TUG/BARGE SYSTEMS

AN ECONOMICAL ALTERNATIVE FOR THE SHORT-SEA

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ALTHOUGH ON INLAND WATERWAYS PUSH TUG/BARGE SYSTEMS HAVE BEEN IN OPERATION FOR MANY YEARS, IT WAS NOT UNTIL THE EARLY 1970'S THAT THE SEA-GOING TUG/BARGE SYSTEMS CAME INTO OPERATION ON A LARGE SCALE (ABOUT 17 UNITS WERE IN OPERATION IN 1973). THE FIRST SYSTEMS WERE INTRODUCED IN THE U.S. AND JAPAN, AND STILL THE BIGGEST PART OF THE TUG/BARGE FLEET HAS ITS USE IN THE U.S. AND JAPAN, BUT THERE IS A GROWING INTEREST FOR TUG/BARGE SYSTEMS IN NORTHERN EUROPE.

GENERAL

The reasons for development of tug/barge systems in the U.S. are mainly the shipbuilding and shipmanning-regulations peculiar to the U.S. trade. Reduced crew size on tug/barge units offers reduced manning costs compared with a conventional vessel. It is also cheaper to build a tug and a barge in separate specialist U.S. yards than an equivalent conventional vessel and because of the Jones Act, the domestic trades are reserved to U.S. built, owned and manned vessels.

These circumstances do not prevail in other parts of the world and thus other advantages of tug/barge systems are necessary to justify the use of these systems. The most important advantage is the ability to separate the propulsion from the cargo compartment and big savings can be made through 'drop and swap' operations, where the circumstances allow this method. The basic idea of such operation is to keep the most expensive part, which is the tug and crew, fully utilized. The tug is constantly moving barges between the ports, while in each port a barge is being loaded or discharged. Especially in Japan many 'drop and swap' operations exist for moving bulk commodities on short hauls to and from the major industrial centers. There is also a growing number of 'drop and swap' operations in the Baltic area.

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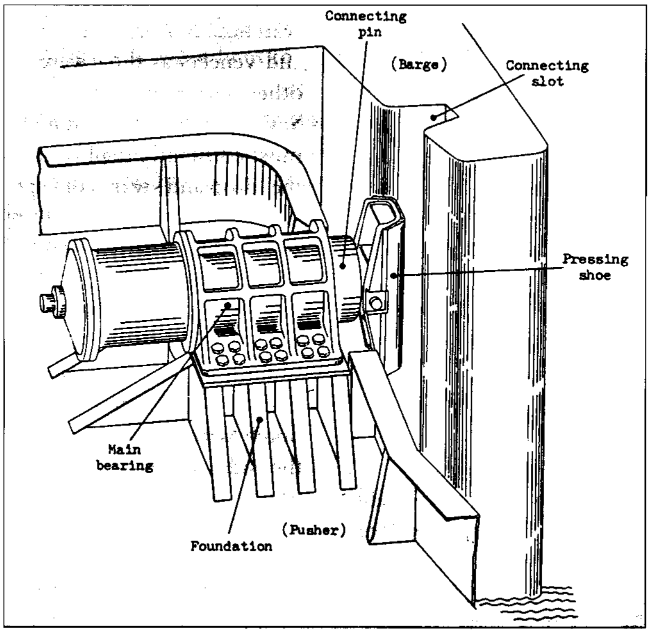


Fig. 2. Articouple-F Series (Deck-Mountable Design)

