strength and very low stretch. The 'Fibre Rope Technical Information and Application Manual' (see References) shows the following differences in properties between Aramid and HMPE fibre properties when compared to other fibres, such as nylon, polyester, polypropylene, polyethylene and older fibres:

- Ropes made of Aramid do not float and ropes made of HMPE do float.
- Weight for weight HMPE is the strongest fibre.
- The surface and internal abrasion resistance of HMPE ropes is excellent and of Aramid ropes fair respectively good.
- Friction coefficient of HMPE fibres is very low.
- HMPE fibres have a melting point of 150° C and Aramid of 425° C.
- Aramid has a fair resistance and HMPE an excellent resistant to ultraviolet sun rays.
- HMPE has better shock load absorption abilities than Aramid.
- Aramid has a 5% lower strength and HMPE the same strength when wet.

The tables in figure 7.17 and 7.18 give an indication of some characteristics of fibres and performance of different rope types. The extension at 50% breaking strength mentioned in the table and as given by one rope manufacturer are for worked ropes, as the stretch of new ropes is higher. The stretch of nylon in wet conditions is also higher.

When reading the tables it should be kept in mind that rope characteristics such as stretch, minimum breaking load, etc. also depend on the construction method of the rope, as indicated previously.

Finishes and coatings

Increased knowledge of yarn-to-yarn friction and abrasion within ropes under operating conditions has led to the development of special overlay finishes that can be applied to yarns during the fibre producing or rope manufacturing process. The term most commonly used for water-resisting overlay finishes is 'marine overlay finish'. Testing has shown that these marine overlay finishes add strength and abrasion resistance to nylon, polyester, and aramid yarns and rope under wet and wet/dry conditions of use.

Fibre type	Density g/cm³	Melting point °C	Extension
Aramid	1·44	425	1%
HMPE	0·98	150	1%
Nylon	1·14	215-250 *	20%
Polyester	1·38	250	12%
Polyester/Polypropylene	**	250/165	9%
Polypropylene	0·91	165	8%

Notes:

Extension shown is at 50% breaking load of a worked eight strand rope

* 215° C for Polyamide 6, 250° for Polyamide 6·6

** Density depends on the combination of materials, generally about 1·1 g/cm³.

Figure 7.18 Table showing some characteristics of different fibre types

Ropes that will be exposed to severe environmental and mechanical stresses can be protected by the application of external coatings. The most common material is polyurethane, although other materials are also used. Coatings can be applied to protect ropes that will be exposed to severe weather, cycling abrasion, marine growth build up, or long exposure in water. Coatings can furthermore be used to improve abrasion resistance, snag resistance, to provide protection against ultraviolet degradation or for colouring coding.

Handling and maintenance of fibre ropes, including tow lines

Consider first the danger of 'snap-back' of fibre lines. Snap-back is common to all lines. Even long wire lines under tension can stretch enough to snap back with considerable energy. Synthetic lines are much more elastic, except for Aramid and Dyneema/Spectra lines, increasing the danger of snap-back, striking anything in their path with tremendous force. Synthetic lines normally break suddenly and without warning.

	HMPE (1)		Nylon (dry)		Polyester		Polypropylene		Polyester/ Polypropylene (2)	
Dia. (mm)	Mass kg/100m	MBL tonnes	Mass kg/100m	MBL tonnes	Mass kg/100m	MBL tonnes	Mass kg/100m	MBL tonnes	Mass kg/100m	MBL tonnes
40	71	111	99	30	121	35	72	21	98	42
44	86	133	120	36	147	41	88	25	118	50
48	103	159	142	42	175	48	104	29	141	59
52	121	186	166	49	205	55	122	33	165	69
56	141	214	193	56	238	65	142	38	191	80
64	184	276	252	72	311	83	185	49	250	103
72	232	345	319	90	393	107	234	62	316	130
80	287	424	394	110	485	130	290	76	391	158
88	344	514	477	131	587	159	351	91	473	190

Figure 7.17 Table giving comparative weights and minimum breaking loads of 8-strand ropes of different fibres (1) refers to Dyneema/Steelite Extra; (2) refers to Euroflex

Whenever possible one should keep away from synthetic lines under tension and when approaching these lines it should be done with care.

Twisted ropes can be harmed by kinking, which may form into hockles if not properly removed. When a kink forms, the load must be removed and the kink gently worked out.

Ropes must be kept clear of chemicals, chemical vapours or other harmful substances. They should not be stored near paint or where they may be exposed to paint or thinner vapours. The susceptibility of the rope depends on its chemical structure and fibre. Nylon is, for instance, attacked by acids and bleaching agents. Polyester is attacked by some alkalis.

Excessive heat can damage synthetic lines, especially polypropylene. Polyethylene and Aramid are vulnerable to ultraviolet rays. Care should be taken when dragging synthetic lines along the deck. Avoid sharp edges, rough surfaces or surfaces with a small bending diameter. When dirt, grit or rust particles are allowed to cling to or penetrate into synthetic ropes, internal abrasion will result. The rope should be cleaned before storing.

To distribute wear equally along all parts of the towline, ends should be reversed periodically. A further reason is that braided ropes, which are torque-free, develop twists when constantly used on a winch by the direction of turn of the winch, or by rolling on the winch drum due to uneven layers. A braided rope can also get twisted through repeated handling on a capstan. Twists make rope handling more difficult and reduce rope strength when not removed. If a twist develops, it should be removed by rotating the rope in the opposite direction when it is relaxed.

Fairleads, warping drums, roller heads, etc. should be in good condition and damage to fibre lines by rust and grooves in fairleads should be avoided (see figure 7.12 for photograph of ASD-tug *Melton* with stainless steel fairleads).

It is recommended to use a pennant particularly for fibre towlines to minimise damage at the ship's end of the main towline. A cow hitch connection between a fibre pennant and a fibre towline, as often used, reduces strength of the total towing connection by approximately 15%. Splices in a rope decrease minimum breaking strength by at least 10%. Towline, stretcher and pennant (if used), must be inspected at regular intervals and these inspections should include, as far as possible, inspection of inner strands, eyes and splices.

Finally, although all aspects mentioned above for proper rope handling and maintenance are important, of at least equal importance is proper tug handling to minimise as far as possible shock loads in the towline.

Damage to towlines

The experience of several towing companies is that most damage to fibre towlines is the result of problems on the ships being towed, such as corroded and deeply grooved fairleads, sharp edges between fairlead and bollards and square sterns of ships.

It should, however, be noted that the cause of grooved fairleads and bollards does not in all cases lies on board the ship. Many ships have fibre mooring lines. Grooves in the fairleads, bollards, etc. may be caused in ports where tugs are using steel wire towlines, or fibre rope towlines with steel wire pennants, which then cause problems for tugs in other ports using fibre rope towlines.

7.5.3 Composition of towlines

The composition of towlines used for harbour towage can be as follows:

- A single steel wire.
- A steel wire towline, stretcher and steel wire pendant.
- A fibre rope towline and steel wire pendant.
- A fibre rope towline with or without a fibre rope pendant.

Although steel wire has little stretch, only steel wire towlines are used. Dynamic loads in the towline can be compensated by towing hooks fitted with springs or by towing winches with tension control.

Wire ropes used as towlines on towing winches are generally 6 x 36 IWRC, tensile strength 180 kgf/mm^2, wires in strands equal lay Warrington/Seale, strands ordinary lay. On very powerful harbour tugs towlines of tensile strength 200 kgf/mm^2 can be found. Usually a steel wire towline is right hand lay, though when a towing winch is used with a spooling device it depends on the heaving and spooling direction of the winch whether right hand lay or left hand lay is required. When wire towlines are not stored on a winch the same type of wire towline can be used, however with a fibre core.

