

SQUAT

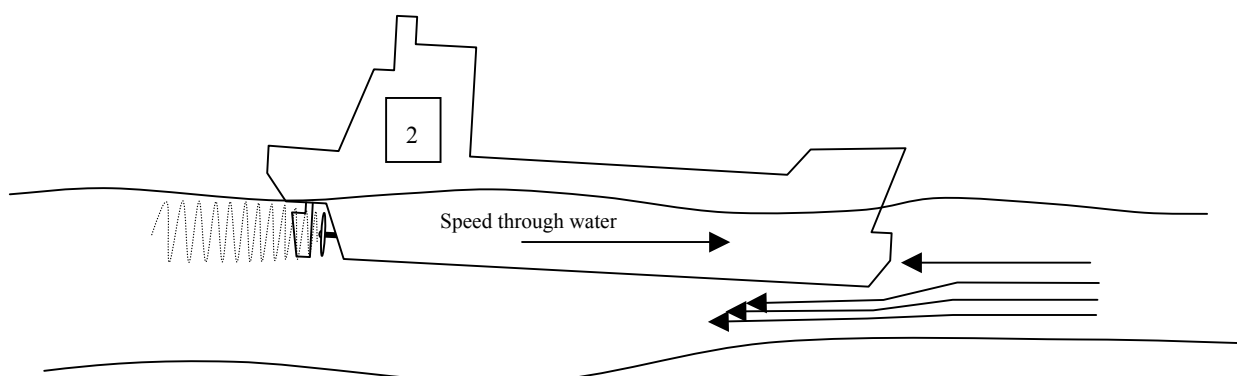
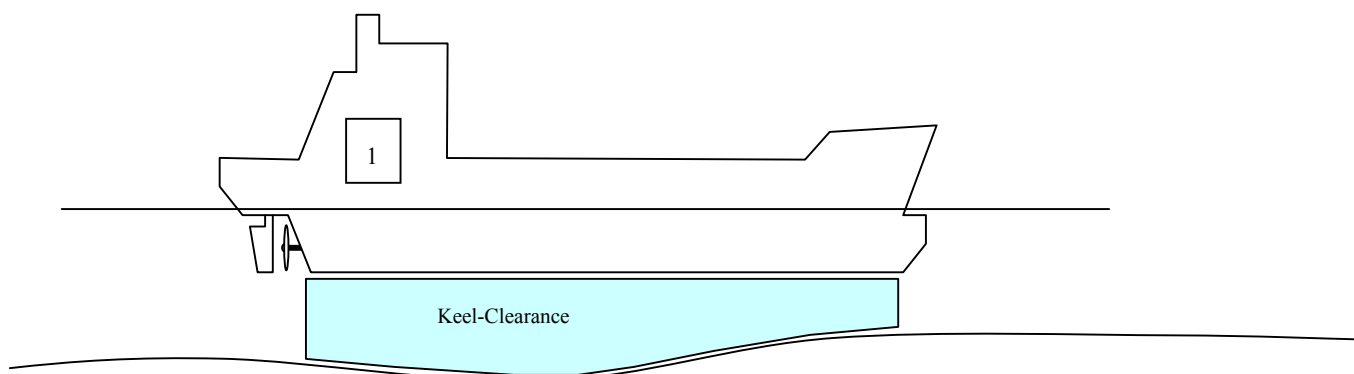
Capt. P. Zahalka

(Cassell's Dictionary: Squat = kauern, hocken, sitzen, sich setzen)

What in fact is Squat and why is Squat relevant for shipping?

Squat is the reduction of a vessels Keel-Clearance, caused by the relative movement of the ship's hull through the surrounding body of water. Compared with the neutral position (1) the hull sinks deeper into the water and at the same time will trim slightly. The algebraic sum of both, sinking and trimming is called Squat (2).

Squat is not the difference of the draught readings of a vessel in her neutral position compared with the readings of a vessel making speed or laying in flowing water (current).





So Squat occurs when a vessel is making speed through the water or a vessel is not making speed but laying in flowing water (current).

The phenomena Squat is already known for a long time. But for shipping it became more relevant recently because ships are growing bigger in dimensions and are getting faster.

Today's vessels draught and the available water depth in the approaches to ports and in the ports demand that Squat is a mandatory factor in voyage planning and the safe operation of a vessel.

How Squat is caused?