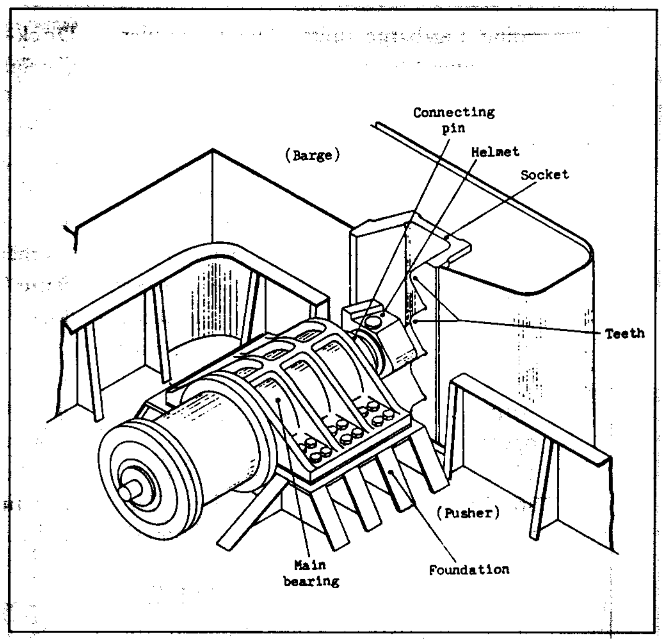


Fig. 3. Articouple-K Series (Deck-Mountable Design).

DEVELOPMENT

For many years tugs and towed barges have been a flexible method of transportation, especially in the United States. A disadvantage of this method is a low service speed, caused by the high resistance of the tug, barge and towing line. Because of the short length, the tug must operate at a relative high speed/length ratio, which induces high wave-making resistance. The barge has a high resistance owing to the skegs, needed for a good tracking characteristic, and the screwrace of the tug. When positioning the tug behind the barge in a stern notch, the wave-making resistance becomes function of the combined length and the tug operates in the wake of the barge. Together with the absence of skegs, due to a better control of the tug over the barge, the total resistance is much reduced.

The connection between the tug and barge was in the first instance one of cables, but this was only possible with a calm sea condition. In rough sea conditions the tug has to take the barge on the line again, because the two vessels are subject to different motion responses due to their shape, displacement and position on a wave. This system is known as the first generation tug/barge system.

It is clear that the longer the time pushing instead of towing, the higher the efficiency of the trip. Second generation systems are designed with a deeper notch and hardware to permit the tug to push in sea conditions with waves up to 3 to 4 meters. Third generation tug/barges systems are designed with a rigid or non-rigid linkage with the aim to permit the tug to push in every severe sea-state.

THIRD GENERATION TUG/ BARGE SYSTEMS

Non-rigid systems

Non-rigid third generation systems have connection devices which allows varying degrees of freedom between the tug and the barge. Most of these systems use a standard tug, fitted with a coupling mechanism, so that the tug can also operate as a salvage or harbour tug. The resistance of these systems is somewhat higher than that of conventional ships of the same size, due to the clearance between the barge and the tug and the non-optimal flowlines in the aftship of the combination. Seaworthy non-rigid systems are the Artubar, Artcouple and Intercon system.

Artubar

The first articulated system was the Artubar concept, developed by E. Fletcher. A standard design tug is provided with a steel hinge pin, which enters a socket in the sides of the barge notch. This allows the tug to rotate in a longitudinal plane about the pin axis in a pitching mode, while all other relative motions are restrained. The pins need to have a large diameter (from 1 to 2 meters) and are lubricated with non-polluting grease. The system has been tank-tested in severe sea conditions, with waveheights up to 14 meters and one of the existing Artubar units has survived hurricane conditions with waveheights up to 10.5 meters.

During a trip through the Gulf of Mexico with the 30,000 dwt. tug/barge unit G.R. Moir/Mary Flood (fig.1) of Gulfcoast Transit, I had the experience that the behaviour of the unit in waves was very smooth. Connection and disconnection of tug and barge took only few minutes, while the hydraulic pins were controlled from the bridge. Connection is only possible at two different draughts, at ballast draught and fully laden draught of the barge, intermediate draughts have to be adjusted by ballasting. Gulfcoast Transit in Tampa, U.S. operates a fleet of 15 tug/ barge units in the coal, phosphate and grain trade in and outside the U.S. The two Artubar units are used for voyages to South America, Africa and Europe.

Articouple

The Articouple linkage was developed by T. Yamaguchi of Taisei Engineering, Tokyo. Articouple comes in a number of variations, and can be fitted to any normal tug.

The F-type (fig.2) was developed for stonedumping-barges and is able to allow quick changes in draught, without separation of the tug and barge. A disadvantage of this system is that it is limited in operation to seas of less than 3.5 m. waveheight. In 1985 a more seaworthiness version of the F-type was developed. The FR-coupler is nearly similar to the F-type, except that the pressing shoe has a hole in its outer end face, from which a wedge is extended out by the function of a sub-cylinder incorporated in the connecting pin. Its sharp tip will engage into the rack, fitted in the vertical groove of the barge. When the wedge is retracted, the coupling is like the F-type, but if the wedge is extended it prevents the pressing shoe from vertical slip, even when the waves are high.

