Britain, 1978) with 230,000 tons. Some other spills are those of the *Exxon Valdez* (Alaska, 1989) 40,000 tons, the *Aegean Sea* (Spain, 1992) 70,000 tons, the *Braer* (Shetlands, Great Britain, 1993) 85,000 tons and the *Sea Empress* (Milford Haven, Great Britain, 1996) with 65,000 tons of oil spilled.

Tanker groundings and collisions seem to account for about 30% each of oil spillage volume due to tanker accidents (see figure 9.1). Many factors contribute to these accidents, including technical failures, reduced visibility and human failures. In 1993 the UK P&I Club published its third Annual Analysis of Major Claims, covering the period 1987-1992. According to this, 50% of all pollution claims were due to human factors.

Whether these accidents could be prevented by the use of escort tugs depends on several factors, such as the real causes of the accidents or the location. One can ask the following questions: Did these accidents take place in a port area or port approach, being locations where escort tugs would normally operate? What were the technical failures leading to the accidents and what was the cause of these failures? Were human failures involved, either on board the tanker or ashore? Would escort tugs have been able to make up for these human failures? Were the environmental conditions such that escort tugs could have provided any reasonable assistance?

9.2 Studies on escort requirements

The answers to the previously mentioned questions should be part of a thorough study into whether escorting by tugs is suitable for a particular port or port approach. Such a study should include:

- A review of the present situation and a risk assessment.
- Based on the findings of the risk assessment, a study focused on whether escorting could reduce the risks during a passage.
- Defining escort tug requirements, escorting procedures and training requirements.

A review of the present situation should consider the following aspects in relation to each other, but not limited to:

- Particulars of a port and its port approach, such as:
  - Restrictions, bends, distances, water depths, vertical tides.
  - Environmental conditions at all parts of the passage, i.e: currents, winds, visibility, waves, swell, ice, day/night.
  - Islands, piers, bottom structure and channel sides – rocky or sandy, flat or steep.
  - Available anchorages.
  - Traffic separation schemes.
- Aids to navigation.
- Vessel traffic services and information exchange with ships and pilots.
- Shipping traffic – number, size, draft, speed and cargo.
- Arrival and departure policy for ships of different types, dimensions and/or draft regarding vertical tide, currents, waves, wind and /or visibility.
- Pilotage.
- Statistics available on past accidents involving transiting ships and the causes of accidents.
- The environmental impact of an incident.
- The available tugs and tug assistance.
- Size, type, loading conditions and manoeuvring particulars and underkeel clearance of ships which are considered to need escorting.

This review may result in an extension or adaptation of certain procedures or port services regarding arrival/departure policy, aids to navigation, the vessel traffic system, tug assistance or pilotage. When the situation is such that no further improvements of the existing situation are possible or the improvements made are insufficient to reduce the risk of groundings and spillage, a risk assessment study can be carried out. This determines the probability and severity of an incident and consequently the areas of concern. Measures such as the provision of escort tugs can then be considered in order to enhance safety of passage. The severity of an incident with respect to oil spillage will, for instance, be less in port approaches or areas with sandy banks. Figure 9.2 gives the results of a Norwegian study showing the effect of some measures. The results shown in the graph are not generally applicable, but are only valid for the area studied.

To find out whether escorting tugs are able to reduce risks during a passage, a number of accident scenarios for the areas of concern should be developed. These should take into account factors such as the navigational restraints, the ships concerned, speed, underkeel clearance, environmental conditions including wind,

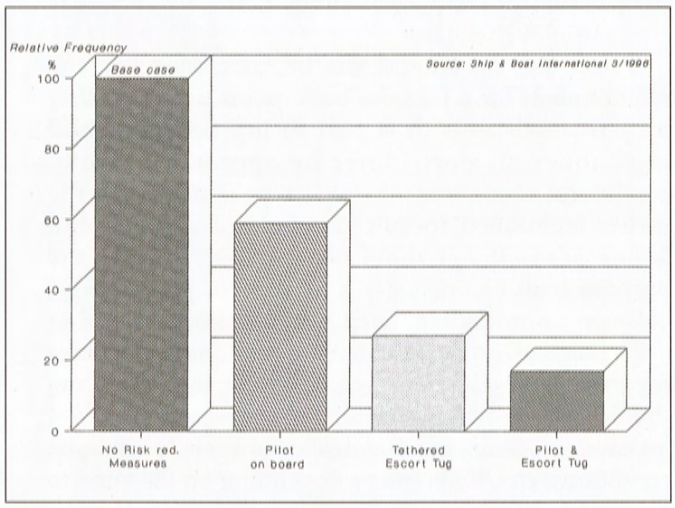


Figure 9.2 Typical effect of frequency reducing measures Grounding under power and drifting – calculated incident reduction with escort

current, waves and swell and, if necessary, other shipping traffic. Scenarios should be developed for engine and rudder failures and possibly scenarios for a ship under power, steering various dangerous courses which, if no measures were taken, would result in grounding and/or collision.

Response times, i.e. the time between the moment a failure happens and the moment the tugs are effective, should also be included in the failure scenarios and be based on realistic assumptions, because this time is very critical to effectively limit the advance and transfer of a tanker after a failure.

When the number of available tugs is found to be sufficient to provide the additional service of escorting, studies should give answers to the question as to whether these tugs are capable of preventing a grounding or collision in case of failure on board a tanker or when steering a dangerous course. Different assisting methods for these tugs can be assessed, with tugs secured or not. The study results might include:

- A recommendation for a particular tug configuration of available tugs, and
- Definitions of acceptable environmental conditions and safe ship speeds, or
- Recommendations and requirements for the design of a totally new type of tug.

The simulation technique mentioned in paragraph 8.3.2 is very suitable for investigating a large number of different scenarios, tug types and tug configurations.

Where the study outcome results in the design of a purpose built escort tug, performance calculation programs can be used at an early stage to predict the performance of different tug types and various design alternatives. Model tests may be required to optimise tug design, evaluate tug performance and investigate safety limits for escort operations.

From the foregoing it can be concluded that the requirements for a purpose built escort tug may differ by port, such as with regard to tug size, type and capabilities, as ports differ by approach, lay-out, conditions, circumstances, ship's type and size. For the earlier mentioned specific port related accident and failure scenarios, it should be studied whether the purpose built escort tug(s) is capable of preventing a collision or grounding. Such a study may also lead to port related escort regulations or operational procedures regarding safe escort speeds, whether the escort tug should be tethered to the ship (active escorting) or not (passive escorting), maximum allowable environmental conditions, etc., if necessary depending on the zone to be passed.

In addition to the port specific escort tug requirements based on research, there might be general legal requirements, e.g. national regulations, to be met with respect to the capabilities an escort tug should have in controlling a disabled vessel.

In cooperation with experienced pilots, ship masters and tug captains, escort tug suitability and related procedures can finally be tested on full mission bridge simulators. They can simulate the escort tug(s), ships to be escorted, areas of concern, and environmental conditions, provided the simulator meets the demanding requirements for this kind of simulation.

Note:

Model tests and simulation techniques are very useful tools to get insight into the capabilities of escort tugs of various designs and into the effect such escort tugs have on an escorted ship's behaviour in various conditions and circumstances. Limitations of simulation, and of model tests, may lead to an overestimation of an escort tug's performance, which may then include a risk for the escort tug, its crew, as well as for the escorted vessel. To what extent study results differ from reality can only be verified during full scale trials under comparable conditions. This applies to normal and certainly to wave and swell conditions, as escort tugs often do operate in exposed areas. Full scale tests are carried out to verify the capability of a new escort tug in delivering the required steering and braking forces, for instance, for an escort tug class notation of DNV. During such trials sea conditions are usually rather fair. In wave and swell conditions, however, high peak forces can occur in the towline if an escort tug has to apply maximum steering forces in case of a failure on board the escorted ship.

Simulation of dynamic forces in the towline, for instance, that result from out-of-phase motion responses of ship and tug to the waves are extremely difficult to simulate. The same applies to a realistic simulation of the characteristics and dynamic performance of a towline and towing winch. The escorted ship does affect the wave pattern, which again affects the escort tug's capabilities (see also References for 'Creating the Virtual Tug'). So, a tug's escorting performance in wave conditions, and particularly safe tug manoeuvres and limits of safe tug operation, also taking into account various directions of incoming waves, can not be determined accurately. This also includes the effect an escort tug may have on the escorted ship in such conditions.

Summarising, verification by full scale trials of model tests and simulator research is needed for both aspects: escort tug capabilities as well as the effect an escort tug may have on a disabled ship in normal and in wave conditions. Further research starting with full-scale measurements may be required to get better insight into the whole interaction process between tug and ship during emergency escorting in sea conditions.

With respect to the latter, for comparable reasons

Maritime Research Institute Netherlands (MARIN) proposes a joint industry project which comprises: 'full scale measurements of towline, winch and tug behaviour under well-defined tug assist operations; modelling of dynamic towline loads, tug motions and stability; assessment of operational safety, as well as design and operation practice' (MARIN Report, April 2002).

9.3 Escorting objectives and methods

The objectives of escorting are:

- To reduce the risk of pollution in port areas and port approaches due to groundings or collisions caused by technical or human failures on board a tanker.
- To apply steering and braking forces to a disabled vessel by escorting tugs and to keep it afloat, or limit the impact of collision or grounding if they unfortunately happen.

Whether steering, braking or both forces are required depends completely on the situation. When failures occur it is steering forces in particular that are mostly required to keep a ship out of a dangerous area. It might even be necessary in certain situations not to reduce ship's speed in case of engine failure in order to avoid grounding. A lot of effort is required by tugs to restore ship's heading or rate of turn when, due to engine or rudder failure, a large loaded tanker with headway takes a sheer, particularly if underkeel clearance is small.

Escort tugs should also be capable of controlling, within reasonable margins, ship's position when speed has dropped, meaning that tugs should be capable of pushing as well as towing, which requires good fendering and the correct static bollard pull. Different methods of escorting are in use, viz.:

- Escorting by a number of normal harbour tugs.
- Escorting by specifically designed escort tug(s).

Escorting tugs accompany a ship either with towline(s) secured or free sailing at close quarters, ready to make fast and render assistance if a failure occurs. Escorting by more or less normal harbour tugs is generally carried out only in port areas, over a relatively short distance and at low speeds. Escorting with specifically designed escort tugs is carried out in port approaches, over longer distances and at higher speeds.

