VOITH

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# Voith Water Tractor – The Hallmark of Improved Ship Safety

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# Summary

**The Voith Water Tractor and Voith-Schneider Propeller are well known in the shipping world. This article discusses the technical and operational aspects of this type of propulsion, highlighting the contribution it makes to ship safety when fitted to tugs engaged in harbour duties and as escort vessels.**

# Introduction

It is natural that in the wake of a major ship accident, international discussion on improving ship safety is clamorous. As time goes by, public interest dwindles and, as a result, the pressure for action reduces. Nevertheless, some steady development does improve ship safety. This paper reviews the milestones on the way to improved ship safety that resulted from the introduction of the tractor concept by Voith – from the first Voith Water Tractor Stier in 1954 (Figure 1 ) to the commissioning of the enhanced escort Voith Water Tractor Lindsey Foss in Seattle in 1994, and recently the most powerful escort Voith Water Tractors Nanuq and Tan'erliq in Valdez, USA (Figure 2).

In the forty-five years between these dates, the main concept developed by Wolfgang Baer in the early 1950s remains unchanged. Only with modified requirements has the power risen from 550 kW for Stier to 6,920 kW for Nanuq by the factor of about thirteen. Continuity proofs: the basic concept of the ideal ship handling vessel was detected as early as 1954. Harbour authorities, pilots and towing operators – a team in close co-operation and responsible for ships' safety in ports, should know details of the reliability and efficiency of the 'external engine and rudder' on the other end of the rope in all circumstances. The features that the Voith Water Tractor offers to the industry, and the enormously increased capabilities by design adaptations during the last years, have proved that under the steadily changing operational requirements around ports, the Voith Water Tractor will play a key role in the total safety system of a port or terminal.

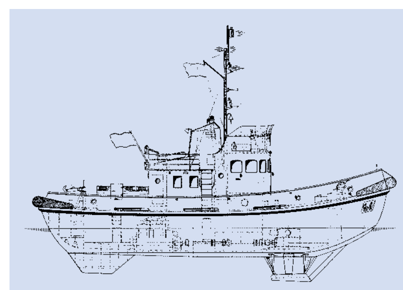

*Figure 1: Voith Water Tractor Stier, 1954 prototype of the safety concept*

*Figure 2: Voith Water Tractor Tan’erliq of 6,920 kW*

# Safety aspects of a Voith Water Tractor

Nowadays, tugs have to be considered as an integral part of the safety system of the port, rather than only aids for mooring and turning during berthing and unberthing. The tug, with its specific capabilities, will be part of a complex safety system, whereby a properly designed tug with superior dynamic ship handling characteristics can reduce costs for shore side equipment, like extension of breakwaters, e.g. can increase or maintain an existing traffic density and may allow approaches to the harbour in much worse weather conditions for all ports, which have to serve larger sizes of merchant ships.

Such a consideration demands a dynamic tool capable of providing shiphandling forces over a large range of speed. With a reduction in ship speed, the controllability of merchant vessels diminishes and external assistance is required. Enhanced ship assistance, or in modern terms – escort, is required where a malfunction on-board a ship may cause serious danger for traffic, shore installations or the environment.

Figure 3 illustrates where and when assistance is required. The efficiency of the ship's own rudder reduces approximately with the ship's speed squared. As a result, the ship's own controllability decreases rapidly. Depending on the ship's size, windage, environmental and local conditions, an enhanced external assistance is required at different speeds.

The concept of a modern ship handling vessel has to be analysed: What size of ship handling forces will be necessary under specific operational conditions and where will be the optimum position for applying these external forces in order to secure the controllability of a seagoing vessel? What are the reaction forces on the tug? And consequently how should a tug be designed to achieve and to control the required forces without risks to the tug's own safety?

The aim of a modern tug design is to improve the safety by choosing a tug capable of performing harbour assistance with multipurpose functions like powerful fire-fighting, oil-pollution control etc., and to be also capable of performing escort operation whereby the additional cost for such an enhanced operation has to be a minimum. The main dimensions for such a vessel have still to be within the size of a harbour tug.

