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SQUAT
INTERACTION
MANOEUVRING

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THE ROYAL HOTEL, HULL
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CONTENTS

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INTERACTION

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1. INTRODUCTION

When ships come close to each other, one is apt to 'feel' the presence of the other to a greater or lesser degree. This may be manifest in a number of ways, ranging from involuntary speed changes to catastrophic (and again involuntary) course changes which may lead to collision, or grounding.

Of course, it is wise to avoid these sudden, unexpected occurrences by leaving plenty of sea room between one ship and another. But this is not always possible : ships in a long narrow approach channel have to pass each other and some (tugs and pilot launches for example), by the very nature of their work, must go in close to the ships they are attending.

The hydrodynamic phenomenon which causes ships in close proximity to exhibit this behaviour is known as interaction and its causes and effects are the subject of this paper.

First we look at the causes, then give some practical aspects which incline toward operations in shallow or confined waters, and finally consider some famous examples of interaction which themselves have spurred research into this important and fascinating topic.

2. WHAT CAUSES INTERACTION?

Interaction at sea has a number of resonances with similar effects on land. The sway that is felt when a car passes (or is passed by) a large lorry on a motorway, the suction created by a high speed train passing through a station (giving rise to the yellow warning lines painted on platforms) and ground effect experienced by aircraft when taking off or landing are all examples. Indeed they all arise from the same basic fluid dynamic cause, although with ships the phenomenon is more insidious and can strike unexpectedly.

In the marine world, interaction is caused when the pressure fields around ships interact. All ships are in a state of balance in the water, held in position at rest by hydrostatic pressures to which are added dynamic pressures when the ship begins to move. Dynamic pressures are those which cause (and indeed are represented by) the familiar diverging and transverse wave systems generated by a ship moving calm water.

If the pressure system acting over the underwater hull of the ship is changed in any way, its state of balance will be affected. It may go faster or slower, move off course, sink deeper into the water or rise on to its surface (squat), or possibly trim differently. If a ship moves from deep into shallow water the presence of the seabed will have an effect on hull pressures as the water gets more shallow. Waves also become steeper in shallow water and so do the ship's own waves. The upshot of this is that the ship expends more energy making its own wave system, so its resistance increases and, unless it changes its engine setting, it will slow down. It will also exhibit an increased tendency to squat. Finally it will cause, and feel, enhanced interaction.

In shallow water, ship-ship interaction becomes more severe from these purely hydrodynamic causes. Figure 1, from reference 1, attempts to demonstrate that, as ships pass close by each other, they may be sucked together or pushed apart, turned toward or away from each other, all due to interaction.

Figure 2 shows some measurements of the surge and sway forces, together with the yaw moments experienced by one model ship when passed by another on a reciprocal course. The effect of reducing water depth can be seen readily and it is of interest to note that transient changes in mean sinkage and running trim (squat) also occur.

As well as ship-ship interaction, there is another form of interaction which occurs when a ship is near a canal or fairway 'bank'. As shown in Figure 3 the bank acts in many ways as a mirror and a ship close to a bank behaves as if it was close to its mirror image. The result is that the ship will be generally sucked toward the bank. But the wave system of the ship will also be affected and the bow wave close to the bank will increase in size and form a pressure 'cushion'. This is enhanced if the bank is sloping, when the wave may locally 'go critical' and get even steeper. This 'cushion' will tend to push the bow away from the bank and, if the speed is high enough, the 'push' from the cushion can overcome most of the suction pulling the ship toward the bank so that it tends to be pushed bodily away.

3. SHIP-SHIP INTERACTION

Having looked briefly at the causes of interaction, what about its effects and how can these be overcome?

Model tests have shown that, in general terms, ship-ship interaction varies.

- as the square of the speed.
- inversely with distance off.
- roughly as the inverse square root of the underkeel clearance to draught ratio.

These mean that:

- the faster the ship moves, the worse interaction becomes.
- the greater the lateral separation between ships, the better.
- the smaller the underkeel clearance, the bigger the effect.

So the lesson to be learnt is that the correct speed and distance off are vital if interaction is to be avoided, or at least its effects minimised. Of course, in some situations it is not possible to reduce speed or increase distance off in which case an awareness of the possibility of interaction and its effects is important. In such cases "fore-warned is fore-armed".

With this in mind, the following general effects of interaction for ships passing on parallel or reciprocal courses are given. They are illustrated diagrammatically in Figures 4 and 5.

3.1 Head-on Passing

1. Interaction begins to be felt with the bows of both ships being pushed away from each other accompanied by a slight increase in speed.
2. At the same time, the vessels feel a slight bodily repulsion.
3. As the ships pass, the 'bow-out' moment turns to 'bow-in' and the repulsion reduces.
4. The 'bow-out' moment then returns as passing continues, but is now stronger. Indeed it may cause both ships to sheer away from each other once they have passed. A slight reduction in speed may also be felt.
5. Finally a weak 'bow-in' moment accompanied by a repulsion may be felt.

Comment

Passing on reciprocal courses has the merit (from an interaction point of view) of being quick so that often the ship does not have time to react to the various interaction forces and moments it feels. Usually the dominant effects are the 'bow-out' turning moments as the ships begin to pass and the stronger bow-out moments once passing is almost over. The former is beneficial and is usually small enough to control, while the latter is much stronger and, if not anticipated, could cause one or other of the vessels to sheer toward the bank of a narrow channel.

3.2 Overtaking

1. As the overtaking vessel overhauls the overtaken vessel, two things happen:

    - a small bow-in moment is experienc xl by both ships.

    - the overtaking ship speeds up and the overtaken ship slows down.

2. As the relative velocity when overtaking may be low, interaction has time to take effect and at this juncture, the overtaken ship may be caused to turn across the bows of the overtaking ship which may perversely turn toward her. As a result both ships may collide (see Figure 5).

3. If a collision does not occur (perhaps because the vessels are on slightly converging courses) then the overtaking vessel will move past the other and both will feel powerful bow-out moments together with a mutual attraction. This may cause both ships to 'fly apart' and their sterns to collide as shown in Figure 5.

4. Usually an overtaking manoeuvre, affected by interaction, does not get as far as the final stages without collision or a violent change of course. If it did, it would find the overtaking ship experiencing an increase in resistance which slows it down. At the same time, the overtaken ship feels its resistance reduce, so it speeds up. The result is that the overtaking ship finds it more difficult to complete its passing manoeuvre and may, in extreme cases, get 'trapped'.

Comment

Overtaking manoeuvres should always be treated with caution. Relative velocities are low so the ships are in proximity long enough for interaction to have an effect. Collisions may result, or the vessels may get hydrodynamically trapped together; the former can be avoided by allowing sufficient distance off, (or not overtaking at all), the latter by one or other of the vessels slowing down.

Interaction when overtaking depends on the relative velocity; the lower it is the more likely it is that problems will occur. If it is zero then the ships are moving along together, as in a Replenishment at Sea (RAS) operation carried out by warships. In such cases the effects of interaction (albeit in deep water and therefore more controllable) must be known so that the most benign position alongside can be found.

Other vessels must move in concert as part of their daily routine, the most obvious being the harbour tug.

3.3 Ship and Moored Ship Interaction

If one of the ships in a passing manoeuvre is stationary (moored alongside a jetty for example) it can still be affected by interaction. Just the same sequence of forces and moments takes place but, because the ship's mooring system is perhaps least stiff in surge, the moored ship may move ahead and astern on her berth. This, coupled with sideways and rotary motions may give rise to snatch loads in any slack or poorly-tended moorings which could break. Once one line has broken, others may soon follow.

Comment

Speeds past moored ships should be kept as low as practicable and should be at their lowest when underkeel clearances are small. Distance off should also be kept as large as is practicable.

3.4 Tug-Ship Interaction

The tug is generally much smaller than the ship it is attending and while a given depth of water may be deep for the tug, it may well be shallow for the ship. This means that, whereas the ship will have a big interactive effect on the tug, the tug will, naturally, have virtually no effect on the ship.

Modern tractor or reverse-tractor tugs have enough power and manoeuvrability to be in less danger from the effects of interaction than their conventionally propelled counterparts. This is not to say that they are unaffected. Figure 6 shows measurements of the interaction sway force and yaw moment felt by a tractor tug model keeping pace with a large ship; it is seen that large forces develop. However, the fast response and enhanced manoeuvrability of such tugs means that they are much more able to manoeuvre out of difficulty.

For any conventionally powered (and steered) tugs and other vessels similarly equipped, Figure 7 shows diagrammatically the sort of interaction forces and moments they will experience when they come alongside. Clearly there are areas near the bow and stern that are best avoided because the control that the rudder exerts adds to, rather than subtracts from, the effects of interaction. Of particular interest is the tendency to turn under the bow of the larger vessel brought about by interaction. This has caught a number of conventional tugs unawares over the years with disastrous consequences. The sudden changes in the interaction forces and moments acting on the vessel as it alters its fore and aft position alongside the bigger ship are largely to blame; if they are not anticipated by the helmsman, the smaller vessel will drive itself under the bow of the bigger ship.

4. INTERACTION NEAR FIXED BOUNDARIES

It has already been mentioned that interaction can occur when a ship is near a bank. In general, fixed boundaries to waterways, whether they be banks of canals, rivers or fairways or whether they are the walls of enclosed docks, can have effects on ships which may be sudden and unexpected. Some of these are now discussed.

4.1 **Bank Effects**

It has already been shown that bank effects are manifest as a bow-out turning moment together with a suction. This will be experienced whether the bank is vertical (as in a waterway with piled sides), flooded (as in a fairway) or sloping (as in a canal). It will also occur if the water shoals to one side of the ship.

The practical outcome of this phenomenon is usually that the ship sheers away from the bank. The 'bow cushion' dominates and turns the ship which then moves away from the bank and, as it does so, experiences less and less interaction as distance from the bank increases. This means that, to move parallel to a bank, interaction is countered by steering toward the bank; if the rudder is correctly set, a balance can, in principle, be found to cancel interaction (see Figure 8).

Clearly, passage along the centreline of a waterway, midway between the banks, should avoid bank effects as they will cancel. This will be true in a waterway such as a canal with uniform banks, but in fairways and rivers whose banks may be anything but uniform, it cannot be relied upon implicitly It is often argued that in such circumstances, the ship will automatically 'find' the centre of the river, the bank effects acting as a form of control device. While it is true that bank effects will turn a ship toward the centre of a waterway, their relationship to the vessel's mass, inertia and turning ability is very unlikely to ensure that the ship does not simply over-shoot the centreline and ground on the other bank.

A possible scenario in such a case is that the ship will sheer off one bank, head across the centre of the waterway to approach the opposite bank at an angle. If this angle is right, the vessel may turn, under the influence of the growing bow cushion, to leave the bank, without touching, and head for the other side of the waterway (Figure 8). Usually this process is divergent and 'reflection' does not occur a second time so that the ship runs aground.

4.2 Ships in Basins

Ships moving in enclosed basins in which other ships are moving or moored can generate interaction-like effects. A few are now considered.

Swinging and Manoeuvring

A ship manoeuvring unaided in an enclosed basin may use a combination of propellers and bow thruster. This may cause the water in the basin to move and the resultant swinging of the ship (which acts as a form of 'paddle') will cause further movement and pressure changes. Ships moored in the vicinity may feel these pressure changes and range or surge on their moorings.

Tug Pumping

The modern harbour tug is usually powered by one or more propellers or, more generally nowadays, by two powerful thrusters. Not only are these good propulsion devices, but in the confined space of a basin they act as effective pumps, setting water in motion. In a very confined space (especially if the tugs are on short lines), they can cause the ships they are attending to move in unexpected ways. Figure 9 (from reference 2) shows a situation which was modelled physically; it shows how the flow induced by tug wash causes local pressure changes which affect the ship. Notice how the ship moves bodily toward the tug even though the direction in which the tug is pulling does not suggest such behaviour. Similar effects have been experienced in lock-bell-mouths when tug action has inadvertently caused ships to move in an unexpected direction. In extreme cases tug wash can cause an effect which is directly contrary to that expected. Figure 10 (also from reference 2) shows the turning moment measured on a ship model when 'towed' by a tug in the manner shown. Notice how the turning moment on the ship actually changes sign (ie. acts in a direction opposite to the expected) at the shallowest water depth. This is yet another example of the powerful effect of shallow water, and suggests that care should be taken when using powerful tugs on short lines in enclosed basins.

The Following Wake

When a ship slows down too abruptly, the water moving with it may not be so obliging. The ship's wake takes time to slow down and, in shallow, confined alters it should be remembered that the body of water which moves with the ship takes time to slow down and in so doing, will overtake the ship. This may often affect the vessel and can move it ahead or, in extreme cases, turn it in an uncontrolled manner (see Figure 11). The lesson is clearly to reduce speed, or a swinging manoeuvre gradually.

5. EXAMPLES OF INTERACTION

There are a number of marine accidents where interaction has played the main, or at least an important, role. Some are listed here and their importance lies not so much in their details as in the fact that most of them played an important part in developing our understanding of the phenomenon known as interaction.

'Olympic/Hawke' Collision

The 'Olympic', the sister ship of the Titanic' was in collision with the cruiser HMS 'Hawke' in the Solent in 1911. Both ships were on similar, but converging, courses and the 'Hawke' suddenly and unexpectedly sheered to port into the 'Olympic'. There was suggestion of both ship-ship interaction and bank effect on the 'Hawke', as well as a demonstration of the effects of speed and converging courses. This case really began the modern study of interaction, for a number of investigations were done for the subsequent litigation and beyond. The 'Olympic' was taken out of service for repair and her presence at Harland and Wolff delayed completion of the Titanic.

Titanic '/'New York'

While leaving Southampton on her maiden (and only) voyage, the Titanic', sister ship of the 'Olympic' was almost in an interaction-induced collision. While passing the Dock Head she passed close to two smaller passenger liners moored abreast. The outer one, 'New York', broke free and drifted toward the Titanic'. Only the quick actions of a tug prevented a collision, although the Titanic' was delayed. It is of interest to note how interaction played a part in the short life of the Titanic'; her completion was delayed by the 'Olympic'/'Hawke' incident and her voyage was delayed by her incident with the "New York'. Had these incidents not occurred, the story of the Titanic' might have been very different.

'Queen Mary7'Curacao'

During the Second World War the 'Queen Mary', in use as a troop transport, cut the light cruiser 'Curacao' in two. Both vessels were moving at speed in deep water and the 'Queen Mary' was carrying out a *zig-zag* manoeuvre. Model tests carried out after the event showed that interaction from the larger ship caused the warship to move toward her from a significant distance off. The investigation (reference 3) provided some illumination of the powerful effect of speed and ship size on interaction.