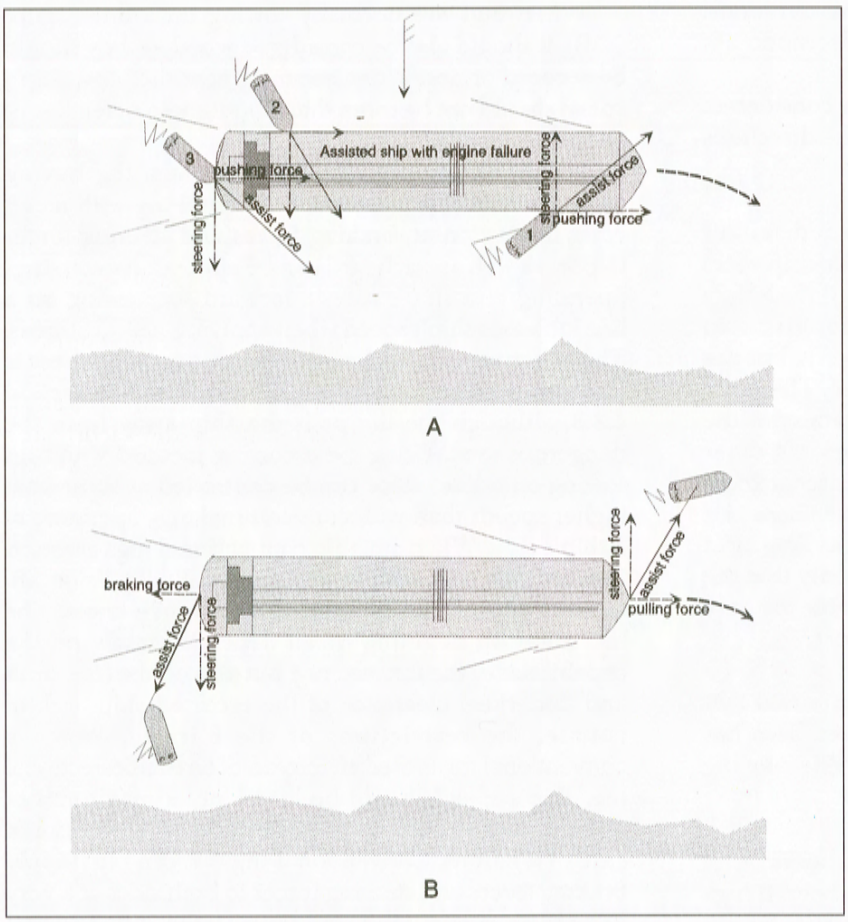


Figure 9.3 Direction of forces applied by assisting harbour tugs
Escorting harbour tugs assisting a tanker in different modes. Tanker had an engine failure and veers to starboard. Tugs are braking the sheer. Directions of longitudinal and transverse forces applied by the tugs are shown

9.4 Escorting by normal harbour tugs

9.4.1 Tug use

In some ports around the world only one harbour tug, which can be of any type, is used for regular escorting of tankers. In other ports the number of tugs is based on size of ship and available suitable tugs. Depending on the situation tugs are secured or not. The escorting distance is generally only a few miles, though ships are sometimes escorted over longer distances through rivers and channels. Usual speeds are about five to six knots, but when the tugs are unsecured or for longer escort distances speeds up to nine knots are not uncommon.

Escorting by normal harbour tugs can be carried out with tugs operating at a ship's side, which may include a rudder tug, or by tugs towing on a line or a combination of these methods. The method used depends largely on local practice and available type of tugs. Whether tugs are secured or not depends mainly on the restrictions of the fairway and environmental conditions. The following should be taken into account:

- It takes time to secure tugs, even when sufficient ship's crew are available and where needed.
- There is no forewarning of the type

of failure, neither when nor where. In event of failure there is no prediction of how the ship will behave. She may go straight on, veer to starboard or veer to port.

Securing tugs can take several minutes. This has consequences for tug response time, the time between the moment failure happens and the moment tugs are effective. Several very costly minutes may be lost.

On the other hand, for tugs operating at a ship's side, securing or not may have consequences for the number of tugs required. When tugs are secured at one side and the ship veers due to a failure, they might not be at the correct side to cope with the sheer. This implies that tugs are needed on both sides if secured. When not secured, available tugs can be directed by the pilot to the required position.

Forward tugs towing on a line are more flexible in applying towing forces to port as well as to starboard. The same applies to after tugs towing on a line when equipped with omnidirectional propulsion. Based on the restrictions of the fairway with respect to ship dimensions and draft and taking into account the available number and type of tugs, it should be carefully considered whether the tugs will be secured or not. Tug positions should be included in these considerations. Current and wind also play a part in the decision.

Different escorting tug positions are now considered. In figure 9.3A and B tugs are shown and the directions of the applied forces.

In the example (figure 9.3A), a loaded tanker underway at speed has an engine failure. The ship veers to starboard, which cannot be stopped by the ship's rudder. As explained in section 4.3.3, tug no. 1 is not in a position to counteract the sheer effectively, but the position of tug no. 2 is much more effective. The same applies for the rudder tug no. 3. Effectiveness of the rudder tug in applying steering forces does not differ much from a tug at ship's side with lines secured, except for wave conditions. In that case the effectiveness of a tug operating at a ship's side declines fast. The most significant difference with tug no. 1 is not only that the rudder tug is in an effective position, but is able to apply steering forces to starboard as well as to port.

Regarding tug no. 1 it should be kept in mind that this tug might even have an opposite effect. This has been further explained in paragraph 4.3.3, Effective tug positions.

If the ship veers to port instead of starboard, tugs nos. 1 and 2 are ineffective in braking the sheer. If tugs are secured at a ship's side in order to anticipate failure they are needed on both sides or at least a rudder tug should be used, provided the tug is sufficiently powerful. When the tugs at a ship's side have a bowline they can apply braking forces as well as steering forces.

Tugs at the ship's side applying braking forces also create a turning moment. This is another reason why tugs are needed at both sides. A rudder tug can apply braking forces without creating a high turning moment.

When tugs are not secured at a ship's side but stand by at a close distance, they can take position depending on the situation that arises due to a failure.

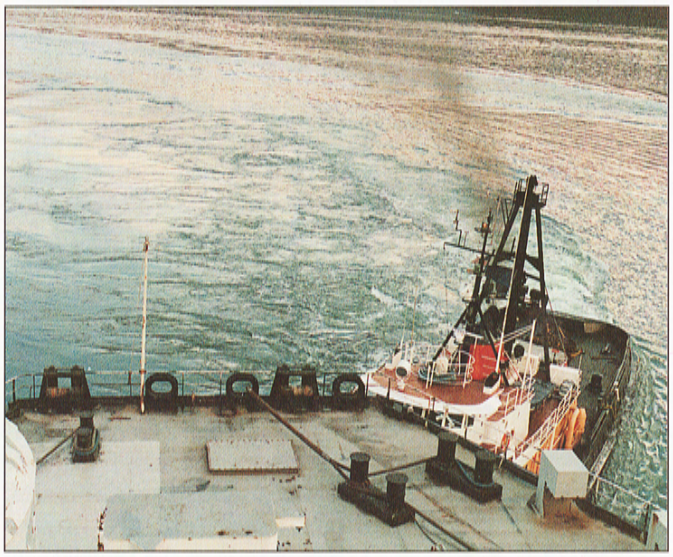
At speeds higher than three to four knots conventional tugs lose their effectiveness in applying steering forces, while applied pushing forces increase. Pushing forces have a tendency to increase ship's speed, which should generally be avoided. Waves further decrease a tugs' effectiveness. Tugs with omnidirectional propulsion are more effective, including at higher speeds, in applying steering forces without increasing ship's speed.

There is another aspect to be taken into account, which could be important, for instance, in situations involving partly loaded tankers and strong beam winds. Although tug no. 2 and 3 are trying to stop the sheer, they will push the ship, together with the wind, into the direction of the dangerous area, while tug no. 1 is pushing in a safer direction.

When tugs are normally towing on a line (figure 9.3B), it should also be considered whether they should be secured or not. When securing near the bow, ship's speed should not be more than about six to seven knots.

When towing on a line with a stern tug having omnidirectional propulsion or a combi-tug with an aft lying towing point, braking forces and steering forces to port as well as starboard can be applied. As with tugs operating at a ship's side, a forward tug towing on a line increases ship's speed when applying steering forces. The effectiveness of a forward tug in opposing sheer is low compared to a stern tug, as explained in section 4.3.3, although the tug pulls the ship away from the dangerous area. Using the escorting method with tugs towing on a line, ships can be controlled at somewhat higher speeds than with conventional tugs operating at a ship's side. When suitable conventional tugs are used forward and tugs with omnidirectional propulsion aft, escorting speed can be around four to five knots. The limitation on escorting speed depends mainly on the capabilities of the forward tug, but also on the size, draft and underkeel clearance of the escorted ship and, of course, the restrictions of the fairway. When a conventional tug is used aft instead of an omnidirectional tug, ship's speed should be low – say a maximum of three to four knots – to permit control of the vessel in case of a failure. Conventional tugs aft can only apply braking forces and steering forces to both sides at a very low ship's speed, while a conventional tug forward cannot apply any braking forces.

Escorting by conventional harbour tugs is still possible in a number of compulsory escort areas in the



Photos: MARIN, The Netherlands

Figure 9.4 Photographs taken during escort trials in Prince William Sound, Alaska, August/September 1993. Three tug positions are shown: 1) pushing at the bow, 2) near the stern and 3) a tug operating as 'rudder tug'. They are twin screw tugs with three rudders. Tugs 1 and 3 have a bollard pull of 68 tons and tug 2 of 50 tons. The tankers are the loaded 'S/R Benicia', 170,000 dwt and the 'Arco Independence', 262,000 dwt, 80% loaded

USA, although escort tugs with omnidirectional propulsion are increasingly used and their escort performance is being further investigated.

A summary is given in paragraph 9.6 of escort regulations in force in the USA and Europe. When escorted by normal harbour tugs, tanker speeds can not be high. This is reflected in the regulations, which state that escorted tankers should not exceed a speed beyond which the escorting tugs can reasonably be expected to bring the tanker safely under control within the navigational limits of the fairway.

Summary

Escorting using normal harbour tugs is comparable with tug assistance in ports as are escorting speeds. The number, type and bollard pull of harbour tugs used for escorting should be carefully considered taking into account the restrictions of the fairway, ship size, draft and freeboard, underkeel clearance and environmental conditions. It should also be carefully considered whether escorting tugs should be made fast to a vessel or not. When tugs have to make fast at a ship's side, it may influence the number of tugs required.

The speed of the escorted tanker with a maximum of about five knots should allow tugs to influence tanker movement effectively in the event of a casualty. Rudder tugs and tugs positioned at port or starboard quarter are at the most effective locations to oppose a sheer. Rudder tugs are most flexible because of their capability of applying steering forces to both sides. These tugs all apply pushing forces at the same time which may increase a ship's speed. The effect is less when omnidirectional tugs are used, which are also more effective at higher speeds. When tugs at a ship's side have a bow line these tugs can, like a rudder tug, also apply braking forces.

A forward tug towing on a line is more flexible in applying steering forces both to port and starboard. The same applies for a stern tug towing on a line, provided the tug has omnidirectional propulsion or is of the combi-tug type. These types of tug can, as a stern tug, apply braking forces as well, which is not possible for a forward tug towing on a line.

If a sheer is towards a dangerous area, the applied steering forces of the after tugs are directed towards the dangerous area and the steering forces of the forward tugs away from it.

9.4.2 Escort training and planning

Also when normal harbour tugs, conventional tugs for instance, are used for escorting, training and escort planning are important subjects, although depending on the local situation. These subjects are amongst others discussed in the next paragraph.