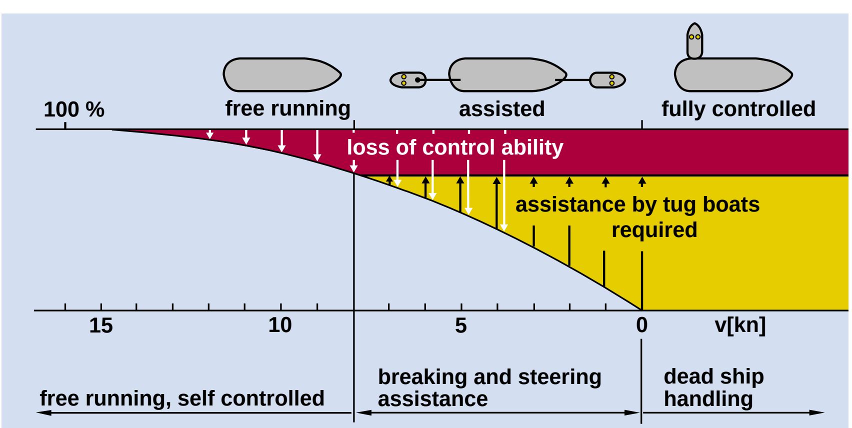


*Figure 3: Ship handling ability of a Voith Water Tractor and its importance for ship's safety*

# Characteristics of the tractor concept

The basis of the tractor concept resulted from a critical analysis of the requirements in ship handling, which is why all essential details of the concept are matched for the job. The Voith Water Tractor concept is mainly characterised by the arrangement of the Voith-Schneider Propellers at one end, well protected by the propeller guard. The skeg and towing equipment are arranged at the other end, and centrally positioned is the control position (Figure 4). Everything else is 'auxiliary' which has to be adapted for use. The terms 'bow' and 'stern' are irrelevant because of the omnidirectional performance of such vessels.

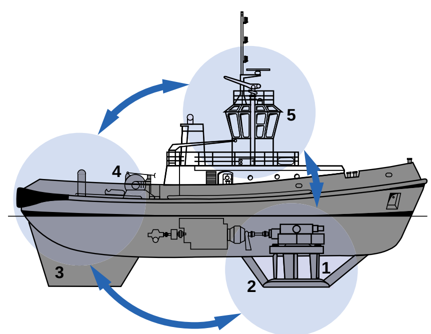


*Figure 4:*
*Characteristics of the Voith Water Tractor concept:*
*1 Voith-Schneider Propeller (VSP) under head of the ship*
*2 Nozzle plate*
*3 Stabilising fin under after ship*
*4 Towing gear*
*5 Central wheel house*

# Bow control of the tow

It is well known that the efficiency of a bow tug is small and decreases when the speed increases. One reason for this is the power consumed to overcome the tug resistance by holding the speed. A further reason is the magnitude of lever between the attack point of towrope force and attack point of hydrodynamic transverse forces.
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Despite this well-known hydrodynamic axiom, making fast to the forward centre lead cannot be avoided in many harbours. To take the heaving line, the tug comes close to the tow's stern. Critical hydrodynamic interaction forces are a result. Additionally, the tow rope force may be critical with regard to the tug's stability. At the beginning of the 1950s, the extensive model analysis of the forces and momenta between the tug and tow resulted in one of the basic features of the Voith Water Tractor, with the direct control ahead of the pivot point of the vessel to overcome this classical safety risk in ship handling. Nowadays this aspect is of fundamental importance as the ship handling speed has increased remarkably as above mentioned. Figure 5 illustrates interaction forces and momenta between tug and tow.

In conjunction with the bow control of a Voith Water Tractor, the protection guard beneath the propeller protects the propulsion system against side contact with the towed vessel (Figure 6). Designed as a nozzle plate, the nozzle effect increases the propeller thrust and also protects the propeller against grounding and supports the vessel in the dry dock (Figure 7).

Redundancy of the two independent propulsion systems is an even more stringent safety aspect, as with high ship speeds the risk of engine failure still exists and the resulting consequences of such a failure without redundancy would be disastrous.

