

**REICHEL PUGH YACHT DESIGN**

**60' CANTING BALLAST YACHT**

**STABILITY ANALYSIS**

## 60' CANTING BALLAST YACHT

The Canting Keel System, with its characteristics, requires us to look at the results of the stability study in a slightly different manner than what we are accustomed to.

A conventional boat with a fixed keel is expected to be in static equilibrium position at 0 degree heel and further analysis is conducted using 0 degree heel as the origin for the measurement of the limit of the positive stability (LPS).

In the case of a Canting Keel Yacht, the static equilibrium does not coincide with the 0 degree heel. (except when the keel position is on CL).

For this analysis, we have identified 5 conditions:

1. Keel on centerline
2. Keel fully canted (40 degrees) to windward. In this condition the yacht will find equilibrium position at 28 degrees of heel to windward.
3. Keel fully canted (40 degrees) to leeward. In this condition, the yacht will find the equilibrium position of 28 degrees of heel to leeward.
4. Keel canted 18 degrees to windward. In this condition the yacht will find the equilibrium point at 10 degrees of heel to windward.
5. Keel canted 18 degrees to leeward. In this condition the yacht will find the equilibrium point at 10 degrees of heel to leeward.

### Analysis:

1. The first condition behaves as any other conventional yacht with an equilibrium point at 0 degrees and LPS equal in value to the range of positive stability (141 degrees).
2. In this condition keel fully canted (40 degrees) to windward, the yacht finds its equilibrium at 28 degrees of heel (28 degrees to windward of vertical). The range of positive stability is 143 degrees and the angle of heel at the upper end of that range is 115 degrees.
3. The third condition, keel fully canted (40 degrees) to leeward will show the yacht finding its equilibrium point at 28 degrees of heel to leeward. The range of positive stability is now 217 degrees with its upper end at 245 degrees of heel.
- 4 & 5. The last two conditions show the keel canted 18 degrees to windward and 18 degrees to leeward. With the keel canted 18 degrees the yacht will find its equilibrium point at 10 degrees of heel. This limitation would allow the yacht to comply with static heel requirements. At the same time, **it is important to note** that it would also reduce the range of positive stability when keel is to both windward and leeward.

Enclosed are GZ curves illustrating the five conditions described above. Also for each condition the stability index STIX and the IMS stability index where calculated.

The following table summarizes the above described calculations.

| Keel position                          | Range of positive stability | LPS <sup>(1)</sup> | STIX <sup>(2)</sup> | IMS <sup>(3)</sup><br>Stability index | Meets<br>IMS<br>Category<br>0 | Meets<br>Sydney<br>Hobart<br>Category 1 |
|--|-----------------------------|--------------------|---------------------|---------------------------------------|-------------------------------|---|
| 0° Cant                                | 141                         | 141                | 69                  | 148                                   | Yes                           | Yes                                     |
| 18° Cant to windward (10° static heel) | 139                         | 129                | 66                  | 136                                   | Yes                           | Yes                                     |
| 40° Cant to windward (max cant angle)  | 143                         | 115                | 61                  | 122                                   | Yes                           | Yes                                     |
| 18° Cant to leeward (10° static heel)  | 144                         | 154                | 63                  | 161                                   | Yes                           | Yes                                     |
| 40° Cant to leeward (max cant angle)   | 217                         | 245                | 50                  | 252                                   | Yes                           | Yes                                     |

- (1) The limit of positive stability should be equal to the range of positive stability if measured from the actual beginning of the positive range. In this table, the LPS shown is measured from 0 deg. heel
- (2) STIX (ISO 12217-2, FDIS Version).

