Tall Ships America
Safety Under Sail Forum:
Sailing Vessel Stability,
Part 2: MCA Squall Curves

Moderator: Captain Rick Miller, MMA

Panelists:
Bruce Johnson, Co-Chair Working Vessel Operations and Safety Panel O-49, SNAME
Jan C. Miles, Captain, Pride of Baltimore II
Jason Quilter, Captain, R C Seamans
David Bank, Director of Marine Operations, SEA
Overview of MCA Curves of Maximum Steady Heel Angle to Prevent Downflooding in Squalls
Part 2
vs
SNAME-Pride of Baltimore II Operator Guidance Approach
See Part 3
MCA Curves of Max Heel

- Two different types: Gust curve, or Squall curve
- Gust curve is for non-squall conditions.
  - Assumes a possible 1.4 increase (41%) in mean wind speed during gusts.
  - Therefore an increase of 2 X the wind pressure.
- Squall curve is for threatening weather.
  - Wind increase in a Squall may be many times that of the preceding wind.
  - Therefore a multiple increase in the wind pressure.
MCA Gust Curve Explanation

- The British have recently adopted a Large Commercial Yacht code based on the GZ value at 60 degrees which is converted to an upright Wind Lever at zero angle (WLO) using a Cos^1.3 factor divisor.
- The derived wind heeling lever represents half the wind force assumed to heel the vessel to 60 degrees and it’s intersection with the GZ curve represents the maximum heel angle which could resist a quasi-equilibrium 41.4% increase in wind speed.
- Note that at the angles of heel up to deck edge submergence, the wind heel rolls off more rapidly than the GZ curve from a straight line, so the vessel stiffens up with heel angle in this range.
MCA Gust Curve Explanation

- WLO (HA₁) = the magnitude of the actual wind heeling lever at 0° which would cause the vessel to heel to the 'down flooding angle' θF or 60° whichever is least.
- Dwhl (HA₂) = the "derived wind heeling lever" at any angle θ = 0.5 x WLO x Cos¹.³θ (this should be heel angle at 0°)
MCA Curves of Max Heel

- Both graphically show the max steady heel angle to prevent heeling to the first down flooding point or 60° angle of heel, whichever is least.
- The downflood point ($\theta_F$) is when the lower edge of a critical deck opening becomes submerged.
- Critical opening: area m2 > disp/1500
- Both curves are custom for each vessel based on $\theta_F$ and righting arm (GZ) amounts.
MCA Gust Curve Assumptions

- Sail plan and apparent wind angle will remain constant during the gust.
- Wind gust will not be more than 1.4 X the preceding mean wind speed.
- As a sailing vessel heels the (horizontal) wind heeling moment decreases and at any heel angle \((\theta)°\) between 0 (upright) and 90 degrees it is related to the upright value by the function:

\[
HM = HM_{0°} \times \cos^{1.3\theta}
\]
Overview of MCA Calculations

- Find HA$_1$ value for downflooding angle (DF):
  - $GZ @ DF/\cos^{1.3} \theta_{DF}$

- Find HA$_2$ value for steady heel angle ($\phi$)5 - 40° before squall.
  - $GZ @ \phi / \cos^{1.3} \phi$

- Find for 30, 45, 60 knot squall speeds ($V_1$) that lead to downflood, when compared to the prior wind speed ($V_2$) at a given heel angle 5- 40°.
  - $V_2 = V_1 \left(\frac{HA_2}{HA_1}\right)^{0.5}$

- Calculations and curve graphed in Excel
MCA Gust Curve example

27° Max Heel to Withstand a 41% Increase of Wind, Up to θF
Assumptions for the Development of MCA Squall Curves I

- The squall curves are based on comparing the righting arm at the downflood point and the righting arm at the heel angle preceding the squall.
- The formulas and procedures then determine the value of the squall wind speed that will heel the vessel to the downflood point.
- If it is presumed a 30, 45 or 60 knot squall will heel the vessel to the downflooding angle, the corresponding heel angle can be found for the vessel with the same sails set in a lesser wind speed which might precede the squall.
Assumptions for the Development of MCA Squall Curves II

- Input regarding the current sail plan is not required.
- Input regarding the apparent wind (AW) direction and point of sail is not required. (caveat, however)
- Required input is steady heel angle ($\theta^\circ$) and mean apparent wind speed before the squall.
- A reliable anemometer and inclinometer are required.
- It is hoped that familiarity with the vessel’s squall curve will enable the master to judge the margin of safety in terms of stability when making a decision whether to shorten sail.
Assumptions for the Development of MCA Squall Curves III

- Heeling Arm Curves are based upon a factor divisor of \( \cos^{1.3} \theta \) for the angle of heel.
- Again, as a sailing vessel heels the (horizontal) wind heeling moment decreases and at any heel angle \( (\theta)^\circ \) between 0 (upright) and 90 degrees it is related to the upright value by the function:

\[
HM = HM_0^\circ \cos^{1.3} \theta
\]
Orientation to the Squall Curve

Max Steady Heel of 10° in 20 Knots AW.
Squall Curve Use: Example 1 Sail Plan

Off Lanai:
Fore & Main Stays’ls
1,542 sq ft
25 knots AW
10° Heel

1st Downflood Point 57°
Robert C. Seamans from Squall Curve
To Prevent Downflooding at Doghouse Skylights 57°

Example #1
Off Lanai
Stays'ls Only
Close Reach
25 Knots AW
10° Heel

Vulnerable to
Downflooding
60 Knot Squall
Squall Curve Use, Example 2 Sail Plan

Off HI Islands:
Fore & Main Stays’ls, Jib, Tops’l
3,476 sq ft
18 Knots AW
8° Heel

1st Downflood Point 57°
Robert C. Seamans from Squall Curve
To Prevent Downflooding at Doghouse Skylights 57°

Example # 2
Off HI Islands
Stays’ls, Jib, Tops’l
Broad Reach
18 Knots AW
8° Heel

Vulnerable to Downflooding
45 Knot Squall
Creating Squall Curves for The Robert C. Seamans

- Procedure & calculations from MCA guidance
  - MCA Model of “Large Yacht Stability Information Booklet”
  - MCA Model of “Sail Training Ship Stability Information Booklet”
- Research papers provided further background
  - “The development of stability standards for UK sailing vessels”, B. Deakin, Wolfson Unit
  - “Stability Regulation of Very Large Sailing Yachts”, B, Deakin – Wolfson Unit
- GZ & DF° needed from RCS stability book
The information cannot be used as a definitive prediction of heel angle in a squall since squall speeds and corresponding wind shifts cannot be reliably predicted.

There is no specific guidance provided on how to reduce the sail plan to achieve lower heel angles. This is left to the Master.
Limitations of MCA Squall Curve 2

- The curves assume that AW° direction does not change.
  - What about a shift from a broad reach?
  - Special care should be taken when sailing with the wind aft of the beam. In the event of an accidental broaching, or a gust striking on the beam, the heeling effects may be increased to a dangerous level even when the preceding angle was thought safe.

- The downflooding heel angle is the principal benchmark; does this provide a suitable margin of safety?