'HMS Nelson' Grounding

Just before the Second World War, HMS Nelson, on leaving Portsmouth Harbour, took a sudden sheer to starboard and ran hard aground on the shallows off Haslar Wall. Subsequent model tests (reference 4) showed evidence of strong bank effect and gave the first published evidence of the interaction caused by a nearby shelving beach.

'Royston Grange[9]*/Tien Chee'*

In 1972 the reefer 'Royston Grange' collided with the tanker Tien Chee' in the River Plate. The 'Tien Chee' was heavily constrained by her draught and was moving more or less on the channel centreline. This caused the 'Royston Grange', who was making good speed, to move well to starboard. This caused her to sheer, from bank effect, into the Tien Chee'. Both ships caught fire and there was heavy loss of life. The subsequent investigation showed the importance of speed in any interaction incident as well as the magnitude of bank effect. It also initiated studies of interaction aimed at explaining the effect and informing the maritime community. This paper is the latest example of that continuing task.

6. REFERENCES

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3. ROBB, A.M.: 'Interaction Between Ships : A Record of Some Experiments and Evidence of Wave Effect' Trans. Royal Institution of Naval Architects, vol. 91. 1949, p. 324-339.

4. GAWN, R.W.L.: 'Steering and Propulsion of HMS 'Nelson' in a Restricted Channel' Trans. Royal Institution of Naval Architects, vol. 92, 1950, p. 82.

FIGURE 1

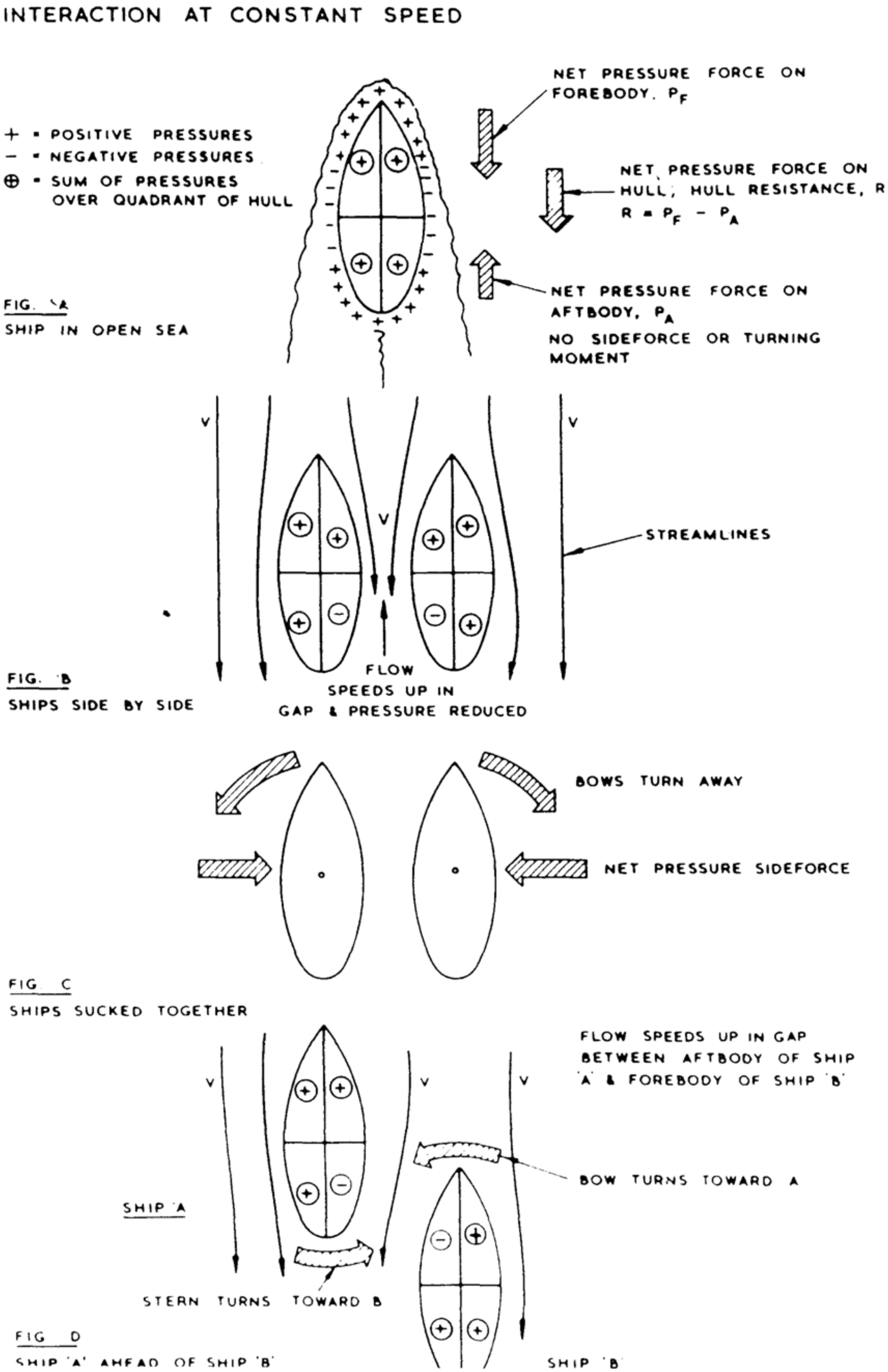
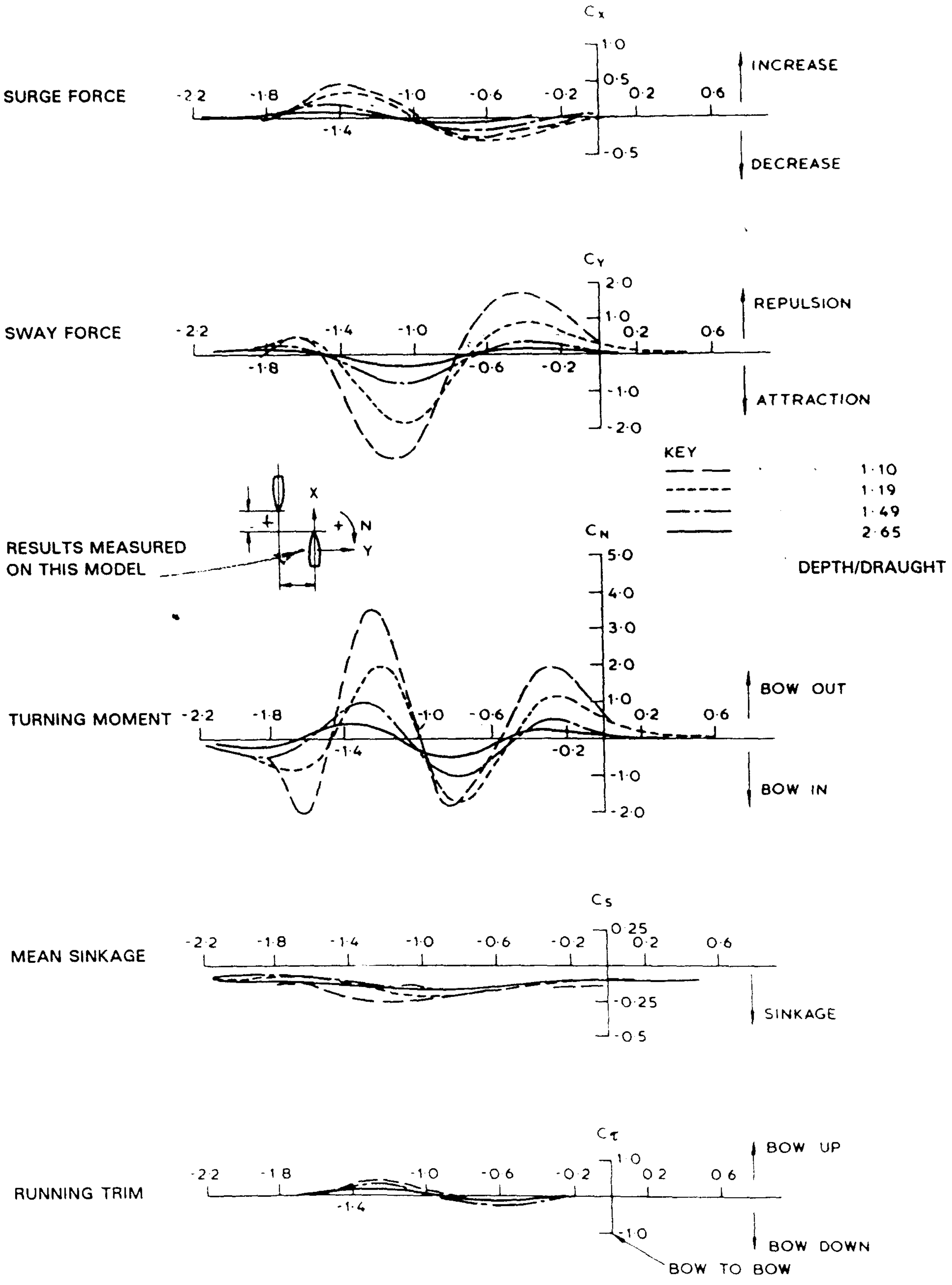
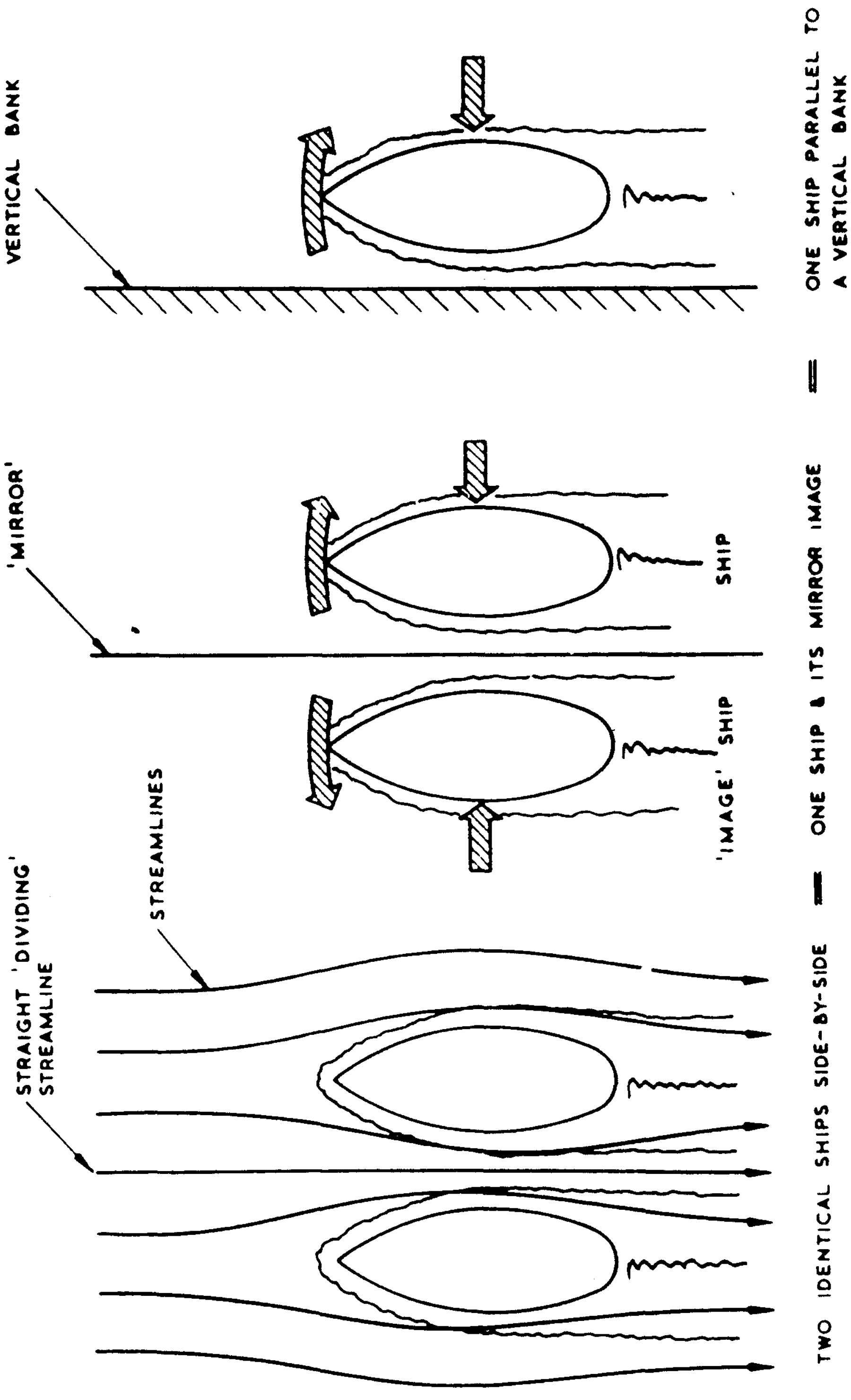

INTERACTION AT CONSTANT SPEED
+ = POSITIVE PRESSURES
− = NEGATIVE PRESSURES
⊕ = SUM OF PRESSURES OVER QUADRANT OF HULL
NET PRESSURE FORCE ON FOREBODY, P_F
NET PRESSURE FORCE ON HULL, HULL RESISTANCE, R
$R = P_F - P_A$
NET PRESSURE FORCE ON AFTBODY, P_A
NO SIDEFORCE OR TURNING MOMENT
FIG. A
SHIP IN OPEN SEA
V
V
V
STREAMLINES
FLOW SPEEDS UP IN GAP & PRESSURE REDUCED
FIG. B
SHIPS SIDE BY SIDE
BOWS TURN AWAY
NET PRESSURE SIDEFORCE
FIG. C
SHIPS SUCKED TOGETHER
FLOW SPEEDS UP IN GAP BETWEEN AFTBODY OF SHIP 'A' & FOREBODY OF SHIP 'B'
V
V
V
BOW TURNS TOWARD A
SHIP 'A'
STERN TURNS TOWARD B
FIG. D
SHIP 'A' AHEAD OF SHIP 'B'
SHIP 'B'

