U.S. Department of Homeland Security

United States Coast Guard

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MEMORANDUM

From: [redacted], CDR [redacted]
CG MSC-1

Reply to Attn of: Mr. Mark Wolf [redacted]

To: [redacted], CDR
Chairman, Marine Board of Investigation

Subj: POST SINKING INVESTIGATIVE STABILITY ANALYSIS OF THE F/V DESTINATION, O.N. 632374

Ref: (a) Your memo dated 26 Oct 2017
(b) Richard W. Etsell, P.E., F/V DESTINATION, Trim and Stability Report, 63 pages, dated 27 Oct 1993
(c) KraftMar Design Services letter, "Stability," dated 28 Jan 2013
(d) Tim Alls Boatbuilding Drawing, "Lines & Offsets," Rev. A, dated 16 Nov 1992
(e) MBI, Assumed Departure Loading Condition at the Time of the Sinking, dated 26 Oct 2017

1. As requested in reference (a), the Marine Safety Center (MSC) performed a stability analysis of the F/V DESTINATION to assist the Marine Board of Investigation (MBI) in determining what may have led to its sinking. The findings are summarized below and enclosure (1) provides greater detail and describes the method of analysis. It is important to note that our analysis required that we make assumptions and estimations involving the vessel hull form, displacement, and location of the weights and centers of gravity; consequently, our findings are subject to uncertainty. Details of our analysis and assumptions are documented in the enclosure.

2. There is no record that the modifications completed in 1993 were formally considered by the Coast Guard to be a major modification or substantial alteration, however the author of reference (b) suggests that the modifications were treated as such. Given the extent of the alteration to the vessel, we reasonably conclude that the alterations were substantial and as such, the DESTINATION was required to meet the intact righting energy criteria of 46 CFR 28.570 and the severe wind and roll criteria of 46 CFR 28.575. The unintentional flooding requirement of 46 CFR 28.580 was not required as this was only applicable to vessels built on or after September 15, 1991.

3. Our calculations show that the DESTINATION did not meet the stability criteria for all loading conditions as asserted by the reference (b). MSC did not have copies of the model used, or the calculations completed by the author of reference (b), and thus was not able to identify the cause of discrepancies between our results and those presented in reference (b). It is perhaps more informative therefore to understand that generally our analysis aligned with that of reference (b) and to consider that the vessel operated under the instructions found in reference (b) and (c) for many years until capsizing. MSC found that on the day of the capsizing, the loading condition far exceeded that anticipated or evaluated in reference (b) and was significantly below

the required standard. As indicated in the report any amount of icing and water in the #3 Hold would further reduce stability as well. Although not explicitly explored by MSC, wind and wave action would have likely further hampered the vessel.

4. Our analysis shows that when loaded as indicated in reference (e) the vessel's righting energy would be reduced far below the minimum required for this vessel. MSC concludes that the internal and external forces that were likely acting on the vessel at the time of the casualty combined to overcome the vessel's righting energy and cause the vessel to capsize.

5. If you have questions or need additional information, please contact Mr. Mark Wolf or Lieutenant [redacted].

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Encl: (1) Explanation of Analysis and Assumptions

USCG MARINE SAFETY CENTER POST SINKING STABILITY ANALYSIS OF F/V DESTINATION

February 9, 2018

EXPLANATION OF ANALYSIS

1. General Comments Regarding the Analysis

- All references in this analysis are as listed on Marine Safety Center (MSC) Memo, Serial No. H2-1800414, dated February 9, 2018.

- DESTINATION was originally constructed in 1981 as an 81 foot US flagged uninspected commercial fishing vessel. In 1993 modifications were completed to lengthen and widen the vessel. In addition to adding approximately 30 feet of length, sponsons were added to widen the vessel from 26 feet to 32 feet. Neither the shipyard nor the owner produced or maintained construction or arrangement plans. Documentation from the time provides varying post modification vessel lengths ranging from 98 feet to 110 feet. The length overall according to references (b), (c), and (d) is given as 110 feet, and is the length used in this analysis.

- There is no record that the modifications completed in 1993 were formally considered by the Coast Guard to be a major modification or substantial alteration, however the author of reference (b) suggests that the modifications were treated as such. Given the extent of the alterations to the vessel, we reasonably conclude that they were substantial and as such, the DESTINATION was required to meet the intact righting energy criteria of 46 CFR 28.570 and the severe wind and roll criteria of 46 CFR 28.575. The unintentional flooding requirement of 46 CFR 28.580 was not required as this was only applicable to vessels built on or after September 15, 1991.

- After the 1993 modifications an inclining experiment was conducted and reference (b) was developed to define safe operating conditions for the vessel. Five loading conditions were defined with varying hold and crab pot usage. Reference (b) indicates the vessel was analyzed for the stability requirements of 46 CFR 28.570 and 46 CFR 28.575, but does not state how the stability calculations were performed or what software was used.

- In 2013, KraftMar Design Services re-analyzed the stability of the DESTINATION following the installation of a bulbous bow. No additional stability calculations were provided as record of this analysis, however reference (c) stated that the addition of a bulbous bow would have a negligible effect on the vessel's metacentric height (GM), and in the author's opinion, the vessel's stability was sufficient to continue using the guidance provided in reference (b).

- Creative Systems' General HydroStatics (GHS) software version 15.5 was used to conduct stability analysis.

- All weights are reported in long tons (LT). One LT is equivalent to 2240 pounds.

- All vertical references and drafts were measured from a baseline drawn horizontally tangent to the lowest part of the molded hull.