Another Articouple coupler is the K-type (fig.3). This coupler is able to operate in any severe sea-state and is used for ocean-

going tug/barge units. The K-coupler can connect the tug to the barge, without previously adjusting the draught, by means of a teeth arrangement in the notch of the barge.
All couplers are available in two models: deck mountable and side mountable types which depends on the forecastle arrangement of the tug. The dimensions of the coupler depends on the natures of the related vessels and conditions of service routes. About 85 tugs have been fitted with Articouple couplers, most of them operate in Japan and the Far East. To date 12 tug/barge units in Northern Europe are fitted with K-type couplers. The Svitzer Salvage Company of Denmark (controlled by the A.P. Moller group) has a large fleet of 5 tugs and 13 barges (including two newbuildings) in the range of 7500 – 12000 dwt. for moving coal from Poland and the U.K. to Denmark and the distribution of coal to the powerplants in Denmark (fig.4).

Intercon
The Intercon is similar in concept to the Articouple K-type, but instead of a hydraulic pressing mechanism they operate by a screw-drive mechanism. One tug/barge unit moving oilproducts in the U.S. is fitted with this connecting system.

Fig. 4. Tug/barge Unit with K-type coupler.

Rigid systems
Tug/barge units of the rigid type have a connecting system that don't allow any relative movement of the tug to the barge. Most rigid systems has essentially the same lines as a ship, giving these tug/barge units the same resistance, motions and fuel economy as conventional ships. Rigid systems are known as Integrated Tug Barge units (I.T.B.) and can be divided in three groups, the dock-like notch type, the catamaran tug type and the three point connection type.

Dock-like notch
Carport and Seawedge
The Carport system, designed by George G. Sharp, was constructed in 1951 and was the first ocean-going I.T.B. The barge had a deep notch with a bottom floor and longitudinal structural overhangs at the main deck level of the barge (fig.5). The tug fits into the barge dock, being restrained at the keel by the wood-sheathed dock bottom and the upper girder overhangs. Before connection, the tug has to be ballasted to be at about the same draft as the barge and enters the barge dock under its own power. The final linkage is made by portable hydraulic jacks and is secured by large turnbuckles at decklevel. Seawedge is basically a mechanized version of the Carport system, so that the large turnbuckles could be avoided.
In 1962 two additional 5590 dwt. barges were constructed in France and were operated with the, to Seawedge converted, Carport unit as a one tug/ three barge system, moving timber and veneers from Belem, Brazil to Savannah, U.S. and grain and general cargo on the return trip. While a loaded barge was sailing between the ports, one barge was acting as a warehouse in Brazil, receiving the timber and veneers as they were cut, while the other barge was being discharged in Savannah. The tug and it's crew were almost constantly deployed, fully utilizing the 'drop and swap' concept.

