UNDERKEEL CLEARANCE
SHIP SQUAT & TIDES

BEST NAVIGATION PRACTICES
DEFINITION OF SQUAT

REDUCTION OF UNDERKEEL CLEARANCE (UKC) CAUSED BY A SHIP’S MOVEMENT THROUGH THE WATER.

(IT IS NOT AN INCREASE IN DRAFT. RATHER, IT IS THE BODILY SINKAGE OF A VESSEL WHICH PLACES IT CLOSER TO THE SEA BOTTOM.)
STATIC DRAFT + SQUAT
SQUAT FACTS

- $C_A > .7$ (bulker) squats by bow. $C_A < .7$ squats by stern
- Squat varies directly with breadth (doubling breadth doubles squat)
- Squat varies by the square of speed (doubling speed quadruples squat)
- Squat can be doubled when meeting another ship
SQUAT FORMULAE

- Five of most user friendly and “popular”
  - Barrass
  - Eryuzlu et al
  - Huuska/Guliev
  - Römisch
  - Yoshimura
- All give bow squat
- Stern squat
  - Only Römisch predicts stern squat for all channels
  - Barrass stern only for unrestricted or open channels and other channels depending on $C_B$ value

Photo Courtesy BAW
BEST GENERAL FORMULA

\[ \frac{V^2}{100} = S \text{ meters} \]

Speed = 6 KTS
\[ \frac{36}{100} = 0.36 \text{ meter squat} \]

Speed = 12 KTS
\[ \frac{144}{100} = 1.44 \text{ meter squat} \]

Doubling the speed quadruples the squat
HULL TYPES

BLOCK COEFFICIENT ($C_\beta$)
LARGE BLOCK HULL

\[ C_\beta > 0.7 \]
FINER HULL

$C_\beta < .7$
VARIOUS SQUAT FORMULAE YIELD SIMILAR CONCLUSIONS

\[
Squat = \left(\frac{1}{30}\right) \times C_b \times \left(\frac{S_2^2}{3^3}\right) \times V^{2.08}
\]

- You can fiddle away with the parameters and get a feeling of the influence on UKC for a ship sailing in shallow water.
- The really important thing about this formula (and all the other squat - formulae, which all look-alike) is what happens with ship's speed.
- Fill in a ship's speed of 5 knots, or 10 knots, the result of the formula is 25 versus 100.
- **Double speed gives four times higher squat.**
SQUAT PREDICTIONS

Susan Maersk Containership

- $L_{pp} = 1,088$ ft
- $B = 140.4$ ft
- **Draft**
  - Light load $T = 46$ ft
  - Full load $T = 47.5$ ft
- $C_B = 0.65$
- $V_K = 8$ to $14$ kts
TIDAL CONSIDERATIONS

ZERO TIDE

Light Load $T=46$ ft, $h=50$ ft ($h/T=1.09$)

- No tide
- Available UKC=4 ft
- Ankudinov & CADET general agreement with PIANC predictions
- Both conservative
- Ankudinov tracks OK
- CADET tracks OK to $V_k=10$ kt
- Example @ $V_k=10$ kt
  - PIANC Ave=1.7 ft
  - Ankudinov=2.3 ft
  - CADET=2.4 ft
- Grounding due to squat at $V_k=12+$ kt
TIDE +4 FEET

Light Load T=46 ft, h=54 ft (h/T=1.17)

- Tide=4 ft, 4 hr/day, 365 days/yr
- Available UKC=8 ft
- Ankudinov & CADET general agreement with PIANC predictions
- Both conservative
- Ankudinov tracks OK
- CADET tracks OK to $V_k=12$ kt
- Example @ $V_k=10$ kt
  - PIANC Ave=1.6 ft
  - Ankudinov=2.1 ft
  - CADET=2.2 ft
- No grounding due to squat
TIDE +8 FEET

Light Load $T=46$ ft, $h=58$ ft ($h/T=1.26$)

- Tide=8 ft, 1 hr/day, 7 days/yr
- Available UKC=12 ft
- Ankudinov & CADET general agreement with PIANC predictions
- Both conservative
- Ankudinov tracks OK
- CADET tracks OK to $V_h=12+$ kt
- Example @ $V_h=10$ kt
  - PIANC Ave=1.6 ft
  - Ankudinov=1.9 ft
  - CADET=2.0 ft
- No grounding due to squat
GROUNDING DUE TO SQUAT

Ship is stationary, with small underkeel clearance. Trim ranges from being on even keel, to being 1/500 by the stern.