- For a detailed assessment of stability, naval architects examine a vessel's righting arm curve. The righting arm curve is a plot of a vessel's righting arm versus angle of heel. A righting arm is a measurement of a vessel's ability to right itself when disturbed from its upright position. In general, the greater the righting arm, the better the vessel's stability characteristics. The area under the righting arm curve (measured in foot-degrees), also called righting energy, is often used as a measure of the vessel's ability to absorb energy imparted by wind, waves, or other forces. The righting arm curve is calculated by multiplying the weight of the ship by its righting arm at each angle of heel. The sum of these moments from zero (if the ship is at even keel) to the angle of vanishing stability is the total amount of energy the vessel has to prevent capsizing. A vessel with very little righting energy could roll past its range of positive stability and capsize as a result of even a relatively small disturbance.

- A term used throughout this analysis is metacentric height (GM). Metacentric height is an indicator of initial stability for a vessel through small angles of heel. It is the vertical distance between the vertical center of gravity (VCG) and the metacenter. The metacenter is a point at which a vertical line passing through the center of buoyancy while the vessel is at equilibrium intersects with other vertical lines stemming from the center of buoyancy as the vessel is heeled. In general, a larger GM indicates greater initial stability and will resist roll. Smaller GM values indicate less initial stability and will resist less against roll disturbances. A negative GM indicates a ship is unstable.

2. Lines Plan and Model Development

In order to validate the stability results found in reference (b), the MSC developed a computer hull model to analyze the vessel using GHS. MSC's model was developed by using a set of lines plans, reference (d), which does not include the later added bulbous bow. It should be noted that while there is some uncertainty in the origin of reference (d), as we were informed there were no construction or arrangement plans produced at the time of the 1993 modifications, it provides what appears to be a complete depiction of the vessel's hull form. Using GHS and reference (d), we independently developed a new hull model from this plan using a hull digitizer to accurately transform the 2-D lines plan into a 3-D computer hull model.

During development of our model, we evaluated a GHS model provided by KraftMar Design Services used in their 2013 analysis, both with and without the bulbous bow appendage added. We found several differences between the KraftMar Design services hull form and reference (d). In comparing the KraftMar Design Services model to reference (d), the following differences in overall dimension were noted:

	KraftMar Model	**Lines & Offsets Plan**
Vessel Length (Watertight Envelope)	113.25 feet	109.25 feet
Beam	32.40 feet	32.17 feet
Depth to Main Deck	15.80 feet	15.68 feet

Table 1: Dimension Differences

Table 2 shows the hydrostatics for KraftMar's model compared to our independently digitized lines plan model. KraftMar's model has consistently heavier displacements and its longitudinal center of buoyancy (LCB) is consistently further aft.

	KraftMar's Hull Model			**MSC Hull Model**		
Depth (ft)	Displacement (LT)	LCB (ft)	VCB (ft)	Displacement (LT)	LCB (ft)	VCB (ft)
9	200.24	0.06 fwd	6.88	193.08	2.64 fwd	6.85
10	266.13	0.96 aft	7.53	255.27	1.86 fwd	7.50
11	337.63	1.97aft	8.16	323.30	0.93 fwd	8.13
12	413.21	2.81aft	8.78	396.12	0.02 fwd	8.75
13	491.65	3.41aft	9.37	471.69	0.65 aft	9.35
14	572.36	3.82aft	9.95	549.19	1.09 aft	9.94
15	655.25	4.08aft	10.53	628.68	1.38 aft	10.52

Table 2: Model Hydrostatic Comparison
Note: LCB is referenced from amidships

When the loading conditions defined in reference (b) were analyzed in GHS, our model generated vessel trims very similar to those shown in reference (b), which further substantiated the hull model we developed. Conversely, the extended length of the KraftMar Design Services model resulted in the vessel trimming significantly farther forward when the same loading conditions were applied. The model developed by MSC was used throughout this entire analysis, unless otherwise specified.

Figures 1, 2, and 3 illustrate the results of the model as a Rhino 3D rendering prior to the bulbous bow addition.