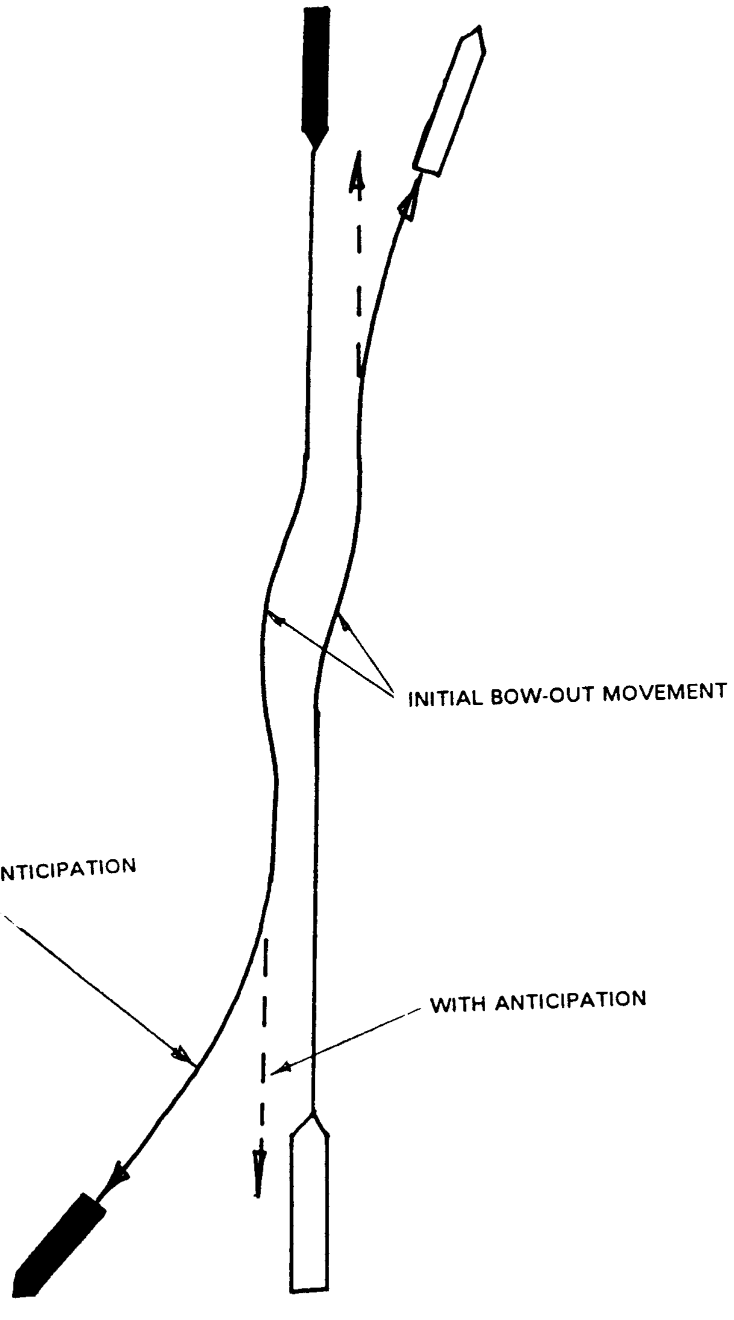
FIGURE 2



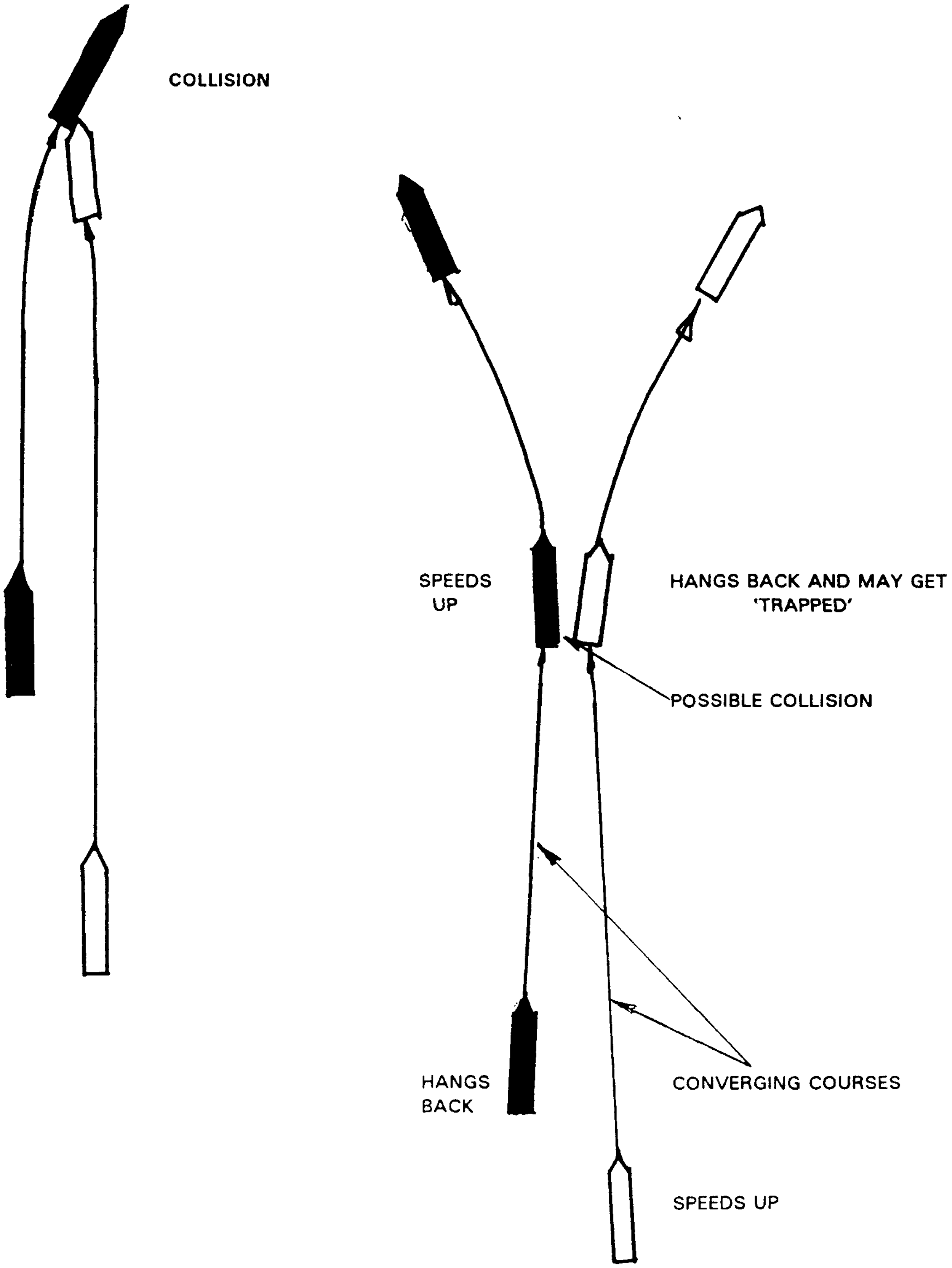
HEAD - ON ENCOUNTER,
EFFECT OF DEPTH / DRAUGHT RATIO