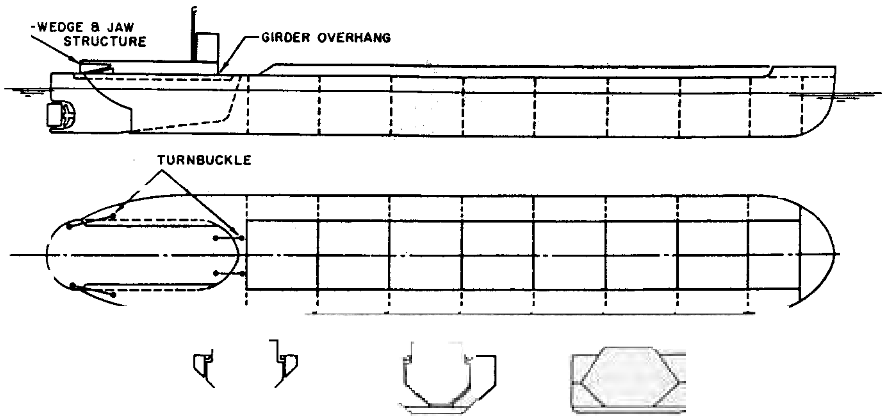


Fig. 5. Carport

Breit-Ingram
This system was developed by Breit Engineering Co. and the Ingram Corporation, both of New Orleans. The basic concept is again similar to the Carport system. The barge has also a deep stern notch with a floor and overhangs along the side of the notch which end in a wedge shape at the stern. The tug has a bow-mounted hydraulic ram which, once the tug is in the notch, extends forward, lock into a barge-mounted structure and than retracts and thus pulling the tug tightly into the notch.
The Ingram Corporation set up the company Tug Barge Systems Inc. (T.B.S.I.) which has all the patent rights and allowed some shipbuilders to construct Breit-Ingram units under license. To date ten units were built according to this system.

Catamaran tug

Catug
Hvide Shipping Inc. of Fort Lauderdale developed the Catug system along with consulting naval architects J.B. Hargrave. The system is of a unique design, incorporating a twin-screw catamaran tug that fits closely over and around a specially contoured barge stern. The barge stern is shaped as a tongue-like and tapered extension to form a wedge. The tug and barge are locked together by two hydraulic tension latches on maindeck level. On the innerside of each tug hull, a ledge extension is fitted restraining, together with the catamaran deckstructure, vertical movement (fig.6).

The catamaran configuration of the tug permits easily fared lines to give a good waterflow to the propellers. A critical factor in the tug design is the longitudinal stability and therefore connection and disconnection has to take place in a harbour and it is not possible to operate the tug separate from the barge. For connection an exact alignment of barge and tug is needed, which is a time-consuming operation. Eleven Catug-units were built, mainly as a 'manning rule beater', because none of them operate in a 'drop and swap' operation.

Valmet Catug
This system, designed in 1984 by the Valmet Shipyard of Helsinki, is similar in concept to the Catug designs of Hvide Shipping. Although no units of this type were built, the idea of Valmet is interesting. The system is designed for both ocean traffic and inland waterways and includes a 2000 HP catamaran tug and a barge, which has an own propulsion unit of 400 HP. For ocean and coastal traffic the barge is pushed by the tug, but on inland routes the barge is able to move independently. The independence of the barge enables barge size and loading capacity to be maximized, to correspond with canal and lock dimensions. Like the Catug designs of Hvide, problems may occur with longitudinal stability and the small enginerooms in the hulls of the tug.