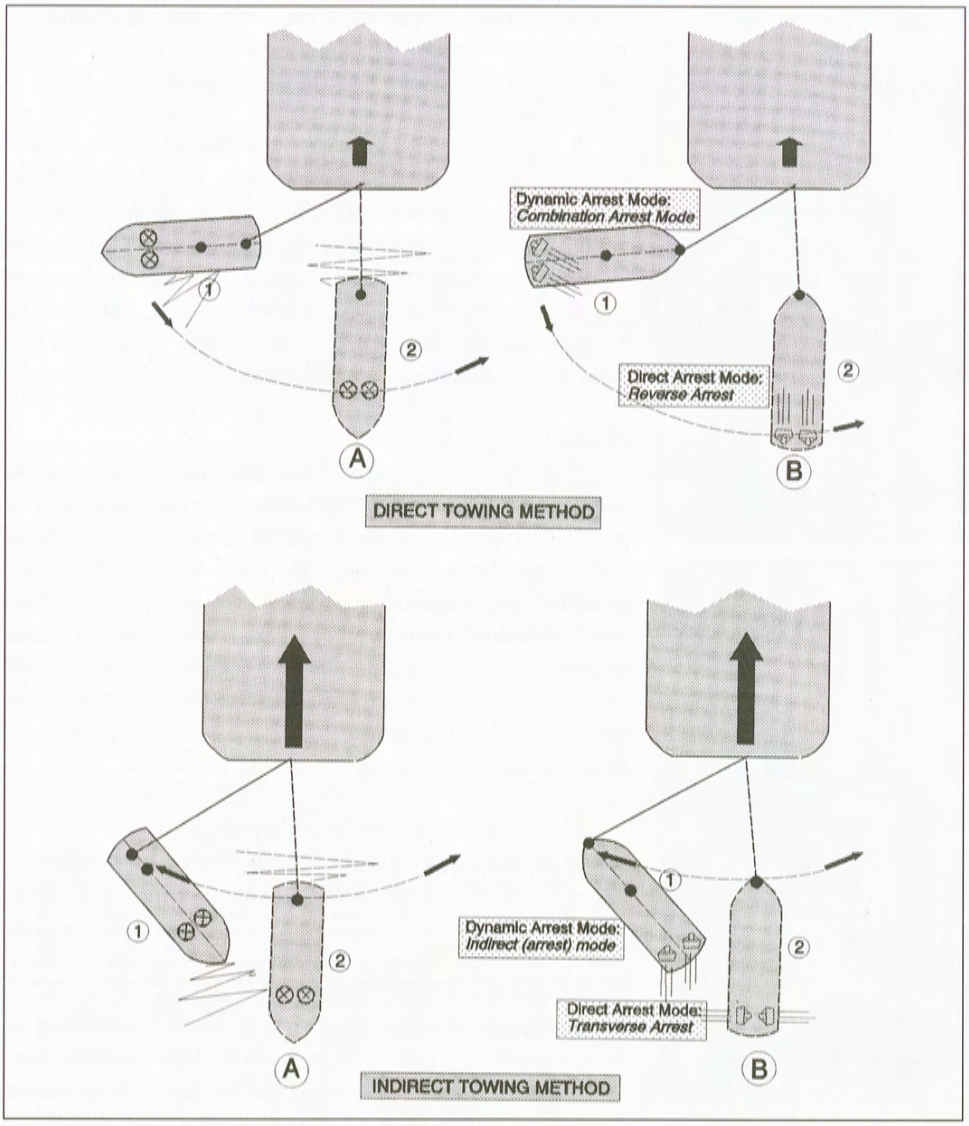


Figure 9.5 Terminology relating to direct and indirect towing methods
A: Tractor tug. B: ASD/reverse-tractor tug
Position 1: Steering and retarding. Position 2: Retarding

9.5 Escorting by purpose built tugs

9.5.1 Type of tugs, performance and operational requirements

Types, terminology and factors affecting performance

The name escort tugs is basically used for tugs specifically designed to escort ships over long distances and at relatively high speeds. Escort tugs are all of the omnidirectional type, whether ASD/reverse-tractor or tractor. Most escort tractor tugs have VS propulsion.

The tugs are secured (tethered) to a ship's stern or unsecured (untethered), but ready to provide immediate assistance in case of emergency. When secured to the stern of the escorted vessel, escort tugs are able to apply high steering and/or braking forces if required in case a failure happens on board the assisted ship. Steering forces at high speeds are generated in the so-called indirect method.

Before discussing important aspects of escort tug performance, a number of somewhat difficult terms are first explained.

Figure 9.5 shows what are generally called the direct and indirect towing methods. In addition, terms are given as used by propulsion manufacturer Aquamaster (figure 9.5B). The indirect arrest mode is recommended for initiating a turn, while the combination arrest mode is recommended for opposing a turn at low and at higher speeds. The achievable braking forces in the reverse and transverse arrest modes have been discussed in section 4.3.2 and are shown in the graph in figure 9.7. According to Aquamaster these forces seem to correlate very well with full scale trials.

In direct mode, achievable steering forces decrease when speed increases. At speeds above normal harbour speeds of about five to six knots and, amongst other things, depending on the bollard pull of the tug, higher steering forces can be achieved in indirect mode (see figure 9.8).

For speeds between three and seven knots a method used by escort tugs in a growing number of USA ports for applying steering forces, is the 'powered indirect

Courtesy: Captain Gregory Brooks, USA

Figure 9.6 The reverse-tractor tug 'Lynn Marie', which has a forward skeg, applying steering forces by using the 'Powered Indirect Manoeuvre'. (For particulars of the 'Lynn Marie' see figure 9.21)