When a steel wire towline is used in combination with a stretcher and pendant, the steel wire pendant will generally be of the same construction as the towline but usually of rather smaller diameter or of used towline of the same diameter. In case of extreme towline forces the pendant will break first and only this part has to be replaced.

Nylon as well as polyester or polyester/polypropylene is used for stretchers, for instance in eight strand braided construction. The stretcher is often doubled as grommet. The length of stretcher is usually about 10 metres.

Although nylon has large stretch, it degrades in strength and abrasion resistance when wet and is subject to torsional damage when used in conjunction with a steel wire towline (see also paragraph 7.5.2 'Finishes and coatings'). Therefore polyester and polyester/polypropylene are often preferred for stretchers. It is recommended that stretchers have a larger breaking strength than the steel wire towline OCIMF recommends nylon tails have at least 37% higher breaking strength than the rope. This is because experience shows that cyclic loading degrades synthetic lines, particularly nylon, more quickly than wire under similar load conditions. The stretcher should therefore have a 25% higher dry breaking strength than the wire. As nylon has a lower breaking strength when wet an additional 10% should be added, giving a total 37% allowance for reduction in strength. The same at least will apply to nylon stretchers in relation to minimum breaking strength of the towline.

When fibre towlines are used the type of towline depends amongst other things on the loads and in particular the dynamic loads that can be expected and whether a towing winch is used or not. As type of tug, operating methods, conditions and circumstances differ by port, different type of fibre towlines are used, such as towlines made of polypropylene, nylon, polyester or polyester/polypropylene. Different constructions such as double braid, 12 strand, eight strand, six strand and three strand can also be found. Three strand ropes are not optimal ropes for towing winches. A pendant may be connected to fibre towlines to protect the main towline from abrasion. Steel wire as well as fibre rope (including HMPE fibre rope) is used for pendants.

Nylon towlines are used particularly in wave and swell conditions because of their high stretch. One towing company working primarily under these conditions prefers three strand loose laid nylon, after having tried out other rope types and constructions, because of the stretch and ease of handling. The line is belayed onto bollards/bitts on board the tug.

Modern fibres such as Dyneema and Spectra are increasingly used for towlines for escort tugs as well as for harbour tugs. The lines can be 12 strand, eight strand or other constructions, depending on the manufacturer and user's needs. A tail of the same fibre type, sometimes with cover, is often connected to the main towline to prevent it from early wear, while pennants made of e.g. nylon or polyester are used as well. This is because of the low stretch of ropes made of Dyneema or Spectra, which has consequences for dynamic load absorption in the towline and which easily results in high peak loads. This may be the case if no use can be made of a load reducing system on the towing winch (which is mostly the case on harbour tugs), but particularly when short towlines are used. The nylon or polyester pennants add some stretch to the towline.

A system used in e.g. several Australian ports is a Dyneema grommet connected to a double-braid polyester main towline, which results in more stretch in the towing connection. The best way found to connect the grommet to the towline is to pass the rope of which the grommet is made through the main towline's eye and then spliced to a grommet. The on-board end of the grommet may be protected against shaving by a seizing. It is important to use compatible ropes, otherwise the pennant may cut through the main towline. The large advantage of the system is that the grommet can be rotated over time to spread 'wear and tear'.

Experience with these modern fibre towlines is still building up, experience that can be used for further improvement.

As already mentioned in the beginning of the former paragraph, there is a large variety in rope types, rope composites and construction methods, and consequently in rope characteristics and applications. Therefore, when selecting a rope for a towline of a tug, a careful consultation with rope manufacturers and/or suppliers is needed regarding the most suitable rope type and recommended use, taking into account tug's capabilities, working methods and conditions.

The reader is further referred to paragraph 9.5 where specific information can be found on escort tug towlines, which is also of relevance for normal harbour tugs.

7.5.4 Basic towline length

The towline length for tugs towing on a line is now considered. However, it will be shown that some conclusions are also applicable to other tug operating methods.

When towing on a line a tug captain determines the length of the towline on the basis of his insight and experience. This concerns tugs with towing winches and tugs using ship lines as towline. On tugs without a towing winch and using their own towlines the available length is usually limited to a preset towline length, as mentioned earlier.

The towline length used while towing on a line depends on factors such as type and length of tug, size and deck height of the ship to be assisted, environmental conditions and available manoeuvring space for the tug. Ship's speed is also important. These factors may result in longer towline lengths in one port than in another and may also differ depending on the tug captain's experience. Towline length also influences ship manoeuvres, as will be explained

Towline length in relation to ship's path width

To show how towline length affects ship's manoeuvres, a forward tug towing on a line is considered. From figure 7.19 it is clear that when required to change from pulling direction 1 to pulling direction 2 tug A needs more time in comparison to tug B owing to the longer distance to be covered. Tug B, with the shortest towline, can react much faster when required, for instance to stop a sudden sheer of the assisted ship. So, with a short towline faster tug reactions are possible than with a long towline. This applies to tugs towing on a line as well as for tugs operating in the push-pull mode at the ship's side. When the length of the towline is doubled the reaction time will also approximately double.

The manoeuvring space required by a ship is smaller when tugs react quickly. A ship passing through a harbour basin with the assistance of tugs, for example, needs a manoeuvring lane of a certain width. This path width is smaller when tugs work on short towlines, because the ship does not have much time to sheer or drift. As soon as it happens and the pilot or tug captains notice, tugs can react very quickly.

The total required manoeuvring lane width for the combination of ship and tugs is also narrower, because tugs towing on short lines require less space. So, it works to double effect. Working on a short towline therefore has three important advantages:

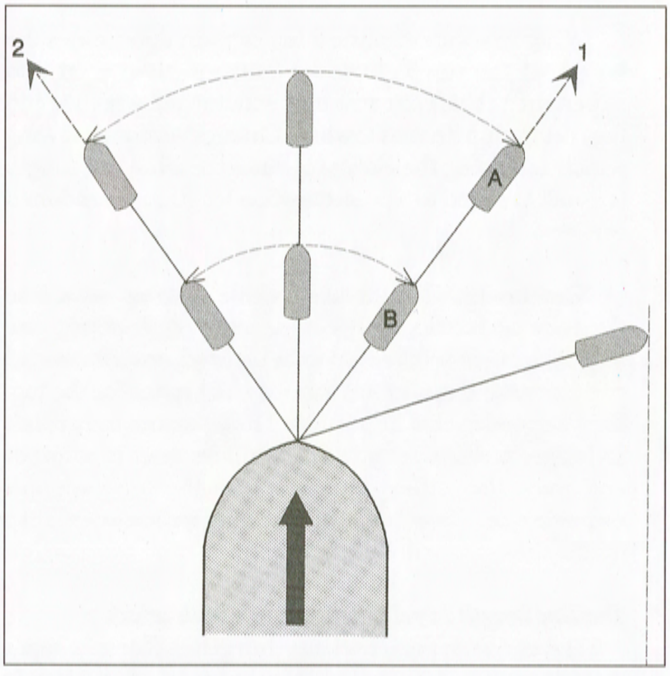

Figure 7.19 Tug reaction time and manoeuvring space required depending on towline length