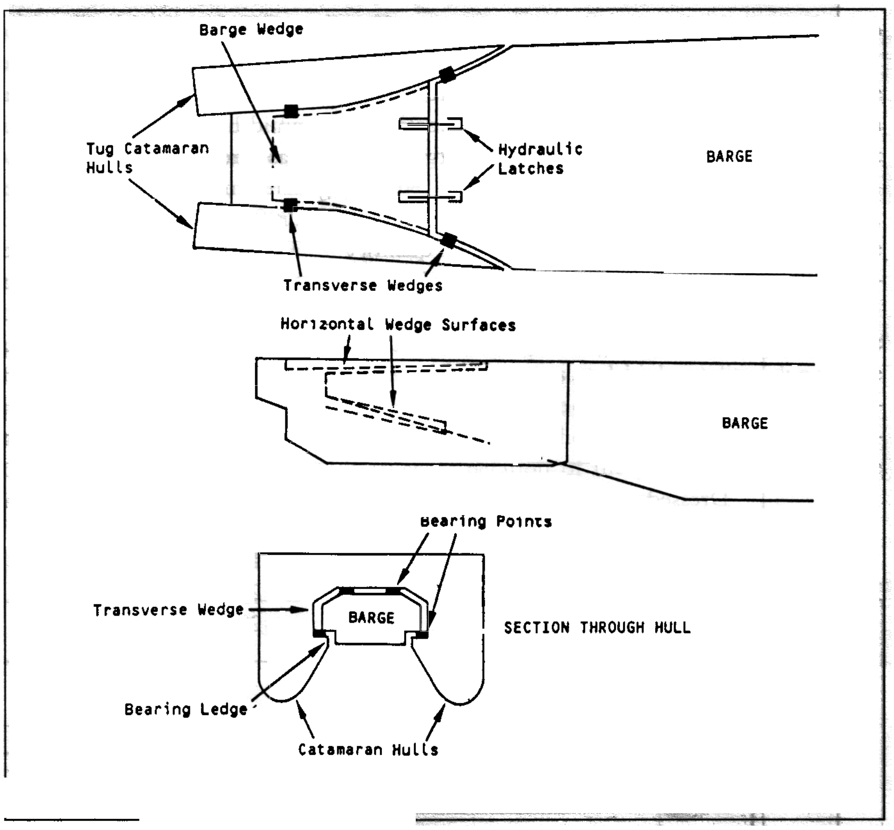
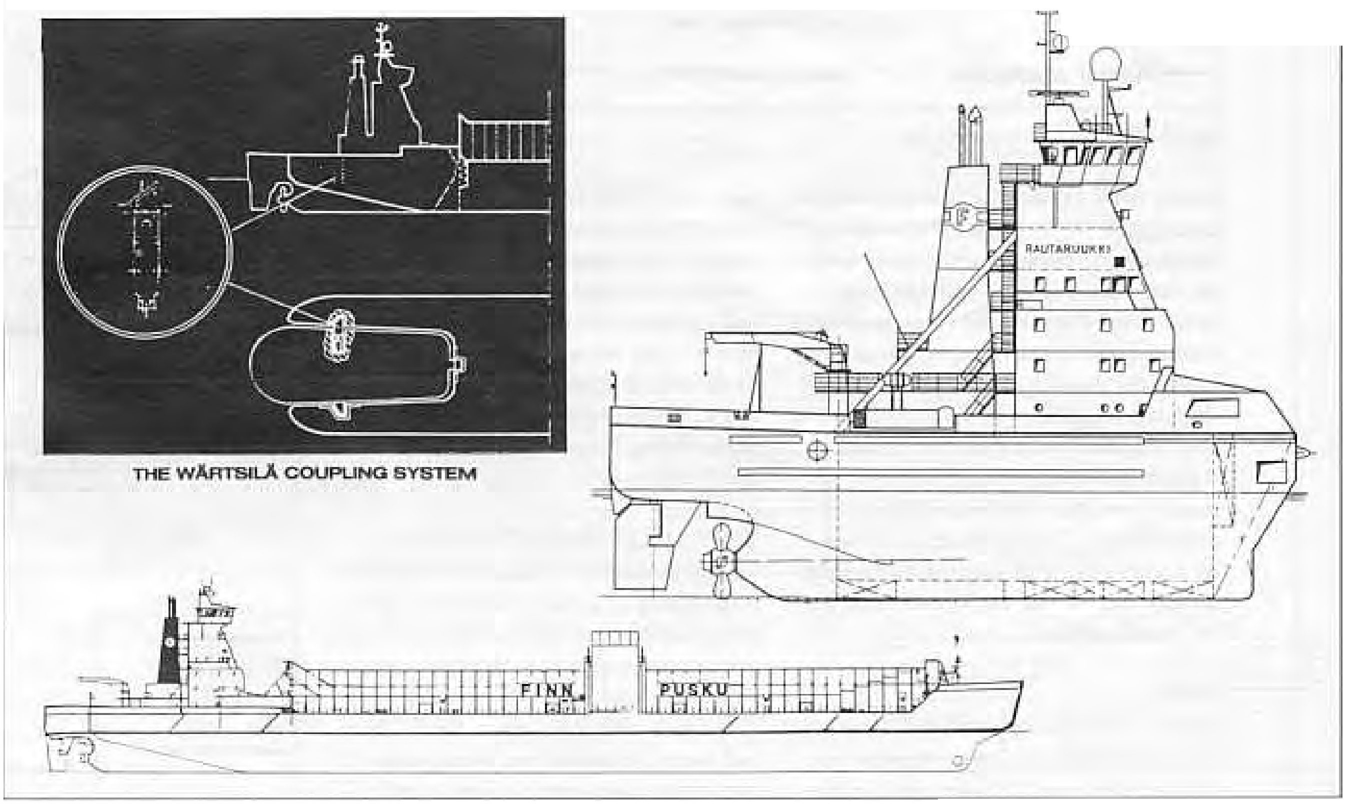


Fig. 6. Catug.