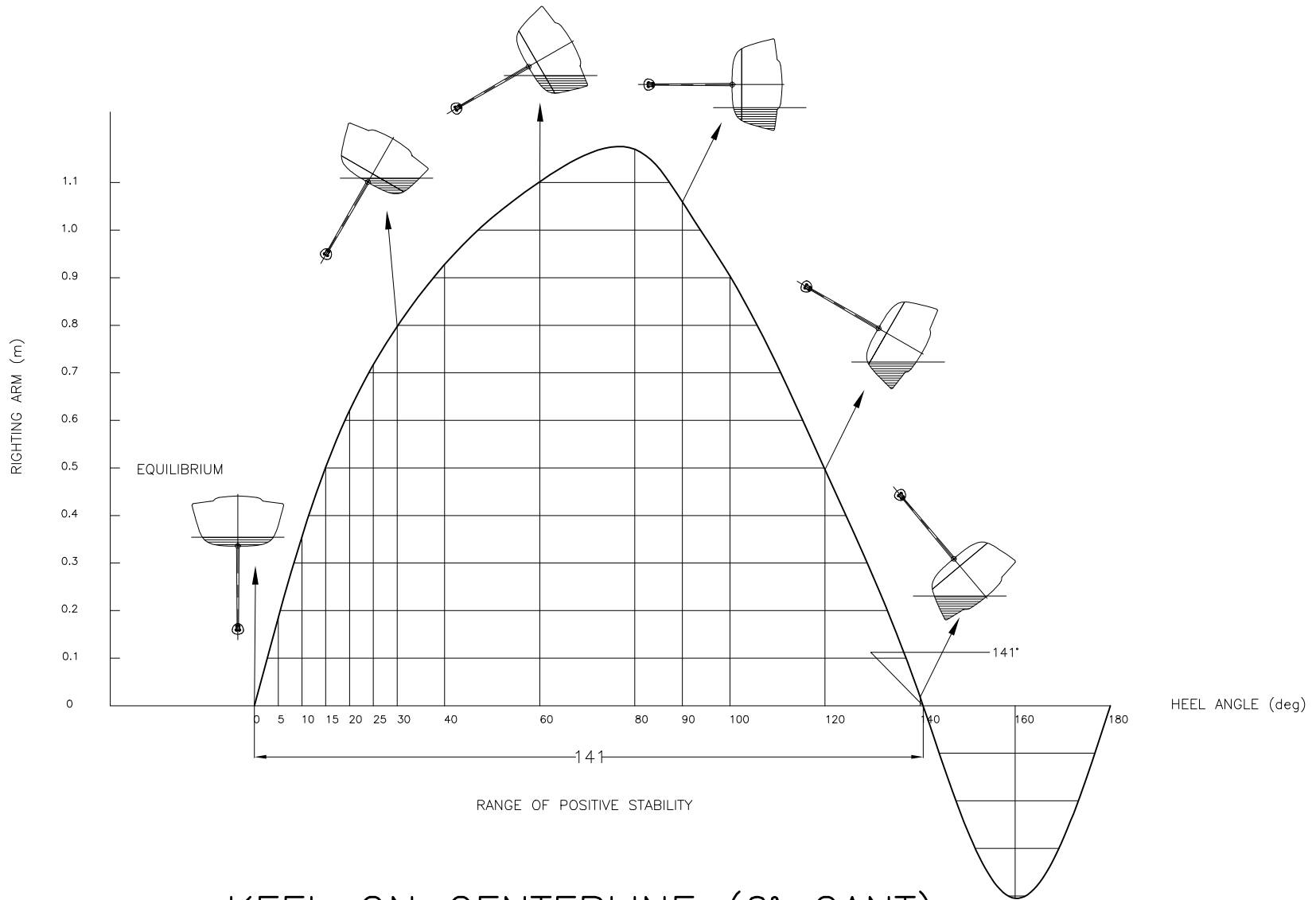
| Design Category  | A  | B  | C  | D |
|------------------|----|----|----|---|
| STIX lower limit | 32 | 23 | 14 | 5 |

Where A is considered very seaworthy and fit for ocean passages and D should be used only in sheltered waters