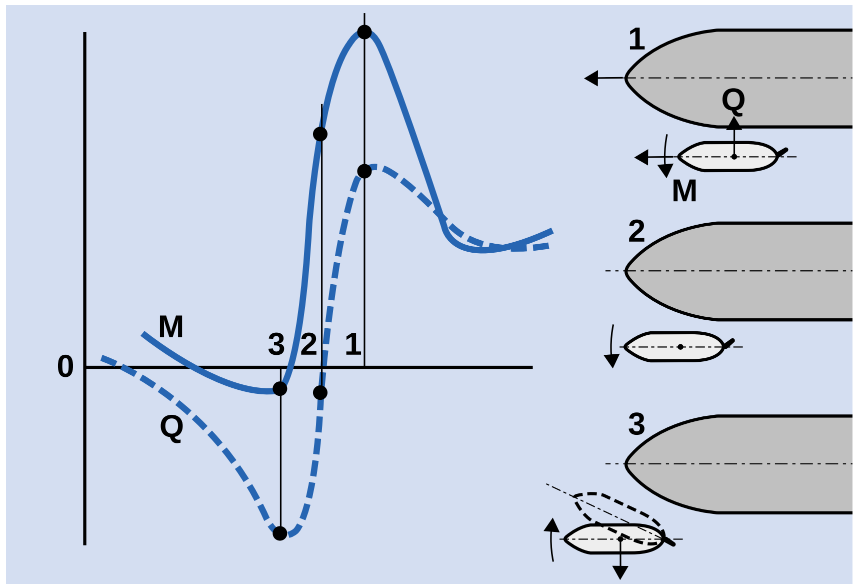


*Figure 5: Interacting forces and momenta*

*M = momentum*
*Q = transverse force*

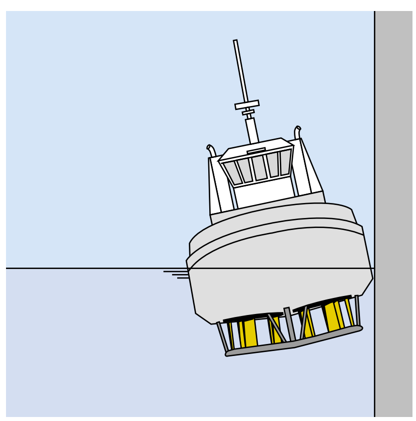

*Figure 6: Function of protection plate: protection of VSP against vessel contact*

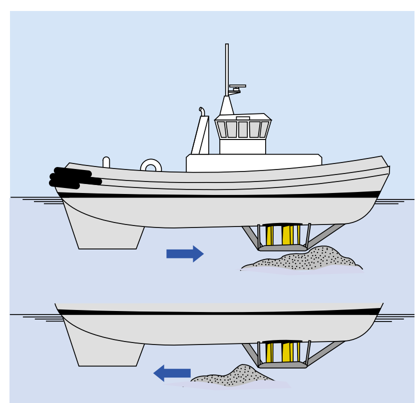

*Figure 7: Function of protection plate: protection of VSP against grounding*

The specific steering characteristic of the Voith-Schneider cycloidal propulsion provides the same controllability, and nearly the same manoeuvrability, with one or two propellers. This again will be an important safety aspect enabling the tug captain to finalise the ship handling job without jeopardising his tug or the tow.

# Making fast, aft centre lead

In the same way that the best position for the propeller and rudder on a conventional vessel is at the stern, the most efficient position for a tug is aft. Because of this, and related to the basic features of the tractor introduced by Voith forty-five years ago, on this type of tug a stable equilibrium exists between the tow rope force and propeller thrust, eliminating the danger of capsizing by transverse tow rope forces such as on any type of stern driven vessel. Such a tractor can safely follow the approaching ship with skeg first. The controllable pitch characteristic of the cycloidal, or Voith-Schneider Propeller, allows utilisation of the full engine power immediately into a braking or steering force, as pitch control allows precise adaptation to any inflow condition and prevents stalling problems on the main engines that occurs with fixed pitch propellers. Again, the redundancy of the entire propulsion system gives a very high degree of safety.

At slow speeds, in addition to the ship's own rudder forces, the thrust of the propellers of the tug will be utilised for steering and braking the tow. With increased ship speed, the direct method cannot be used any more, as the side force necessary to keep the tug in position consumes a higher percentage of installed power and reduces the tow rope force. At a certain speed, the tow rope force drops to zero. For higher speeds the indirect method has been developed for Voith Water Tractors. In this condition, the hydrodynamic lift from the tug's hull and the highly efficient skeg will be used to develop a large force for transmitting through the rope into the tow (Figure 8).