BANK EFFECTS
COURSE OF SHIP PARALLEL TO LINE OF BANK

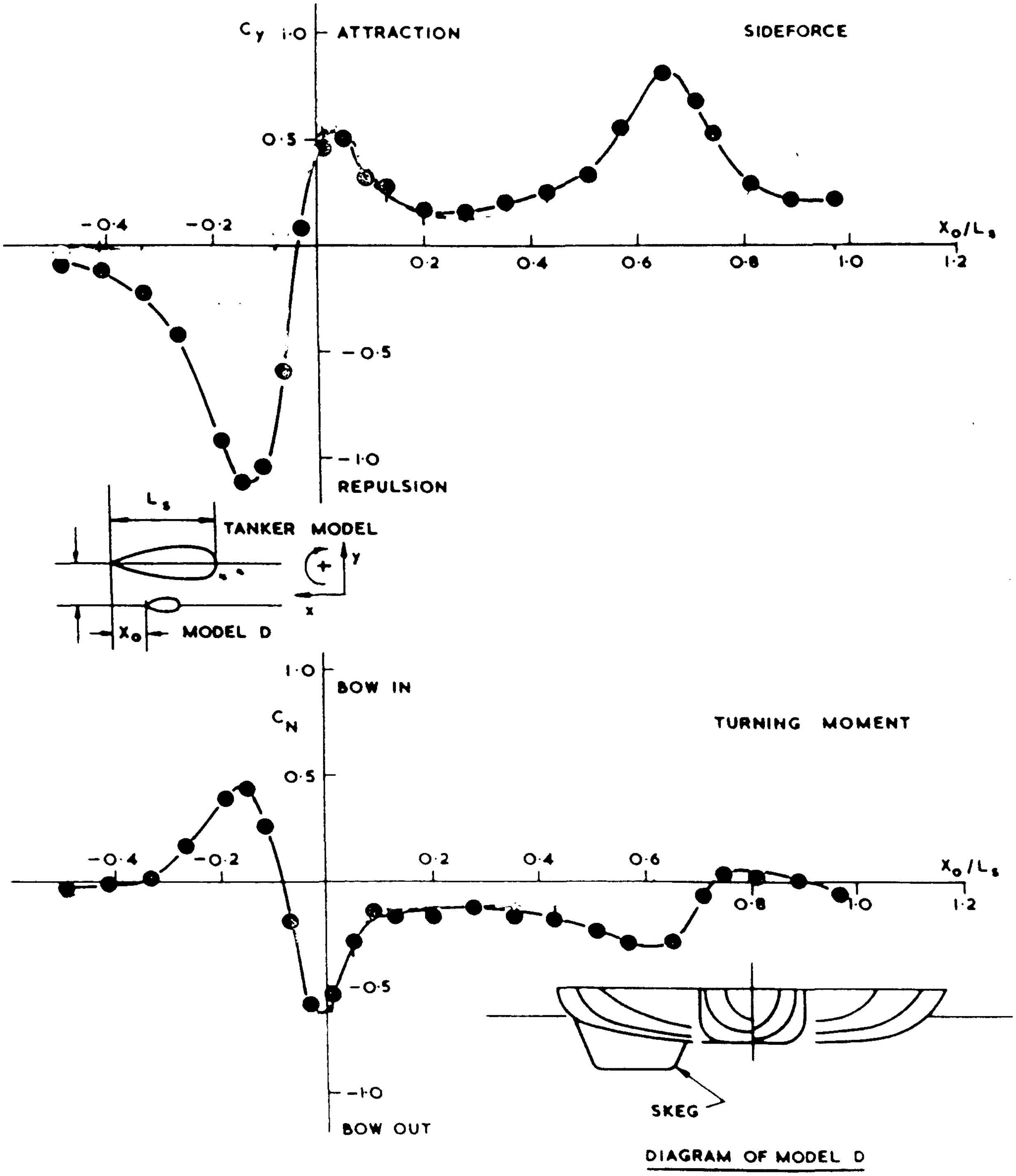


INTERACTION DURING RECIPROCAL PASSING



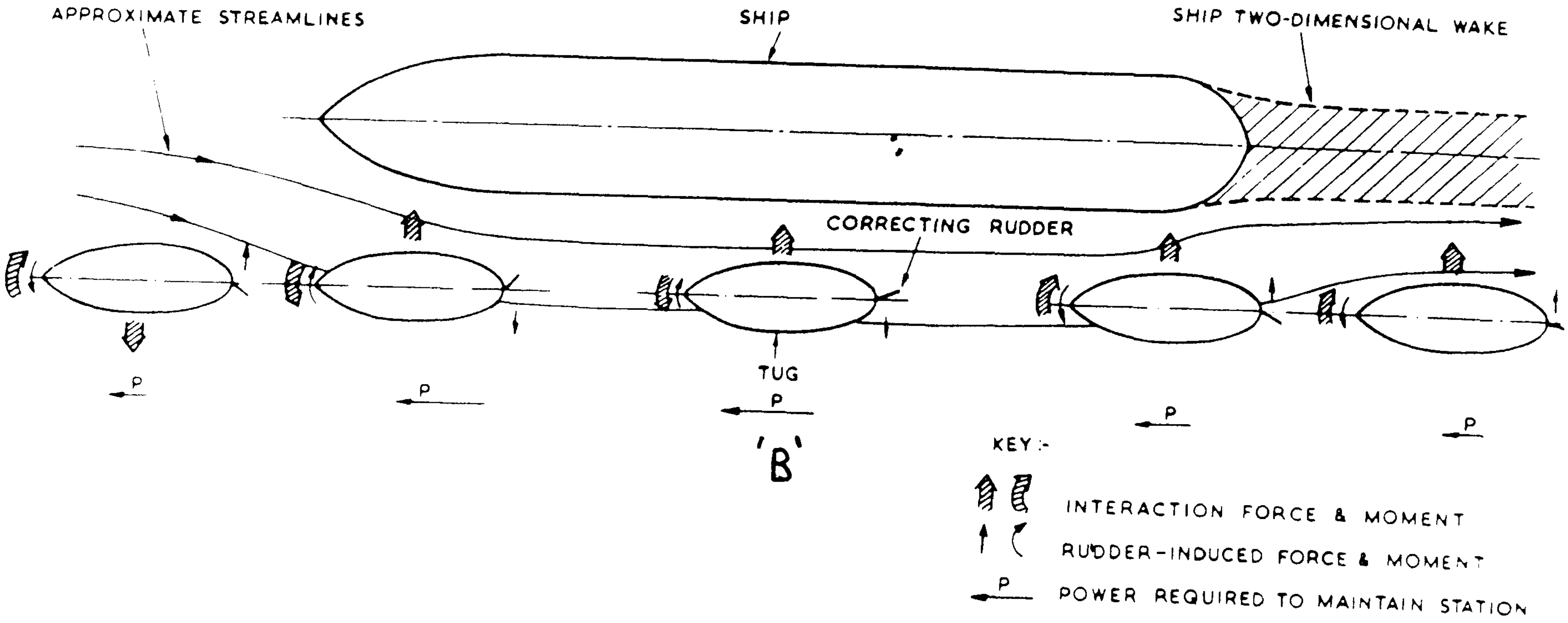
INTERACTION WHEN OVERTAKING : ALTERNATIVE SCENARIOS

FIGURE 6



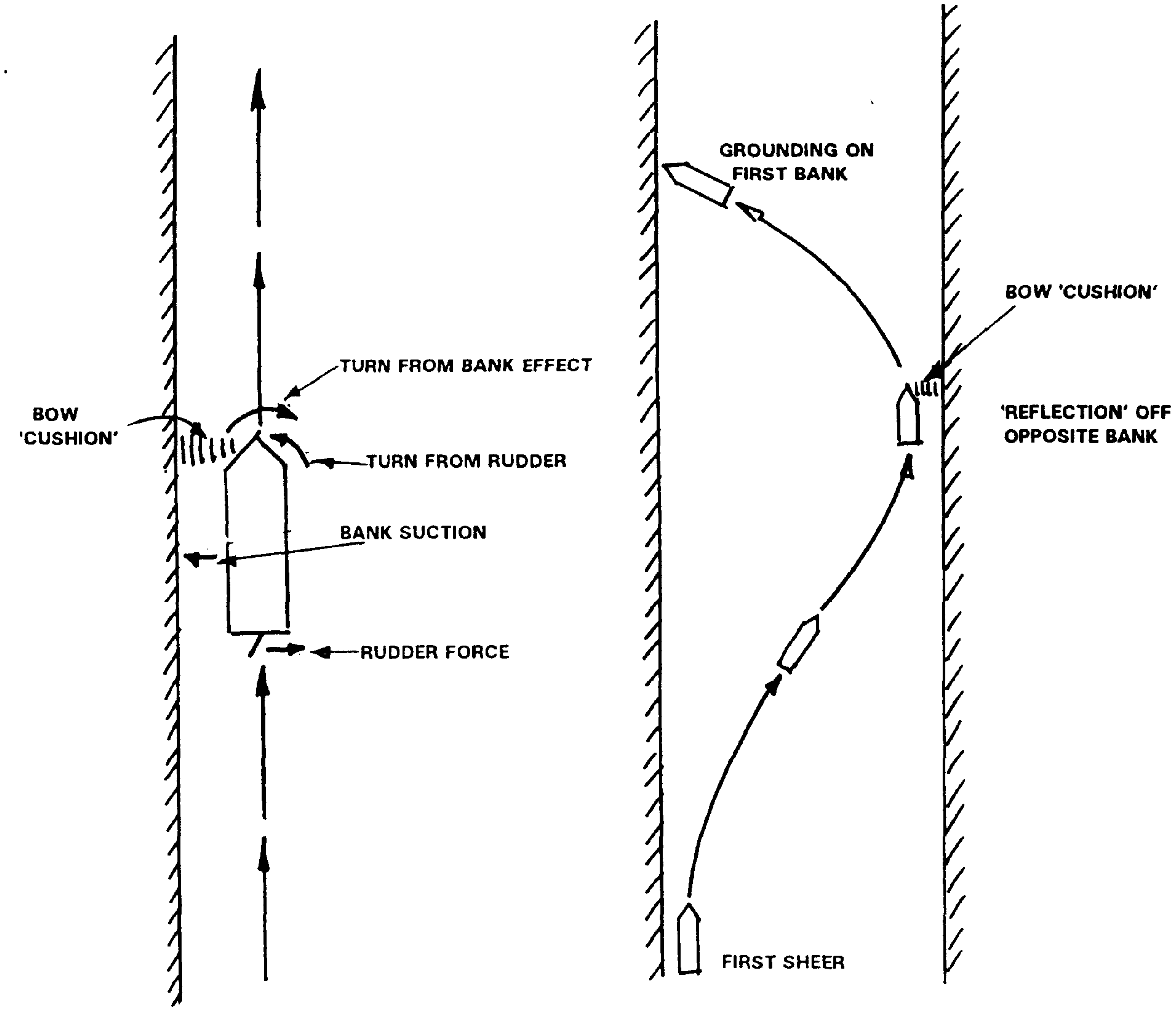
INTERACTION FORCES & MOMENTS INDUCED ON

TRACTOR TUG MODEL BY TANKER MODEL



TUG-SHIP INTERACTION

'B' IS POINT OF SAFE APPROACH
FOR THE SMALLER VESSEL AS
ITS CONTROL ACTIONS WILL COUNTER
INTERACTION



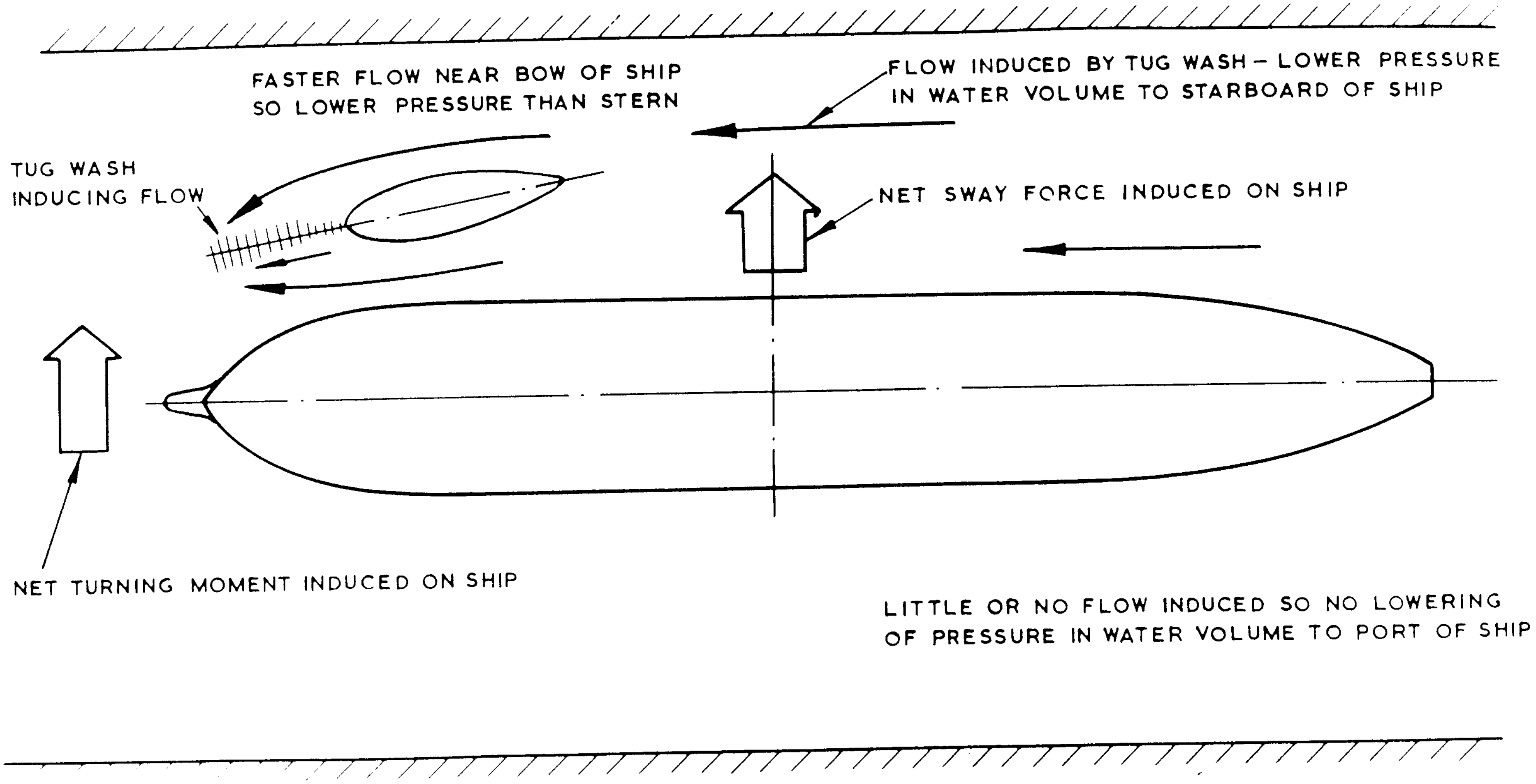
CONTROL

UNCONTROLLED SHEERS

TRACKS DUE TO BANK EFFECT

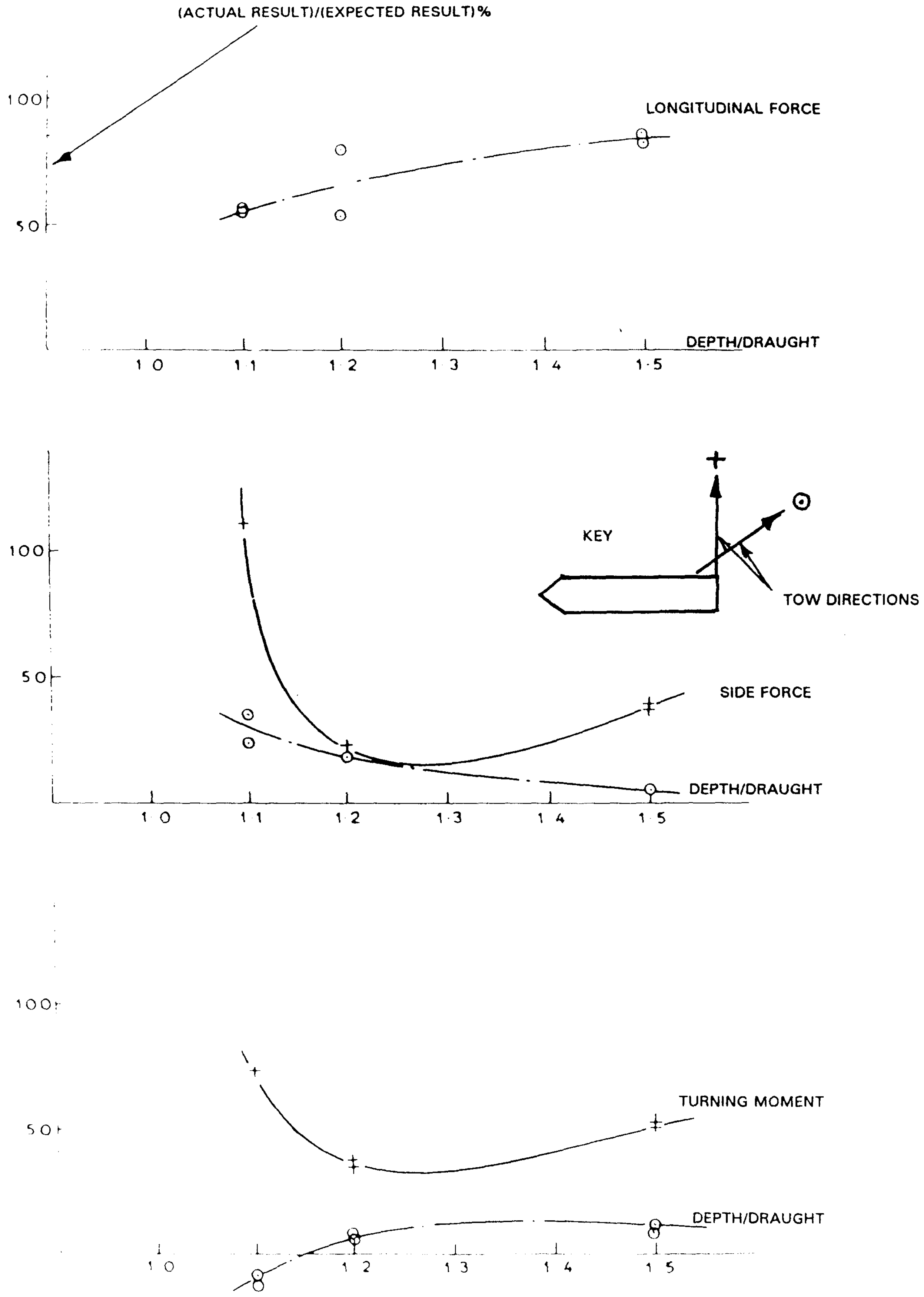
(DIAGRAMMATIC ONLY)

FIGURE 9

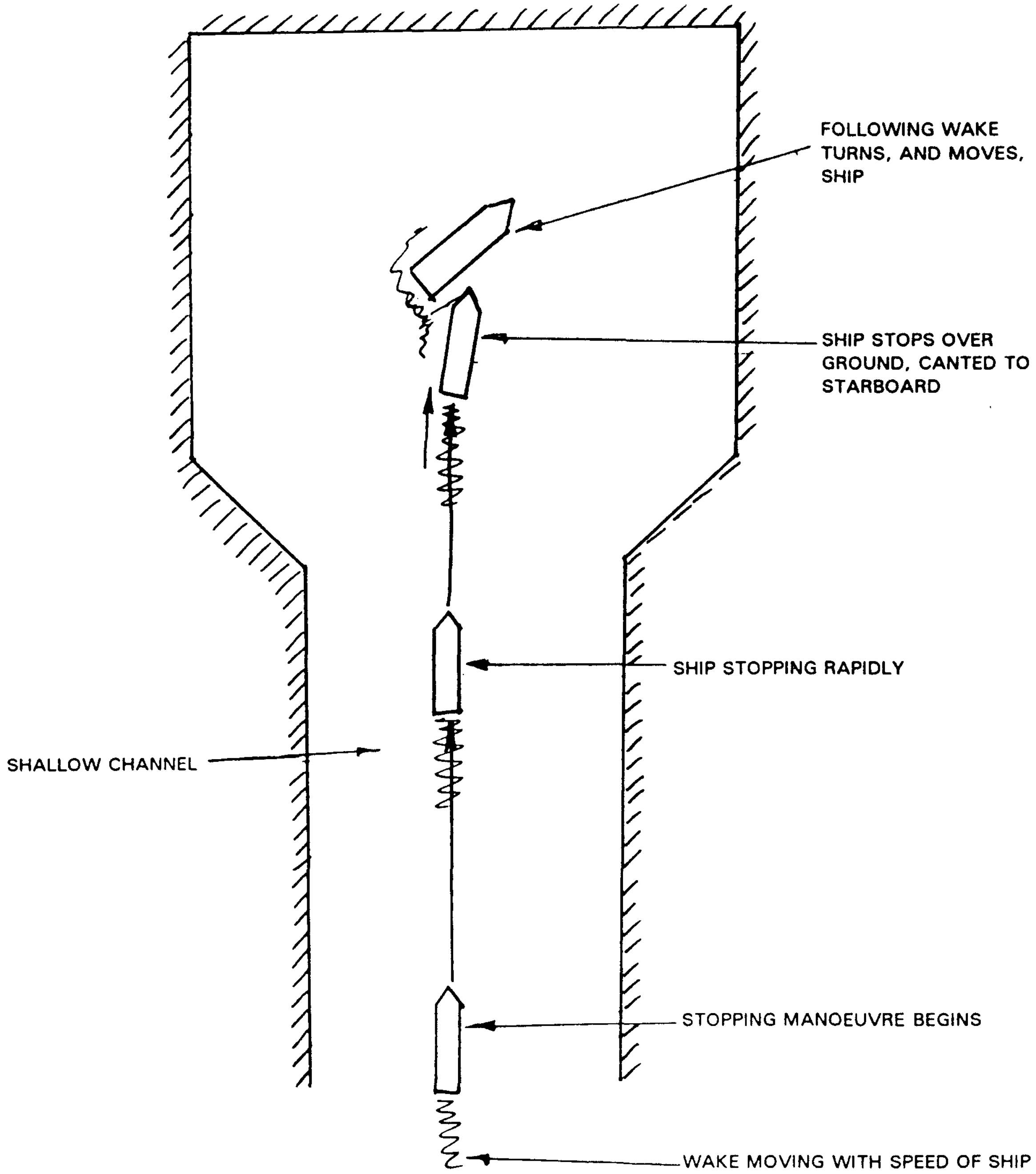


INDIRECT EFFECT OF TUG WASH IN CONFINED WATER

FIGURE 10



TUG WASH EFFECTS IN A CONFINED SPACE



THE FOLLOWING WAKE

SHIP SQUAT

by Dr. C. B. Barrass

Abstract
The lecture begins with a description of what exactly ship squat is. Details are given on how squat predictions are very important for vessels with large DWT like supertankers or high speed ships like container vessels.