- (3) IMS Stability Index

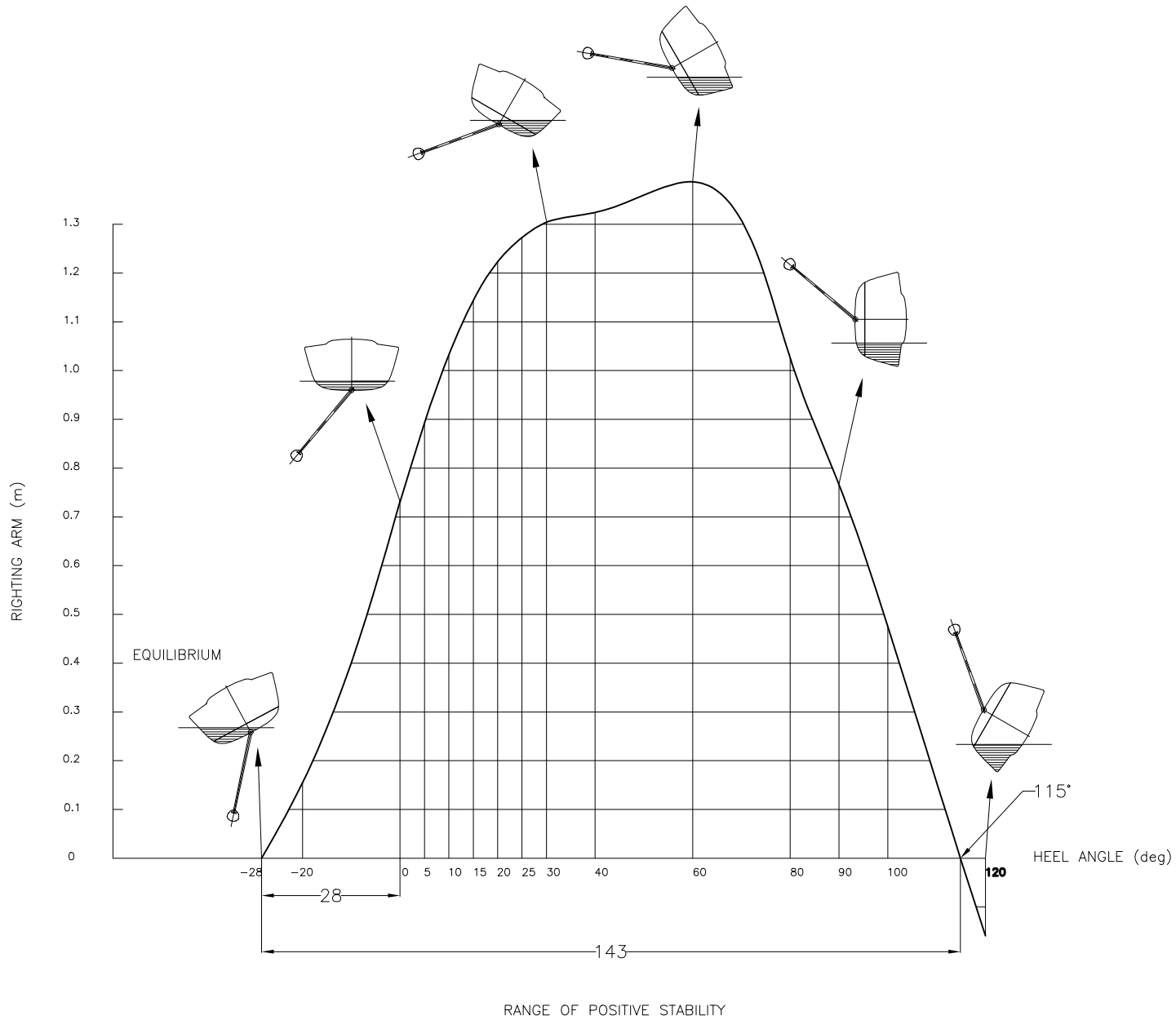
| ORC Race Category | Minimum Stability Index |
|-------------------|-------------------------|
| 0                 | 120                     |
| 1                 | 115                     |
| 2                 | 110                     |