A speed making vessel pushes a mass of water in front of her bow. This water must flow back under and at the sides of the vessel (backflow) to replace the water displaced by the ship's hull. In shallow and/or narrow waters the water particle's velocity of flow increases which results a pressure drop (Bernoulli's Law).

$$p + \rho gh + \frac{1}{2} \rho V^2 = const$$

p = static pressure

ρ = density

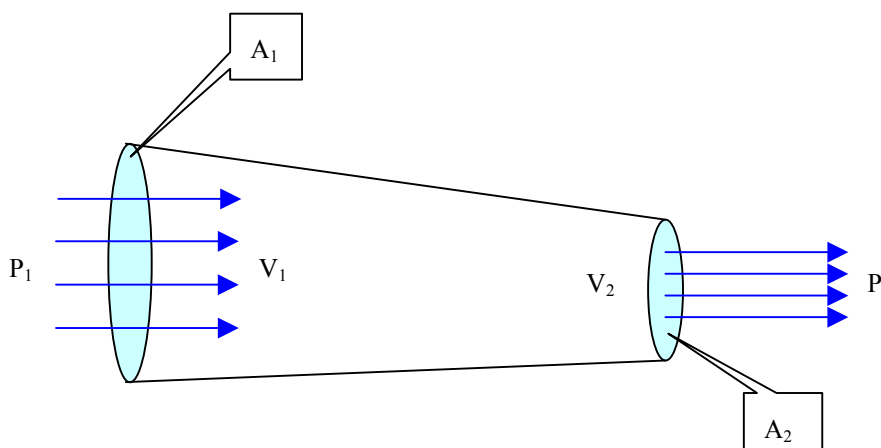
V = speed

g = gravity

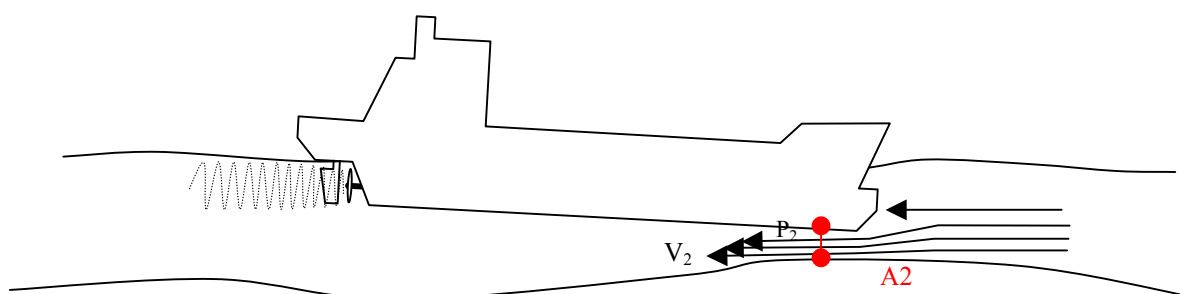
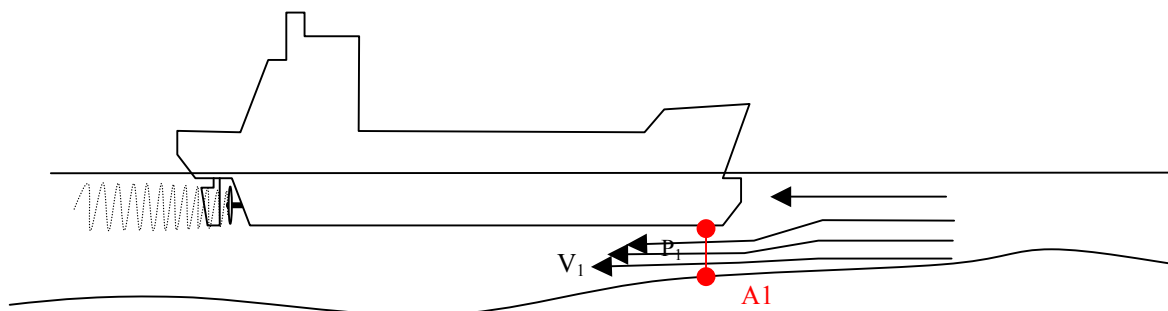
h = height

Bernoulli's Law implies that inside a liquid the sum of hydrostatic pressure "p", gravity pressure " ρgh " and hydrodynamic pressure " $\frac{1}{2} \rho V^2$ " stays constant.

Consequently the increase of hydrostatic pressure is equal to the decrease of hydrodynamic pressure, caused by the increase of velocity of flow.



Result:



$A_2 < A_1 ; V_2 > V_1$
decreasing area = increasing speed

$V_2 > V_1 ; P_2 < P_1$
increasing speed = decreasing pressure

The drop of pressure below the ship's bottom causes a vertical sinking of the ship's hull in the water, at the same time and depending on the vessel's block coefficient C_b she will trim forward or aft or will sink deeper into the water on even keel. The sum of all vertical sinking and trim is called "SQUAT".

