## APPENDIX D2 Squat Assessment Methodology (provided by British Waterways)

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# Squat formula for ships in rivers

**Following on from his June 2004 article concerning squat and *Queen Mary 2*, Dr C B Barrass proposes a suitable formula for all naval architects and ship masters to predict the necessary under-keel clearance when navigating in a river or canal.**

WHEN a ship is in shallow waters and at forward speed, there is the danger that she will go aground due to the phenomenon known as 'squat'. The danger is greater when the ship is in a river or canal; this is because of interaction effects with the adjacent riverbanks and the sides of a moving vessel. The narrower the channel, the greater will be the ship squats.

By definition, ship squat is the loss in under-keel clearance as a ship moves at forward speed, compared to when she is stationary. At high speeds, a ship may squat until the static under-keel clearance has been equalled. The ship has then grounded.

Because of erosion to river banks and interaction with moored ships in a river, the forward speeds of ships are a lot less than when 'at sea' or open-water conditions. Some port authorities 'request' maximum speeds of only 4knots in their rivers; others may allow slightly higher transit speeds, commensurate with ship size.

Another restriction often put on incoming ships is a minimum static under-keel clearance. Some port authorities require at least 10% of the mean draught; others demand at least 1.0m. Others again can request a static under-keel clearance of at least 1.25m.

The author, in the interests of safety, favours the minimum requirement to be irrespective of a ship's static draught and to be in units of metres. After all, 10% of a ballast draught is less then 10% of a fully-loaded ship.

To predict maximum ship squat in river conditions, the author has produced a diagram that involves 'K' coefficients (Fig 1). For this study, the value of 'K' will range only from 1.0 to 2.0. If 'K' < 1 on the diagram, then use 'K' = 1. If 'K' > 2 on the diagram, then use 'K' = 2. The parameters associated with this diagram are H/T and B/b.

- H = depth of water in a rectangular cross sectional-shaped river (m)
- T = ship's static even keel draught (m)
- B = breadth of water in a rectangular cross sectional-shaped river (m)
- b = breadth moulded of ship in transit (m).

In this article, concentration is on shallow waters where the static H/T ranges from 1.10 to 1.30. It is in this range of 10% to 30% under-keel clearance that there is greater chance of a ship going aground. At greater than 30% static under-keel clearance, likelihood of touchdown is greatly decreased.

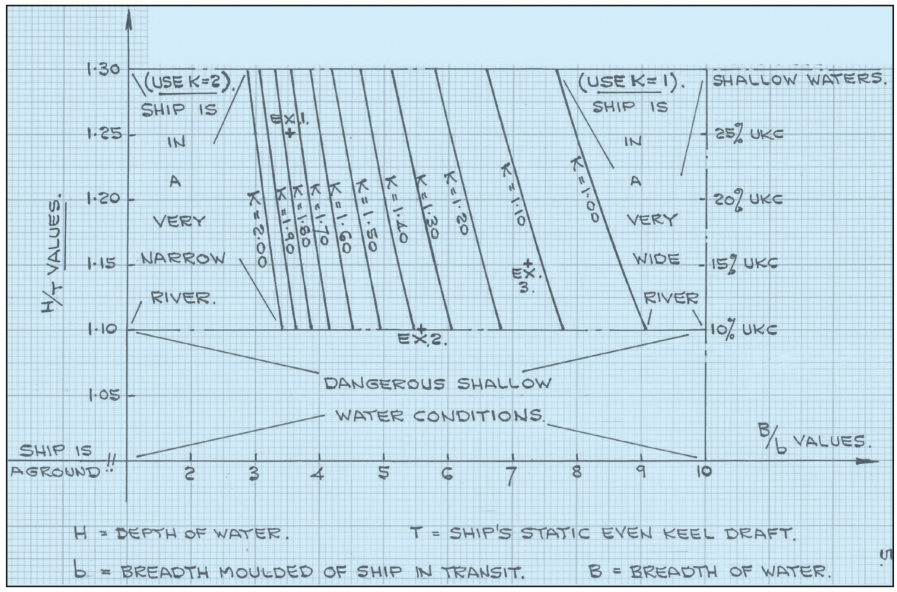

**Fig 1. 'K' co-efficients for rectangular-section rivers.**

## Procedure for using Fig 1

The following procedure should be followed:

1. determine and record the values of H, T, B and b
2. calculate the values H/T and B/b
3. enter Fig 1, and plot the intersection point of H/T with B/b. See the results for the three worked examples below
4. using this intersection point and the 'K' contour lines, determine the value of 'K' appropriate to the river condition under consideration.

Having now obtained a value for 'K', the next step is to link it with two more variables. They are the block coefficient Cb and the ship speed V, measured in knots. The Cb will depend on the ship type being considered.

For each ship type, Cb will depend on the condition of loading, being less at lower draughts.

The speed V is the ship speed relative to the water. Tidal speed and direction of current must always be taken into account by a ship's pilot.

| | |
|---|---|
| Cb = | volume of displacement / (LBP x b x d) |
| LBP = | length between perpendiculars |
| b = | breadth moulded of the considered ship |
| d = | even keel draught, ranging from light ballast to fully-loaded departure condition. |

Table 1 illustrates typical Cb values for several merchant ships, but a note of caution should be added: whilst Table 1 shows Cb values at fully-loaded conditions, it must be remembered that ships do go aground at draughts less than their moulded draught. In recent years, 16 ships have done so.

## Calculation of maximum squat

To obtain the maximum squat for these ships in a river, the squat predicted for open-water conditions must be multiplied by the previously determined value for 'K'. Hence, maximum squat in a river or canal = 'K' x {Cb x $V^2$/ 100} metres.

Whereabouts does the maximum ship squat occur? Assume first of all that each ship when stationary, is on even keel. This appears to be a sensible pre-requisite prior to entering shallow waters. If this is so, then: If Cb > 0.700, then maximum squat occurs at the bow. If Cb < 0.700, then maximum squat occurs at the stern. If Cb is approximately 0.700, then maximum squat extends from stern to amidships to bow.

However, if a ship when static has an aft draught greater than its forward draught, then the maximum squat will occur at the stern. Squat will also occur at the bow, but will be of less magnitude.

Furthermore, if a ship when static has a forward draught greater than the aft draught, then the maximum squat will occur at the bow. Squat will also occur at the stern, but will be of less magnitude.

## Worked example 1

A container ship has a Cb of 0.575. She is proceeding upriver at a speed (V) of 6knots. This river, of rectangular cross-section, has an H/T of 1.25 and a B/b of 3.55. When static, the ship was on even keel. Calculate her maximum squat at this speed and whereabouts it will occur.

Using Fig 1, at the point of intersection of 1.25 and 3.55, the 'K' value lifted off is 1.752, so maximum squat

= 'K' x {Cb x $V^2$/100} metres.
= 1.752 x {0.575 x 6 x 6}/100
= 0.36m

This squat will be located at the stern, because her Cb < 0.700 and the ship when static was on even keel.

## Worked example 2

A general cargo ship has a Cb of 0.700. She is proceeding upriver at a speed (V) of 5knots. This river, of rectangular cross-section, has an H/T of 1.10 and a B/b of 5.60. When static, she was on even keel. Calculate her maximum squat at this speed and whereabouts it will occur.