Indications that a ship has entered shallow water conditions are listed to assist shipboard personnel.

The main factors or variables for estimating maximum squat are discussed in detail. Three formulae are given for estimating maximum squat and whereabouts along the ship's length it is likely to occur.

One of the three formulae is complicated. The other two formulae, however, are quick approximations giving answers that err on the high and therefore safe side.

Measured squats on ship models and full sized ships are referred to, including the examples of *"Herald of Free Enterprise"* and the "QE //".

Finally, a summary is given to show the advantages for shipowners, the ship's officer of the watch, the ship's pilot and the Port Authority, now that the maximum squat for ships can safely be predicted. I look forward to the discussions that follow the paper.

What exactly is ship squat?

Ship squat can be caused in two ways. On most occasions squat is caused by the forward motion of a vessel.

Squat is the decrease in underkeel clearance caused by this forward motion.[0']

As the ship moves forward she develops a mean bodily sinkage together with a slight trimming effect. The algebraic sum of bodily sinkage and the trim ratio (forward or aft) is known as "ship squat".

It must be emphasised that for any draught, squat is NOT the difference in reading between the situation when a vessel is stationary and when she is underway. This mis-conception is inaccurate and misleading.

For example, the difference in bow draught readings due to forward motion might be 2m, whilst the decrease in underkeel clearance might only be 040m.(1)

The other occasion where squat will occur is with a moored vessel, in an ebb tide, alongside a jetty. (6)(14) Tide speed along the stationary vessel produces, as before, components of bodily sinkage and trimming effects. The two combined give ship squat for a stationary vessel.

Maritime personnel, taking draught readings say for a draught survey, must be aware that the second situation could lead to underloading cargo aboard a vessel being loaded ready for departure.(6)(14)

Ship squat has always existed on smaller slower vessels. It only amounted to a few centimetres and was therefore inconsequential.(3)

In the 1960s and 1970s several new specialised ship types were developed. Two of these were the supertanker and the container ship.

Supertankers of 250,000t DWT became common. They were almost too big for ports to accommodate them, resulting in static underkeel clearances as low as 1-Om to l-5m.

At the same time container ships were replacing many of the older general cargo ships. Service speeds for these container ships gradually increased from 16 knots up to as high as 27 knots. Passenger liners also followed this specification for higher and higher speed up to 30 knots.

However, with oil fuel costs in mind, for the 1990s new orders for container ships tend to specify service speeds ranging from 18 to 22 knots. In 1995, even passenger liners like the new *"Oriana"* operate with a design service speed of 24 knots. Still high, but not as high as yesteryear.

As underkeel clearances decreased and design service speeds rose, maximum squats gradually increased until they can be in the order of l-5m to l-75m. These are by no means inconsequential.

Developments in ship design have, therefore, made the prediction of squat much more important from the safety point of view. Much more so in the 1990s than say 30 years ago.(3)

A vessel behaves differently in shallow water than she does when she is in deep water. 13) It becomes necessary to know when a ship has entered shallow waters. This can be determined using a depth of influence co-efficient F_D in the following manner.

Let 'H' be the depth of water and let T' be the mean draught of the static ship, measured at or near to amidships. $^H/_T$ is then worked out and compared with the F_D value for each ship type.(4)

for a supertanker $F_D = 5.68 \times T$
for a general cargo ship $F_D = 7.07 \times T$
for a passenger vessel $F_D = 8.25 \times T$
for a ro-ro vessel $F_D = 9.20 \times T$
for a *"Leander"* frigate $F_D = 12.04 \times T$

If $^H/_T$ is above the respective F_D value, the vessel's resistance will not alter, her speed will remain constant, her propeller revs will remain steady and her squat will remain unchanged. She is in fact operating in deep water conditions.

Below the corresponding value of F_D for each vessel, each ship will be in shallow water conditions. Below this F_D value, the vessel's resistance will increase, her speed will reduce despite the same input of engine power, her propeller revs will reduce and her squat will increase as $^H/_T$ approaches 1.10. *(7)*

Other indications that a ship has entered shallow waters are:—(3)

a) wave making increases at the forward end of the ship;
b) vessel becomes more sluggish to maneouvre;
c) ship may start to vibrate suddenly because of entrained water effects causing resonance;
d) rolling, pitching and heaving motions decrease due to the cushion of water beneath the vessel.

The main factors affecting ship squat are:—

a) the forward speed V_K which is the speed of the ship over the ground. This is the most important factor because ship squat varies directly as V_K^2. If the speed is halved then the squat is quartered.
b) the block co-efficient C_B. This also is important. Squat varies directly with the C_B. In other words, oil tankers and OBOs will have comparitively more squat than passenger liners and container ships. This is shown graphically in figure 3.
c) the relationship between the depth of water (H) and the static mean draught of the ship (T). In my research I particularly considered measured squats for $^H/_T$ range of 1.10 to 1.40. As $^H/_T$ decreases, squats increase.
d) the presence of river or canal banks. The closer banks are to the sides of a moving vessel, the greater will be the squats.(8)
e) the presence of another ship in a river in a crossing or passing manoeuvre.(9) The presence of the second ship increases the squats on both vessels.

In open water conditions, having no adjacent banks, it is possible to calculate an artificial width of water to represent the river banks. This is known as a "width of influence" (see later notes).(4)

Practical calculations for squat(3)

An important factor is the blockage factor 'S', where S = b x T/B x H as shown in figure 1. From this we obtain the velocity-return factor S_2, where $S_2 = S / 1—S$ as shown in figure 1.

<u>Method 1</u>:—

Maximum squat = $'\text{ʃ}'_{\text{max}} = C_B / 30 \times S_2^{2/3} \times V_K^{2{\cdot}08}$ metres, for open water and confined channel conditions.

<u>Method 2</u>:—

Maximum squat = $'\text{ʃ}'_{\text{max}} = C_B \times V_K^2 / 100$ metres in open water only.

<u>Method 3</u>:—

Maximum squat = $'\text{ʃ}'_{\text{max}} = 'K' \times (C_B \times V_K^2 / 100)$ metres in open water and confined channels, where $'K' = [\, 6 \times S \,] + 0{\cdot}400$. See related reading. (8)

<u>Method 4</u>:—

Maximum squat = $'\text{ʃ}'_{\text{max}} = 2 \times (C_B \times V_K^2 / 100)$ metres in confined channels when the blockage factor ranges 0·100 to 0·265.

Methods 2, 3 and 4 will give approximate squats. These will err slightly on the high side and contain, therefore, a small margin of safety.

A worked example at the end of this paper illustrates the use of these various methods. The shown formulae were derived after a detailed analysis of measured results on ship models and ships. (5)

Knowing how to predict maximum squat is important. Equally important is knowing whereabouts on the moving vessel it will occur. It all depends on how each ship is trimming when static. Trim is the difference between the aft draught and the forward draught.

Consider first of all ships that are on **even keel when stationary**. In other words, their **trim is zero**. As soon as each ship moves she will:—

a) **trim by the head** if her C_B **is greater than 0·700**;
b) **trim by the stern** if her C_B **is less than 0·700**;
c) **usually not trim** if her C_B is 0·700. Her squat will consist only of the mean bodily sinkage component.

Thus,

— for full-form vessels, $'\text{ʃ}'_{\text{max}}$ will occur at the **bow**;
— for fine-form vessels, $'\text{ʃ}'_{\text{max}}$ will occur at the **stern**;
— for medium form vessels, $'\text{ʃ}'_{\text{max}}$ will occur at the **stern**, **bow** and **amidships**, i.e. all along the bottom shell of the ship.

However, if each vessel is trimming (2) when stationary, then the following applies:—

a) if a vessel is static and trimming **by the head**, then when she is underway bodily sinkage will occur plus a slight trimming effect also **by the head;**
b) if a vessel is static and trimming **by the stern** then when she is underway bodily sinkage will occur plus a slight trimming effect also **by the stern**.

In both cases, any static trim on a ship will be **increased in the same direction** when she is at forward speed. '$\int$'$_{max}$ will occur and be added onto the larger of the two static end drafts. (2)

The width of influence 'F_B' is an artificial width of water used in squat calculations. (4) It is used for a ship operating in open water conditions. It is dependent on the type of ship being considered.

for a supertanker	$F_B = 8{\cdot}32 \times B$
for a general cargo ship	$F_B = 9{\cdot}50 \times B$
for a tug (coastal)	$F_B = 12{\cdot}69 \times B$
for a '*Leander*' frigate	$F_B = 13{\cdot}75 \times B$

where 'B' is the ship's maximum breadth, at or very near to amidships.

By using this width of influence, one can place the ship in an artificial channel/canal and then proceed; calculating the maximum squat as though the vessel was operating in a river or canal.

Any width of water beyond F_B will give identical squat values. This is why it is termed the "width of influence". (4)

Any width of water less than F_B will produce increased resistance, loss of speed, loss of prop revs and increases in ship squat. (7)

A worked example at the end of this paper illustrates this concept of "width of influence".

Consequences

I have been asked on several occasions to indicate where excessive squat has caused grounding of a vessel.

Two recent incidents are:—

a) "*Herald of Free Enterprise*" on 6th March 1987. (2)
b) "*QE2*" grounding on 7th August 1992. (2)

The "*Herald of Free Enterprise*" left port with her bow doors open and trimming heavily by the head. In shallow water conditions she quickly attained a speed of

18 knots. As described previously, this would produce a mean bodily sinkage plus additional trim by the head.

Maximum squat occurred at the bow, resulting in water entering the vessel and leading to capsize of the ship. Almost 200 people lost their lives.

The "QE2" was leaving port in shallow water conditions. In the technical press it was reported that the forward speed was 24 to 25 knots just prior to grounding of the vessel.

According to Lloyds Lists, costs to the owners were $13.2 million in repairs and some $50 million in lost passenger bookings !!

These two examples illustrate that squat can be linked to financial loss and, more importantly, to loss of life.(2)

When a ship grounds due to excessive squat shipowners may be faced with the following costs:—

a) repair costs for the ship;
b) repair costs for repairs to lock sills;
c) compensation claims for oil spillage;
d) drydock charges for inspection of a ship;
e) time out of service. Loss of earnings can be as high as £100,000 per day.

Prevention

One way of preventing excessive squat and its effects is to reduce speed. This is the most efficient way. Another way to consider is to increase $^{H}/_{T}$ value. This can be achieved by discharge of loading within the ship such as water ballast, or to move the vessel into deeper water.

Reducing the loading within the ship decreases the value of T which in turn increases $^{H}/T$ Reducing this draught T also reduces CB value. C_B at a lower draught will, as formulae show, reduce squat value.

The possession of a computer program to predict squat data would also be of benefit to ships' officers.(10) There is one which prints out the following:—

a) whether ship is in open waters or in a confined channel;
b) gives maximum squats and where they occur;
c) gives remaining underkeel clearances at bow and stern;
d) gives the speed required for the vessel to go aground at the bow and at the stern.

This computer program covers all types of ships, for all relevant speeds, and is able to predict for both open water and confined channel conditions.(10)

Shipboard personnel such as the master and deck officers need to know about the theory and possible dangers resulting from excessive squat.(11)-(12) (16)

Ship pilots also need a detailed appreciation of this topic when assisting with the passage of ships along narrow rivers and through canals.(11) (12) (16)

A third group of personnel needing to know about ship squat is the Port Authorities. Some of them, aware of possible grounding problems, "request" a static minimum underkeel clearance of 1.Om to l.25m before allowing entry of a vessel into their river. (11)(12)(16) Maximum transit speed is also "requested".

In the past there has been a tendency to overestimate squat on certain routes and to underload the cargo accordingly. Now that squat can predicted be more accurately, the ship can sometimes be loaded up an extra few centimetres giving the vessel extra earning capacity. Leadline limits, of course, always have to be adhered to.

In the past ship's pilots have used 'trial and error', 'rule of thumb' and years of experience to bring their vessels safely into and out of port.

The positioning of a simple graph of ship speed against maximum squat placed on the bridge may be all that is required. See figure 2 for such an example.

The pilot can observe quickly from this graph a speed that could cause problems and then a speed that would give a squat which would leave the ship with a safe dynamical underkeel clearance.

By maintaining the ship's trading availability, this paper assists in safeguarding and possibly increasing the shipowners annual profit.

After all, prevention is better than cure........... and a lot CHEAPER!!

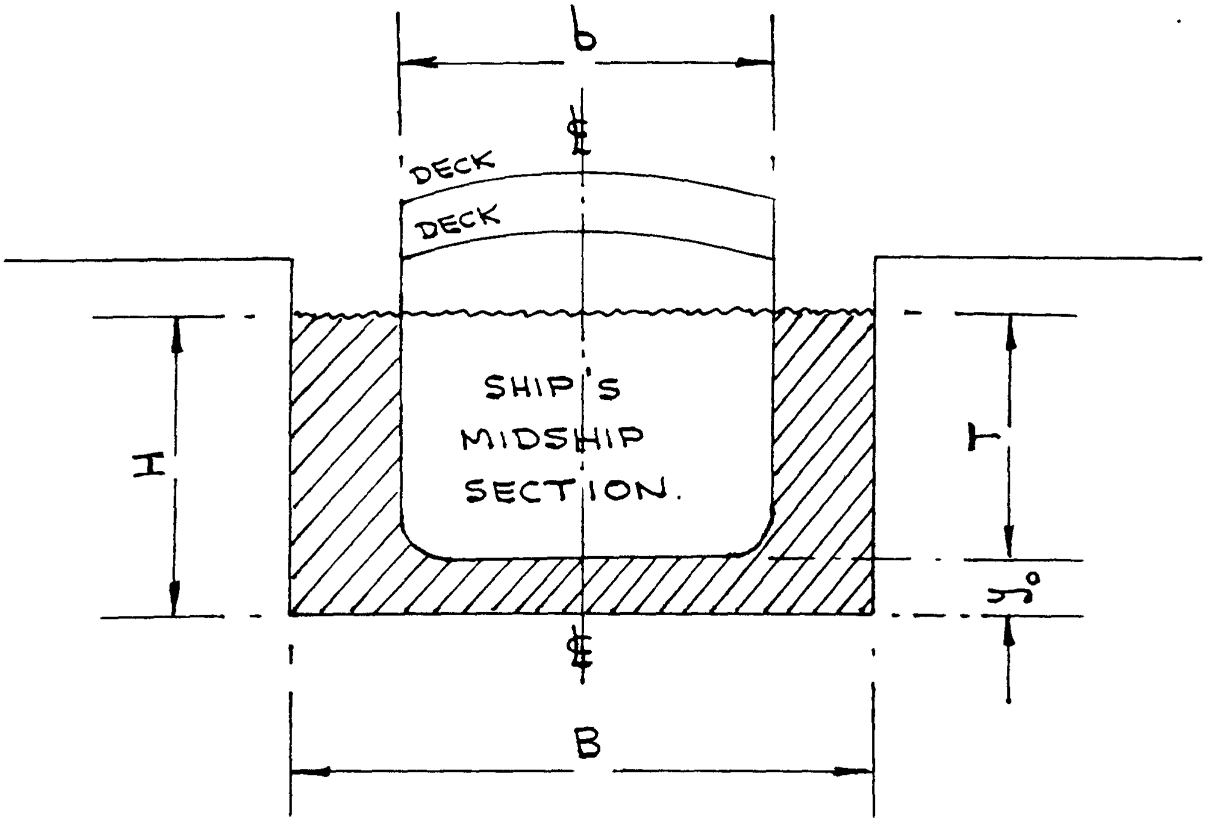


FIGURE 1. SHIP IN A CANAL IN STATIC CONDITION

A_S = CROSS-SECTION OF SHIP AT AMIDSHIPS = $b \times T$.