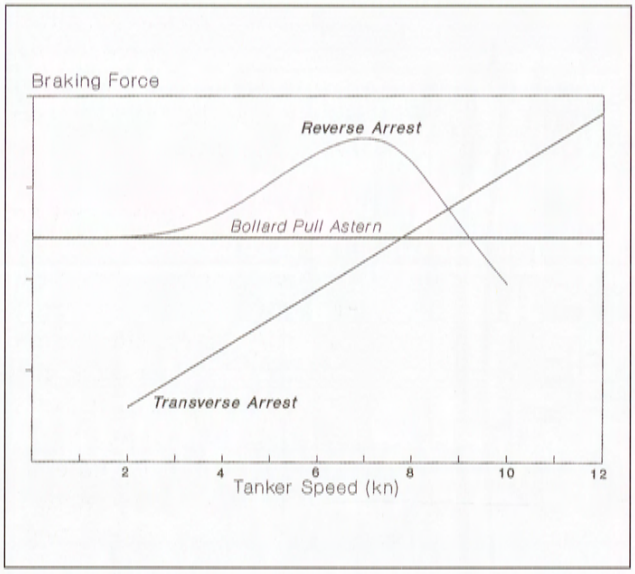


Figure 9.7 Maximum direct braking forces azimuth drive

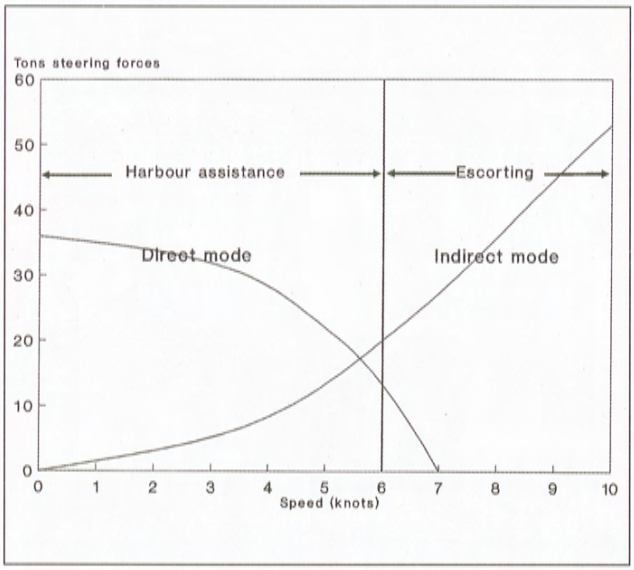


Figure 9.8 Approximation of steering forces of a 36 tons tractor tug

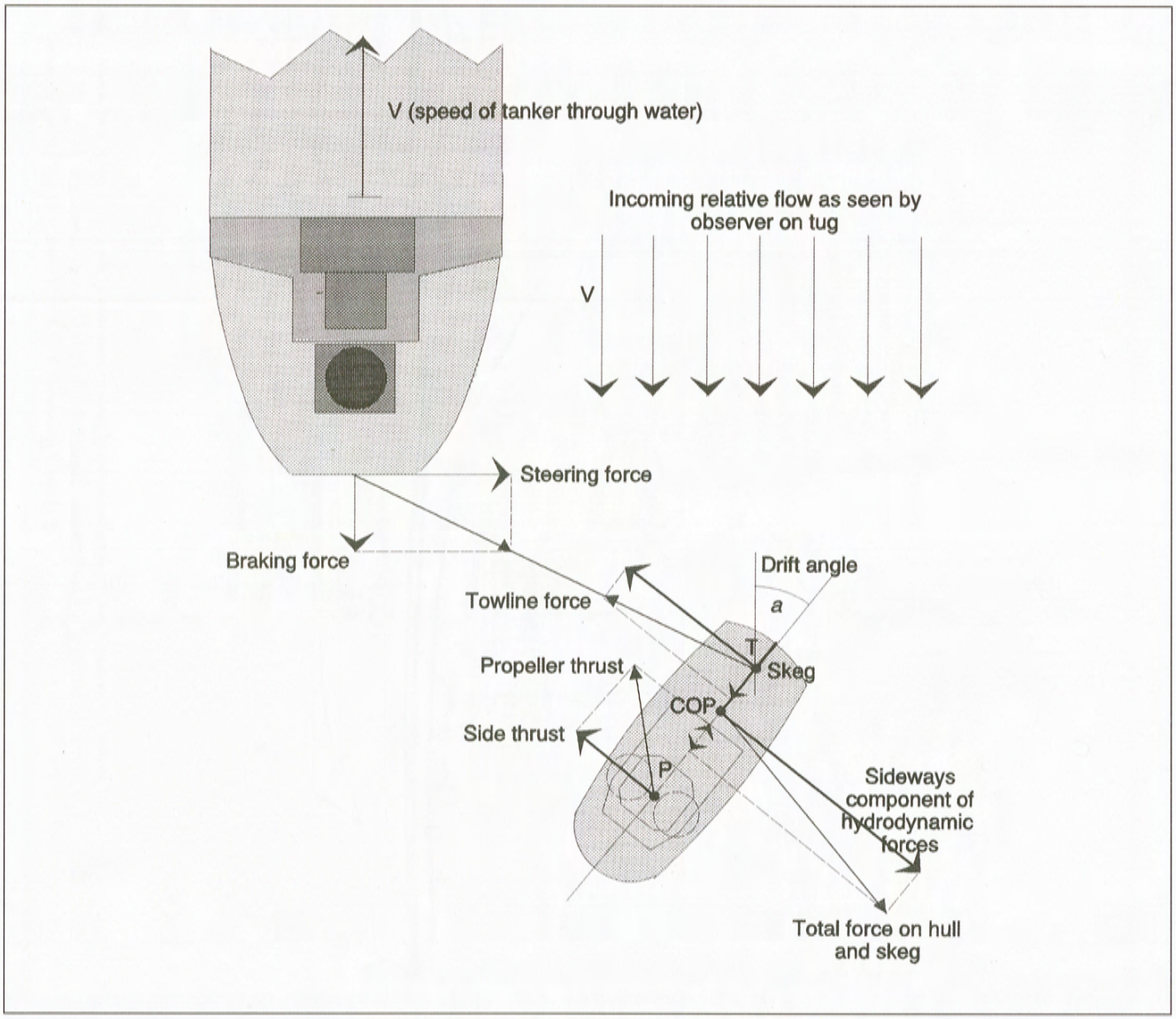
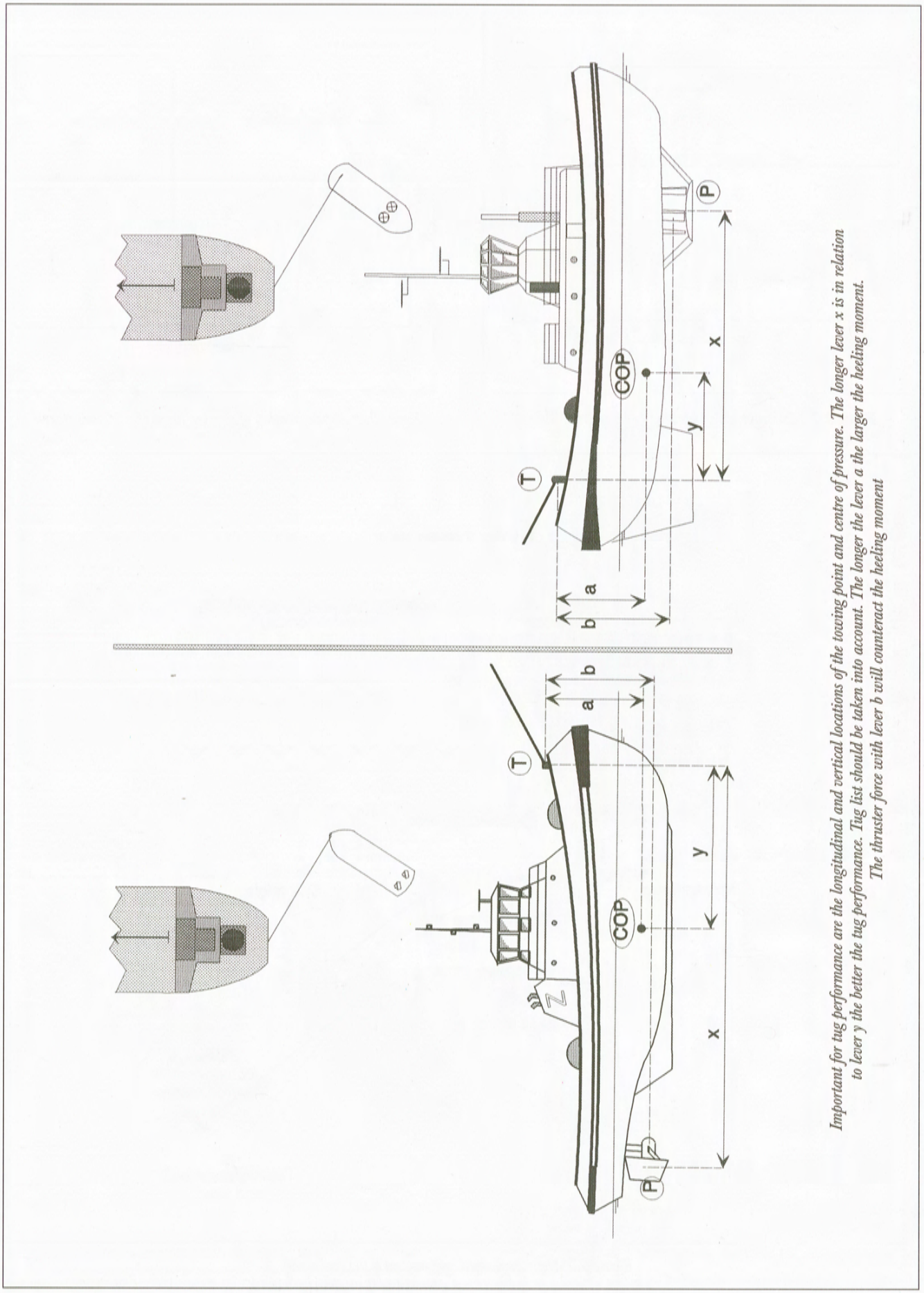


Figure 9.9 Definition sketch of forces on a tug and a ship
Sketch of a tractor tug assisting a tanker in the indirect mode.
The propeller thrust keeps the transverse forces and longitudinal forces, resulting from the hydrodynamic force on the hull and skeg and from the towline force, in balance



Important for tug performance are the longitudinal and vertical locations of the towing point and centre of pressure. The longer lever x is in relation to lever y the better the tug performance. Tug list should be taken into account. The longer the lever a the larger the heeling moment. The thruster force with lever b will counteract the heeling moment

Figure 9.10 Importance of proper locations of centre of pressure and towing point

manoeuvre'. The tug then drives itself out further than position A1 or B1 (see figure 9.5 for Indirect Towing Method) and depending on the speed may reach a position at which the towline is at a 90 degrees angle to the ship's centreline. Then full power is given, with the tug at perhaps up to 70 degrees angle to the incoming water flow. High steering forces can be generated, higher than in the direct towing method. In the five to seven knots speed range line pulls of 75 – 125% of the tug's bollard pull have been measured. See with respect to these forces, the forces shown in figure 9.8 for the same speed range. Capabilities of the escort tug, of course, play an important role. It is furthermore important to note that with this method steering forces can be delivered much faster than with the direct towing method, whereby the whole tug's body has to be pulled through the water against the incoming water flow from position 2 to position 1 (figure 9.5 'Direct Towing Method'). It has been experienced that this can take a long time, particularly in this five to seven knots speed range. The same method is sometimes used in other ports around the world by VS tugs during normal harbour assistance.

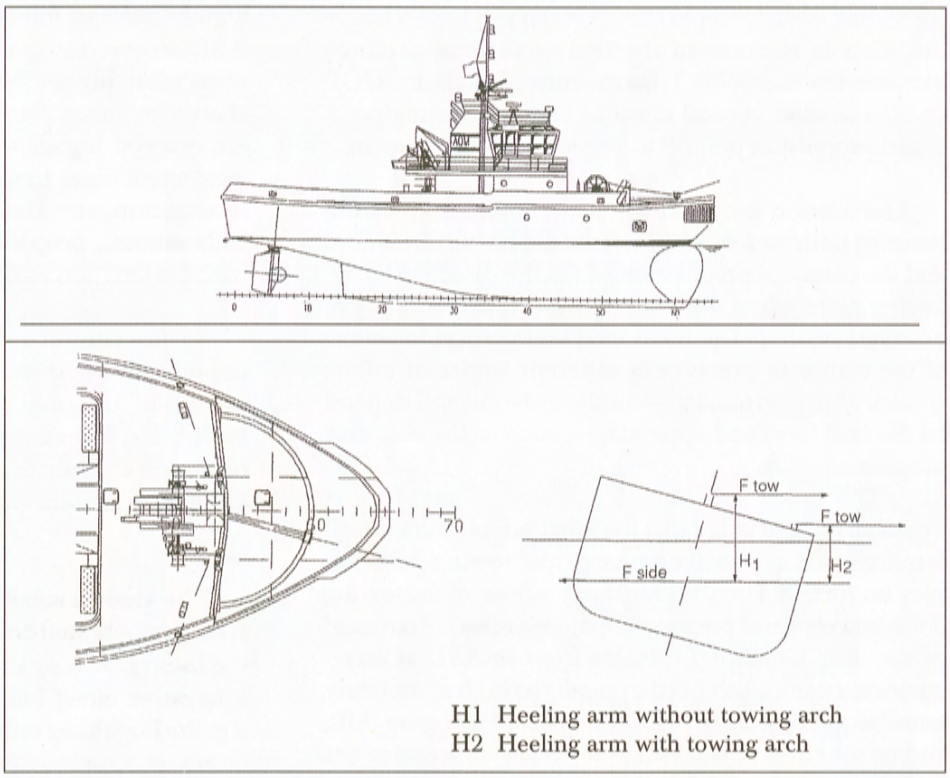


Figure 9.11 Aquamaster escort tug concept – The Towliner with towing arch

It is further worth mentioning a specific way of escorting by using two escort tugs as a tandem, both tethered, which is utilised in the Port of Long Beach, California. It is called team towing or tandem escort towing, for which modern VS tugs or ASD/reverse-tractor tugs can be used. With this method relatively small escort tugs can be used to handle heavy ships. Specific tug procedures have been developed for this method. Escort speeds while utilising the team towing system are relatively low, generally approximately six knots, with a possible upper limit of eight knots, depending on tug design, crew training, and the sea conditions to be faced during the escort.

Although escort tugs should also perform well at lower speeds, the indirect mode is further discussed because escort speeds can be up to 10 or even 12 knots.

In figure 9.9 a tug is operating in indirect mode and the forces acting on the tug and ship are shown. Concerning tug performance, the magnitude of the transverse forces and in particular the points of application of these forces are most important. For generating the highest steering forces, angle (a) is predominant, while keeping the towline angle at approximate 90°. For the highest steering forces, angle (a) differs by tug type and is generally larger for ASD/reverse-tractor-tugs, which can clearly be seen in the TUGSIM performance graphs of eight knots speed in section 4.3.2.

Discussion amongst propulsion designers mostly concerns the performance of azimuth stern drive tugs compared to tractor tugs, particularly tractor tugs with Voith propulsion. Two escorting tugs are shown in figure 9.10 of which one is an ASD-tug and the other a VS tug. In this figure the most important aspects of tug performance in the indirect mode are shown. The centres of pressure are approximated for an angle of inflow (angle a) of 90°.

Firstly, the larger lever x is compared to lever y, the less sideways thrust is needed to balance hydrodynamic forces at the centre of pressure (COP) and the higher the towline forces will be. Secondly, the larger the vertical distance between towing point T and centre of pressure COP, lever a, the larger any list will be. However, the larger the vertical distance between propulsion point P and towing point T, lever b, the more list is reduced by the sideways thrust of the propulsion.

As escort tugs should be designed such that any required sideways thrust to balance the hydrodynamic forces at COP is small, the height of the towing point above the centre of pressure becomes particularly important with respect to heeling moments.

When comparing the ASD-tug to the VS tug as shown and assuming the same stability, then it can be seen that

with equal towline forces the ASD-tug will have a larger list. This is because of the higher vertical distance between towing point T and centre of pressure COP and the smaller vertical distance between towing point T and propulsion point P to oppose heeling moment.