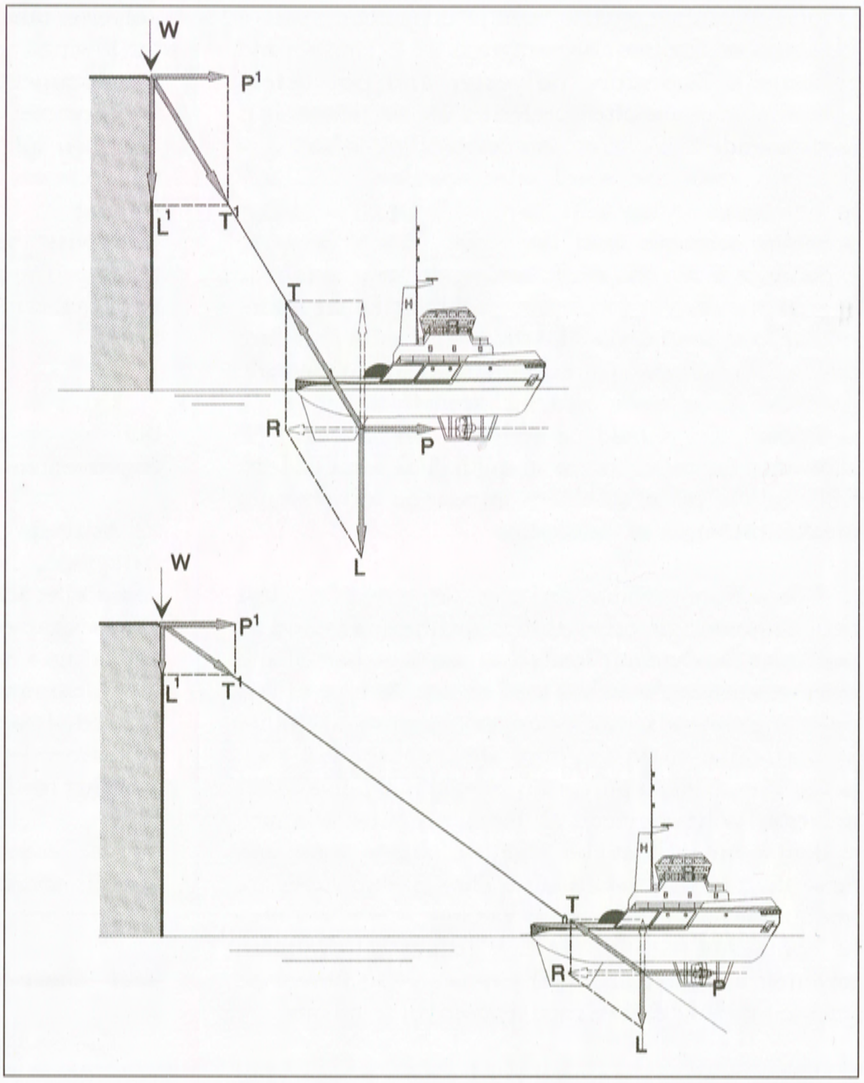

Figure 7.20 The effect of different tow line lengths

- Faster reaction time of tugs.
- Reduced ship's path width.
- Less manoeuvring space required for the combination of ship and assisting tugs.

These aspects are of particular importance when manoeuvring space is limited as is the case in most port areas. It all sounds very logical. However, the experience of some ship masters is that in a number of ports long towlines are used too often. It then takes too long before a tug can exert towing forces in the required direction. In the meantime the ship is drifting or swinging in the wrong direction.

Some comments should be made. The advantages of short towlines include quick reaction times of tugs and minimum required manoeuvring space. However, it will to some extent reduce a tug's effectiveness due to the counteracting effect of the tug propeller wash on the ship's hull. Tugs should therefore have sufficient bollard pull to compensate for part of the loss in

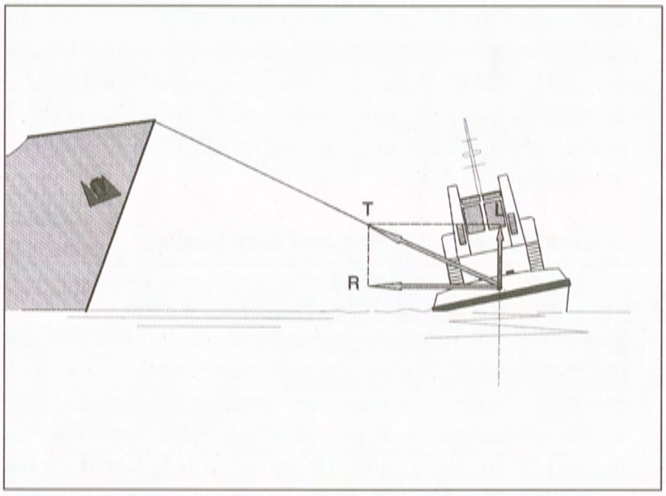

Figure 7.21 Tug operating broadside while ship is moving astern

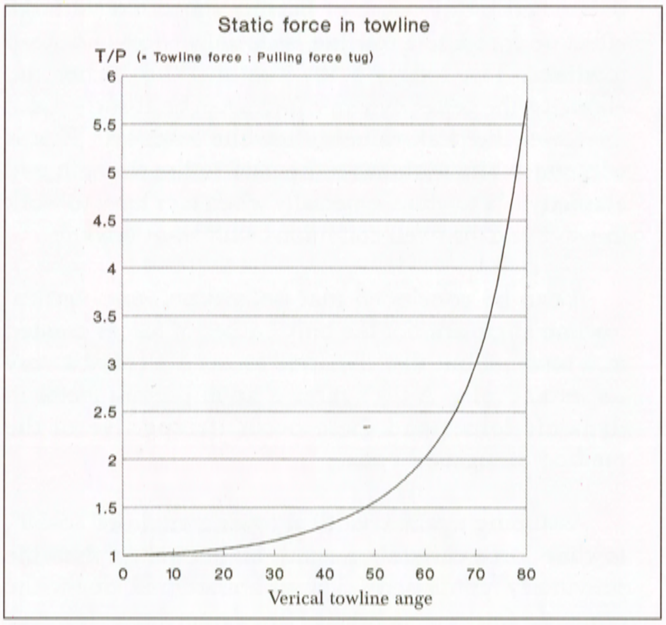

Figure 7.22 Static force in a a towline

Photo: F. v. Lameren

Figure 7.23 Two conventional twin screw tugs, 'Smit Ierland' and 'Smit Denemarken' (l.o.a. 28·4m, beam 8·5m, bollard pull 28 tons) operating broadside at the stern of a tanker entering a basin at the port of Rotterdam

effectiveness resulting from the relatively short towlines. In addition, the higher the bollard pull the faster tugs can restore a ship's position or heading, for instance when the ship starts drifting or veers off course. So the available bollard pull also influences a ship's path width.

When manoeuvring space for a ship is very limited tug reaction time should be very high such as when assisting in dockyards and when passing narrow bridges. Two short towlines should be considered in this case for the forward tug as shown in figure 3.11. A tug secured that way can react much more quickly.

The effectiveness of a tug on a short steep towline

Irrespective of assisting method, the vertical towline angle can be quite large when short towlines are used. There has been a lot of discussion about whether, apart from the interaction effects of a tug's propeller wash, tug efficiency is otherwise affected when the towline is shortened.