A_C = CROSS-SECTION OF CANAL = $B \times H$.

BLOCKAGE FACTOR = $S = \frac{A_S}{A_C} = \frac{b \times T}{B \times H}$.

y_0 = STATIC UNDERKEEL CLEARANCE.

VELOCITY-RETURN FACTOR = $S_2 = \frac{S}{1-S}$.

H/T RANGE IS 1·10 TO 1·40.

BLOCKAGE FACTOR RANGE IS 0·100 TO 0·265.

WIDTH OF INFLUENCE = $F_B = \frac{\text{EQUIVALENT 'B'}}{b}$ IN OPEN WATER.

V_K = SPEED OF SHIP OVER THE GROUND, IN KNOTS

$A_W = A_C - A_S$. HENCE S_2 ALSO = $\frac{A_S}{A_W}$.

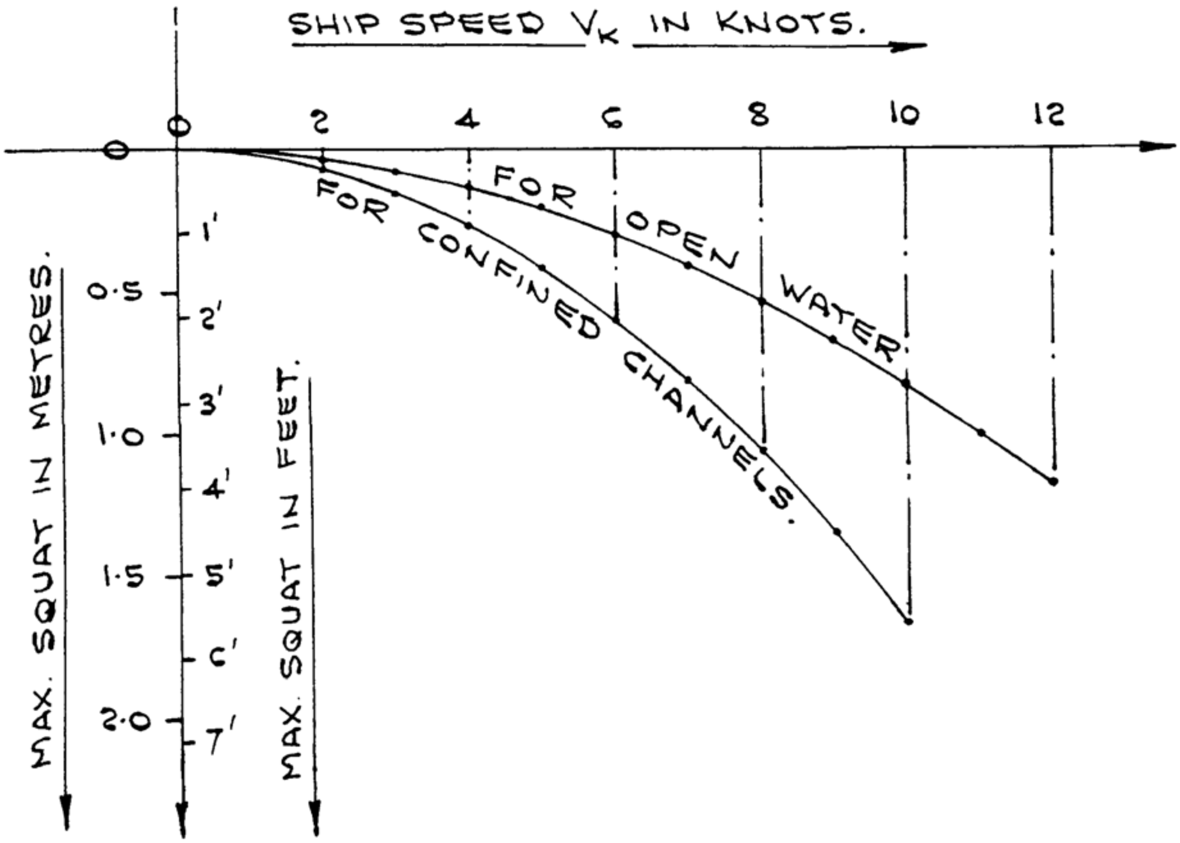


FIGURE 2. MAXIMUM SQUATS AGAINST SHIP SPEED FOR A 250,000 t VLCC.

H = WATER DEPTH.

T = SHIP'S EVEN KEEL STATIC DRAFT.

ASSUME STATIC H/T = 1·10 FOR GRAPHS.

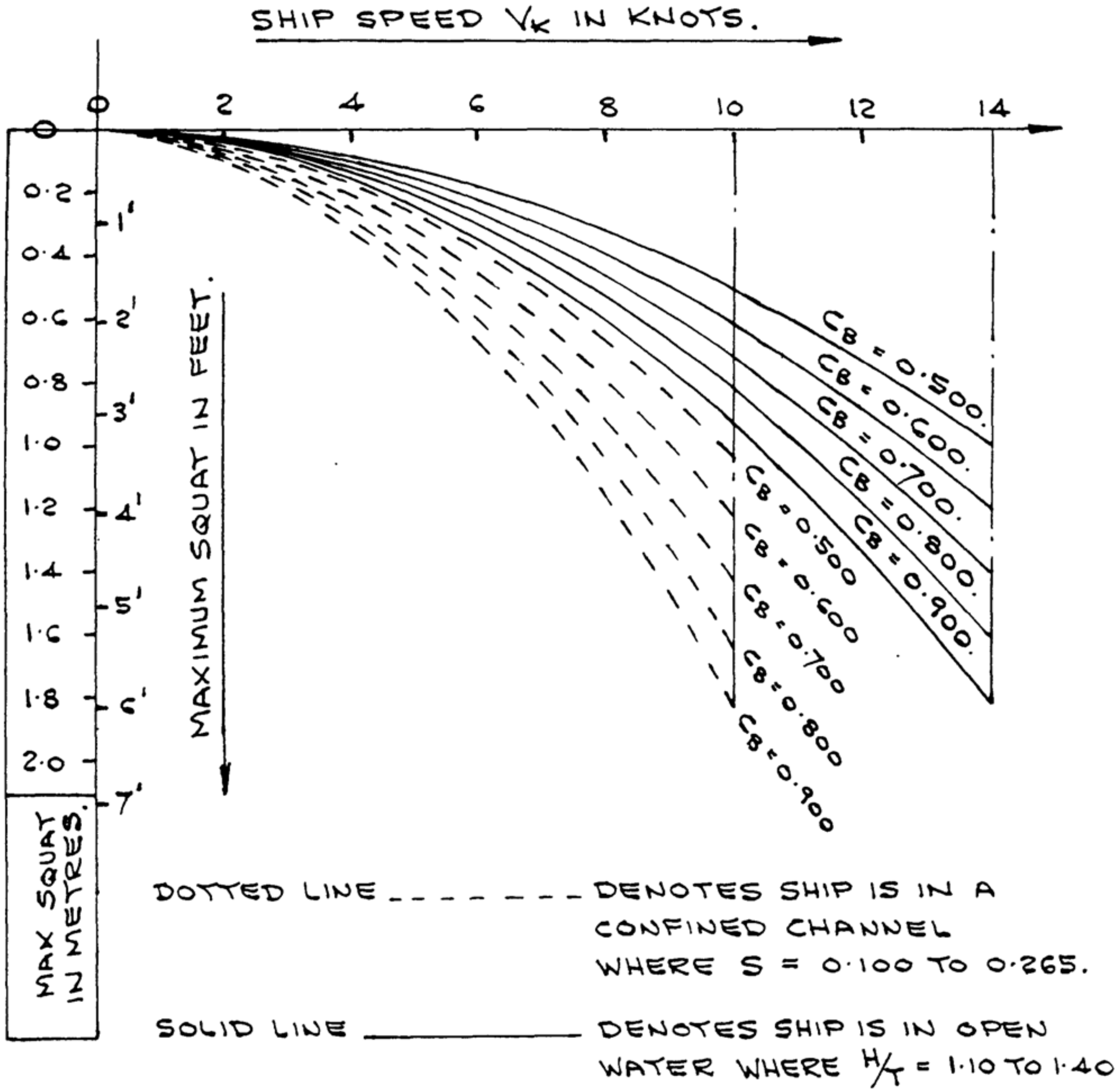


FIGURE 3. MAXIMUM SHIP SQUATS IN CONFINED CHANNELS AND IN OPEN WATER CONDITIONS.

SHIP TYPE.	TYPICAL C_B, FULLY-LOADED.	SHIP TYPE.	TYPICAL C_B, FULLY-LOADED.
ULCC	0·860	GENERAL CARGO.	0·700
SUPERTANKER	0·825	PASS$^{GR.}$ LINER.	0·625
OIL TANKER	0·800	CONTAINER SHIP.	0·565
BULK CARRIER	0·750	COASTAL TUG.	0·500

APPENDIX

Worked Example
The following information is known for an oil tanker operating in a wide river.

Breadth of ship (m) .... = 55 C_B .... = 0·830
Width of river (m) .... = 478 Ship speed (kts) .... = 11
Depth of water (m) .... = 14·5
Even keel static draught (m) .... = 12·5

a) determine whether this oil tanker is in open water conditions or in a confined channel situation.

b) calculate the maximum squat 'ʃ'max by THREE methods and suggest, with reasoning, whereabouts on the vessel it occurs.

Answer:—

a) $F_B = 7{\cdot}7 + 20[1 - C_B]^2 = 7{\cdot}7 + 20[1 - 0{\cdot}830]^2$

therefore $F_B = 8{\cdot}278$ ship breadths $= 8{\cdot}278 \times 55 = 455{\cdot}29$m

Width of river is given as being 478m. Width of influence is less, at 455·29m. Hence this oil tanker is operating in **open water conditions**. Any width of water greater than 455·29m will give similar 'ʃ'$_{max}$ value. Thus, use width of influence value of 455·29m.

b) Blockage factor $= S = b \times T \;/\; B \times H = 55 \times 12{\cdot}5 \;/\; 455{\cdot}29 \times 14{\cdot}5$

therefore $S = 0{\cdot}104$. Note $^H/_T = 14{\cdot}5 \;/\; 12{\cdot}5 = 1{\cdot}16$

Velocity return factor $= S_2 = S \;/\; 1 - S = 0{\cdot}104 \;/\; 1 - 0{\cdot}104$

therefore $S_2 = 0{\cdot}116$

__Method 1__

Max squat = 'ʃ'$_{max}$ $= C_B \;/\; 30 \times S_2^{2/3} \times V_K^{2{\cdot}08}$ metres

therefore 'ʃ'$_{max}$ $= 0{\cdot}830 \;/\; 30 \times 0{\cdot}116^{2/3} \times 11^{2{\cdot}08}$

therefore 'ʃ'$_{max}$ = __0·97 metres at the bow__

Method 2

‘ʃ’$_{max} = C_B \times V_K^2$ / 100 metres for open water conditions

‘ʃ’$_{max} = 0{\cdot}830 \times 11^2 / 100$

therefore ‘ʃ’$_{max}$ = 1·00 metre at the bow

Method 3

$K = [\, 6 \times S \,] + 0{\cdot}400 = [\, 6 \times 0{\cdot}104 \,] + 0{\cdot}400$

therefore K = 1·024

‘ʃ’$_{max} = K \times (C_B \times V_K^2 / 100)$ metres $= 1{\cdot}024 \times (0{\cdot}830 \times 11^2 / 100)$

= 1·03 metres at the bow

‘ʃ’$_{max}$ will occur at the bow because this tanker was on an even keel when static and she had a $C_B > 0{\cdot}700$.

Methods 2 and 3 err on the high and therefore safe side when compared to the more complicated Method 1.

If we take the average ‘ʃ’$_{max}$ as being 1·00m, minimum remaining or dynamic underkeel clearance is 1·00m whilst travelling at a forward speed of 11 knots.

A fourth method sometimes used ‘rule of thumb’ by ships’ pilots to predict ‘ʃ’$_{max}$ is:—

‘ʃ’$_{max} = V_K^2$ / 100, i.e. $11^2 / 100$ = 1·21m at the bow, this again estimating on the high and safe side.

References*

1. C. B. Barrass "Further discussion on Squat", SEAWAYS March 1994
2. C. B. Barrass "Changes of trim as a ship squats", SEAWAYS October 1994

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3. Ship Squat Manual — involving 23 years of research.
4. Width of influence and depth of influence for ships in open waters.
5. Measurement procedures for squat on ships.
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11. Ship squat — a guide to masters.
12. Bibliography survey listing 115 references re ship squat.
13. Ship handling problems of vessels in shallow waters.
14. Problems of underloading a ship due to squat in an ebb tide situation.
15. Change of trim characteristics for a ship squatting in shallow water conditions.
16. Twenty Questions ... and Answers, on the phenomenon of ship squat.

* Anyone interested in acquiring any of these listed papers should apply to Dr. C. B. Barrass directly or through the Nautical Institute secretariat at Lambeth Road, London.

Extra notes

Questions "from the floor" after the lecture:

1. Have the DTp issued any *"M'* notices making reference to ship squat ?

2. How is squat affected when one vessel overtakes another vessel in a narrow river? Are the increases 25%, 50% or 100% ?