# 60' CANTING BALLAST YACHT



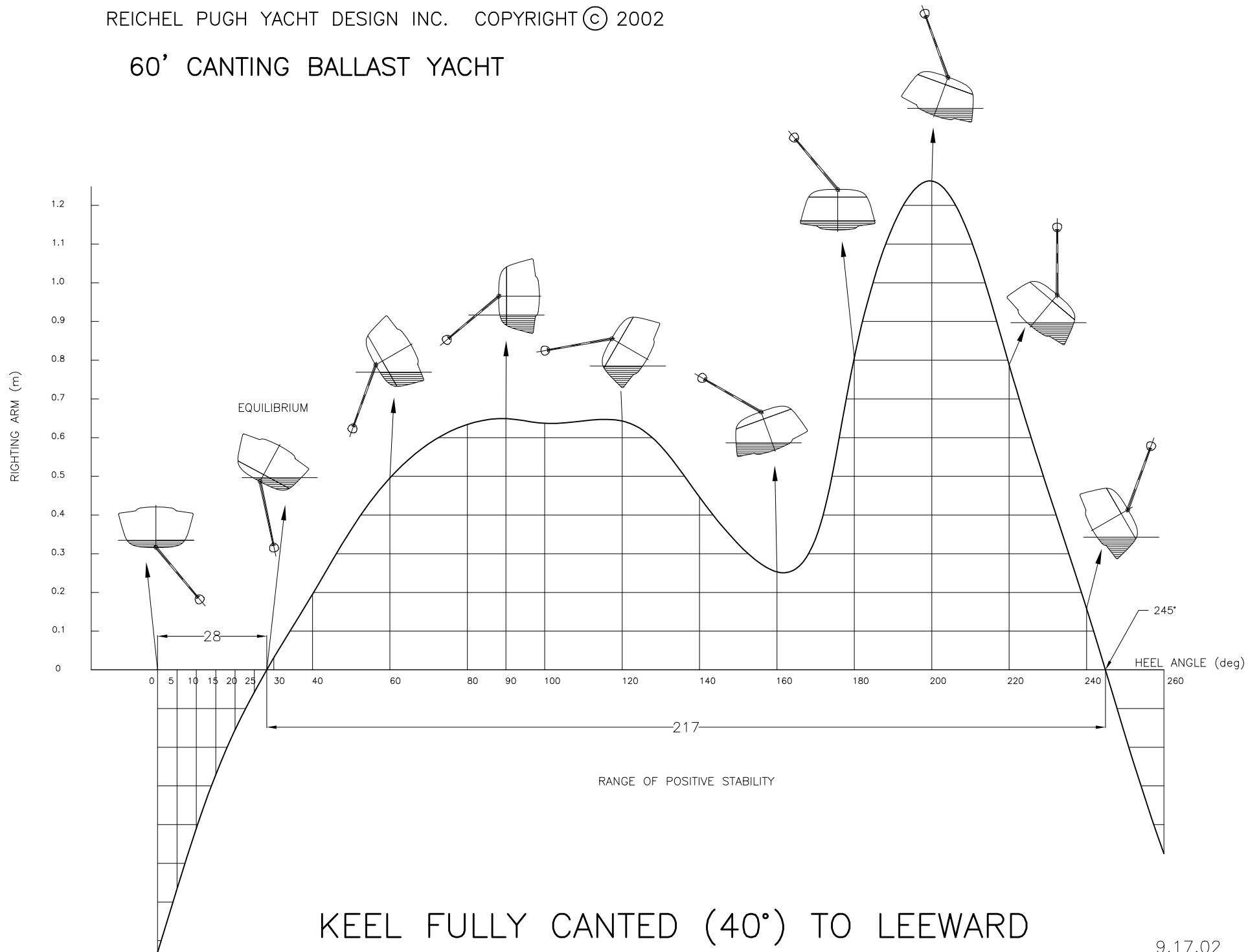
KEEL ON CENTERLINE (0° CANT)