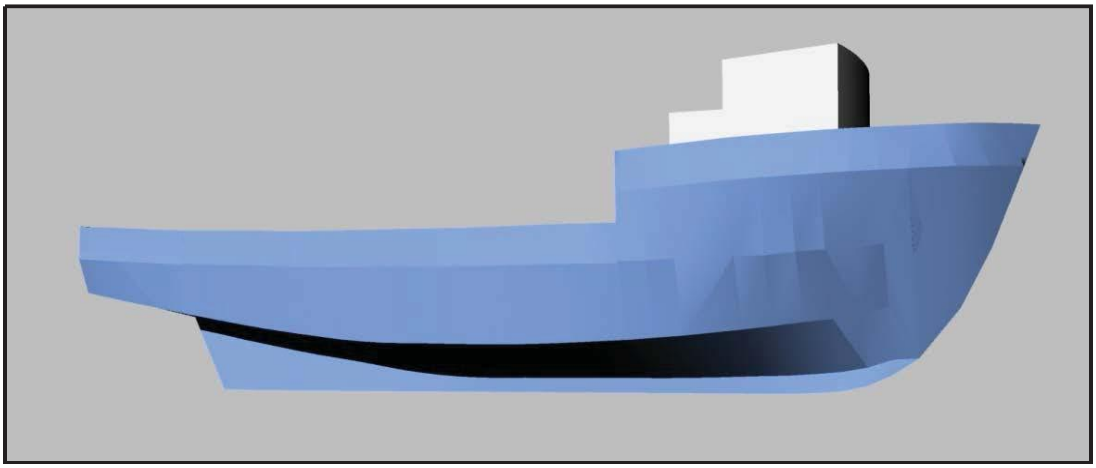


Figure (1): MSC Generated Hull Model: Starboard Profile View

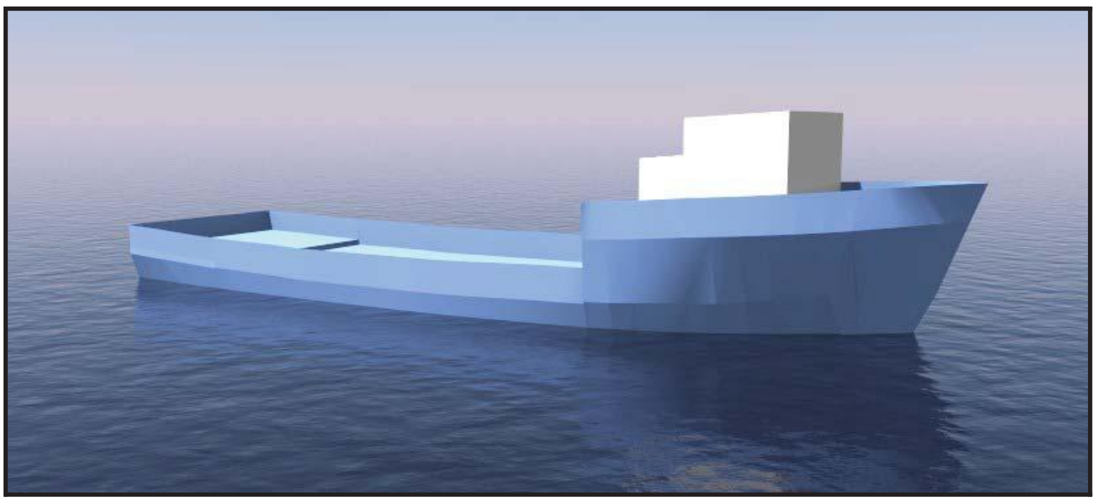


Figure (2): MSC Generated Hull Model: Starboard Bow Top View

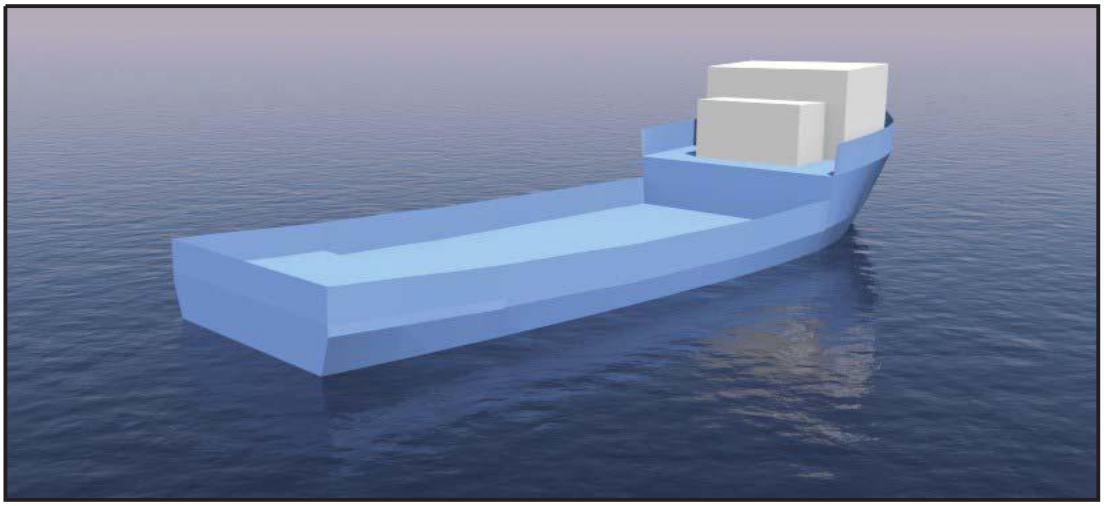


Figure (3): MSC Generated Hull Model: Starboard Quarter Top View

3. Lightship Value Estimation

A stability test was conducted on the vessel following the modifications on October 17, 1993. Reference (c) indicated that an additional incline test was to be conducted in 2013, however no evidence was found to suggest another test was conducted.

Using our model, we recalculated the lightship values using the stability test data and the vessel's hydrostatic table found in reference (b). We were unable to replicate the provided results exactly, the calculated displacement used in the stability calculations at the time was approximately 2% heavier than that determined by our calculations, with a negligible difference in the vessel's centers of gravity. The lightship values we calculated are presented in table 3 below compared to those listed in reference (b). We do not believe the differences noted in the lightship characteristics would have a significant impact on the vessel's intact stability, as the displacement difference equates to a less than 1% difference for the assumed departure loading condition outlined in reference (e).

	T & S Book Lightship	MSC Generated Hull Lightship
Displacement (LT)	221.85	216.61
VCG (ft above baseline)	15.03	15.35
LCG (ft fwd of amidships)	8.29	8.43

Table 3: Lightship Values comparing T & S Book and MSC Generated Hull Model

4. Loading Conditions

Five distinct loading conditions were analyzed in reference (b). Each loading condition was analyzed for both summer and winter conditions. Winter loading conditions were evaluated by adding the weight effect of icing as detailed in 46 CFR 28.550 (1.3 inches on all horizontal surfaces and 0.65 inches on all vertical surfaces). These loading conditions differ in how many fish holds are full and whether or not the vessel has full or low consumables. We used our model to analyze whether the DESTINATION, when loaded in each of these five conditions, met the applicable intact stability criteria.