The propulsion of the tug may be seen as a steering gear forcing the rudder, i.e. the tug's hull and skeg, in the necessary angle of attack to generate the highest lift forces. In this situation, heeling forces on the tug, rising with the square of the speed, are an accepted side effect; the propulsion and it's proper location become additionally important with regard to safety. Again, it must be pointed out the need for redundancy, as in such situations any uncontrolled side forces must be avoided.

The designer's challenge for a modern tug design is the optimum selection of the main dimensions of the vessel, the fine design of ship lines and the skeg, and the relevant appendages with respect to lift coefficients; and also, the proper balance of forces to minimise the power requirements and to accommodate the large tow rope forces under dynamic ship handling and different sea states, with respect to the stability of the tug and the technical limits of the towing gears and rope properties. Especially the design of lines, together with the appendages, to achieve the optimum lift coefficient has to be considered in close relationship to the corresponding attack point of hydrodynamic forces (CLR) and a very fine tuned position of A-staple. The design of high-lift skeg configurations is very important to meet the requirements on high lift coefficients as well as an optimised position of CLR (Figure 9). It is evident that tug design becomes more complex than ever before and that only a consideration of all operational requirements will lead to a cost-effective and very competitive design suitable for all future ship handling requirements.

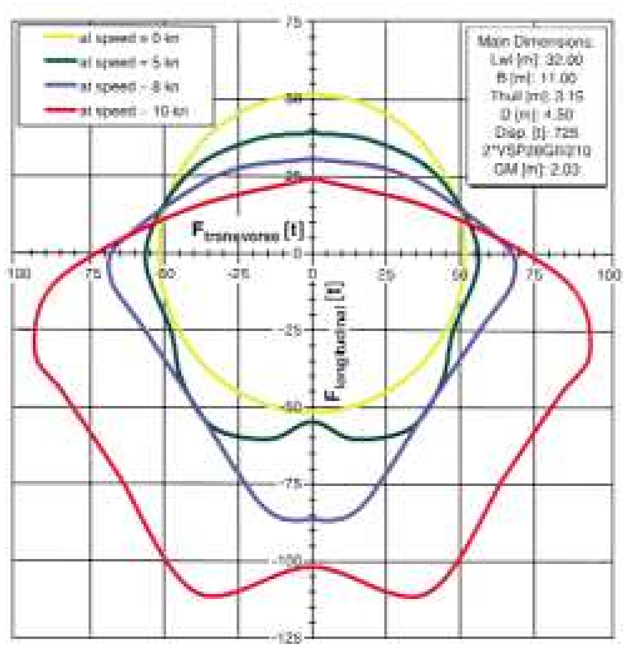


*Figure 9: Voith Water Tractor with escort capability. Dynamic shiphandling forces*

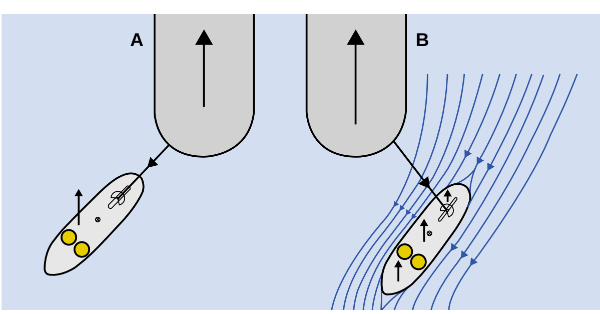


*Figure 8: Operating on a tow line: A - Direct steering mode, B - Indirect steering mode*

# Control system of the tractor

A very important aspect of the safety system is the human factor. Empirically, a high percentage of accidents are caused by human errors. The operability of the control has a high importance for the safety of the system. It is a feature of the Voith-Schneider Propulsion that full thrust can be exerted in any direction, almost instantaneously and also directly, without any intermediate thrust angles. The result is high thrust with rapid, delicate and precise control. This working principle of the Voith-Schneider Propeller together with the human engineered control system offers decisive advantages. The arrangement of controls on the centrally located bridge allows steering in any situation. Re-thinking or re-orientation is not necessary if the mode of operation is varied from bow to stern tug or from direct to indirect method, or even if two, or only one, propeller is operational. This avoids panic reactions in emergency situations, with the possibility of mistakes with great consequences. In Figure 10, a control stand installation with mechanical control transmission from the bridge to the propeller is shown. The transverse components (steering pitch) of both propellers are synchronised and adjusted jointly by one steering wheel. The longitudinal components (speed pitch) of both propellers can be adjusted independently of each other by speed levers.