Three point connection

Finnpusku
After many years of research carried out by Wärtsilä in cooperation with Finnlines, a new integrated tug/barge system came into service in 1986/87, known as Finnpusku. The system (fig.7) includes two tugs and five barges which are fitted with the Wärtsilä Marine Locomotive connecting system.
The main features of the connecting system are the tapered shape of the pusher, a fixed bow wedge and two hydraulically

Fig. 7. Finnpusku.



operated wedges, far aft on each side of the pusher hull. In the barge the connecting sockets for these wedges are located at three levels, which gives the possibility to connect the pusher to the barge at different loading conditions.
The two tugs and five barges can carry about 3 mln. tonnes a year. This quantity is distributed among the following cargoes and routes:

ticouple couplers. The Triofix system consist of 3 hydraulically operated rams, one in the bow and one on each side, amidships of the tug. The barge notch has three mating surfaces with a rack arrangement, providing connection at any draft.
The two side couplers are designed for two connecting modes. The first mode is when only the pressing shoe is extended,

			Loading hours	Unloading hours
Dressed ore	Lulea – Raahe	40%	5	24
Coal	Tahkuluoto – Raahe	10%	32	32
Coke	Ventspils – Raahe	10%	36	32
Coal	Gdansk – Southern Finland	20%	36	36
Logs	Gdansk – Southern Finland	20%	48	48

Tabel 1.

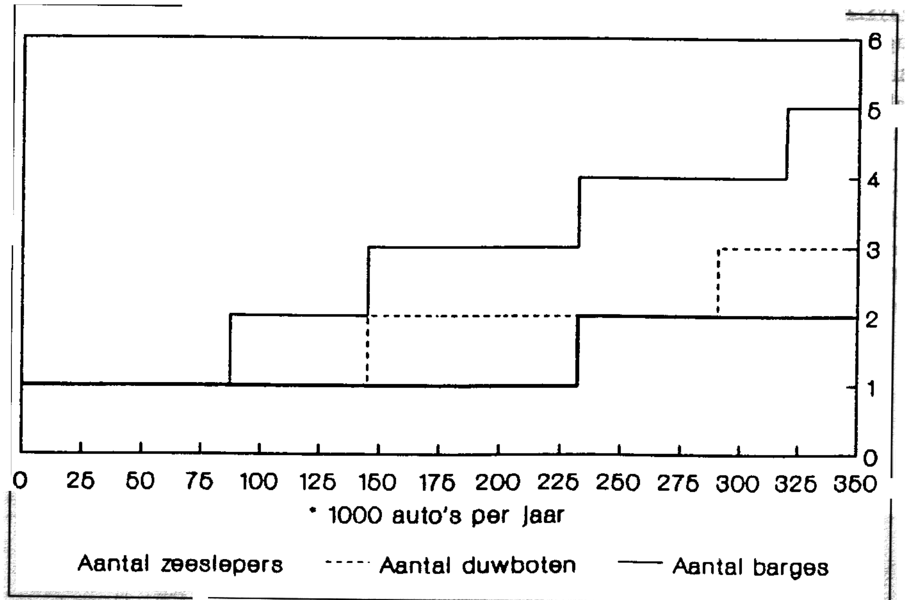


Fig. 9. Build up of transportsystem.

On the route Lulea – Raahe dressed ore is transported to serve the steelworks of Rautaruukki. Because of the short loading time, the tug stays with the barge at Lulea, from there it sails seven hours to Raahe, picks up an empty barge and leaves the loaded one behind for discharging at Raahe.
That tug and two barges are owned by Rautaruukki itself and are in the winter season available for time-charter. The second tug and three barges are owned by a consortium of companies and the management of all the vessels is in the hands of Finnlines.