5. Intact Stability Assessment

As previously stated, the DESTINATION was required to meet the intact righting energy criteria of 46 CFR 28.570 and the severe wind and roll criteria of 46 CFR 28.575. The results presented in reference (b) indicate that the vessel met all applicable criteria. In some loading conditions the vessel's maximum righting arm occurred at angles of heel less than 25°. In such cases, as permitted by 46 CFR 28.570(c), the requirements of 46 CFR 170.173(c) were applied. Tables 4 and 5 below summarize the intact righting energy criteria for both 46 CFR 28.570 and 170.173(c).

Our analysis showed that in all loading conditions, the vessel's maximum righting arm occurred at an angle of less than 25°. Therefore, in our analysis we also applied the criteria in 46 CFR 170.173(c). Our results show that five out of the ten conditions were not in compliance with the intact stability criteria. Specifically, conditions of loadings 3 - winter, 4 – summer, 4 – winter, 5 – summer, and 5 – winter did not comply with the intact stability criteria.

Table 4 and 5 compare MSC results to the results presented in reference (b) for the Winter Loading Condition 5. While we note there were differences in the calculated values, it must be stressed that MSC was unable to review or verify the model or calculations used to produce reference (b).

Limit	Required	T & S Book	MSC Results
Initial Metacentric Height (GM)	> 1.15 ft	5.71	5.38
Righting Arm (GZ) at an angle of heel of not less than 30°	> 0.66 ft	0.84	0.57
Angle of Maximum Righting Arm	> 25°	21.00	15.31
Area up to 40° or Downflood Angle	> 16.9 ft-deg	28.37	21.76
Area up to 30°	> 10.3 ft-deg	20.88	17.19
Area between 30° and 40°	> 5.6 ft-deg	7.49	4.57
Positive Righting Arm	> 60°	54.00	47.45

Table 4: 46 CFR 28.570, Intact Righting Energy Criteria – Winter Loading Condition 5

Limits from 170.173 (c)	Required	T & S Book	MSC Results
Initial Metacentric Height (GM)	> 0.49 ft	5.71	5.38
Angle of Maximum Righting Arm	> 15˚	21.00	15.31
Area up to 40˚ or Downflood Angle	> 16.9 ft-deg	28.37	21.76
Area between 30˚ and 40˚	> 5.6 ft-deg	7.49	4.57
Area at Max Righting Arm	> 12.54 ft-deg	13.17	7.64

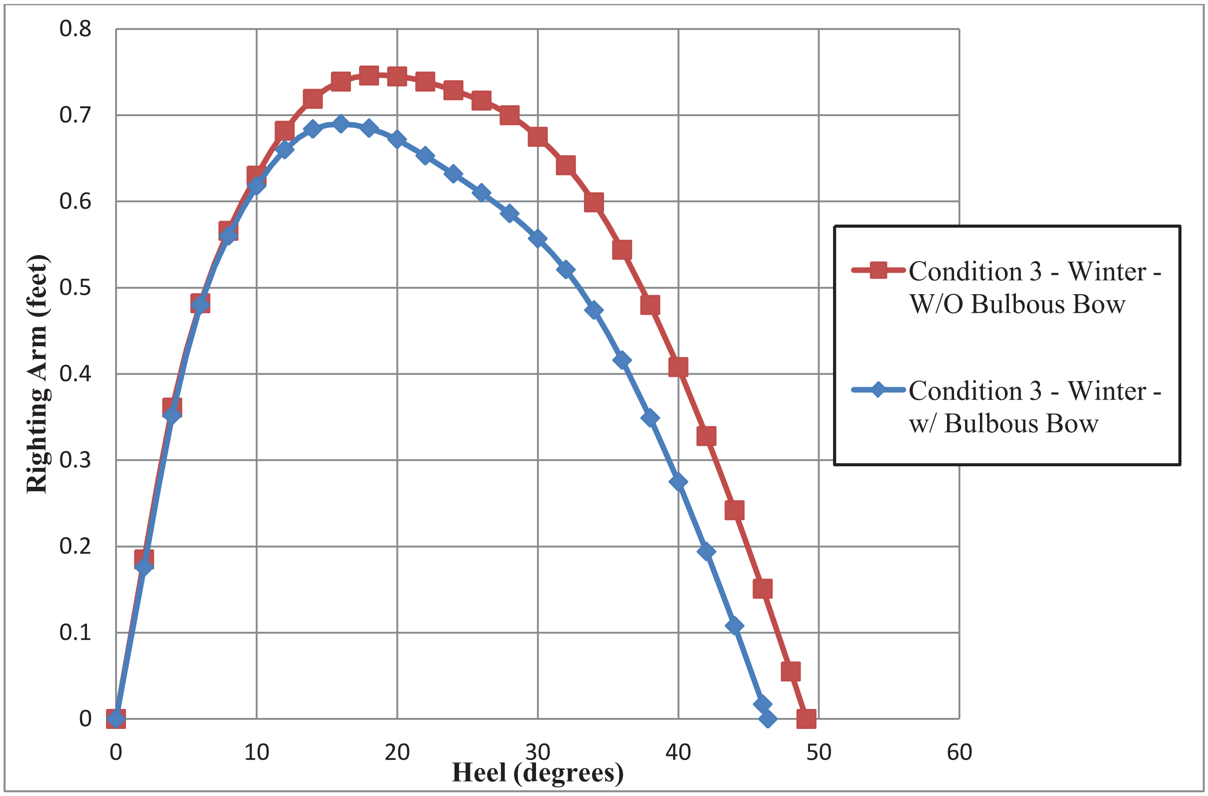
Table 5: 46 CFR 170.173 (c), Intact Righting Energy Criteria – Winter Loading Condition 5

DESTINATION was also subject to 46 CFR 28.575, severe wind and roll criteria. Given that our results show the vessel not complying with the righting energy based criteria, and the number of assumptions that would have to be made, we did not evaluate severe wind and roll.

