuvrability of ships when entering and leaving locks etc.

5. Final Remarks

The four questions posed at the beginning have been answered in detail within the two chapters 1 and 2. In conclusion it can be noted that spectacular innovations referring to new types of ships as well as to their equipment with modern nautical and technical components do not exist nor are under development. The progress in inland navigation is characterized by evolution but clearly visible when market tendencies are applied. Mostly, innovations will be introduced or carried out, if the transported goods require a change, i.e. because of high quality or quantity. Rather uncommon is the opposite way, i.e. planning, developing and offering sufficient modern tonnage adequate to the market analysis or the transport conditions earlier than charterers demand it. A change in ship operator's view would be reasonable.

Finally, I would like to thank all persons who helped and supported me by frankly answering all my questions, namely

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duisport, Duisburger Häfen AG, Duisburg / Germany, Mr. Staake

Gefonzo B.V., Mr. Fongers, Veere / The Netherlands

Haeger & Schmidt, Mr. Koch, Duisburg / Germany

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In closing, I would like to also thank Mrs Scholten for supporting me in editing this paper as well as Mr Holbeck and Mr Rück for adapting the figures.

A handwritten signature in purple ink, appearing to read 'E. Müller'. The signature is written in a cursive style with a small '4' above the 'l'.

Prof. Dr.-Ing. E. Müller

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