The relation x:y as shown in figure 9.10 is about the same for both tugs. However, it should be borne in mind that the centre of pressure moves in the direction of the towing point when the angle of inflow, the drift angle, becomes smaller. The horizontal and vertical locations of the centre of pressure at different angles of inflow can only be determined by model tests and will depend on the hull form and appendages, such as the skeg and propulsion units.

It can be concluded that the longitudinal and vertical locations of the centre of pressure and towing point are very important. For a VS tug the positions of the towing point and centre of pressure are more or less determined by the skeg. Good performance from an ASD/reverse-tractor tug can be achieved by a not too high and slightly more aft lying towing point than shown in figure 9.10, and by a hull form such that the centre of pressure lies as far forward as possible. This has, for instance, been achieved in the Aquamaster escort tug concept Towliner (see figure 9.11). This is an ASD-tug with a bulb and box keel. A towing arch is suggested for the lead of the towline, being a similar system to that discussed in section 4.2.3. Other ASD-tugs may have a bulb and forward skeg, which also results in a more forward lying centre of pressure.

Apart from the aspects already mentioned, form and lateral area of the tug's underwater body are important factors for generating the highest possible towline forces in the indirect mode. For that reason specific high lift skegs are developed for VS escort tugs. Many ASD escort tugs are equipped with a long skeg underneath the hull or with a box keel as with the Towliner concept, while tug's underwater form is often subject of continuous research.

Tug's stability should be well considered if an ASD-tug or reverse-tractor tug is to be equipped with a skeg underneath the hull, because it does increase the towline forces, and consequently the heeling forces. It is, furthermore, good to note that when a tug's lateral area reduces, performance in applying steering and braking forces reduces. This will be the case when a tug's bunkers are nearly empty. On the other hand, a minimum ballast and fuel onboard may improve a tug's performance with respect to some important aspects. The hazard of early deck immersion reduces and the tug becomes more responsive.

The performance of VS tractor tugs is often compared to that of ASD-tugs, though comparison is difficult because the tugs differ in many respects. In general, tractor tugs seem to be able to exert somewhat higher steering forces in indirect mode than present ASD escort tugs, while the ASD-tugs can apply somewhat higher braking forces, though this may change by speed. Steering forces are very important for escorting at higher speeds, though it depends on the local situation as to what is chiefly needed. Former US towing company Hvide Marine opted for a tractor tug with azimuth propulsion, the *Broward*, because of the high braking forces that can be achieved.

So far attention has been paid to those aspects important for a good performance, such as location of centre of pressure, height of towing point, tug's underwater form and lateral area. This should, of course, be seen in combination with an optimum stability, which is addressed later.

Note:

The design aspects discussed in this section are specifically aimed to improve a tug's performance in the indirect towing mode. Some of these features have a negative effect for the direct towing mode, such as e.g. the large skeg underneath an ASD-tug. Such a skeg increases a tug's underwater lateral resistance, making it, for instance, even more difficult to apply steering forces in a fast and effective way in the direct towing mode. Ships' speeds during tug assistance and the most important tug operating modes should therefore be taken into account with respect to the design aspects, particularly those relating to tug's underwater body.

Braking and steering forces

Escort tugs have to deliver steering and/or braking forces in case of emergency. Steering forces are considered to be particularly important. That is true as long as there is sufficient room ahead and bends to be navigated are not too sharp. In that case a ship can be steered and kept free from dangerous areas. However, it depends on a number of factors whether the steering assistance of an escort tug will be sufficient to keep a ship in safe waters. For example, environmental conditions may have such an influence that a ship starts drifting into a dangerous direction as soon as speed decreases due to an engine failure, regardless of the steering assistance provided.

When an engine or steering failure happens while the manoeuvring area or distance ahead is very restricted, braking power is required. The most effective means to take way off, provided there is sufficient room, is to initiate a turn. This has the effect of slowing down the tanker and reducing head reach.

After an engine and/or rudder failure has been recognised and before assistance is given by the escort tug, the ship may already have built up a rate of turn. For large loaded tankers it is hard to stop such a turn and bring the tanker back onto a safe course. In most cases, if circumstances allow, it is better to assist the

Type of escorted ship	Required tons steering pull at 10 knots speed
40,000 dwt bulk carrier	40
70,000 dwt bulk carrier	60
150,000 dwt tanker	88
300,000 dwt VLCC	116
30,000 m^3 gas carrier	32
60,000 m^3 gas carrier	43

Figure 9.12 Steering forces required based on 15° rudder angle

escorted tanker to turn, for instance, 180 degrees or 360 degrees, particularly at higher escort speeds. It should, however, be noticed that assisting tanker turns at relatively high speeds imposes high loads on the tug (and tanker) and may be unsafe, as tug speed will increase appreciably above tanker speed when on the 'outside' of the turn. While turning, ship's speed decreases quickly; consequently after a short period delivering steering forces in the indirect mode, the tug has to switch over to the direct mode (combination arrest mode, see fig. 9.5) to stay effective.

It depends entirely on the situation during a failure what kind of assistance is required. But, as indicated, escort tugs should be able to apply high steering forces. These should meet a ship's rudder force with the propeller turning while matching ship's speed. The Norwegian Hesnes Neptun Group has worked out the steering forces required for safe handling of a number of different sizes and types of ships, as shown in figure 9.12.

For navigating a not too sharp bend at 10 knots speed, which means for many tankers a telegraph setting of half speed, or full maneuvering speed, a rudder angle of 15 degrees, on which the values are based in figure 9.12, can normally be regarded more or less as a maximun. The related rudder forces(i.e lift forces) at this speed give an indication of the required steering forces in case of a rudder failure.

In other cases higher steering forces may be required, which can be the case when due to a technical failure on board the escorted vessel the rudder becomes blocked at a certain rudder angle. Whether it should then be possible to counteract rudder forces depends again on the local situation.

Rudder forces on a ship with the rudder blocked at a certain rudder angle are reduced when the propeller is stopped, and in case of a controllable pitch propeller, when pitch is set for zero. It enlarges the possibilities for an escort tug to steer the tanker. Det Norske Veritas assumes the rudder lift forces without propeller turning to be 0.53 times the forces with the propeller turning. If circumstances allow the ship could also be stopped by using its engine and with the assistance of the escort tug.

Figure 9.13 gives an indication of the rudder forces, (i.e lift forces) of three large tankers at different speeds and rudder angles with the propeller turning while matching ship's speed. The rudder forces are based on a study carried out for the Norwegian Sture Crude Oil Terminal. It gives an indication of the required steering forces to steer a tanker at different speeds in case of a rudder failure and of the rudder forces to be overcome, if necessary, in case the rudder is blocked at a certain angle.

It is important to keep in mind that the required steering and stopping forces increase when underkeel clearance decreases, as discussed in Chapter 6. It should also be noted that after an engine or rudder failure, beamy full-bodied ships have the tendency to develop the fastest rates of turn.

Therefore, insight into ship's behaviour is important with respect to escort requirements. The book 'Ship Bridge Simulators. A project handbook' (see References) includes relevant information on ship manoeuvring particulars.

What maximum steering and braking forces a local escort tug should be able to apply should be based on a study of failure scenarios representative of the ships and areas concerned, including the local situation and

	Tanker size and rudder angle											
	100.000 dwt				200,000 dwt				300,000 dwt			
Speed	10°	15°	25°	35°	10°	15°	25°	35°	10°	15°	25°	35°
6 knots	25	30	45	30	30	50	60	50	40	55	80	60
8 knots	35	55	75	60	55	85	115	90	70	100	140	105
10 knots	60	85	120	90	90	130	185	145	110	155	220	165
12 knots	85	120	175	135	130	190	260	205	160	230	320	245

Figure 9.13 Rudder forces in tons for different loaded tankers, speeds and rudder angles. Rudder forces are largest at approximately 25° rudder angle. Round figures are used

Photo: Foss Maritime, U.S.A

Figure 9.14 Tug 'Lindsey Foss' applying steering forces in the indirect mode

circumstances, as mentioned in paragraph 9.2. Practical tests should be carried out to validate the results as far as possible. The failure scenarios, taking into account active as well as passive escorting, may for instance include:

- Steering a tanker on a straight course and through bends in the fairway after a rudder failure and/or engine failure or steering as well as stopping the tanker after such failures.
- Steering and/or stopping a tanker with rudder jammed at a certain rudder angle, or the same but including an engine failure.
- Different escort speeds.

It can be expected that for the given failure scenarios, a tethered escort tug can react faster and consequently needs to apply relatively lower steering forces than when passive escorting is utilised. In that case there is a much larger time delay before an escort tug can be effective. As mentioned already, in the meantime the tanker may have built up a rate of turn, or have travelled in the wrong direction and, to stop such a turn with a loaded tanker and bring it back onto a safe course, the escort tug should be able to generate very high steering forces, particularly in shallow waters. The required forces may even be too high for any tug when the fairway dimensions are very restricted. So, not only a tanker's dimensions and displacement are important factors, but also the local situation and conditions such as speed, underkeel clearance, environmental conditions, fairway constraints, whether active or passive escorting is applied and the type of failures that may happen. The outcome of the failure scenarios study should be weighed in a sensible and practical way regarding tug requirements, escort method and escort speed. For the same tanker size, requirements for maximum achievable steering and stopping forces of an escort tug may, therefore, differ between ports.

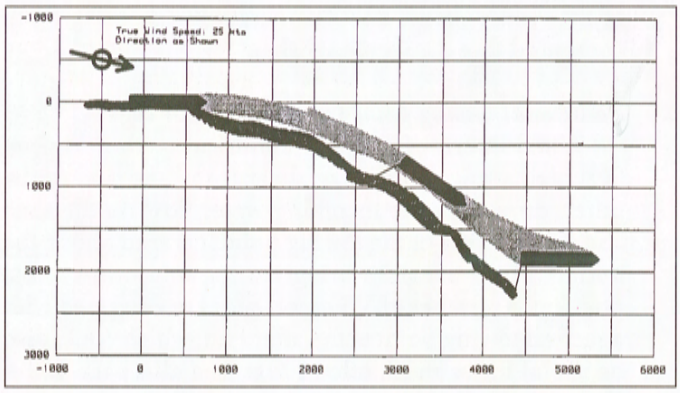
Several full scale trials have been carried out, including one in 1991 near the Isle of Wight, UK. A normal stern drive tug of 53 tons bollard pull escorting a 130,000 dwt tanker showed that it could steer the tanker over a range of 5·9 to 8·8 knots using the indirect method and below 5·9 knots using the direct method. At a speed of 10 knots the tanker could be stopped in 15 minutes over a distance of one and a quarter miles, in almost a straight line.

The graphs in section 4.3.2 show achievable steering forces at a speed of eight knots for a normal ASD and VS tug. These forces approximately equal the bollard pull, while the maximum achievable braking forces are already much higher than the bollard pull. When speed increases further the steering forces increase considerably.

It should be noted that amongst other things the negative effect of the ship's wake on the achievable braking forces is not included in the graphs.