6. Stability Evaluation Post Bulbous Bow Installation

Following our analysis of the DESTINATION using the loading conditions outlined in reference (b), we repeated the process with our independently digitized model modified to include the bulbous bow. We adjusted the vessel's lightship characteristics by incorporating the estimated weight change of the bulbous bow as provided in reference (c). We then revisited the intact stability criteria of 46 CFR 28.570 using the new model.

In general, our results showed the bulbous bow reduced the righting arm values and provided no additional benefit to the vessel's stability as all stability criteria results further decreased. Figure 4 below compares the righting arm curves of the winter loading condition 3 from reference (b) with and without the bulbous bow appendage.



Limits from 170.173 (c)	Required	Attained Condition 3 w/o Bulbous Bow	Attained Condition 3 w/ Bulbous Bow
Initial Metacentric Height (GM)	> 0.49 ft	5.29	5.02
Angle of Maximum Righting Arm	> 15˚	18.00	16.00
Area up to 40˚or Downflood Angle	> 16.9 ft-deg	23.79	21.05
Area between 30˚and 40˚	> 5.6 ft-deg	5.62	4.35
Area at Max Righting Arm	> 12.54 ft-deg	9.49	7.76

Figure (4): Comparison of Righting Arm Curves and Stability Criteria for Bulbous Bow Addition

While reference (c) states that stability is negligibly reduced and that the owner "should be totally safe to operate the vessel in accordance with the current booklet," our analysis shows eight out of the ten loading conditions do not meet the intact stability criteria. Most typically, the vessel fails to meet the righting energy requirement of 46 CFR 28.570(a)(7) and 46 CFR 170.173(c)(5).

Reference (c) also states that a computer model was created to use in all stability calculations. While MSC was not provided with the results of KraftMar's intact stability calculations, we independently analyzed the loading conditions presented in reference (b) using their GHS model. Contrary to the analysis done with our model, these results show that the vessel meets the applicable stability criteria of 46 CFR 58.570 and 46 CFR 170.173(c). Some of the disparity between the results of the stability analysis using our model and the one provided by KraftMar can be attributed to the differences in the models, however, we cannot confirm that this was the only contributing factor without evaluating calculations that may have been performed by them.

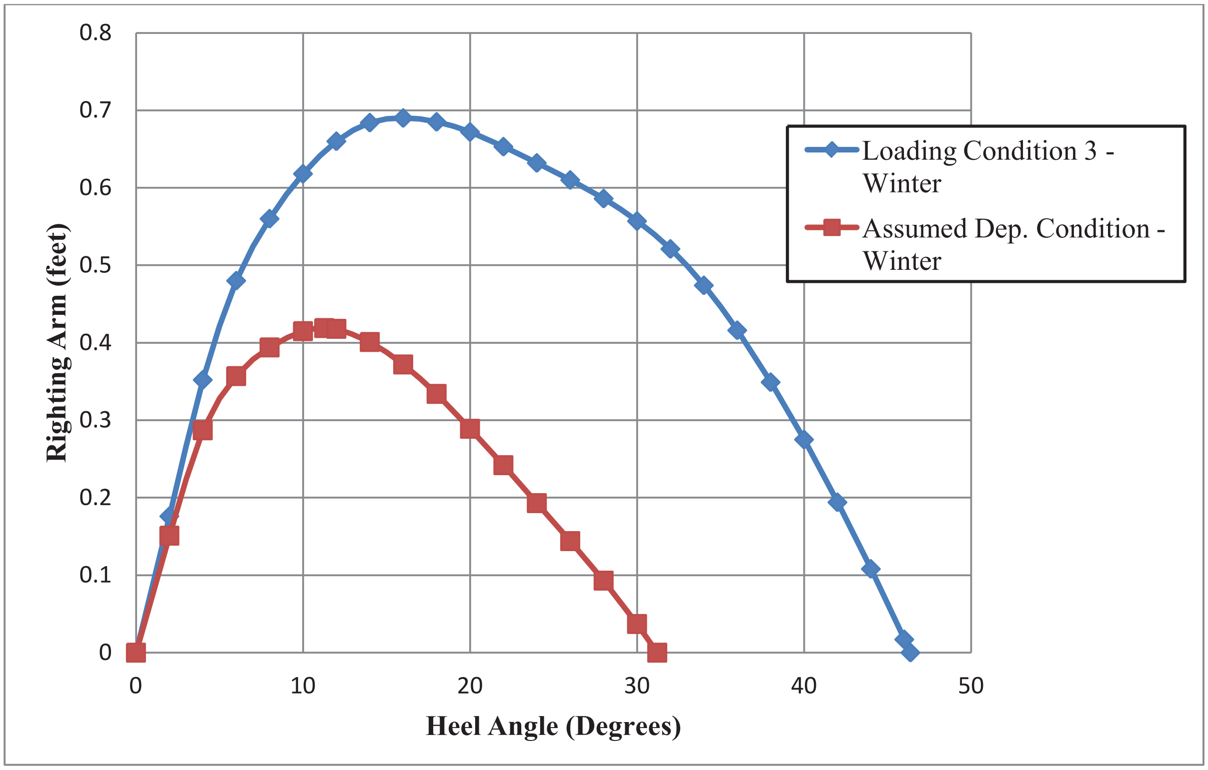
It should be recognized that reference (c) discusses the negligible impact the bulbous bow addition would have on the metacentric height (GM). In our independent analysis, it was confirmed that the vessel consistently met the initial GM requirement of 46 CFR 28.570(a)(1) in all loading conditions. However, after a modification such as this, the entire range of stability should be analyzed as GM is only an indicator of initial stability, not a good predictor of overall stability through larger angles of heel.