Ship Squat

Ship is in dynamical condition. Grounding occurs at the stern.
• Vertical squat is **not** extra draught due to shallow water effect. (Ships would *sink*, if this was true.)
• Vertical squat is due to **waterflow** being restricted under the ship's hull (and in a channel; also along the sides of the ship). It's called Bernoulli's Law.
  • **Waterflow** is restricted
  • **Waterspeed** is increased
  • **Waterpressure drops**
  • **Waterlevel drops**
Bernoulli’s Law 
Illustrated
Increased Effect in Confined Channels

Maximum predicted squat in confined channels and open water conditions
PILOT’S CONSIDERATIONS

- Warning: every ship reacts different in shallow water, concerning trim, list during turning, steering capabilities, course stability.
- And you have to be **really** sure about some values:
- **waterdepth** in the channel: that means the channel has to be multibeam measured completely, and the depth of the shallowest part has to be measured beyond any doubt. Nothing less will do.
- Tidal height has to be an actual measurement, not simply an astronomical (calculated) tidal height. You'll need **realtime** online tidal height onboard.
- The ship's draught sensors have to be reliable, accurate and exact,
- and don't forget to adjust the density of the seawater in your loadcomputer.
TIDAL CONSIDERATIONS
USING TIDE TO GOOD ADVANTAGE

• NOAA’S “PORTS” TOOL ONLINE
• LOCAL KNOWLEDGE OF PILOTS
• CREDIBLE PREDICTIONS OF METEOROLOGICAL FACTORS ON TIDES (NOAA’S FORECAST PROGRAM)
NOAA’S OPERATIONAL FORECAST SYSTEM
NOAA'S PHYSICAL OCEANOGRAPHIC REAL-TIME SYSTEM (PORTS)

SCREEN SHOT 7/24/11
NOAA’S SEARCHABLE STATIONS
www.tidesandcurrents.noaa.gov
PORTS COMPOSITE PAGE

CHESAPEAKE CITY, MD

Water Levels of Chesapeake City
Valid Time: 1342 (EDT) 07/24/11
Observed Height: 0.75 ft
Predicted Height: 0.85 ft

Currents at Chesapeake City
Along-Channel (38° T)
Valid Time: 1337 (EDT) 07/24/11
Observed Current: 1.68 Knots
Predicted Current: 1.88 Knots

Water Temperature of Chesapeake City
Valid Time: 1342 (EDT) 07/24/11
Water Temp: 87.6 °F

Winds of Chesapeake City
Valid Time: 1342 (EDT) 07/24/11
Wind Speed: 5 Knots
Gusting To: 6 Knots
Wind Direction: 325° T

Currents at Chesapeake City
Cross-Channel (188° T)
Valid Time: 1337 (EDT) 07/24/11
Observation
Prediction

Chesapeake City
6 ft Below Surface
1337 (EDT) 07/24/11
PORTS AIRGAP OBSERVATIONS
C&D CANAL

Air Gap at Chesapeake City Air Gap
Valid Time: 1336 (EDT) 07/24/11
Air Gap: 143.2 ft.

Air Gap at the Navigation Light on the East Side of the Chesapeake City Bridge
South Bank
North Bank
143.2 ft. (43.6 m.)

Air Gap at Reedy Point Air Gap
Valid Time: 1342 (EDT) 07/24/11
Air Gap: 140.0 ft.

Air Gap at the Navigation Light on the East Side of the Reedy Point Bridge
South Bank
North Bank
140.0 ft. (42.7 m.)
“H” FLAG
PILOT ON BOARD