Change of trim by squatting of a vessel on even keel or at already existing trim:

- Ship on even keel and $C_b = 0,7$ – Ship is squatting with no change of trim
- Ship on even keel and $C_b > 0,7$ – Ship is squatting and trimming to forward
- Ship on even keel and $C_b < 0,7$ – Ship is squatting and trimming to aft
- Ship with existing trim to aft – Ship is squatting with trim to aft
- Ship with existing trim to forward – Ship is squatting with trim to forward

The main factors, affecting the size of Squat, are:

Present water depth,

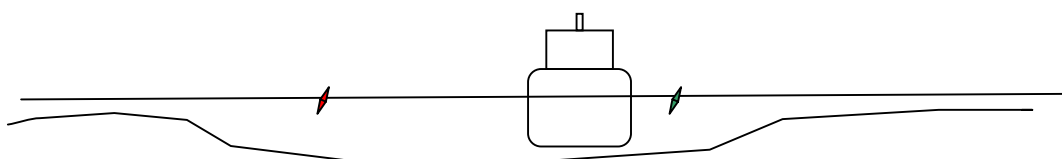
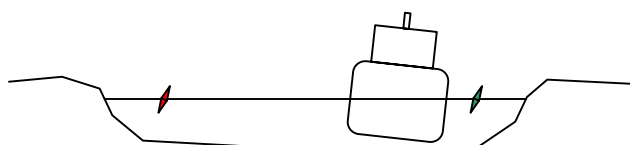
Ships speed through water,

Ships block coefficient (C_b).

It is also relevant whether the vessel is sailing in shallow and unrestricted water,



or in restricted waters (Canal, River).



In the last said case extended Squat will occur. Other factors affecting the under keel-clearance (distance from ships lower bottom to ground) might be a possible list of the vessel and/or swell resulting in heaving and/or pitching of the ship.

Even if all these factors are taken into consideration there remains a residual risk due to uncertain information about water depth and density of the water. Due to local meteorological influences the water level might be different to the available charts and tidal data or the bottom profile of a river or canal has changed. Keeping this uncertainty in mind it is recommended to establish a **safe minimum keel-clearance** under consideration of Squat and other predictable factors.

A lot of different persons and institutions have dealt with the phenomena “Squat” in a scientific and also in an empirical way (Empirism = Science, only accepting experience as a source of cognition).

Up to now there is no exact prediction of the expected Squat possible. It is recommended to ship’s command to use an evaluation method for route planning which is known as reliable from a sufficient number of practical trials and which will deliver results on the so called “safe side”.



After consideration of other uncertain factors like afore said, and thereby keeping an adequate keel-clearance the practitioner can assume to reach his destination without grounding.

In the course of these studies a number of formulas and calculation schemes with different accuracy of the occurring Squat were developed.

In praxis, especially in German waters, formulas developed by Dr. Barras, an English professor, are in use. These formulas are of an empiric nature and based on about 500 measurements both on real vessels and on ship models.

The simplified formula for vessels in unrestricted waters (open water conditions) reads as follows:

$$Squat(\sigma) = C_B \times \frac{V^2}{100} [metres]$$

In restricted waters (confined water condition) Dr. Barras assumes an increase of Squat as follows:

$$Squat(\sigma) = 2C_B \times \frac{V^2}{100} [metres]$$

V = speed through water in knots

According to Dr. Barras both formulas are rough estimates and will err on the safe side.

The following method is more complicated but is providing more realistic values.

The writer has implemented this formula into an EXCEL Spreadsheet to provide a possibility to carry out fast calculations with variable parameters.

By using this implemented EXCEL Spreadsheet (doubleclick and EXCEL must be installed on your PC) it has to be borne in mind that this empiric formula also only tries to deliver results as close to reality as possible.

Values calculated with this formula, compared with measured Squat-values, have shown that this formula also has a tendency to deliver too big values.

(Attention: - Outside the yellow marked areas the spreadsheet is protected.)