For an explanation that no loss in effectiveness occurs when the towline is shortened, see figure 7.20. Both tugs are exactly the same and both are pulling ahead with equal full power P. This gives a force T in the towline. This towline force has a vertical component, which lifts the tug a little out of the water, but is compensated for by the tug's increased apparent weight L. Force L together with the towline force T gives a resultant force R, equal to the pulling force P of the tug in a state of equilibrium. The towline force $T = T^1$ on the ship, can be resolved in a vertical force L^1 and in a horizontal force P^1. The forces P^1, which are the tugs' pulling effects on the ship, are equal to the towing forces P of the tugs. So it can be concluded that shortening the towline does not affect a tug's effectiveness.

However, there is an important aspect to be taken into account and that is friction force L^1. The figure shows that when using a short towline this friction force is very large, resulting in high temperatures and considerable wear so imperilling the towline's life. Where tugs have to work with such short and steep towlines strong pendants are recommended, if they can be used, because they can easily be replaced when damaged.

Tug safety in relation to towline length

Although using a short towline has advantages, one should carefully consider the towline length of a forward tug assisting a ship under speed. When using a short towline the distance between forward tug and ship's bow is very small. Consequently, the time available for a tug captain to react is very limited and when ship's speed is high the reserve engine power of a tug to react quickly is small. That is why he has constantly and closely to observe ship's course and speed changes. On the other hand pilots have to be careful with rudder and engine manoeuvres and have to keep a tug captain well informed about intended manoeuvres, because the safety of tug and crew is involved. For this reason forward tug captains don't like to tow on a short towline in dense fog or when an attended ship has rather high speed. Moreover, with increasing speed other effects such as interaction effects might come into play.

When tugs are operating broadside as shown in figure 7.21, the steeper the towline the larger the righting force L. A short towline in this case has a positive effect on tug safety.

7.5.5 Strength of towline and safety factors

As stated in the introduction to this chapter, the towline is the crucial connection between tug and ship. It should be a reliable connection, not limiting a tug's performance. The length of towlines as well as different types having been discussed, attention now turns to the required strength of towlines.

Static forces in short and long towlines

A tug captain towing on a line may be forced in certain situations or circumstances to use a very short and steep towline, shorter and steeper than he would normally use. This may happen in situations such as when dry-docking practically empty ships with large freeboards, when assisting high freeboard ships in narrow basins and when entering locks or passing narrow bridges. Such situations are quite common to harbour tugs and towline strength should be capable of coping with them.

For forces in the towline look at figure 7.20 again. With an equal towing force P for the tugs the force T in the line of the tug with the steep towline is considerably higher than in the line of the tug with the longer towline. How static forces increase compared to vertical towline angle can be seen in the graph of figure 7.22. Up to a vertical towline angle of 40° the influence is not so large. However, when the vertical towline angle further increases the force in the towline increases very rapidly. At a vertical towline angle of 60° the force is already twice the exerted towing force of the tug. A vertical towline angle of 45-50° for tugs secured at a ship's side is not too large but when towing on a line it is a large angle, although it does happen. In this case the static force in the towline is already 1·5 times as high as the towing force of the tug. The towline force further increases by the tug's underwater resistance when the tug is also drawn in the direction opposite to its pulling direction. In the case in figure 7.20 the tugs would then be pulled backwards.

There is not always a direct relationship between towline force and the towing force exerted by the tug. In situations where the tug is steering broadside to a ship which has sternway (see figure 7.21), the force in the towline is caused only by the tug's underwater resistance. Tugs operating in the indirect towing method, particularly at high speeds as is the case with escort tugs, experience very high towline loads mainly due to high lift forces generated by the tug's underwater body and skeg, if fitted. However, the main factors for the maximum static forces in the towline during normal harbour operations are the tug's bollard pull and the towline angle.

Dynamic forces in a short and long towline

In addition to static forces, dynamic forces can also occur in a towline and can reach high values. They are generated, for instance, by sudden accelerations of the tug, wrong tug manoeuvres, waves, swell and so on, creating shock loads in the towline. Horizontal tug accelerations can be kept under control to some degree by careful manoeuvring. However, this is not the case with vertical accelerations due to waves and swell. It is obvious that these vertical accelerations, which can even be created by the wash of passing ships, have a large effect on forces in a towline, especially short and steep towlines. The longer a towline and the higher the elasticity, the better dynamic forces can be absorbed and the lower the peak values of towline loads are. That is why much attention has to be paid to the strength and elasticity of a towline, especially when tugs have to work in wave and/or swell conditions with short towlines.

It can be concluded that bollard pull and vertical towline angle are not the only causes of forces created in a towline, but that dynamic forces also play a very important role. A tug's mass is an important factor in dynamic forces and these occur irrespective of the method of tug assistance.

Assuming again a vertical towing angle of 45-50°, towline force certainly reaches higher values than the previously mentioned 1·5 times bollard pull, due to the dynamic forces generated. How large these dynamic forces are depends, amongst other things, on length, type and/or composition of the towline. But towline forces in excess of twice the bollard pull of the tug are not uncommon, particularly when towlines with little stretch, such as steel wire, are used. It is clear that when brake holding power is less than this value the brake of the towing winch may slip sometimes. This is, of course, only when the minimum breaking strength of the towline is sufficient to cope with the high dynamic forces.

Safety factors regarding towline strength

The question now is what the towline strength should be in relation to the bollard pull of a tug. This is considered starting with a steel wire towline. Two aspects are important when using steel wire towlines. Steel has some elasticity. This means that under load a steel wire elongates and when the load is removed it returns to its original length. This is only true up to the so-called 'elastic limit', approximately two thirds of the minimum breaking load of the wire. When load exceeds this limit it results in permanent elongation of the wire.

The so-called 'endurance limit', approximately half the minimum breaking load, is also of great influence on the life of a steel wire. Tests have shown that when a steel wire cable has several times endured a load higher than the 'endurance limit' its life is very short and it breaks without ever being exposed to a load up to the 'elastic limit'. It is clear that shock loads play an important role.

Taking into account the towline force of two times the bollard pull of a tug, the minimum breaking strength of a steel wire towline should then be at least four times the bollard pull of the tug, in order to stay within the 'elastic limit' and 'endurance limit'.

Peak values in towline loads due to dynamic forces are lower in 'conventional' fibre lines than in steel wire ropes. These fibre lines have better dynamic load absorbing characteristics. According to OCIMF, due to the lower recommended allowable loads the safety factor for these synthetic (mooring) lines should be 10-20% higher than for steel wire ropes, depending on the type of fibre rope. Because of the lower peak loads occurring in 'conventional' fibre lines in combination with a higher safety factor, in practice approximately the same safety factor is assumed applicable to steel and fibre towlines. For the time being, this will also include towlines of harbour tugs made of the more modern HMPE fibres. More information regarding this rope type may become available in the near future, for instance by OCIMF publication (see References) or otherwise. See, however, also the relevant sections of par. 9.5.1 in the escort tug chapter.

Photo: Author

Figure 7.24 VS tug 'Matchless' (l.o.a. 27m, beam 9·7m, bollard pull 34 tons) of Port of Chennai, India, made fast with two ship's lines. The eyes of the lines are led through the tug's fairlead and secured on the towing bitt

Although only an approximation, the safety factor of at least 4 times the bollard pull corresponds reasonably well with those applied by a number of large harbour tug companies, viz. 3·5 to four times the bollard pull. A factor of six times the bollard pull can be found, and also much smaller safety factors, twice the bollard pull for instance. Such a low safety factor affects a towline's life.

Note: It has already been indicated that the bollard pull of a tug is not the only important factor for the minimum breaking strength of a towline. But for harbour tugs it can be considered the most important because other factors such as mass or underwater plane of a tug generally have a close relationship with tug size and consequently with the installed engine power and the bollard pull of a tug.