3. What is "transverse squat" on container vessels and modern supertankers?

4. From which areas of the world have measured full-size squats been analysed ?

Answers to these 4 questions given on separate sheet (see over page).

Answers to questions on page 33

1. Yes; the DTp have issued several 'M' notices making reference to ship squat plus notes on interaction. These notices are numbered as follows:— M 854 (August 1978), M930 (April 1980), M 1015 (March 1982) and M 1470 (November 1991).

2. When the amidships of both vessels are in line with each other across the river the squats of both vessels when moving ahead can be <u>increased by 50% to 100%</u> compared to a single ship moving ahead up the river.

3. In the situation described in answer 2, both vessels will move towards each other accompanied by an angle of heel. The bilge plating of both vessels nearest to the river banks will move nearer to the river bed. This is "transverse squat", that is, loss or decrease of underkeel clearance. Too much "transverse squat" causes grounding and damage of the bilge keel and/or bilge keel plating strakes.

4. <u>Measured full-size squats</u> have been studied from the following areas:— St. Lawrence Seaway, Panama Canal, Malacca Straits, Persian Gulf, Lake Maracaibo, Manchester Ship Canal, River Gironde, River Elbe, River Tees, River Humber, Port Wellington and Bromborough Lock.

The Voith Water Tractor and its uses

S.R. Taylor BSc(Hons). Partner, E.G. Goldsworthy & Co.

What is a Voith Water Tractor

The principal characteristics of a modem Voith Water Tractor (see fig. 1) are :-

1. Twin Voith Schneider propellers arranged athwartships no more than 30%lwl from forward.

2. A nozzle or guard plate which acts both to augment thrust and protect the propeller blades from grounding or contact with another vessel's hull. The construction of the supporting struts is such that a modern guard arrangement should be able to withstand very high impact forces without the propeller blades suffering damage or the watertight integrity of the hull being compromised.

3. A stabilising fin aft. This was originally conceived and designed as an aid to course stability but in the early development it was found that this fin has significant uses in towing, indeed special towing concepts and procedures were developed to utilise the effects of the fin.

4. One set of towing gear, now almost exclusively from a winch (tractor crews never trust ships lines) through a towing bollard or staple situated over the centre of the fin (in practical terms this point is a compromise position, for towing ahead of a vessel the ideal point is nearer the inboard end of the skeg, as stern tug it would ideally be nearer the outboard end). For escort services where for most of the time the tractor follows the ship passively but made fast with a slack line, a second towing point may be arranged in the bulwark over the outboard end of the skeg to reduce the helmsman's efforts during a routine operation.

5. Reduced tug manning and the need for all-round visibility during towing operations has led to the small central wheelhouse, in some cases for one man operation with all propeller engine and winch controls arranged on a central control stand.

A brief history lesson

In the early 1950's Voith in Germany developed a new style tug in response to tug losses through girting and being overrun under a ships bow (see fig. 2). The fundamental change was that the Voith Schneider propellers to be used were arranged forward and the towing point aft to avoid the unstable equilibrium which existed with a conventional tug's midship towing point and propulsion aft. In manoeuvring with this forward propelled vessel, the immediate difference was that it steered in to a turn rather than the stem swinging outside the turning circle as with stem propelled vessels. The introduction of such vessels known in generic form as Voith Water Tractors was obviously slow in the earlier days but they now number approximately 600 world-wide (with free-running speeds up to 15 knots and bollard pulls in excess of 70 tonnes) and have had a major influence in tug safety.

Towage requirements

The requirement for towage assistance may taken as the period when the ships reduced speed means that she is no longer under total self control (see fig. 3) and has insufficient sea room to manoeuvre safely without external assistance. This period however may be somewhat extended by the modem requirement for escort services for ships carrying dangerous cargoes in restricted waters. However from the tractor's point of view this escort requirement is merely an extension of the normal service though up to much higher speeds than in the past.

This question of speed not only applies to escort services. Many ships at sea today have very high minimum speeds which may be above safe operating speeds for some tugs, leaving the ship in limbo until the speed is reduced sufficiently. The sight of a tug in the vicinity of the ships bow or stem should not be taken as reassurance that practical assistance is immediately available. The trend in modern tractor design i towards being capable of assistance at speeds in the region of 10 knots and above rather than the lower speeds of the past. This means real assistance, not just for show, as the vicinity of a ship moving at 10-11 knots is a much more arduous working environment than near a ship moving at half that speed. Not only do things happen twice as fast but forces involved generally increase with the square of the speed. The question arises then that if the tug is not capable of providing the required assistance at that speed then should it be made fast in the first place whether on a slack line or not?

Tractors do not come cheaply, so in economic terms the fewer the better. This places further burdens on the modem tractor in that in addition to the required capability of working at higher speeds it will often work the end of the ship alone, obviously meaning no back up in case of problems (here the question of reliability and the ability to work with one propeller only, without exerting adverse thrusts assumes great importance). The days when one tug would push the bow in and another would check are nearly gone.

Modem towing operations

There are four main positions around a ship where a tug will exert a towing force :-

1. Line tow forward
2. Push/pull shoulder
3. Push/pull quarter
4. Line tow aft

Forward

Traditionally this has been the position for the first tug to be made fast although new research has backed up modern thought that this is really the least effective position in that the steering forces that can be exerted with a stern propelled tug are minimal until the way is almost off a ship and braking forces are nil until the tug can either come around through 180 degrees or pull the ship into a tight turn to reduce its speed. Not only is the bow the most difficult position for the tug at speed, it is also the least effective point to apply a turning moment through the lever arm being short and the applicable force being limited.

A pilot's comment on being faced with this dilemma was that he felt comfortable seeing the mast of the tug under the fo'c'sle, he could not see the stem tug without going out to the bridge wing. Only in the final approach to a berth or lock when the speed is minimal does this tug come into its own.

Evidence of the limited help of the bow tug was noticed in one of Europe's busiest container ports when the conventional single screw tug was attempting to pull a modest sized first generation container vessel into a starboard turn of approx. 70 degrees with an ebb tide of approx. three knots on the starboard bow . The 40 tonne bollard pull tug was fifteen minutes holding a safe position on the starboard bow and pulling at maximum power to make the turn. In order that the tug was not put into a girting situation the ship was unable to use more than the occasional burst at dead slow to overcome the ebb tide .

As already stated, these problems were the driving force behind the development of the tractor, with the forward propulsion reducing the dangers of girting. However the limitations of pulling on a short lever arm still apply. Because there are circumstances when a strong pull on the bow is the best alternative, the thrust distribution of the Voith Schneider propeller is now arranged to permit relatively high steering forces to be used without loss of forward thrust. This permits turning forces at larger towline angles and quicker movement from one bow to the other without slacking the line.

Shoulder

This was a secondary position forward but is used to reduce the danger to the tug and simplify the towing gear and crew requirements. Push/pull operations were developed particularly in USA , Japan and Australia where lock systems did not complicate the towing operation. However the effectiveness of trying to turn a vessel from here is somewhat similar to the forward position but several special points need addressing. To turn a vessel, a tug positioned on the inside of the turn (i.e. acting as a backspring against the ships motion) will assist the turn much more than pushing from the outside of the turn. Indeed the pusher may initially drag the ship into a turn the wrong way due to the resistance of the, tug inducing a backspring type effect. Swell conditions are the enemy of this operation as not only is the tug likely to range up and down the ship's side, the short tow lines used minimise any spring properties . However off the berth the push on the shoulder is invaluable. Modem ships with enormous flare and overhang often mean the tug is positioned so far aft to be pushing at the pivot point meaning there is no turning lever, merely a push bodily through the water.

Quarter

Again flare and overhang influence the effectiveness of a tug working in this position as to how far aft the effective push may be applied. Obviously the further aft the better but then the tug is both drawn in to the low pressure zone but may also become perilously dose to the rotating propeller. For a safe approach it is often necessary for the tug to land amidships and then move aft to the towing lead. Often the lead is near the bridge front which means that for a 30 metre tug the safest position is to lie forward of the towline until required. However once in this position good turning forces are achievable, but only when positioned on the inside of the turn.

Aft

Line towing at the stern is now well recognised as the most effective towing position with respect to both braking and steering assistance, but only since the advent of modem manoeuvrable tractors such as the Voith Water Tractor has this become day-to-day practice, since conventional tugs are only effective in this area at minimal speeds. The single biggest advance in modem towing, that of indirect towing came about through the hull design of the tractor with the skeg under the afterbody (see fig. 4). It was found that with careful positioning of the towing point above the skeg, the tractors hull resistance (aided by the large skeg) when being pulled through the water at oblique angles to the towline, could generate massive towline forces far in excess of the nominal bollard pull. Furthermore in contrast to other towing methods the towline force actually increased with the ships speed. Considerable research and development has gone into refining this towing method particularly with escort towage becoming today's catchword with its demands for dynamic assistance in potentially catastrophic circumstances of steering and or engine failure in confined waters. In this operation the hull and skeg resistance generate the towline force with the propellers merely aligning the hull to the correct towline angle both to itself and the ship.

It is erroneous to say that any modern omni-directionally propelled tug can perform effective high speed indirect towing, even any Voith water tractor without due consideration of the speed and other circumstances, such as towing gear, tractor stability, hull form, control systems etc. Coincidentally the factors leading to a good indirect towing vessel also minimise the perceived problems of working the skeg close to the ships propeller wash. However in escort operations normally no assistance is required from the tractor so to minimise the workload on the tractors helmsman during long passive periods, a second towing point at the outboard end of the skeg can pin the tractor under the line and reduce the steering effort required. This towing point can either be fixed as with a Panama lead or removable so that the point of attack can be moved back to the centre of the skeg when required. The only drawback to towing through a fixed point in the end of the skeg is that higher steering forces are required to place the tractor in the correct attitude to obtain maximum towline forces. In practice though, this causes no problem as the highest achievable forces need only approximately half the tractors installed power to hold the required attitude

The other significant towing operation at a ships stern is applying braking forces to the ship (see fig. 5). Again the tractor permits such operation from zero up to the highest speeds. This is mainly due to the controllable pitch characteristic of the Voith Schneider propeller with its open attitude to inflow from any direction. Using full engine speed, reverse pitch can be applied until full power is absorbed from the engine without fear of excessive overload. Thus when arresting the ship's movement the nominal bollard pull is exceeded due to the propeller thrust being augmented by the resistance of the hull being pulled through the water. Any fixed pitch propeller whether on a conventional shaft or in a Z-drive unit suffers from the very real problem of stalling once speeds are above six knots in this operation.

Simplicity is a key attribute of the Voith Water tractor. In all four of the towing positions discussed, the tractor's one towing point is at the most effective end, hence there is no embarrassment in sending her to any of these positions and certainly no need to consider letting go and reconnecting the towline through another lead. This is of particular signifcance to pilots and ships masters who have much else to consider when in close proximity to a berth, and are often relying on deck crews of limited number and/or strength and competence. The control of the tractor is also the simplest system. Whichever way the tractor is moving the skipper has a logical control system of wheel and levers to turn or push in the natural direction, limiting the chances of mistakes due to controls applied in unwanted directions. Because of the simple towing arrangement and the precise manoeuvrability, moving to and from bow to shoulder or stem to quarter during one operation presents no problem.

Towline systems

After the basic hull/propeller layout is settled in a new tractor design, the next highest priority is the towing arrangement of winch, staple and towing gear. Because a Voith Water Tractor can easily generate at least double the nominal bollard pull whilst towing by the indirect method, enormous safety margins are now needed for winch capacity and towline breaking strains. It is common for an owner building a 50 tonne nominal bollard pull tractor to specify 150 tonnes brake capacity and an all rope towline of 180 tonnes capacity. Historically a sacrificial pennant or 'junk' of lesser breaking strain than the winch line was connected in the end of the towline to limit the loss of gear when the line parted at the most common point - the ships lead. With modern all rope towlines of such strength and high brake capacities on the winch, the idea now is that there is no weak link in the towline; if an unlikely emergency arose to place the tractor in jeopardy then the emergency release on the winch is activated to dump the entire towline which can then be recovered and reused. With the high cost of modern tow ropes the last thing the tractor owner wants is broken gear, so to protect the rope where it passes through the ships lead, sacrificial sleeves may be used. The two main reasons for moving to an all or part rope system for modern towing methods are :-

1. The weight of the towline to be handled by the ship's deck crew. If 180 tonne BS wire were used then this could be almost impossible to handle.

2. Stretch is needed. When working push/pull on the shoulder or quarter, only short towline lengths are used so there is never any catenary spring effect. Another significant point is that connecting the tow in these positions must often be done by hand as there is no lead to a winch on the ship's deck.

Typically a modern tow winch will need a brake capacity of at least three times the nominal bollard pull with simple brake/clutch control adjacent to the skipper, a very high light load recovery speed (e.g. 90 metres/min.) and a drum designed to limit spooling problems.

Conciusion

The modem Voith water tractor continues with the original conceptual layout as developed in the early days but tendencies nowadays are :-

1. Nominal bollard pull of 40 - 55 tonnes for a harbour operation.

2. Larger displacement and underwater lateral area to maximise the use of the hull as a steady towing platform and as added resistance during high speed operations.

3. Large beam and freeboard to maximise dynamic stability criteria and to avoid deck edge immersion at normal angles of heel when indirect towing.

4. Freeboard aft the same as freeboard forward for working at speed in either direction. The modern tractor hull is almost a double ended form with speed skeg-first typically being only approximately half a knot less than propeller-first. Indeed modern operations are beginning to be confused by the terms bow and stern, to the tractor skipper more importance is placed on propeller-end and skeg-end.

5. High performance towing systems.

These tendencies are due to the need for the same safety and simplicity of operations over the higher speed ranges demanded today, but without making such tractors hybrids of limited use in general towing operations. Fewer tractors with small crews are the only real solution available to the tug owners dilemma of offering economic but safe towage services.