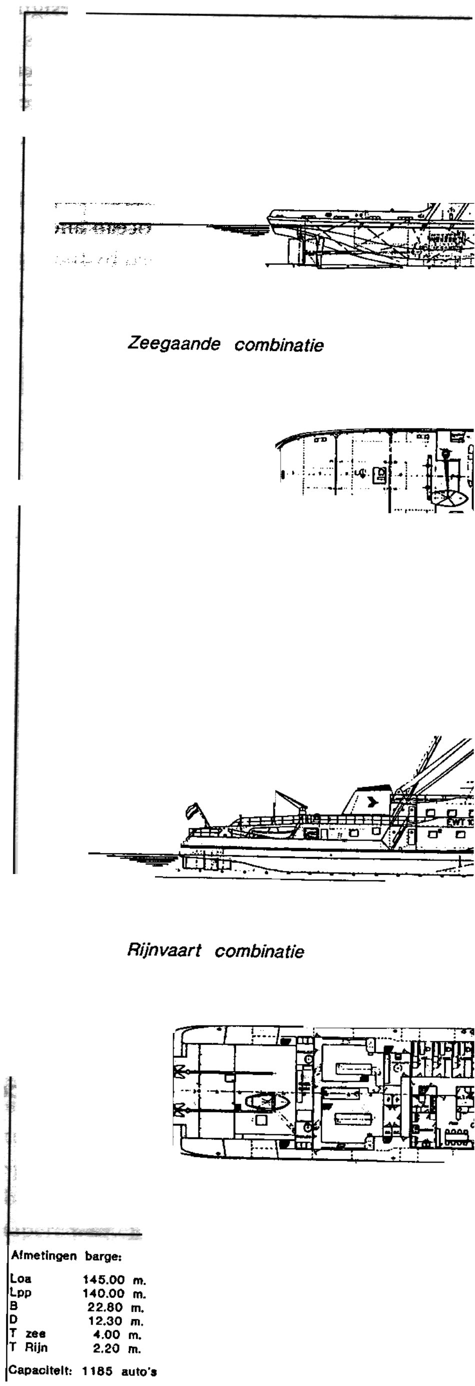
Triofix
Triofix is a rigid connecting system recently developed by Taisei Engineering, Tokyo, the same designers of the Ar-

allowing the tug to move vertically to the barge for instance during loading of the barge. The second mode is when the pressing shoe and tip are both extended and together with the extended bowcoupler a rigid three point connection is made, which let the combination act as a single vessel in waves. To date seven japanese tug/barge units are fitted with the Triofix system.

WHY TUG/BARGE SYSTEMS ?

One of the features of tug/barge systems is the ability of a 'drop and swap' operation. Calculations proved that such an operation can give cost reductions up to 30% compared to a conventional ship. The favourable conditions for a 'drop and swap' operation are: a high ratio of port-time to sea-time (at least a ratio 1) and a limited number of ports (2 or 3) and also the need for short-term warehouses can be an important factor.
An other advantage of tug/barge systems is the reduced manning, due to the low gross tonnage of the tug, a reduction of 1 to 7 people can be achieved under dutch regulations, depending on the G.T. of the comparable ship.
In the combined Rhine-sea trade tug/barge systems can offer cost advantages by pushing shallow draught barges at the Rhine by small river pushers with a shallow draught, low profile and 'river'-manning. At sea the barges can be pushed by a sea-going tug with unrestricted

Fig. 8. System for cartransport



draught (and thus large propeller diameter) unrestricted profile and manning according to the regulations for sea-going tugs.

CAR TRANSPORT

My graduate work at the department of Marine Technology, T.U. Delft, incorporated a design and feasibility study of a tug/barge system for car transport (fig.8) on the Rhine and North Sea.

The cars will be transported on the route between the U.K. and Cologne. Two barges will be pushed at sea by a 3980 kW, sea-going tug and at the Rhine by a 1840 kW, river pushboat. The barge can sail at the Rhine with a full load of 1185 cars at a draught of 2.20 m. and with a shallow draught pushboat pushing, the combination will not be effected by low waterdepths in the summerseason. For a good behavior at sea, the barge can be ballasted at a draught of 4.00 meters. The connection between barge and sea-going tug is made by the deck mountable Articouple K-type coupler, because of the proven seaworthiness and simplicity of fitting out a normal tug with these couplers. Connection between river pushboat and barge is a conventional one with cables. The two barges meet each other in Rotterdam and change from pusher, one will go further to Cologne and one to the U.K.

With the combination of two barges, one river pushboat and one sea-going tug, a yearly transport capacity of about 145,000 cars one way, can be reached. The total system can easily be build up, step by step, in accordance with the transport capacity which is needed by adding more barges and pushers (fig.9). The system is able to transport cars at low costs and high quality, due to the avoidance of transhipment of cars in Rotterdam, the reduction of manning and seperation of the propulsion unit for the sea- and river-part.