For escort tugs the high towline forces that can be generated in the indirect mode are much higher than the bollard pull and therefore a more appropriate criterion for the required minimum breaking strength of the towline.

7.5.6 Ship's mooring lines as towlines

Using ship's mooring lines as towlines is not recommended. Strength and composition may not be in accordance with tug towing force, particularly of more powerful tugs. Taking into account the recommendations of Classification Societies for mooring lines, the minimum breaking strength of these lines should be roughly 50 tons for a bulk carrier of 50,000 dwt and 70 tons for a bulk carrier of 200,000 dwt. Assuming a bollard pull of 30 tons for attending tugs, then the minimum breaking strength of the towlines should be about 4 x 30 = 120 tons. A bulk carrier's mooring lines do not meet this breaking strength at all, not even with a safety factor for tug towlines of 2–2·5.

Ship's lines used for tugs are also frequently used for mooring and are subject to intensive wear. The quality of these lines may also be affected by sun, oil, chemicals and so on. Consequently they usually have a much lower breaking strength and often low reliability.

7.6 Towline handling

As tug power increases, especially when steel towlines are used, the towlines become more difficult to handle. Fibre towlines, particularly those made of the newest fibres, have a much lower weight but are only used on a limited though increasing number of tugs. A gradual change in the use of towlines can be expected.

On board ships the number of crew members is still gradually decreasing. This is evidently without sufficient appreciation of the workload and manpower requirements associated with arrival/departure activities such as towline and mooring line handling. For the few remaining crew members it is a difficult job to secure and release towlines within an acceptable time. The reduction in crew size is an incentive for development of alternative systems for attending towlines of harbour tugs. There are ships where boatmen are engaged who board the vessel together with the pilot and assist the crew in attending a tug's towlines and when mooring.

7.6.1 Safe handling of towlines aboard ships

Most of the following rules for safe handling of towlines aboard ships are listed in the OCIMF booklet 'Effective Mooring':

- A sufficient number of heaving lines of proper length and strength should be ready at mooring stations in good time for hauling tug towlines aboard.
- The condition of a tug's towlines is unknown, and crew at mooring stations are not normally aware of when a tug is actually towing or what load is applied to the line. It is therefore important to stay well clear of the towline at all times.
- When a tug is being secured or let go, the person in charge of the mooring should monitor the operation closely to ensure that no loads come onto the line before it is properly secured, or whilst being cast off.
- Never let a tug go until instructed to do so from the bridge; do not respond to directions from a tug's crew.
- If the towline is provided with an eye, heave this past the bitts so that there is sufficient slack line to work with, stopper off the line, then put the eye on the bitts. Do not try to manhandle a line on to a bitt if there is insufficient slack line. If the line has no eye and is to be turned up on the bitts then it should always be stoppered off before handling.
- Do not try to hold a line in position by standing on it just because it is slack – if the tug moves away so will the person standing on the line.
- When letting go do not simply throw the line off the bits and let it run out; always slack it back to the fairlead using a messenger line and lower it as far as possible in a controlled way onto the tug's deck.

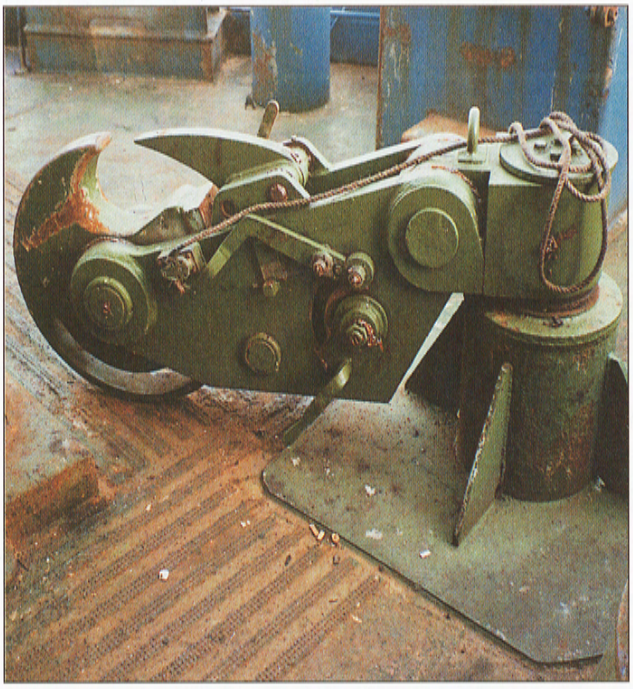

Photo: Author

Figure 7.26 Quick release hook used on ferries of North Sea Ferries for securing a tow line when a tug is required

7.6.2 Some methods for passing, taking and/or securing towlines

Cranes for towline handling

Tugs can be equipped with a crane fitted with a hydraulic clamp to deliver a towline to a ship to be assisted. Such cranes for towline handling can, for instance, be found on board some of the reverse-tractor tugs of the Canadian tug company C.H Cates & Sons

Photo: C. H. Cates & Sons Limited, Vancouver, Canada

Figure 7.25 Reverse tractor tug 'Charles H Cates 1' (l.o.a. 22·5m, beam 8·5m, bollard pull ahead 38 tons, astern 32 tons) with line handling crane

Ltd. The heavier the towline the more advantageous such a system can be. However, the increased use of lighter, high-strength towlines make these cranes virtually redundant.

Quick release hooks on board ferries

Ferries do not usually use tugs, though in adverse weather conditions it may sometimes be necessary. For easy fastening of a towline and to be able to release it in a minimum of time and with only one person, some ferries have a quick release hook fitted on the fore and after deck for towline connection. see figure 7.26.

Automatic hook up system

A system that has been proposed is an automated hook up system, the 'Aarts Autohook' of Aarts Autohook B.V., Amsterdam. No crew is required on the deck of the ship or tug to secure or release towlines. Securing or releasing the towline can be achieved in a minimum of time and at a rather high ship's speed.

At the end of the tug's towline a simple ball is fastened, the connector. The connector is placed by a specially designed tug's crane, the manipulator, in a hook-up point aboard the ship to be assisted. The crane is controlled from the wheelhouse. The system can be used, for instance, at terminals where the same ships call regularly, because in order to use the system the ships must be fitted with a number of these hook-up points at convenient locations for the tug assistance required. The deck mounted and/or hull mounted hook-up points must also be placed in such a way that the ship can be handled in a loaded as well as in a ballasted condition.