# 60' CANTING BALLAST YACHT

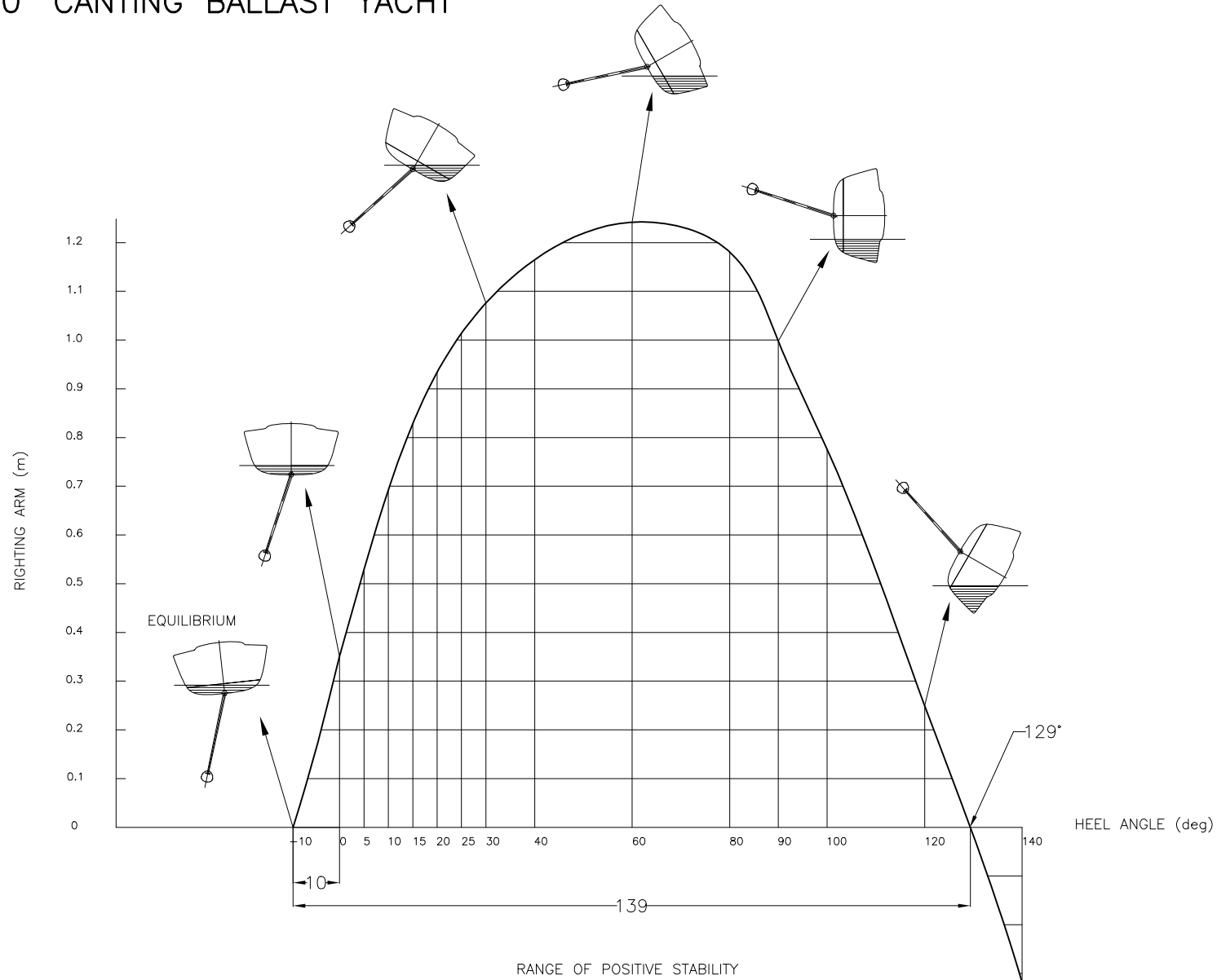


KEEL FULLY CANTED (40°) TO WINDWARD

# 60' CANTING BALLAST YACHT

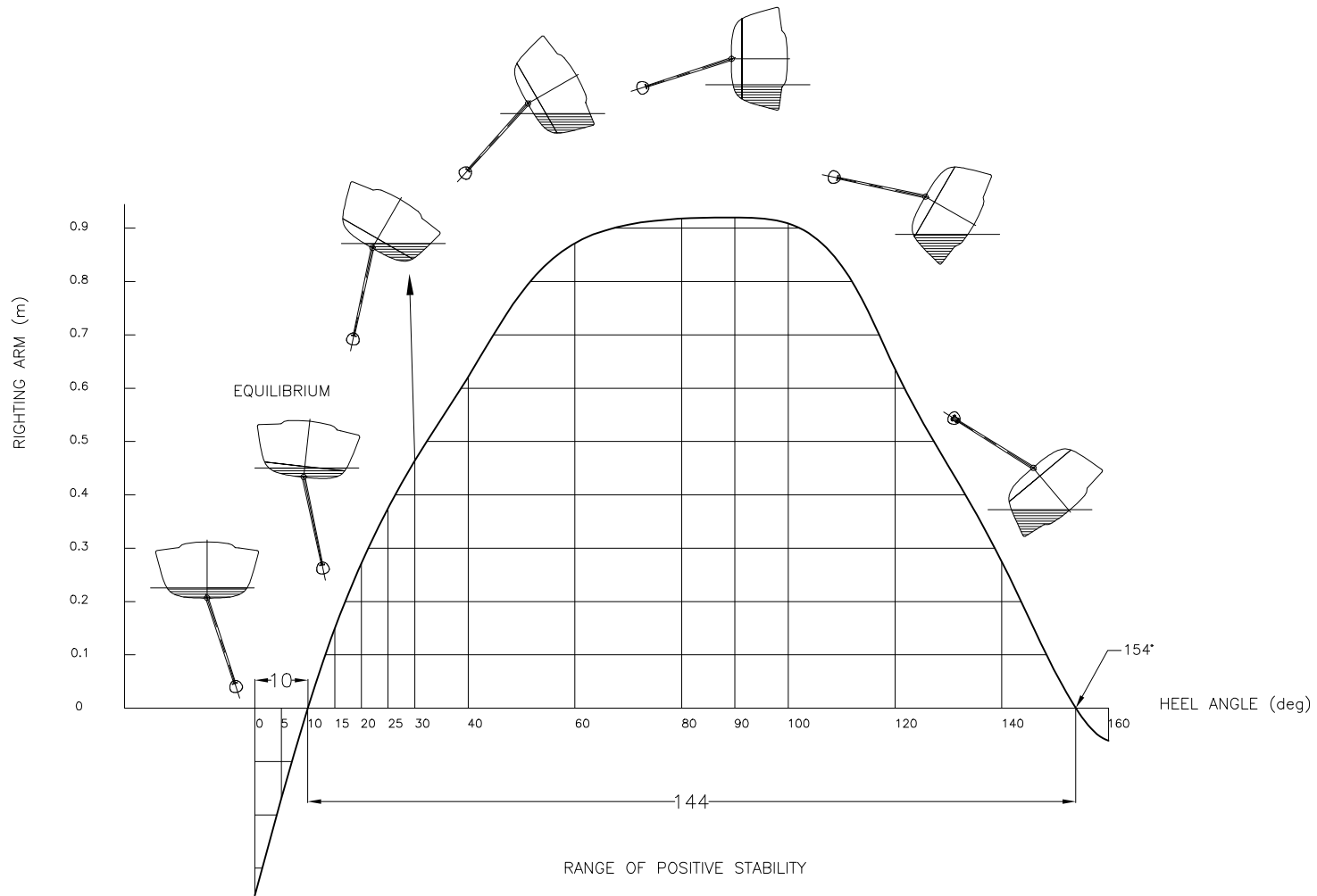


# 60' CANTING BALLAST YACHT



KEEL CANTED 18° TO WINDWARD  
(MAX CANT FOR 10° STATIC HEEL)

# 60' CANTING BALLAST YACHT



KEEL CANTED 18° TO LEEWARD  
(MAX CANT FOR 10° STATIC HEEL)

## **60' CANTING BALLAST YACHT**

### **Conclusions**

The analysis of the preceding data yields the following conclusions:

The case of keel on centerline ( $0^\circ$  Cant) has, as most conventional yachts, a range of heel in which it is stable in the inverted position.

In the cases with  $40^\circ$  cant angle, the yacht will tend to right itself in one direction or the other at any angle of heel.

As the canting angle decreases the yacht's behavior approaches that of the  $0^\circ$  cant case.

At the  $18^\circ$  cant condition there is a small range of heel at which the yacht will remain stable in the inverted position.

In the case of this yacht the range of inverted stability with the keel at  $0^\circ$  cant is  $78^\circ$ , from  $141^\circ$  to  $219^\circ$  of heel.