Several other full scale trials have been carried out, of which results depend on tug type, ship's size and draft, escort speed, failure scenario and experience. Results of one will be mentioned below. It concerns a full scale trial with the fully loaded 125,000 dwt tanker *Arco Juneau* in April 1997. The large VS escort tug *Lindsey Foss* was tethered to the stern of the tanker (see figure 9.14). Particulars of the escort tug are given in figure 9.21.The tanker had a speed of eight knots. The wind was on the port quarter with a speed of 25 knots, while sea conditions were nominal.

With the ship on a steady course, the rudder was put hard-a-starboard. Thirty seconds later the failure was 'recognized' and the engine stopped. After another thirty seconds, thus a total time delay of one minute, the tug was ordered to stop the turn by applying steering forces in the indirect mode. At the time the ship was back on the original course it was more than 500m off track during two similar tests! The results of one such test are presented in figure 9.15. The results show the importance of a tethered escort tug and of a proper recognition time, while tug the master's experience plays a crucial role as well. Although the one minute time delay can be considered as rather large (an alert and well trained bridge team will recognise a failure and take action much earlier), the results illustrate that even with a large purpose built escort tug and a not too large tanker, off track distances can be large and may increase considerably at higher speeds. The results also show why it is so important to have full scale tests.



Courtesy: Floss Maritime, USA

Figure 9.15 Plots of a full scale trial with the loaded 125,000 dwt tanker 'Arco Juneau' and the purpose built escort tug 'Lindsey Foss' (distances in feet). The tanker while having a speed of eight knots had a simulated rudder failure with the rudder blocked at hard-a-starboard

The maximum braking and steering forces that can be achieved by a specific escort tug depends on the escort speed and also on sea conditions. Performance of tugs decrease in wave conditions, as will be the case with escort tugs. In wave conditions at high escort speeds it might not be possible to apply the maximum steering and braking forces and/or the captain could, for reasons of safety for his tug and crew, decide to apply lower steering forces, or the ship's speed could be slowed down in order to enable the escort tug to apply the steering and/or braking forces required in case of a failure.

Maximum wave height for the largest purpose built escort tugs seems to be around four metres. Not much data based on practical experience is available. With this wave height steering and braking assistance can still be applied, provided the tug has a towing winch with a load reducing system.

Furthermore, certain tug assist manoeuvres at high speeds and in wave conditions may become risky, as may be the case with transiting from one assist manoeuvre to an other, for instance from braking to the indirect steering mode, if not carried out in acorrect way.

Good insight should therefore be obtained into to what extent wave conditions affect an escort tug's performance and what safe working limits are at various escort speeds and wave conditions. With respect to this, the tug master's experience is again a crucial factor.

Required maximum speed free sailing

Maximum escort speed usually lies between 10 and 12 knots. However, safe escort speeds depend on factors such as tug design and capability, weather, sea and swell conditions, configuration of channels, underkeel clearance, the nature of the bottom and traffic.

As escort speed can be up to 12 knots, the maximum free sailing speed of escort tugs should be higher. The maximum free sailing speeds of present escort tugs is about 14 knots, but varies between 12·5 and 15–16 knots.

Free sailing speed of an escort tug depends amongst others on the maximum escort speed as determined for a port or port approach. For a number of reasons escort tugs should have a reasonable over-speed compared to the maximum escort speed, due to the fact that the escort tug should be able to overtake the escorted ship within a limited time span. It should be able to overcome the ship's propeller slipstream when approaching the ship's stern to pass or connect the towline and the escort tug should have sufficient reserve power to handle safely any interaction effects that might arise between tug and ship, which can be very strong at high speeds. Finally, in adverse sea conditions a tug's maximum speed may decrease faster than a large ship's speed.

Stability

Stability has been addressed in section 4.2.3 and is extremely important for escort tugs. Towline forces can reach very high values, up to one and a half to two times the bollard pull at 10 knots escort speed in indirect mode, while escort speeds may even be higher. Waves and tug manoeuvres can further increase towline forces, another reason for keeping the towing point as low as possible to reduce heeling moment. A method applied to reduce heel angle is the construction of hull side sponsons, which provide a substantial increase in reserve buoyancy and result in larger righting moments.

Good static and dynamic stability, taking into account changing trim during escorting, is necessary to operate safely at high escort speeds. It should also be remembered that towline length and characteristics influence a tug's heeling angle. Forces reach higher values when low stretch towlines are used, often the case with escort tugs. The longer these towlines are the better the dynamic forces can be absorbed. High stretch towlines, however, may cause larger movements of the tug.

A minimum metacentric height of three metres is generally recommended. It is advisable to avoid excessive values of metacentric height. In adverse sea conditions these might lead to acceleration forces that could be prejudicial to the tug and its equipment. It makes, furthermore, life and work on board almost impossible and so affects safety of operations.

Classification society Det Norske Veritas (DNV) gives dynamic stability requirements for escort tugs in their rules for escort vessels, which are included in the Appendix.

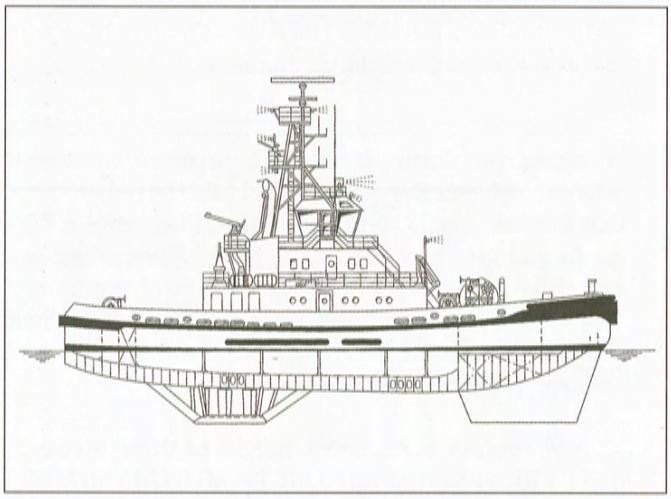
The heel angle at which maximum steering and braking forces are determined should be well considered. It has to do with operational safety. If deck immersion is regarded as the limit, then only a small safety margin is left. A golden rule used by an experienced escort tug training master is: '*Do not immerse the deck line*'.

A maximum heel angle based on righting energy criteria, as is the case with the DNV escort tug rules, includes a certain margin of safety for the dynamics

in operations. Further research is needed in order to come to generally accepted, safe and workable stability requirements and criteria for different types of escort tugs.

Design developments of escort tugs

An escort tug must, obviously, be seaworthy and able to perform escort duties by utilising her best capabilities. ASD-tugs, free sailing or escorting in tethered mode run bow first. This is the normal, fastest and, for the deck crew, the safest operating direction particularly in high wave conditions, at high speeds and when performing in the indirect towing mode. At high free running speeds tractor tugs normally run bow first. However, when escorting in tethered mode they run stern first, with the lower afterdeck in the sailing direction. Maximum speed when running stern first is lower. At higher speeds and in wave conditions water comes over the after deck easily. The design of a number of VS escort tugs has changed, therefore, as can be seen, e.g, with the *Bess* and *Boss*. At the skeg end, the sheer and after bulwarks are made higher and the hull form is more pointed. In addition, the wheelhouse is turned 180°, thus providing the captain with an excellent view in the operating direction. The



J. M. Voith GmbH

Figure 9.16 VS escort tug 'Bess' with modified tractor tug design (l.o.a. 36·2m, beam 12·2m, draught 5·2m, bollard pull 57 tons)

same change in design is more or less the case with a number of other VS escort tugs. There are continuous developments in the design of escort tugs based on experience, research and new insights, all concentrating on improvement of the escort tug capabilities. Design developments focus on aspects such as optimum skeg and hull form, optimum location of towing point(s), and in particular for ASD-tugs the height of the towing point. Specifically for VS escort tugs, design attention for a good performance when sailing skeg-first can be added. Developments on skegs and skeg form concern both VS escort tugs and ASD escort tugs. Modern VS-tugs have high lift skegs, also called hydrofoil-shaped skegs. One of the latest skeg developments for VS escort tugs is the Voith Turbo Fin (VTF). This VTF has a rotating tube at the end of the skeg, which causes a considerable increase of lift. Voith claims an 18% increase in steering force compared to a conventional skeg.

Additional towing point for escort tractor tugs

When astern of a vessel underway with a towline fastened, a tractor tug may sheer from one side to the other, caused by the incoming water flow on the skeg and the location of the towing point, centred above the middle of the skeg. To bring the tug to a more stable position, a number of VS escort tugs are equipped with a second towing point at the after end, which could also be useful for azimuth tractor tugs (see also page 152 – Operating reliability and fail safe). When running in line and astern of a tanker the towline then passes through a fairlead, a kind of hook or towing pins at the after end of the tug, similar to the towing pins shown in the photograph of the afterdeck of tug *Maasbank* (figure 7.7). When a failure happens aboard a tanker and the tug has to provide steering assistance, it should be able to take the towline out of this far aft lying towing point, otherwise achievable steering forces are lower. This is indeed possible on a number of tugs, where the hook or towing pins can be opened hydraulically in order to use the original towing point above the middle of the skeg again.

Towing pins have been developed specifically designed for escorting. These pins make it possible to release the towing line when under tension, even with the towline angled upwards, from the most aft lying towing point.

In addition to the use of the secondary towing point for reasons mentioned above, tests with radio-controlled models showed that in extreme conditions the use of the secondary towing point adds to the safety of operations. In waves the aft deck is more easily submerged when the main towing point is used. At high speeds and in rough conditions, the use of the secondary towing point makes it more difficult for the tug captain to get into trouble. It also seems to make the tug's motions less severe.

Deck equipment, towlines and towline handling

Towing equipment of harbour tugs has been dealt with in Chapter 7. Amongst others, towing winches, towlines and towline handling have been discussed. The following applies more in particular to escort tugs, although much of the items discussed below are of importance for harbour tugs as well, particularly when involved in escorting and/or using towlines made of HMPE fibres.

Requirements for towlines and tug deck's equipment

The minimum breaking strength of a towline of an escort tug should be at least two and a half to three times the maximum achievable braking and steering force, which gives some allowance for e.g. peak loads when taking into account present OCIMF safety factors of 2·0 – 2.2 for synthetic lines.

Escort tug rules of classification society DNV requires the towing line to have a breaking strength of at least 2·2 times 'the maximum mean towing pull' as measured during active escort tests, which is specified in the rules. The rules require the towing winch to have a load reducing system.

All towing equipment should have high operating reliability and be designed for the highest towline loads that can be expected. Towing winches on escort tugs should have high brake holding power, a fast line deployment and retrieval capability and a high pull, in particular if the tug is equipped with a towline tension control.

Because of the high towline loads it is recommended that the towing winch has a load reducing system to avoid excessive loads in the towline, which particularly may occur in wave conditions.