7. Assumed Departure Loading Condition

MSC was provided with an assumed departure loading condition at the time of the sinking as outlined in reference (e). This condition was similar to the winter loading condition number 3 of reference (b), with the following differences:

- Crab pots are stacked in five tiers rather than four, with the lowest tier set on end
- Crab pots are assumed to weigh 840 pounds rather than 700 pounds. A crab pot was recovered from DESTINATION using a remotely operated vehicle. This crab pot was weighed after being allowed to dry several days and was recorded as 840 pounds.
- An approximate total of 19,706 pounds (8.8 LT) of bait is stored on the vessel in various locations, rather than 6,048 pounds (2.7 LT) of bait in the freezer

As previously presented, our analysis indicates that the winter loading condition number 3 failed to meet the stability requirements in 46 CFR 28.570 with the exception of the initial metacentric height (GM) criteria. Therefore, as we anticipated, our analysis of this modified loading condition shows that the DESTINATION failed to meet any of the intact stability requirements in 46 CFR 28.570 with the exception of the initial metacentric height (GM) criteria. Figure (5) below compares the righting arm curves for the assumed departure condition versus the loading condition 3 winter from reference (b) using our hull model.



Limit	Required	Attained Condition 3 - Winter	Attained Assumed Dep. Condition
Initial Metacentric Height (GM)	> 0.49 ft	5.02	4.32
Angle of Maximum Righting Arm	> 15°	16.00	11.27
Area up to 40° or Downflood Angle	> 16.9 ft-deg	21.05	8.27
Area between 30° and 40°	> 5.6 ft-deg	4.35	0.02
Area at Max Righting Arm	> 12.92 ft-deg	7.76	3.34

Figure (5): Righting Arm Curves and Stability Criteria for Assumed Departure Loading Condition - Winter

As noted above, the assumed loading condition of reference (e) does not correspond directly to an examined loading condition in reference (b). Both of these curves account for 1.3 inches on all horizontal surfaces and 0.65 inches on all vertical surfaces. In accordance with 46 CFR 28.530(b), each vessel must be provided with loading constraints and operating restrictions which maintain the vessel in a condition meeting all applicable stability requirements, as developed by a qualified individual. If the operators failed to load the vessel in accordance with the stability instructions, it is the responsibility of the owner/operator to contact the qualified individual to receive additional guidance.

8. Discussion of Substantial Alteration

While the loading condition of the DESTINATION at the time of the casualty was not in accordance with any of the stability instructions, it did not constitute a substantial alteration as defined by 46 CFR 28.501 and 28.510, such. A substantial alteration refers to physical modifications made to a vessel that would change its lightship characteristics, hull underwater shape, angle of downflooding, or buoyant volume. The way in which the DESTINATION was loaded adversely affected its stability as additional weight would have been added above the prescribed vertical center of gravity in reference (b), but this was not a result of physical modifications made to the vessel itself.

9. Potential Causal Factors

9.1 Freeing Port Area

As shown in figure (6) below, the vessel had nine freeing ports on each side. Reference (a) indicates that each had an estimated area of 120 in^2 resulting in a total freeing port area on either side of the vessel of 1,080 in^2. For a vessel with a bulwark length of 72 feet, in accordance with 46 CFR 28.555(d), the required freeing port area per side is 2,390 in^2 (16.6 ft^2). The required freeing port area far exceeds the actual freeing port area (1,080 in^2). Additionally, the port side of the DESTINATION had a raised shelter bulwark from the deckhouse to the midship crane. Per 46 CFR 28.555(e), this would increase the required freeing port area on the port side by an additional 550 in^2.

Figure (6): Starboard Profile Showing 9 Freeing Ports

Figure (6) shows the starboard profile with the nine freeing ports. A vessel with insufficient freeing port area would likely result in more seawater becoming trapped on the main deck in foul weather. This water would add additional weight to the vessel, raise the vessel's overall vertical center of gravity (VCG), and increase the free surface moment acting on the vessel as the water flows side to side. These factors would negatively impact the vessel's intact stability.

9.2 Maximum Draft and Trim

Using GHS, we analyzed the maximum VCG curves at varying drafts and trims. The results are displayed below for the 46 CFR 170.173(c) stability criteria. As the drafts and displacements increase, the maximum VCG for which the vessel passes the applicable stability criteria decreases. A point representing the assumed departure condition from reference (e) is plotted on Figure 7. The assumed departure condition point clearly falls outside the maximum VCG curves. Our calculations indicate that a trim of 6 feet forward or greater would be required to allow the vessel to pass the stability criteria given the assumed loading condition VCG and draft. This draft is well outside the normal operating trims in which the vessel would have been operating.