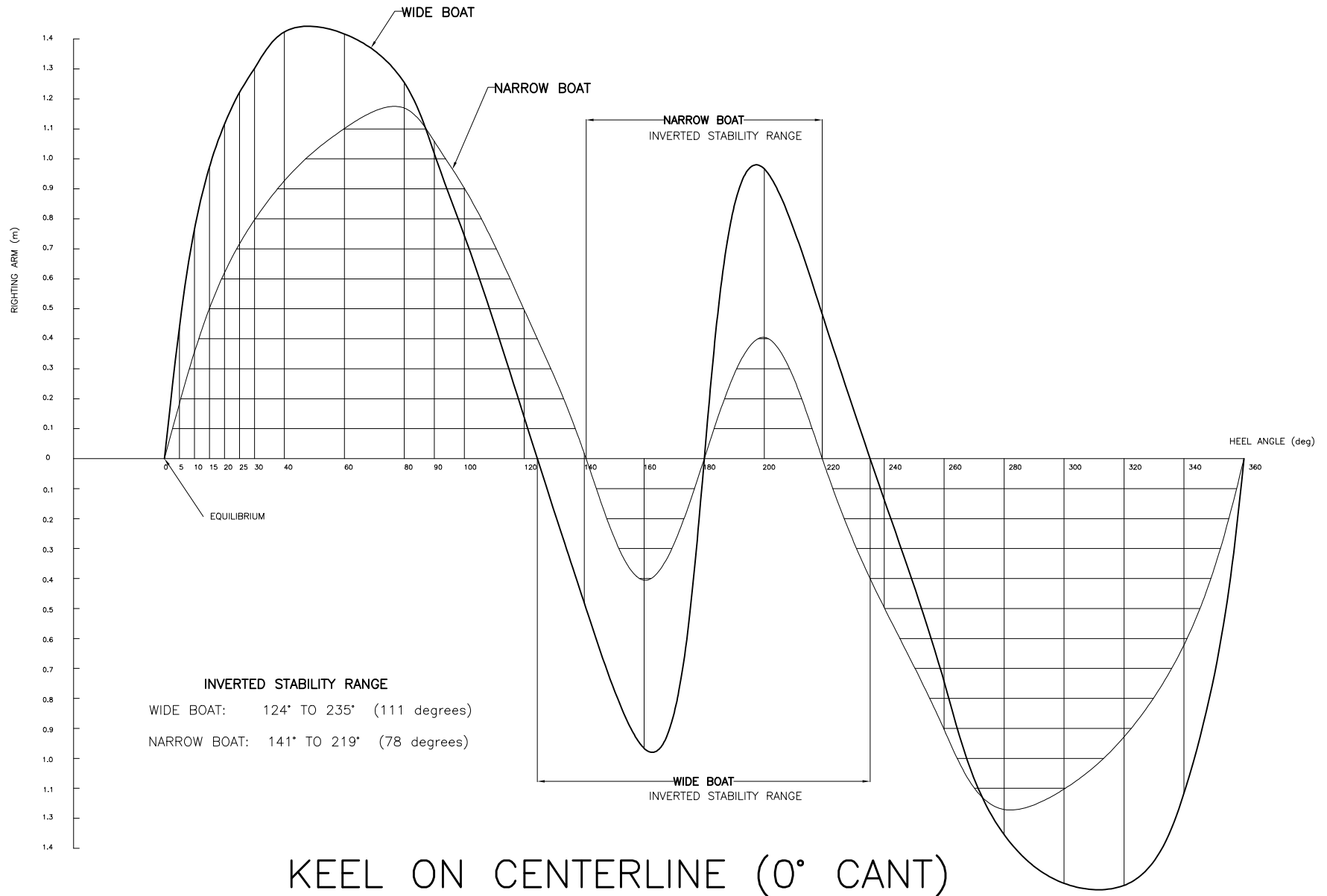
With the keel canted  $18^\circ$  to windward, the range is  $13^\circ$ , from  $193^\circ$  to  $206^\circ$  of heel and with the keel canted  $18^\circ$  to leeward, the range is also  $13^\circ$  from  $154^\circ$  to  $167^\circ$  of heel.

With this range being so small it is likely that almost any external influence, such as waves, would move the yacht outside this range causing it to right itself.