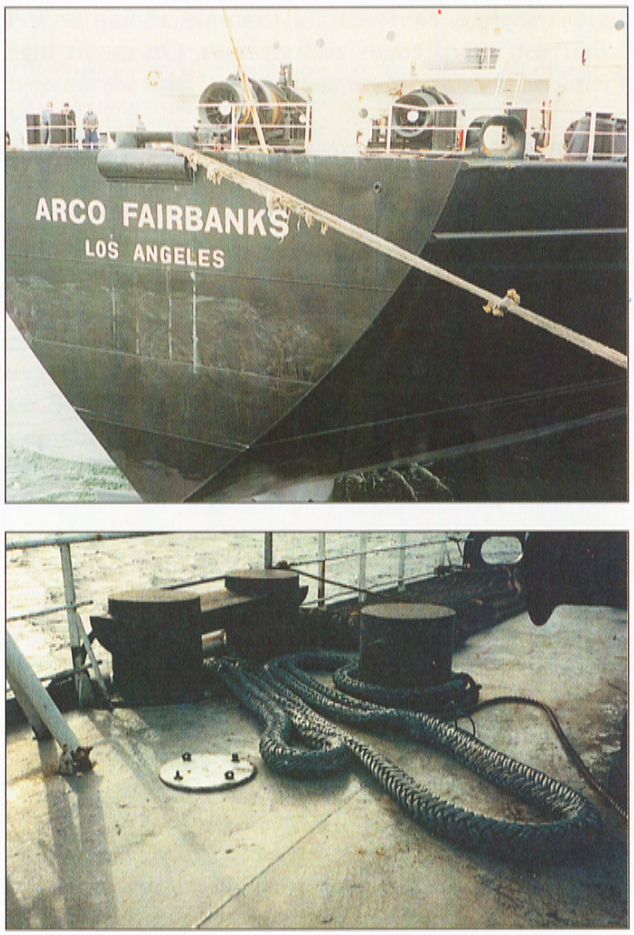
The high pull of the towing winch enables the towline to be paid out and recovered when the line is under high tension, while rapid line handling is essential to allow immediate positioning of the escort tug, particularly when in an emergency, an untethered escort tug has to make fast to a ship.

Ship's deck equipment requirements

Deck equipment construction on board the escorted vessel should be suitable for high towline loads and for the type of towline used. This is a very important aspect, because there have been several complaints regarding the lack of suitable strong points and fairleads on board ships to be escorted, deck provisions not properly sized and located and not strong enough to withstand the high peak loads generated in the towline of the escorting tug. A reduction in escort speed may be warranted if the ship's fittings are not strong enough to withstand the towline forces that would be imposed on them.

In the year 2002 OCIMF published "Recommendations for Ships' Fittings for use with Tugs with Particular Reference to Escorting and Other High Load Operations". This document provides a proper guidance to the tanker industry regarding the provisions of ships fittings for use with tugs. The guidance includes, amongst others, the safe working load and dimensions of fittings (including certification). Certain ports may use the OCIMF recommendations as a requirement for ships to be escorted in their port.

Polar tankers, for example, have specially designed stern fittings to accept the high towline loads of large and powerful escort tugs, such as the *Lindsay Foss*. The strong point and fairlead of the emergency towing arrangements required by SOLAS could be used for securing the escort tug's towline, provided they are suitable for this dual purpose and provided also that such use does not in any way compromise the deployment and use of the emergency towing



Photos: Foss Maritime, U.S.A

Figure 9.17 Specially designed tanker stern fittings on the former ARCO tankers, now Polar tankers

arrangements for their SOLAS purpose (see the above mentioned OCIMF publication).

Towline performance and use

Many towing companies use towlines made of HMPE Spectra or Dyneema fibres, with pennants of the same material and sometimes with nylon stretchers, though steel wire towlines with a nylon stretcher, polyester or polyester/polypropylene towlines are also used for escorting. Towline lengths used for escorting are generally 100 to 150 metres, though smaller towline lengths, e.g. 60 to 80 metres, are also used at the tug captain's discretion.

Modern HMPE fibre lines are light and easy to handle, important factors not only because of reduced crew numbers on board ships, but because an emergency response may be needed when no power is available on the deck of the ship and the crew may have to lift the towline aboard manually. Another feature of this type of towline is that it floats and does not easily foul propellers.

Spectra or Dyneema fibre towlines have a very high breaking strength but their stretch is very low, which should be taken into account. To minimise abrasion, towlines and/or towline pennants should be protected

against chafing. Fairleads, for example, should be free from rust, sharp edges and grooves. On escort tugs, therefore, more and more stainless steel fairleads are used.

There is ongoing research in the field of HMPE fibres and ropes in order to increase performance. Experience gained on board tugs is most important to understand the factors that play a role in the functioning and lifetime of towlines, experience that can be used for further improvements. As already said, many escort tugs use towlines made of Dyneema or Spectra fibres (at the moment mostly Dyneema is used). Wear is largest at that part of the towline that is taken on board the ship. A pennant increases the main towline's lifetime. (An active working tension control of the towing winch may cause additional wear on the tug's part of the main towline, from the winch through the tug's fairlead.) The pennant, often made of the same material as the main towline and of the same and sometimes larger breaking strength, is either cow-hitched or spliced eye-through-eye to the main towline. This is the case when a single pennant is used. Other systems are also used, for instance a grommet as pennant, which makes it possible to distribute the wear over the whole pennant. (see also paragraph 7.5.2 and 7.5.3).

Towlines made of HMPE fibres are high performance ropes, perfect ropes for the high towline forces that can be generated by escort tugs. Two aspects require attention, viz. the low stretch and the strength reduction of the towline during a certain period of use or after a certain number of jobs. The latter applies, of course, to other types of towlines as well.

If short towlines of low stretch are used, it easily results in high peak forces due to the low dynamic load absorption of the towline. This effect is less for escort tugs operating in port approaches. These tugs normally use rather long towlines and often have towing winches with a load reducing system. However when such a system is not available, and when operating with short towlines, as is the case in harbour areas, the low stretch may present a problem. A pennant with more stretch, e.g. of nylon or polyester, or a stretcher, can then be used, although this reduces ease of towline handling. In all cases much depends on the tug captain's ability in controlling his tug in such a way that peak loads in the towline are as much as possible reduced.

Strength reduction in a towline will take place over a certain period of time and/or after a number of jobs. It is important to know the level of strength reduction and the factors that play a role, taking into account the fact that much depends how towlines are treated on board the tugs.

Samson Rope Technologies and DSM High Performance Fibers (producer of Dyneema HMPE fibre) carried out a study with the objective to develop retirement criteria to be used by a towing company to gauge when a rope should be removed from service (see References for the report 'Residual Strength Testing of Dyneema, Fibre Tuglines'). For that visual inspections and break tests were performed on towlines used on the escort tugs of Crowley Marine Services. The towlines were 12-strand ropes made from Dyneema SK75 fibre. Pennants on board the Crowley tugs are generally used for one year and the main towlines for two years. After one year the main towlines are reversed, 'end-for-end'. The average number of jobs carried out with the main towline was around 1200 and with the pennants around six hundred.

What can be learned from this study, based on tests with the one year used pennants and the two year used main towlines, can be found in the conclusions of the study:

- The ends of the towline, up to 65m from the end, had on average a strength retention of 61% of the original strength, which means a loss in strength of almost 40%.
- Strength retention of the midsection of the towline was higher (81%), while the pennants had on average a strength retention of 63%.
- Abrasion, compression and line twists resulted in the total strength reduction of up to 40%.
- Abrasion and cutting damage accounted for a strength loss of 5-10%
- Compression from the drum accounted for a strength loss of 12%.
- Line twists of one to one and a half turns per foot equated to a 15-20% strength reduction.
- Shock loading seems to have no effect on the residual strength of the towline, if due diligence is exercised in tug handling.

Important findings are that shock loading seems to have no effect on the residual strength of the HMPE towline, provided the tug is handled in a controlled manner. The study results show how important good towline care is. Abrasion, cutting damage and line twists should as far as possible be avoided and a twist in the line, if possible, be removed before storing the line on the winch.

The importance of a proper safety factor is also shown by this study, seeing the rather large average reduction in towline strength of almost 40%. Tests of residual strength of other HMPE towlines and towing companies show values of strength reduction of 50% (and higher). DNV, for instance, requires the towing line to have a breaking strength of at least 2·2 times "the maximum mean towing pull" as measured during active escort tests. Assuming a strength reduction of 50%, such a safety factor can be gradually degraded to 1·1, which means there is hardly any safety margin left. One should be well aware of this fact – a fact that does not just apply to towlines made of HMPE fibres, but to towlines made of other synthetic fibres as well.

With respect to this there is another aspect to be taken into account, and that is what is regarded as the breaking strength of a towline. In the United States it is the practice to use spliced ropes to develop breaking strengths. Breaking strengths are reported approximately 15% higher when no spliced samples are used. The possibly lower strength of the connection between the pennant and main towline, depending on the type of connection, is also a factor to be taken into account. In fact, the minimum breaking strength of the total towline should be taken into account for the required breaking strength of a tug's towline.

Based on what has been discussed, the following aspects are important for the condition of towlines on board escort tugs, particularly those made of HMPE fibres, and for safety of towing:

- Logbook.
  It is recommended to maintain a log of towline usage, noting factors such as the number of jobs performed, the results of visual inspections and facts that may have influenced the towline's service life.
- A program of residual rope strength testing.
- A program aimed to determine the effects that influence the service life of a rope and to develop retirement criteria for when a towline and pennant should be removed from service.
- A realistic minimum breaking strength of the towline.
  The minimum breaking strength of the towline should clearly be defined, stating whether the strength refers only to the rope of which the towline is made, or also including the weaker parts such as splices and, if relevant, the pennant–towline connection.
- An appropriate towline's safety factor.
  The required towline's safety factor to be based on a realistic minimum breaking strength of the towline, taking into account the reduction in rope strength during the lifetime of the rope.
- Proper rope care, which includes proper tug handling.

  Proper rope care has been discussed in paragraph 7.5.2.

Finally, further study is needed to get a better insight into the long term performance of towlines made of synthetic fibres in general, and specifically of escort towlines made of HMPE fibres, how performance of these lines can be improved and/or strength loss can be minimized, which also should include minimum safety factors to be applied, based on the specific towline characteristics, towline use and strength decrease.

Connecting and disconnecting towlines

As escort tugs may keep pace with a ship while not secured, they must be able to secure quickly and efficiently, in order to be able to deliver the required steering and braking forces within the shortest possible time. In such situations and for tethered escort of arriving ships, making fast is generally done at a rather high ship's speed. When making fast, the escort tug generally comes close to a ship's stern to pass the towline. This is easier for stern drive than for tractor tugs, since the latter experience the effect of the ship's propeller wash on their skeg. Sea and swell conditions make it more difficult to pass a towline safely or even make it impossible. When a towline slips into the water, caused by tug movements due to sea and swell or unprofessional line handling on board the tug or attended ship, it may foul the tug's propellers, making the tug useless.

When conditions are such that it becomes difficult to pass a towline, a line-throwing gun can be used to pass a heaving line and messenger line, which is possible, for instance, at the approach towards the Sture and Mongstad terminals at Norway's west coast and at San Francisco, USA.