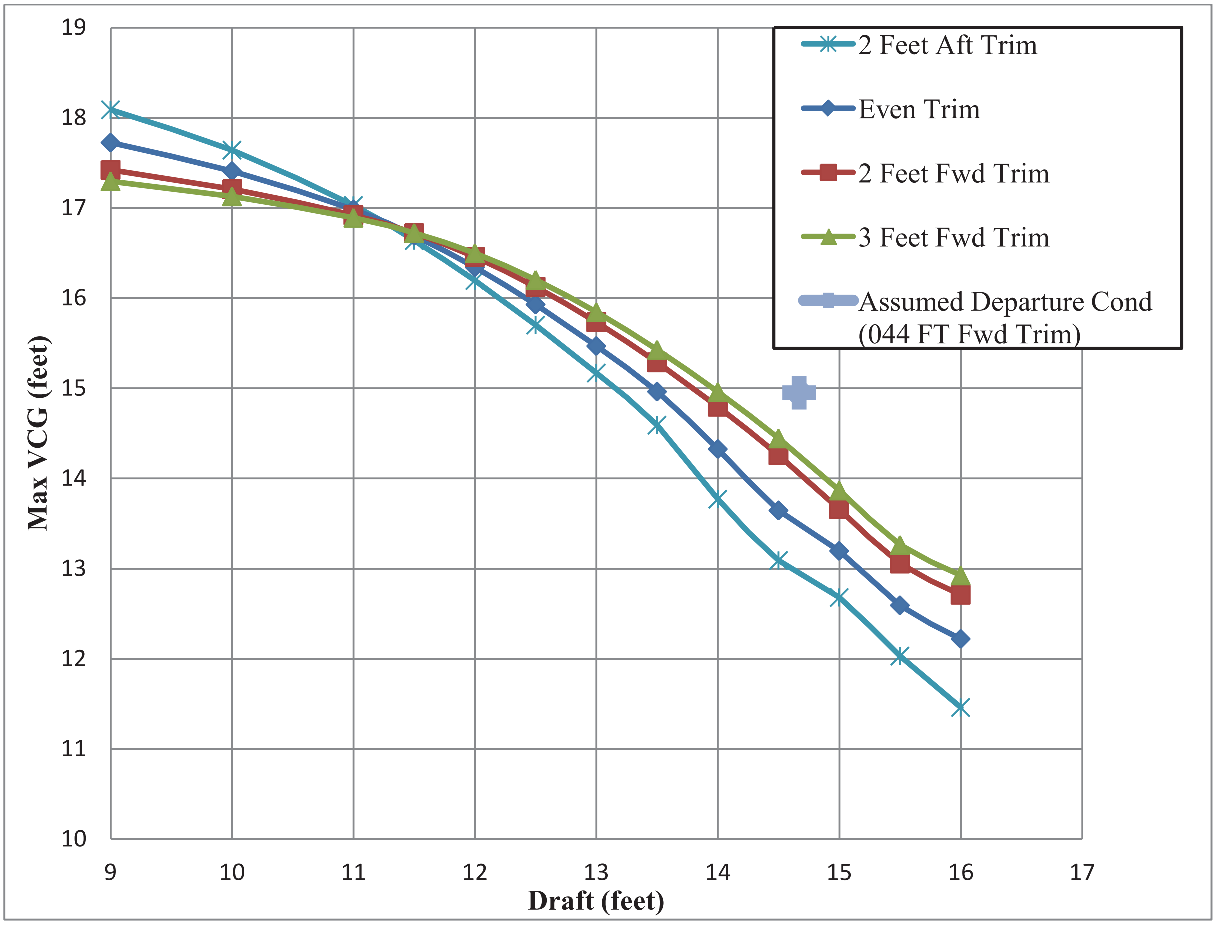


Figure (7): Maximum VCG Curves for Various Trims (46 CFR 170.173 Criteria)

10. Casualty Scenarios

10.1 Incremental Ice Loads

We analyzed the assumed departure loading condition provided in reference (e) with increments of icing ranging from 1 - 12 inches. The respective righting arm curves are shown below in Figure (8) for icing loads ranging from 0 – 8 inches. Ice loads greater than 9 inches are not shown, as they resulted in negative initial metacentric heights.

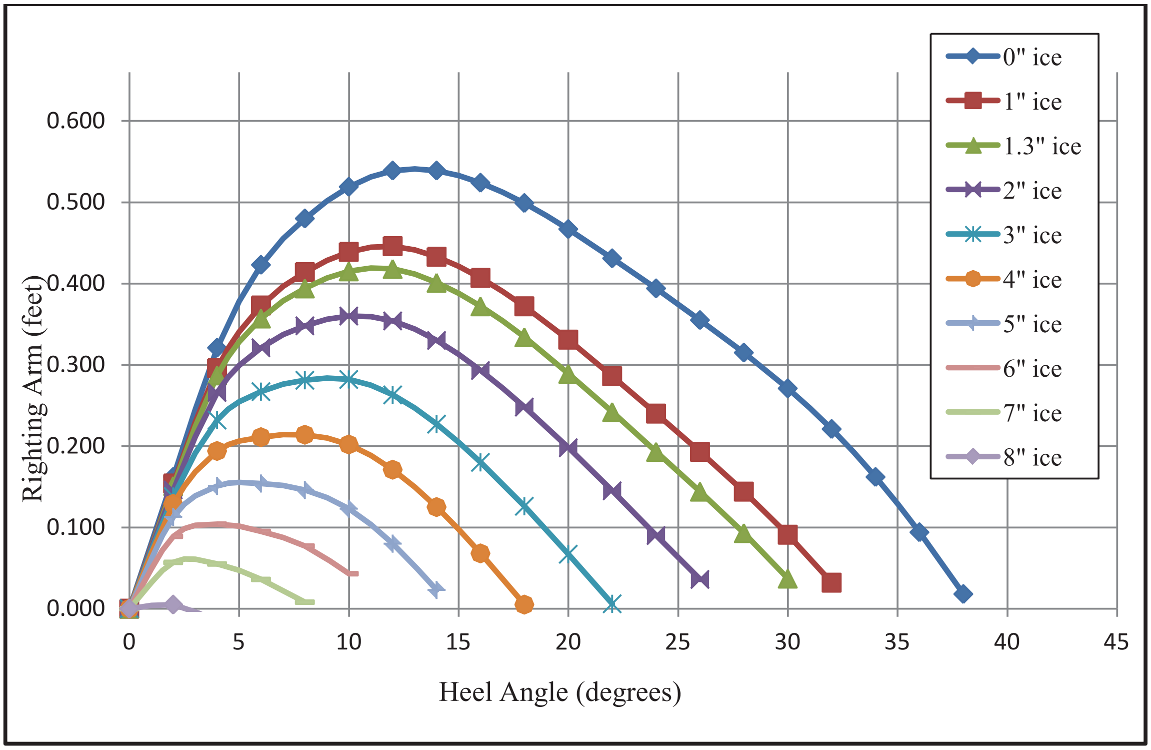


Figure (8): Righting Arm Curves for Incremental Ice Loads

In general, and as demonstrated above, icing weight would impair stability as icing equates to weight addition up high on the vessel. Our analysis showed no icing load conditions passed the intact stability criteria with the exception of the required initial GM. In our analysis, we used the center of gravities provided in reference (b) for all increments.