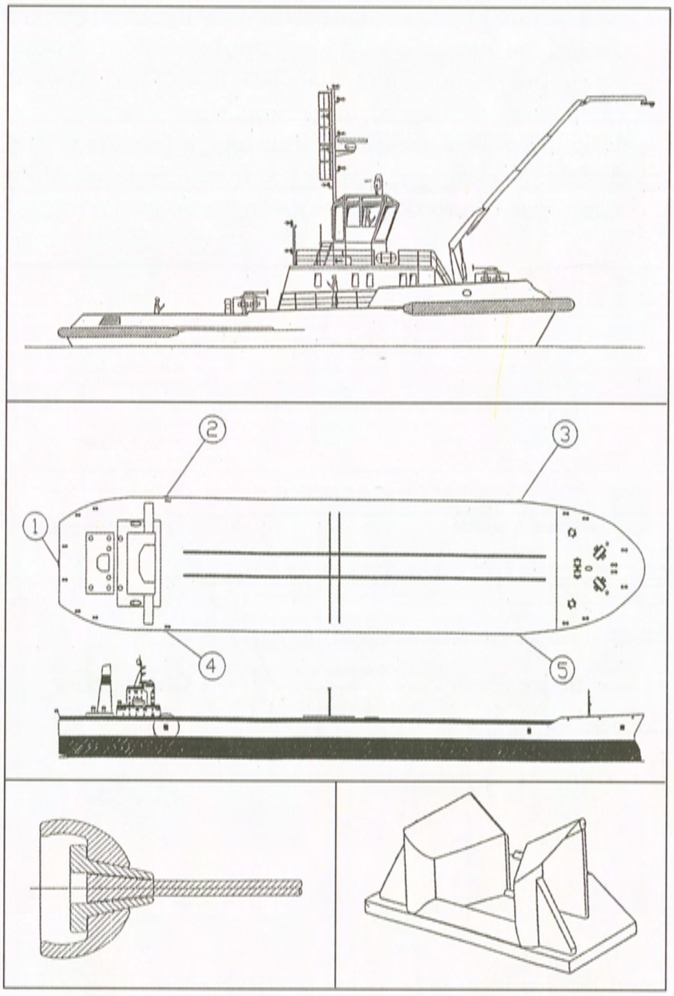

Figure 7.27 Automatic hook up system, Aarts Autohook
One of the proposed tug designs, Triple E, with the manipulator, the proposed hook up points on a tanker, the connector and a passive hook up point for deck mounting

There are two types of hook-up points: passive and active. Connection and disconnection to passive points is by means of the manipulator. For disconnecting from the active points there are two possibilities, either by manipulator or from the ship by remote control from the wheelhouse or locally, activating a hydraulic cylinder which lifts the connector out of the hook-up point.

The system can be fitted to any type of tug but certain tugs have been designed specifically for this system. The Triple A design concerns harbour and terminal tugs, whether stern driven or tractor type. The Triple E type is also equipped for escorting, emergency towing and emergency response duties, such as firefighting and oil spill control.

Controlled placing of the connector by the manipulator in the hook-up points of a ship having a rather high speed could be difficult at night, in reduced visibility or in wave and swell conditions, particularly near the shoulders. At the stern of the ship it should be easier. Problems may arise when a line breaks, though wear will be less because the towlines do not pass through ship's fairleads.

Emergency towing equipment

Emergency towing equipment has less to do with harbour towage, but is mentioned here because of its importance in ship handling in an emergency. Emergency towing equipment is more of a safety requirement for open sea, to facilitate towing the tanker out of danger in order to prevent the risk of pollution in case of emergency such as loss of propulsion and/or manoeuvrability, although it may also be suitable for connecting the towline of an escort tug (see paragraph 9.5.1)

Emergency towing arrangements are required by regulation II-1/3-4 of the 1974 SOLAS Convention, of which a new text was adopted by resolution MSC.99(73) at MSC 73 on 5 December 2000. The amended regulation entered into force on 1 July 2002. The following is required by regulation II-1/3-4:

1 Emergency towing arrangements shall be fitted at both ends on board every tanker of not less than 20,000 tonnes deadweight.
2. For tankers constructed on or after 1 July 2002:
   .1 The arrangements shall, at all times, be capable

of rapid deployment in the absence of main power on the ship to be towed and easy connection to the towing ship. At least one of the emergency towing arrangements shall be pre-rigged ready for rapid deployment; and

2 Emergency towing arrangements at both ends shall be of adequate strength taking into account the size and deadweight of the ship, and the expected forces during bad weather conditions. The design and construction and prototype testing of emergency towing arrangements shall be approved by the Administration, based on the Guidelines developed by the Organization.*

3. For tankers constructed before 1 July 2002, the design and construction of emergency towing arrangements shall be approved by the Administration, based on the Guidelines developed by the Organization.*

* Refer to the Guidelines on emergency towing arrangements for tankers adopted by the Maritime Safety Committee by resolution MSC.35(63).

IMO has adopted amendments to resolution MSC.35(63) at session MSC 75 on 22 May 2002 by resolution MSC.132(75) to bring the contents in line with the new requirements of regulation II-1/3-4 of the 1974 SOLAS Convention.

The 'Guidelines for Emergency Towing Arrangements for Tankers' apply to tankers, including oil tankers, gas carriers and chemical tankers. According to these guidelines the major components of towing arrangements should include (see figure 7.28):

	Non pre-rigged	Pre-rigged	Strength requirements
Pick-up gear	optional	yes	–
Towing pennant	optional	yes	yes
Fairlead	yes	yes	yes
Strongpoint	yes	yes	yes
Roller pedestal	yes	depending on design	–

	Forward of ship	Aft of ship	Strength requirements
Chafing gear	yes	depending on design	yes

At least one of the emergency towing arrangements should be pre-rigged and capable of being deployed in a controlled manner in harbour conditions in not more than 15 minutes. The pick-up gear for the pre-regged towing pennant should at least be designed for manual operation by one person, allowing for no power available and the potentially adverse environmental conditions that may prevail during emergency towing operations.

The non pre-rigged emergency towing arrangement should be capable of being deployed in harbour conditions in not more than one hour. The forward emergency towing arrangement should at least be designed with a means of securing a towline to the chafing gear using a suitably positioned pedestal roller to facilitate connection of the towing pennant. Pre-rigged

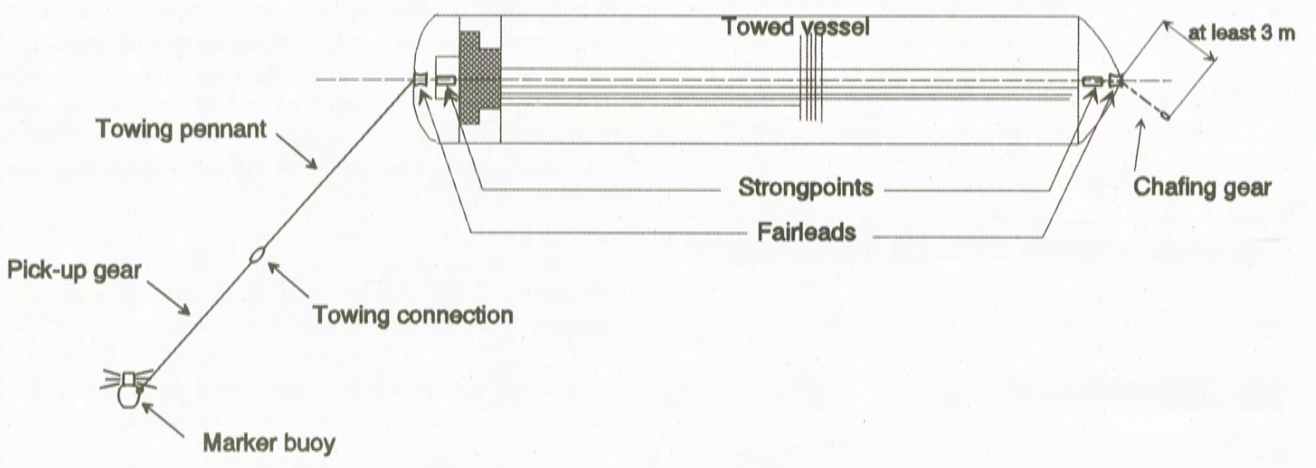

Figure 7.28 Typical emergency towing arrangement

emergency towing arrangements at both ends of the ship may be accepted.

More detailed requirements are given by the IMO and by Classification Societies regarding strength of towing components, length of towing pennant (IMO: at least twice the highest seagoing ballast freeboard at the fairlead plus 50 metres), locations of strongpoints and fairleads, size of fairleads, type and length of chafing chains (if used) and so on.