Letting go an escort tug whilst underway can be carried out at fairly high speeds but it should always be done safely. When the towline is to be released by a ship's crew, they should be ordered to stand-by and await the tug, which steams up through the ship's wash until almost touching the stern. When the tug is in position and signals the ship's crew to let go, the towline should be lowered gently so that it does not fall into the water and foul the tug's propeller. When approaching a berth and the escort towline is being released, the ship's crew should be instructed to handle the towline in a similar way.

Different systems are used to reduce the time required for securing. Foss Maritime, for example, has developed a special towline connection link for that purpose (see fig 9.18). On board their tractor tugs escorting and assisting tankers in Puget Sound is a special towline connection, the Foss Transom Link. This enables a free-sailing escort tug to establish a towline connection in a minimum of time and with a minimum of manpower when a tanker loses power or steerage. No

Photo: Foss Maritime, U.S.A

Figure 9.18 The Foss Transom Link

crew members of the tanker are required to secure the escort tug and only one man is required on the tug deck. In addition, this link allows the escort tug to 'make-up' to the escorted vessel on demand while avoiding the hazards associated with tethered escorts.

The link must be seen in connection with a readily available towline pennant on board the tanker being escorted. This should be of high tenacity fibre, such as Spectra, hanging over the stern to which a messenger line is connected. The link is a large hook made of extra strong, lightweight, titanium alloy. A towline pennant is spliced onto the eye of the hook. The pennant and the winch mounted towline are connected in such a way that they are readily separated. The link is mounted in a cradle at the tug's transom.

When assistance is required, the tug manoeuvres stern first close to the tanker's stern. By picking up the messenger line the ship's towing pennant is taken on board the tug by just one man. The pennant's eye is inserted into the jaw of the hook, which is equipped with a spring loaded gate to hold the pennant in place. The tug then moves away from the tanker and the link connecting the ship's pennant and tug's towline is pulled from the transom-mounted cradle as the tug pays out the Spectra towline.

Tankers calling at Prince William Sound, Alaska, should also have a towing pennant made fast at the stern, ready for use. This emergency hawser should be a nine inch Spectra line (or equivalent) at least 300 feet long. Attached to this Spectra towing pennant, a suitable floating messenger line should be connected and be ready so that it can be deployed rapidly to the escorting tug. This arrangement should allow the tug to approach the tanker's stern, take up the messenger, pull the towing pennant free and secure without requiring any assistance from the tanker crew. Similar systems may exist in other escort areas, though whether such systems are utilised or required depends on how escorting is carried out.

Operating reliability and fail safe

Escort tugs often operate as a single unit over relatively large distances, so operating reliability must be high. If for some reason or other a tug experiences a loss of propulsion while giving steering assistance, its towing point should be such that hydrodynamic forces will turn the tug safely towards a safe position. This was addressed in Chapter 4 when discussing the towing point of tractor tugs. The same applies to escort tugs of the ASD/reverse-tractor type. In addition, model tests have shown that for azimuth tractor tugs operating in the transverse arrest mode at high speeds it is safer to use a far aft towing point to avoid capsizing when one of the propulsion units fails and no immediate action is taken by the tug captain.

When one propulsion unit fails it should, with a well designed tug, still be possible to give steering assistance. Whether this will be possible in an emergency, starting from a position behind a ship's stern, should be tested.

Communication and information exchange

Good radio communications between pilots and tug captains are always necessary and a good information exchange.When proceeding at speeds up to 10 to 12 knots with an escort tug secured aft, and often not in the pilot's field of vision, a good and reliable communication system is indispensable. Ships may be escorted over large distances and may take several hours. This should not affect a tug captain's alertness but may do so. Regular radio contact and information exchange between pilot and tug captain is required, therefore, regardless of the fact that the information that comes available to the tug captain via his instruments is increasing.

Good communication between pilots and tug captains is of particular importance during failures, for instance, when a disabled tanker should be navigated round a bend in the fairway. The escort tug should then steer the tanker through the bend, continuously taking into account the required rate of turn, which includes increasing, decreasing or stopping the applied steering forces at the correct moment, checking the rate of turn by applying steering forces at the other ship's side, and steering the tanker on a new steady course. This requires continuous information exchange between pilot and tug captain.

Good communication between pilots and tug masters does also include clear tug commands, not open for any misinterpretation. Although a difficult item, uniformity in basic escort tug commands between escort ports of one country is needed, and preferably between escort ports of different countries. In the Vessel Escort & Response Plan for Prince William Sound some standard tug commands are mentioned. With respect to this much promotion work has been carried out by Captain Schisler, pilot/instructor Long Beach, USA, with his report "Proposed Standardized Tug Commands as they apply to Assist and Escort Tugs" (see References).

Essential information regarding tug securing must be exchanged between pilot, ship captain and tug master prior to the start of the escort voyage as mentioned in the section 'Escort planning' of this paragraph. If the ship has certain limitations regarding manoeuvrability, tug securing, mooring and anchoring equipment, the ship captain should inform the pilot, and the relevant authorities.

Active and passive escorting. Versatility of escort tugs

Escorting may take place untethered or tethered. The first is also called passive escorting and the second active escorting. Whether escort tugs are engaged in passive or active escorting depends on factors such as the constriction of the fairway in relation to a ship's dimensions and draft, environmental conditions and the time needed for securing

– the same factors as when normal harbour tugs are used for escorting. A decision on tethered or untethered escorting should be well judged.

In restricted channels and fairways, only a tethered escort provides the possibility of avoiding a grounding or collision. When active escorting and just following the ship in line, the escort tug should not interfere with pilot manoeuvres.

Some port approaches are subdivided into areas for passive and for active escorting. Although escort tugs are built for the sea conditions prevailing in the escort area, the choice between active or passive escorting also depends on the swell and sea conditions. These may be such that it is hardly possible to pass a towline safely or to provide any useful assistance in the case of an emergency. Visibility can also be a limiting factor for safe escorting. Some ports and terminals give a visibility of 1 mile as the lower limit for escorting but it also depends on ship size and constrictions in the fairway.

Some oil ports where escorting is applied have the same tankers calling at the port regularly, well equipped for escorting and familiar with the escort procedures. Other oil ports and terminals may be visited by all kinds of tankers, tankers with a captain and crew with no experience in escorting and without any special equipment for fast and reliable towline securing. In addition, the escort tugs may not have the light modern fibre towlines. Extra manpower on board the escorted vessel is then required for towline handling, which often presents a problem due to the reduced manning.

In all these cases it is much safer to fasten the tugs as soon as possible, in order to be ready immediately when assistance is required.

When escorting in passive mode, tugs should keep pace with a ship at close distance, positioned abeam, slightly forward or aft of the escorted tanker. A good position can be about four points on the bow and approximately two cables off. In this position tugs provide an additional lookout, for small craft for instance. When required, the tug can be secured more quickly to the escorted tanker than if it had to overtake from a position astern. However, the best tug position during passive escorting is best arranged locally.

Provided that an escort tug can be made fast immediately at a ship's stern if required in the event of a failure on board an escorted vessel, the passive mode enhances the opportunity to provide other useful assistance, such as pushing at the fore or aft shoulder or picking up or passing a towline at the bow. This may be required to keep a ship free from a dangerous area when it loses speed after an engine failure and starts drifting due to currents or wind. Escort tugs should be designed and equipped, therefore, in such a way that they can safely and efficiently provide assistance in different ways, which also places great demands on fendering and on static bollard pull.

ASD-tugs have the advantage that they can also effectively tow on a line at rather higher speeds when using their after towing winch.

Photo: Tore Ofteness, U.S.A

Figure 9.19 Two escort tugs of towing company Foss Maritime keeping pace with a ship

A tethered tug is limited in its operations. It is not without reason, therefore, that the USA federal rules on escorting tankers in Puget Sound and Prince William Sound require at least two tugs so as to improve the possibility of rendering useful assistance in case of an emergency This even when purpose built escort tugs are used. The same kind of rule can be found in the port of Sullom Voe, UK. If an escort tug is used as the primary tug, the second tug could be a normal conventional harbour tug.

Escort tugs, except for the very large ones, are also used for berthing/unberthing operations. When used for berthing/unberthing they sometimes have a specific towline for escorting (Spectra/Dyneema) and another for berthing operations.

Escort planning

Escorting should be well planned in consultation with the pilot and tug captain(s) and, if possible, with the ship's master. Escort plans should include the following:

- Dimensions, draft and manoeuvring particulars of the tanker.
- Destination, transit route, passage times, planned escort speeds, emergency anchorages.
- Shipping traffic and hazards.
- Environmental conditions likely to be encountered.
- Size, type and bollard pull of escort(ing) tug(s) and method of escorting; when there is no tethered escort, the required position of tugs relative to the vessel.
- The maximum towline forces the escort tug is capable to generate at the escort speeds.
- The SWL (safe working load) of the fairlead, bollard and/or strong point on board the ship to be used for escorting.
- The escort tug rendezvous position.
- Communication equipment and channels.
- Requirements regarding towing equipment and towline handling.

The ship's master should be informed in good time about the escort plan. In compulsory escort areas of the USA a pre-escort conference is mandatory, covering subjects as mentioned above. A standard pre-escort checklist, adjusted to a specific situation, is an effective tool for that purpose.

Escort tug standardisation

After years of research, development and practical experience some standardisation of indicating escort tug performance would be useful. An optional class notation for the independent rating of escort tugs was launched in January 1996 by the Classification Society, Det Norske Veritas (DNV). The class notation expresses tug performance in terms of the maximum continuous steering force the tug is capable of providing to a vessel proceeding at a given forward speed. The DNV class notation and requirements, which apply to hull design, towing winch, towline strength, fail safe and full scale testing, are mentioned in Appendix 3.

Photo: J. M. Voith, GmbH

Figure 9.20 Large VS escort tug 'Garth Foss' (l.o.a. 47·2m, beam 14·0m, draught 6·1m, bollard pull 80 tons)

At present the American Bureau of Shipping (ABS) is the only other classification society having a specific class notation for escort tugs.

In the USA The Glosten Associates, Inc. cooperated with a number of industry representatives in developing an American Society for Testing and Materials(ASTM) standard for escort tugs, the Standard Guide for Escort Vessel Evaluation and Selection (first edition published November 1998; see References). The purpose of this standard is to facilitate a common understanding and approach to the evaluation and selection of escort tug(s) to match a ship's manoeuvring and stopping requirements within the navigational constraints of a particular fairway. Much of the proposed standard is a description of acceptable methods for computer simulation which can be used for escort evaluation and tug selection.

The useful guide describes in detail the whole process how to come up with a ship or waterway specific escort plan. All factors of influence are addressed, fairway specific as well as ship and tug related aspects. Presented are methodologies to determine escort tug capability for a certain fairway and/or ship(s), by full scale trials and computer simulations, as well as methodologies for escort tug selection.

9.5.2 Escort tugs in use

The table in figure 9.21 gives a selection of tugs in use for escorting. Although it does not include all such tugs and all escort areas, it gives a good idea of the types of tugs, dimensions and power, and the escort areas where they are used.

The types of tugs are ASD/reverse-tractor tugs as well as VS tugs and the bollard pull ranges between approximately 40 and 140 tons.