*Figure 10:*
*VSP control stand in the wheel house*

# Safety for vessels carrying dangerous cargo

From the beginning, Voith Water Tractors have been used for dynamic ship handling, without using any term like escorting, e.g. the Voith Water Tractors safeguarding vessels at the Panama Canal.

Already the Amoco Cadiz accident in 1978 on the French coastline had bred the idea of preventive safety for vessels carrying dangerous cargo. Two Voith Water Tractors, Abeilles 31 and Abeilles 32, have been constructed for salvage, harbour assistance, fire-fighting and oil-skimming.

The idea of escort vessels was first published after the accident of the Exxon Valdez in Alaska. Since then the controversy has been discussed publicly. In the United States, the development has passed the discussion stage and as a result of extensive research in the Gulf of Mexico the Voith Water Tractor Loop Responder acts as an Emergency Response Vessel (ERV) in daily operation at the local offshore oil terminal. Also, on the Pacific coast in the Puget Sound area, close to Seattle, the first enhanced escort Voith Water Tractors Lindsey Foss and Garth Foss had been set to work in 1994. At Canada's revolutionary oil platform, Hibernia, which is the world's first iceberg resistant platform, two escort Voith Water Tractors built for Newfoundland Transshipment Ltd. are safeguarding tankers leaving the refinery at Placentia Bay. The final decision of the Department of Environmental Conservation of Alaska, after several years' investigation concerning the application of best available technology for escort vessels, led to the construction of the most powerful escort Voith Water Tractors, Nanuq and Tan'erliq.

The Norwegian company Bukser og Bjergning A/S built their first purpose-designed escort Voith Water Tractors for the 'skeg-first' mode. Six in total of these designs are in operation at important Scandinavian oil terminals (Figure 11).

*Figure 11:*
*Voith Water Tractor Bess of 4010 kW*

# Conclusion

Ajax, the most powerful escort Voith Water Tractor for Østensjø Rederi A/S Norway, has been in operation since late 2000.

Despite the development in power, size and design of these purpose-designed and enhanced escort vessels, the basic features and results can be used by modern harbour Voith Water Tractors with escort capabilities. According to our understanding, escort is nothing more than ship assistance according to the common ship handling requirements, with some additional tasks at higher speeds.

At the beginning of the 1990s, the tragic accident of the tanker Aegean Sea at the entrance to La Coruna, Spain, influenced the tug owners to adapt their Voith Water Tractor new-buildings for escort duties.

Similarly, in Southampton (UK), Cork (Ireland), Antwerp (Belgium), Venice, Trieste and Ravenna (Italy), Valencia (Spain) and Bremerhaven (Germany), Voith Water Tractors are used for multipurpose harbour duties and escort capabilities.

The technical progress in Voith Water Tractor design is based on an on-going comprehensive investigation programme, comprising model tank tests in-house and at different model tank test laboratories world-wide, computer simulations, as well as full scale measurements at different terminals and locations. The goal of these studies is to find an answer for the ship handling part of the complex situation of a total safety system of a port or terminal, in order to assist all parties involved, such as tug operators, oil companies, harbour authorities, safety bodies, insurance companies, etc. in finding an answer when striving for real preventive measures to minimise the risk.

For today and the future, tug operators with the best and most versatile equipment are going to attract the most business. With the Voith Water Tractor, pilots and tug operators, communicating through the tow rope, have the ideal tool for modern ship handling, especially when ship handling ability, safety, reliability and versatility count. The long time proven basic features of the Voith Water Tractor and the increased capabilities by design adaptations of this type of vessel in recent years are the answer for a cost-effective, multipurpose harbour with escort capabilities. In this process, the Voith Water Tractor will play a key role in the total safety system of a port or terminal.

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