Large numbers of tankers are already fitted with this emergency towing equipment. Different systems exist and other systems are planned. The main components, in line with IMO requirements, are:

- A strong point to which the towing connection on board the tanker is secured.
- A ship's fairlead. The strong point can be integrally designed with the fairlead.
- A ship's towing connection, which can be a chafing chain to which a towing pennant is connected. The pennant can be made of Dyneema or Spectra fibre which floats. In addition, a nylon shock absorber may be used. Instead of a chafing chain and fibre towing pennant a steel wire towing pennant may be used, stored on a winch drum.
- A pick up gear consisting of:
  - A messenger line (to be) connected to the pennant and made of synthetic rope, often of the floating type, or a combination of synthetic rope and steel wire.
  - A pick up line, connected to the messenger, with one or two light buoys.
  - Or just a floating messenger line with marker buoy.

Pick up gear and towing pennant are optional for the non pre-rigged emergency towing arrangement. Deployment of emergency towing systems depends on their design. Most systems have to be deployed manually by launching the pick up gear or, locally or remote controlled on board, by an air rifle which shoots a pick up line away from the tanker. The salvage tug takes the messenger on board by the pick up line and deploys the emergency towing pennant and chafing chain, if used, by heaving on the messenger line. The ship's emergency towing pennant is then connected to the tug's towline. One of the available systems can, as an option, also be remote controlled when the crew has already left the ship. A remotely controlled air rifle shoots a line to be picked up by a salvage tug.

Other systems also exist for which no crew is needed for deployment. So, there is a large variety of emergency towing arrangements that have been developed, many of which are reviewed in 'A guide for the emergency towing arrangements' (see References).

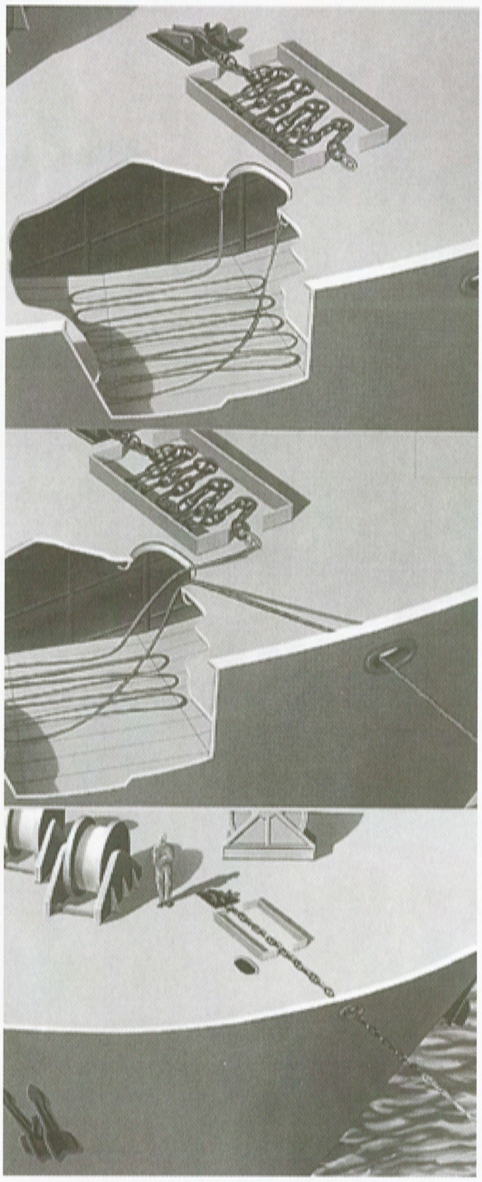

Figure 7.29 One of the emergency towing systems in three phases of deployment – Smit Safe Fast – with Smit bracket, chafing chain (of such a length that the endlink reaches about 4 metres outside the fairlead), fairlead and towing pennant (about 100 metres Dyneema/Deenaflex hawser) and messenger line (120 metres polypropylene – not shown)

MarineSafety International Rotterdam (since December 2000: Maritime Simulation Rotterdam)

Figure 8.1 Simulator lay-out with five bridge manoeuvring simulators, a VTS simulator and instruction rooms. The bridge manoeuvring simulators can operate interactively

Chapter EIGHT
TRAINING AND TUG SIMULATION

8.1 Reasons for training

TRAINING IS PART OF THE LEARNING PROCESS for a pilot or tug captain. It is a continuous process which does not stop the moment pilots or tug captains are appointed. Learning continues during their whole career.

Training can include practical 'on-job' training and a more theoretical phase. In several ports tug captain training is still only carried out 'on the job' and the same is true for most ports with respect to pilot training on the subject of tugs and tug use.

Training 'on the job', gathering experience in practice, is essential to becoming a skilled pilot or tug captain. However, if only using 'on-job training', a system of 'trial and error', there are risks involved because of the 'errors'. It is time consuming and can therefore be expensive, also because of the possible 'errors'. Besides, tug captains or pilots only pass on to a trainee the experience they have built up themselves. This includes any shortcomings and accumulated bad habits and may not, therefore, result in the most efficient and safest use of tugs. This may particularly be the case when 'on-job training' is carried out by just one person.

Providing pilots and tug captains with both theoretical and practical background knowledge of the capabilities and limitations of tugs, and of what can be expected in practice when tugs render assistance, gives a better understanding of tugs and their performance and results in more efficient and safer ways of building up practical experience during 'training on the job'. This also applies to simulator training, which should not be seen as a substitute for 'training on the job', but as a substantial improvement.

The importance of proper training has grown since the appearance of tugs with different propulsion systems such as azimuth thrusters or Voith Schneider propulsion. Tugs are a costly investment and should therefore be used in the most efficient way. Not only that, but port developments don't always keep pace with increased ship size or draft and a minimum of tugs is often used due to economic pressure. All this results in diminishing safety and operational margins and a more essential role for the remaining tugs. This role can also be enhanced by the increased power of tugs, resulting in the use of fewer tugs per ship.

Pilots and tug captains should therefore possess the ability to use or handle a tug to its fullest capabilities, which can be achieved by proper training. Experience can be gained more quickly and the highest level achieved when a tug captain handles just one tug or tug type. When, as is the case in some ports, tug captains shift between different tug types, the need for proper basic training increases.

In addition to basic training, focused on the local situation, there can be several other reasons for training, such as:

- Specific situations, conditions or bottle-necks in a port requiring special attention.
- Port developments, for example a new harbour basin or berth.
- Specific large or deep draught ships expected to call at a port.
- A new type of tug to be introduced into a port.

It will be clear that training is not limited to new pilots or tug captains. In particular the four training purposes mentioned above are for experienced tug captains and pilots as well.

Depending on port requirements, tug captains and crews are often trained in fire fighting and pollution control. Some knowledge of these subjects would be welcome even when not required by a port, since tugs have to handle all kinds of ship, some with dangerous cargoes. Emergency tug assistance may be required and the more knowledge about the risks involved the better. However, this chapter only deals with training in shiphandling with tugs and the use of simulators, particularly matters to be considered when using full mission simulators as a training tool for tug operations.

8.2 Different training objectives

As mentioned, there can be different reasons for training in tugs and tug use apart from normal training on the job. These different objectives are considered though it depends entirely on the local situation of a port which of the following courses is required, although basic training is always very useful.

8.2.1 Basic theoretical-practical training

Theoretical-practical training cannot be carried out without the knowledge of experienced pilots and tug captains. They should have the ability to pass on their knowledge and experience in a clear and understandable way. The reason the term theoretical-practical training is used is because training should not be purely theoretical but should have a strong relationship to daily practice.