Prediction of SQUAT, KEELCLEARANCE and GROUNDING SPEED in open and confined waters			
Only use this program if (Water Depth) / Ships Mean Draft is 1,1 - 1,4			
		$Squat_{max.} = \frac{C_B}{30} \times S_2^{2/3} \times V^{2,08} \text{ [metres]}$	
Name of ship	Passenger Liner		(by Dr. C.B. Barnes)
Length (Lpp)	L	157,00 m	
Breadth	B	25,00 m	
Draft aft	D1	8,88 m	
Draft midships	T	8,88 m	H/T value too low, please modify H and/or T
Draft forward	D2	8,88 m	
CB	C1	0,700	
Ship speed relative to the water	V _k	6,00 knots	
Depth of water	H	9,76 m	
Width of influence		238,00 m	
Width of channel	B2	100,00 m	Ship is in confined channel condition
Angle of heel		0,00 °	
Angle of pitch		0,00 °	
Max. Squat occurs at the bow		Not applicable	m
Max. Squat at the stern, amidships and bow		0,43	m
Max. Squat occurs at the stern		Not applicable	m
Remaining underkeel clearance at the bow		Not applicable	m
Remaining underkeel clearance-even keel		0,45	m
Remaining underkeel clearance at the stern		Not applicable	m
Min. underkeel clearance allowed		0,50	m CAUTION !! underkeel clearance too small !!
Speed when ship grounds at the stern, bow or on even keel respectively (Speed = Speed relative to the water)		8,50 knots (calculating range: 5-25 knots)	

The formula underlying this spreadsheet allows calculations both, for unrestricted and for restricted waters. The “width of influence” calculated on the basis of the entered variables and the variable “width of channel” are the control mechanism for corresponding calculations. If the value for “width of channel” ≤ “width of influence” calculated Squat-values are applying for restricted waters. If the value for “width of channel” > “width of influence” calculated Squat-values are applying vice versa for unrestricted waters.

If one enters all variables into the spreadsheet and defines the necessary remaining keel-clearance under keeping in mind all adverse circumstances; it is easy to ascertain a max. speed (through the water) which is still safe in the particular fairway, by entering different speed-values (trial and error method).

Please keep in mind; by applying the values “water-depth” and “channel width” only, the profile of a Fairway can not be defined adequately. Thus, the calculated speed-values have to be looked at critical, so it is recommended to implement a safety-factor in favour of the ship.



How to recognize whether / when Squat occurs?

If a vessel reaches shallow waters and “feels the ground” following changes will be observed:

- Change of wave pattern at the stern and the bow of the vessel,
- The vessel becomes dull when carrying out manoeuvres,
- The revolution of main engine decreases obviously, in restricted waters more obviously than in unrestricted waters.
- The ship’s speed decreases, in restricted waters more obviously than in sideways unrestricted waters.
- Appreciable vibrations of the ship’s hull occur

How to prevent Squat?

As previously mentioned, main factors of Squat are:

- Existing water depth,
- Vessel’s speed through the water,
- Vessel’s block coefficient (C_b)
- Steaming in shallow and restricted or unrestricted waters.

The only effective measure by the ship’s command to minimise or eliminate commencing Squat is the **immediate reduction of speed**.

Squat-values changes about the square of the ship’s speed through the water.

By reducing the speed through the water by about **a half**, the Squat reduces to about **a quarter**.

Squat Literature

The aforesaid is an attempt to approach the subject SQUAT in a simplified and understandable way and provide some tools to the practitioner to pre-calculate Squat-values for a safe passage.

For occupying yourself more intensively with this subject, it is recommended to study following literature:

- 1) Kapt. Michael Urlaub
Squat und Kielfreiheit – Probleme und Auswirkungen aus der Sicht eines Lotsen
Schiff & Hafen 01/1993
- 2) Dr.-Ing. H. Hilgert, Dr.-Ing K. Benedict,
Kielfreiheit in begrenzten Fahrwassern,
Schiff & Hafen 12/1990, 01/1991.



- 3) Prof. Dr.-Ing. habil. Klaus Römisch,
a) Der „Squat“ im begrenzten Fahrwasser – Betrachtung aus hydrodynamischer Sicht,
Schiff & Hafen 10/1993
b) Squat der hydrodynamisch bestimmte Anteil der Underkeel Clearance,
Schiff & Hafen 4/2003.
- 4) Dr. C.B. Barras, M.Sc. C. Eng. F.R.I.N.A.
a) Ship Squat - A guide for masters, 1995
b) Computer programme for ship Squats, 1995
c) Ship-Handling problems of vessels in shallow water.
- 5) Gerd Flügge und Klemens Uliczak,
Fahrverhalten großer Containerschiffe in extrem flachem Wasser
Schiff & Hafen 12/2001.
- 6) A.- Härtling / J. Reinking,
Natur-Messung des Squat,
HANSA, 1999 – Nr. 8
- 7) A.- Härtling / J. Reinking,
Efficient determination of ship Squat,
Schiff & Hafen 3/99.
- 8) Prof. Dr. Ralf Wandelt,
Squat – eine Bestandsaufnahme,
Schiff & Hafen 7/99.
- 9) Torsten Stengel,
Elektronische Tidefahrpläne,
HANSA, 2002 – Nr. 4

Bremen, 31.03.2005