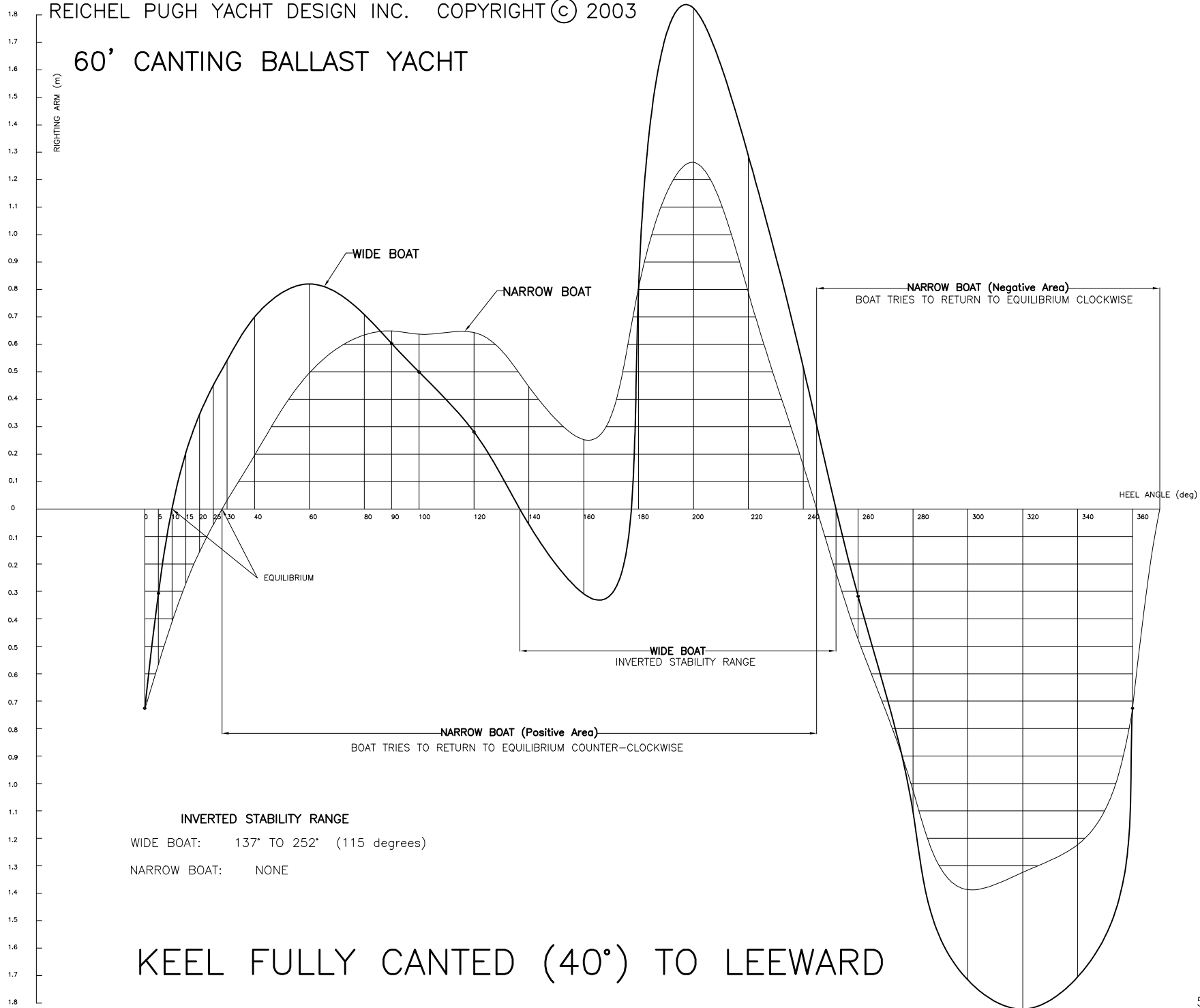
The negative values from the GZ curve are only an indication of the direction of rotation and not of inverted stability. The fact that, in a yacht with the keel on centerline position, the range of inverted stability coincides with the negative GZ values has led to the misconception that it is true for all GZ curves.

It was stated by Andy Claughton in his book "Sailing Yacht Design" that these values "serve to counter the common misconception that offset ballast will jeopardize the safety of a yacht in the event of a capsize"

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**INVERTED STABILITY RANGE**  
 WIDE BOAT: 137° TO 252° (115 degrees)  
 NARROW BOAT: NONE

KEEL FULLY CANTED (40°) TO LEEWARD

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