Basic theoretical-practical training gives tug captains and pilots an insight into the most relevant aspects of shiphandling with tugs. It takes into account the capabilities and limitations of tug types used, type of ships calling at the port, specific characteristics of the port and environmental conditions, with the objective of achieving efficient and safe tug use. A basic training is intended for both trainee pilots and tug captains, but can also be useful for experienced pilots and tug captains, when they have not had an earlier opportunity to attend such training.

In a large number of ports theoretical-practical courses in tug assistance are given. Training arrangements and target groups, including the tools used, differ between ports. Without going into too much detail, the most important aspects of basic training are considered next. For basic training in shiphandling with tugs the following main subjects are important:

For pilot training:

- Ship handling.
- Knowledge of the capabilities and limitations of tugs while rendering assistance.

For tug captain training:

- Handling a free sailing tug.
- Knowledge of the capabilities and limitations of ships and of tugs while rendering assistance.

It is assumed that pilots have already gained experience in and knowledge of shiphandling and tug captains of at least handling a free sailing tug. Other aspects have specifically to do with shiphandling with tugs and are discussed below in more detail.

What knowledge of tugs and tug use is required by a pilot?

The following knowledge is required to gain insight into the performance of tugs:

- Knowledge of what tug types are available in the port.
- Understanding various tug types and their propulsion and steering system functions.
- The bollard pull of tugs, ahead as well as astern.
- Knowledge of how different tug types operate when rendering assistance, including the use of towlines and towing equipment.
- Knowledge of the capabilities and limitations of tug types when rendering assistance and how tugs can be used in the most advantageous way. This applies to situations when the ship is stopped in the water as well as when making headway or going astern.
- Understanding the interaction effects between tug and ship and insight into how interaction may affect tug performance and safety and how these influences can be limited.
- Apart from interaction effects, knowledge of the relationship between:
  a) Ship's engine and rudder manoeuvres and speed.
  b) Tug performance and safety.

When a port has only one type of tug the same, but type-related, knowledge is required by pilots. It is not only necessary to have knowledge of the different tug types in use in the port in general, but also of each tug in particular. This is necessary because within a certain type the design of various units may show marked differences not only in appearance but also in performance and capabilities.

In addition to the training subjects mentioned above, a pilot should be trained to be able to:

- Establish the required bollard pull for ships, taking into account factors such as ship particulars, underkeel clearance, environmental conditions, particulars of the passage to the berth and berth location.
- Determine the most effective positions of the available tugs and tug types, taking account of when, where and how tug assistance is required during passage towards the berth, at the berth and when departing.

The knowledge gained above contributes to effective and safe tug use.

What is useful for a tug captain to know about ships?

For optimum shiphandling a pilot should have a good insight into what a tug can do, including its limitations. For the same reasons it is useful to provide tug captains with knowledge about the manoeuvring capabilities of ships they assist. The following are recommended:

- Basic knowledge of manoeuvring characteristics of ships, especially medium and low speed manoeuvring, including the influence of wind, current, shallow water and banks on a ship's behaviour.
- Basic knowledge of the working of different ship propulsion and rudder types and their effect on tug assistance.
- Performance of bow and stern thrusters.
- Relationship between a tug's position and ship's response to the forces exerted by a tug.
- Basic understanding of the interaction effects between tug and ship and insight into how interaction can affect tug performance and safety and how these influences can be limited.
- Apart from the interaction effects, knowledge of the relationship between:
  a) Ship's engine and rudder manoeuvres and speed.
  b) Tug performance and safety.

This knowledge gives a tug captain a basic general insight into a ship's manoeuvring behaviour and capabilities. Taking into account different ships and the situations and circumstances in a port, the knowledge gained may contribute to improved anticipation of a ship's behaviour and a pilot's intentions.

A tug captain should also acquire knowledge of the following:

- The capabilities and limitations of tug types while rendering assistance and in particular of the tug he has under command, which should also include the capabilities, limitations and efficient use of the propulsion and steering control systems of the tug, also in case of a single lever control system, and how to respond to propulsion and steering control system failures.
- How to make use of the capabilities of his tug in the safest and most advantageous way when passing or releasing towlines, when coming alongside or departing from a ship's side and when rendering assistance, taking into account all the risks involved related to tug or tug type.
- Proper towline handling and appropriate towline lengths.
- The most effective positions for various tug types, taking into account when, where and how tug assistance is required such as for compensating influences of wind or current, and with respect to particulars of the passage towards a berth and berth location.
- Safety regulations and measures, for instance the need to maintain watertight closed condition of spaces below when a tug is rendering assistance.

As with pilots, the knowledge gained contributes to safe and efficient tug use. Some towing companies have good training manuals, which include several of the aspects mentioned above. It should be noted that theoretical-practical training gives a basic insight, but the required experience can only be acquired 'on the job'.

Additional training aspects

With the exception of the basic manoeuvring characteristics of ships, all the important training aspects have been discussed in the foregoing chapters of this book.

Training for pilots and tug captains has been dealt with separately up till now, but as they should work as a team, training should include more time together. A very important objective of training should be the creation of good understanding and cooperation between pilots and tug captains. Not only between pilots and tug captains but also amongst tug captains, because they have to coordinate manoeuvres in such a way that the most effective tug forces are delivered to a ship. When, for example, two tugs are assisting a ship and one makes a mistake, the effect of the other tug may also be spoiled. To achieve good cooperation it is essential to include the following elements in all training courses:

- Effective communication between pilot and tug captain; attention to this aspect has already been paid in paragraph 4.7.
- Optimum information exchange between pilot and tug captain and between the tug captain and his crew regarding tug placement, destination, intended manoeuvres, propeller use, towline use, etc.

How can basic training be given?

The knowledge of experienced pilots and tug captains is a requirement for successful basic training, which can be given as follows:

- By a classical course, making use of overhead transparencies, slides and/or videos.
- By a classical course and the use of simulations. Simulators can be used to give participants insight into various aspects of ship handling with tugs. For some training objectives, desktop simulation programs are appropriate, or in some cases remote controlled tug models, whether or not in combination with manned ship models, otherwise full mission bridge simulators can be used.
- For junior pilots part of the training should be undertaken on board tugs, while trainee tug captains should accompany pilots on board ships for a time.

Several of the training subjects for pilots and tug captains are similar. Combined training is therefore very effective, particularly when part of the training is given on a full mission simulator. However, the contents of basic training may differ between ports because of the differences in level and background of pilots and tug captains. The background of pilots may also be such that they have already gained considerable experience in tug assistance, especially in ports where pilots are recruited from local tug captains. Whether completely or partly combined training should be given for pilots and tug captains, therefore, should be considered locally.

Regardless of basic training, regular meetings between pilots and tug captains, common practice in a large number of ports, are very useful to discuss problems encountered daily and suggestions of ways of solving them.

8.2.2 Training for specific situations and conditions

This kind of training is sometimes required for problematic areas in the port or port approaches or for difficult environmental conditions such as strong currents or fog. Restrictions in force for certain port areas, harbour basins or berths with respect to tidal currents or wind are sometimes considered too stringent, especially from an economic point of view, and relaxed regulations are issued. For pilots and tug captains the situation then becomes more difficult due to the greater influence of wind and/or current and training will familiarise them with the new and more severe conditions and smaller margins. In most cases such training follows a feasibility study, often carried out on a ship manoeuvring simulator