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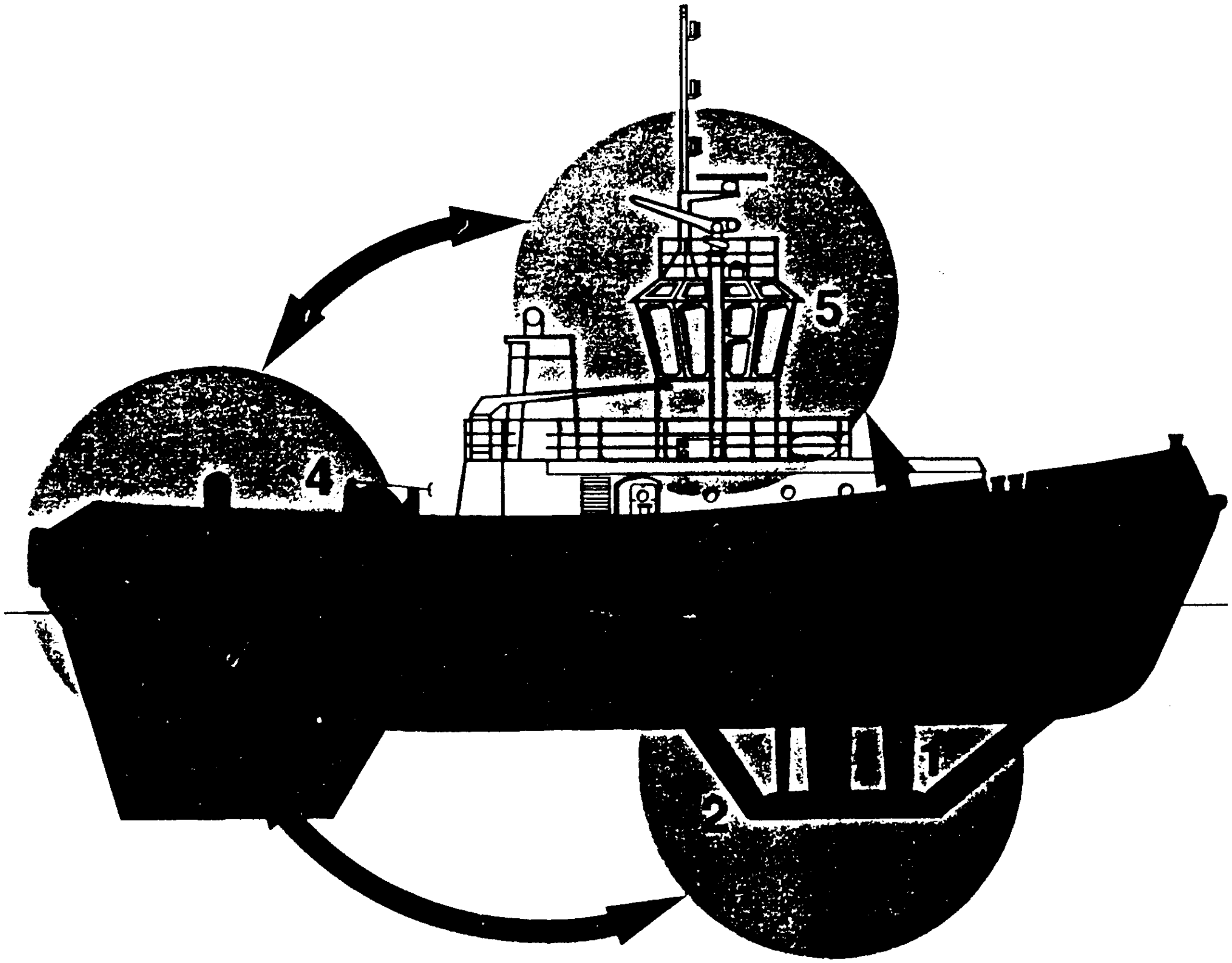
Voith Water Tractor

Characteristics of the tractor concept

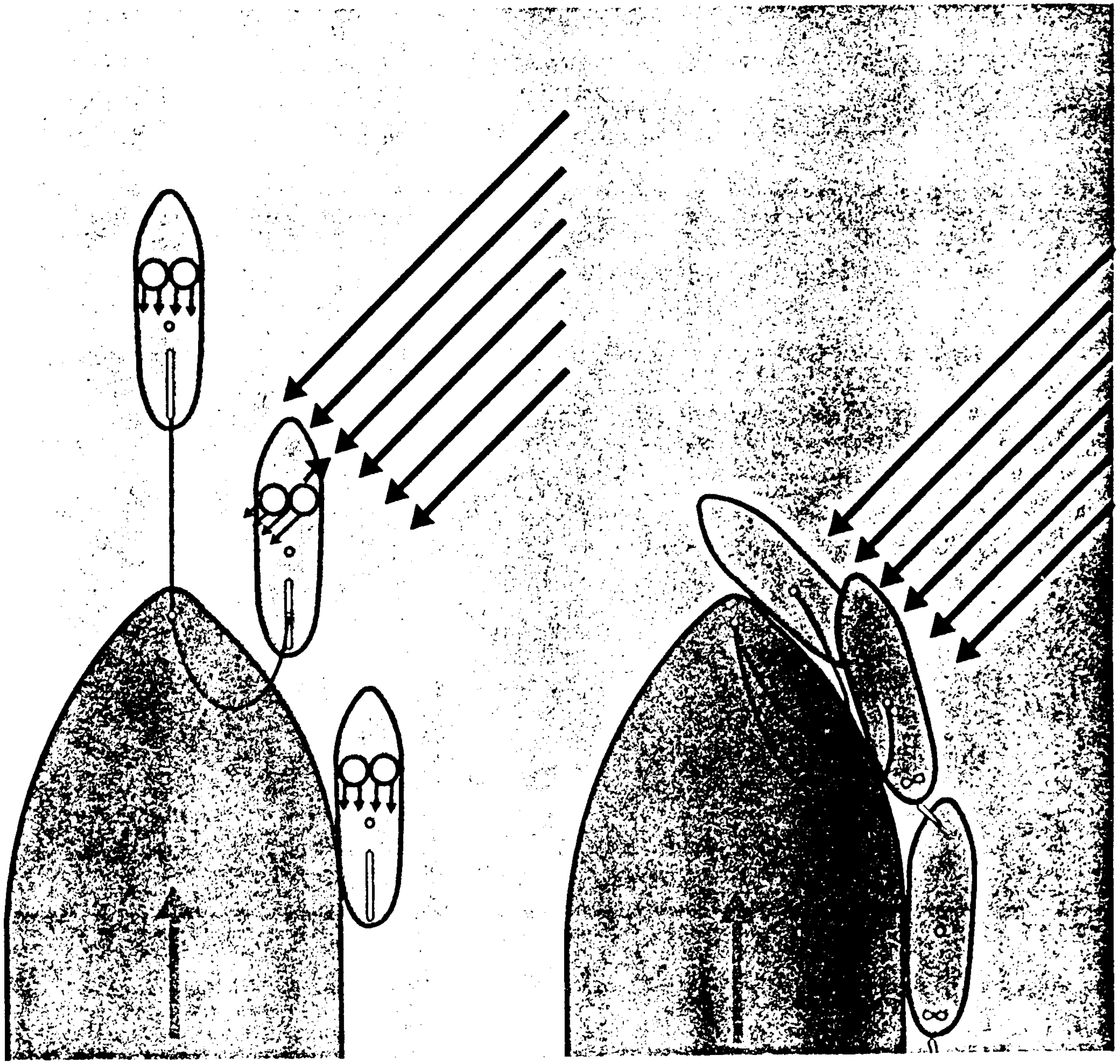
1 Voith-Schneider-Propeller under head of the ship
2 Nozzle plate
3 Stabilizing tin under after ship
4 Towing gear
5 Central wheel house



VS 137e

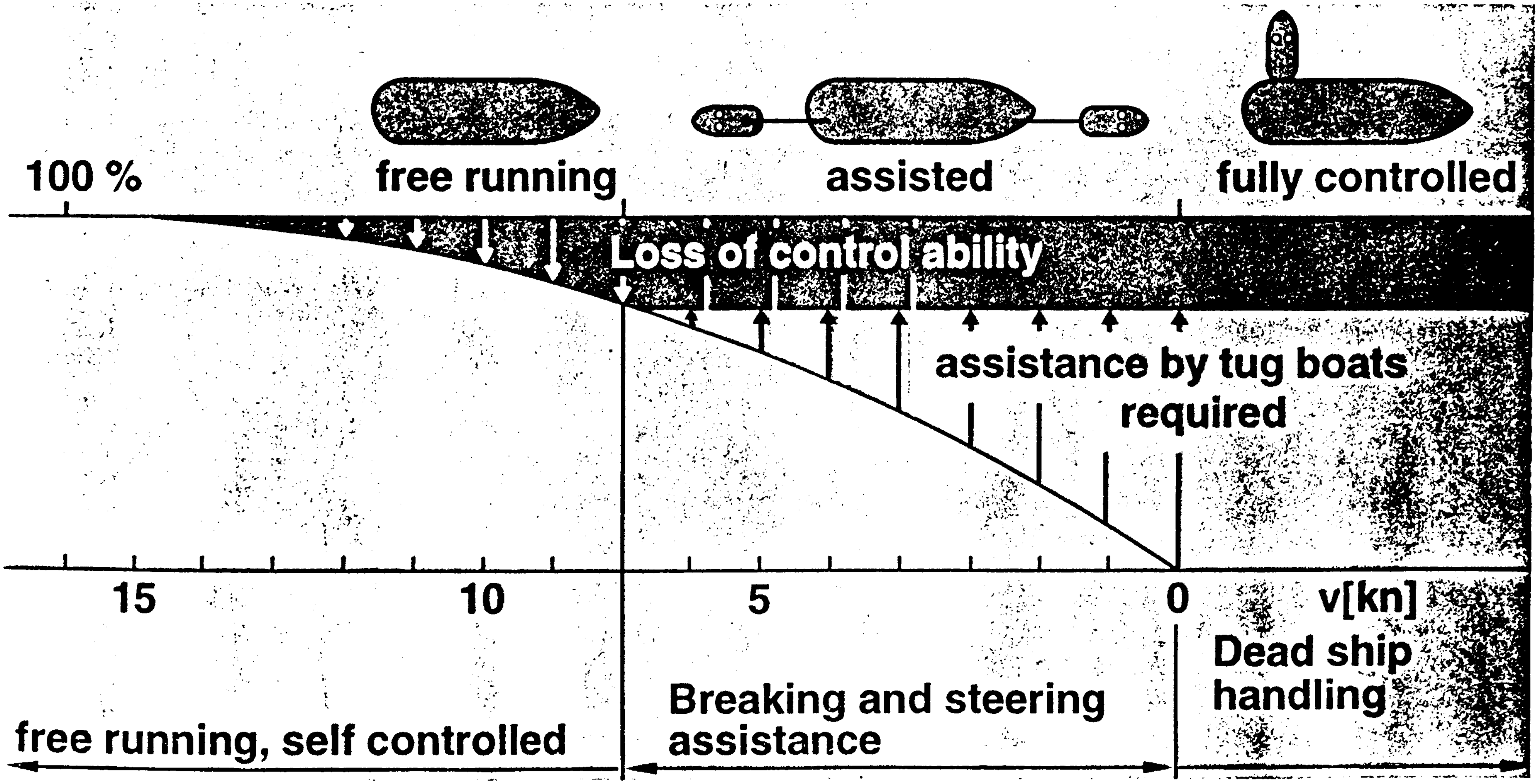
Tractor / Tug

Taking over
the bow line



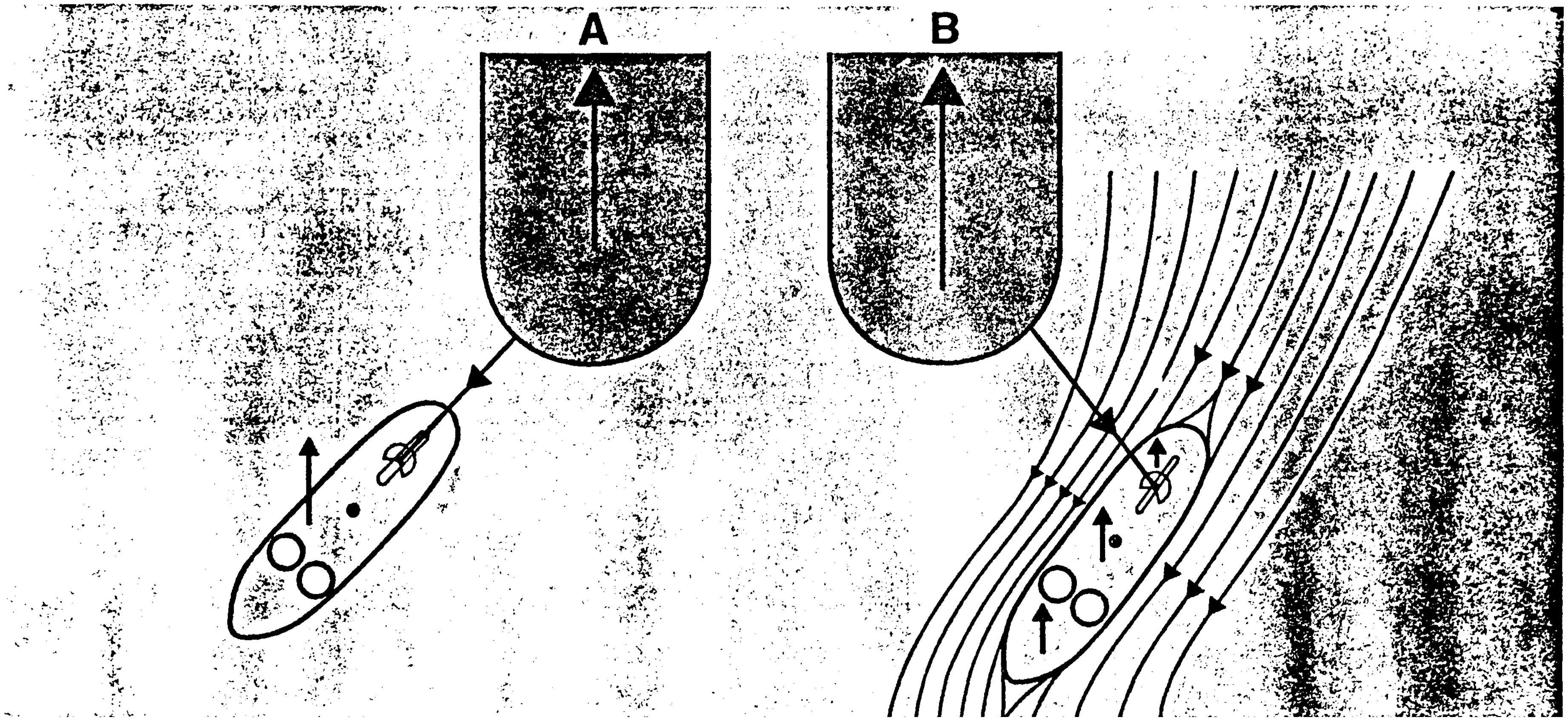
Voith Water Tractor

Shiphandling ability of a Voith water tractor and it´s importance for ship´s safety



Voith Water Tractor

Safety
A direct steering mode
B indirect steering mode



Voith Water Tractor

Braking assistance in negative flow conditions