10.2 Incremental Seawater Loads

It was reported that the vessel would operate with the #3 RSW Hold deck hatch left open, prompting the request for the analysis of water in the hold. We analyzed the assumed departure loading condition provided in reference (e) with incremental levels of salt water in the No. 3 hold ranging from 0 – 6 feet. The respective righting arm curves are shown below in Figure (9).

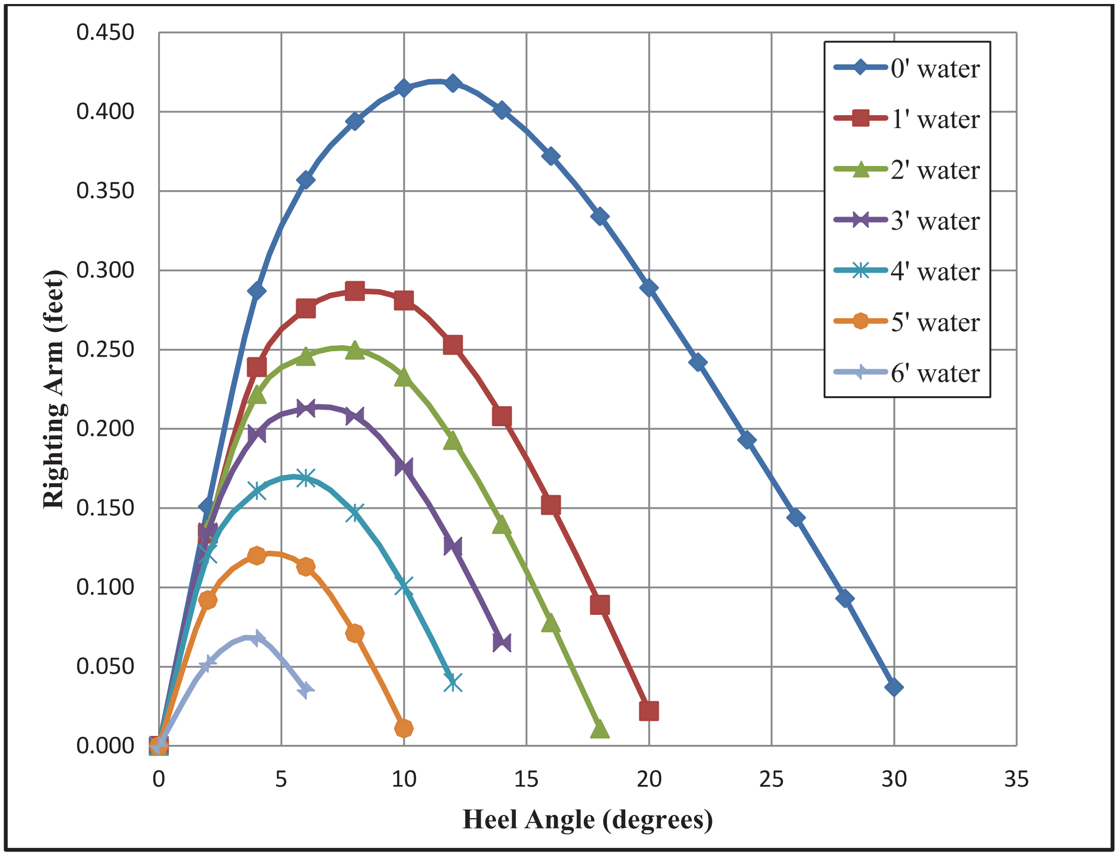


Figure (9): Righting Arm Curves for Incremental Filling of No. 3 RSW Hold

Hold #3 levels greater than 6 feet resulted in negative initial metacentric heights. The maximum sounding of Hold No. 3 per reference (b) is 9.75 feet. Again, our analysis of these incremental levels of salt water in Hold No. 3 using the assumed departure condition as a baseline, shows that the DESTINATION failed to meet any of the intact stability requirements in 46 CFR 28.570 with the exception of the required initial GM. In general, allowing the #3 Hold to be partially filled would impair stability by increasing the free surface effect and increasing the vessel's aft draft.

11. Results

The DESTINATION was a US flagged uninspected fishing vessel over 79 feet in length and, therefore subject to USCG stability regulations. The vessel was required to meet intact stability righting energy criteria found in 46 CFR 28.570 and the severe wind and roll criteria of 46 CFR 28.575.

Using a hull geometry model derived from reference (d), MSC analyzed the loading conditions presented in reference (b), and found that the majority of these conditions do not pass the applicable stability requirements of 46 CFR 28.570. However, the results presented in reference (b) indicate that all loading conditions met the regulatory requirements. We found that our model confirmed the lightship values presented in reference (b) within 1%

and our model trimmed and heeled as expected when using the loading conditions presented in reference (b). This would indicate that our model was very similar in form, size, and weight to that used to produce reference (b). It is unclear from reference (b) how the stability analysis was originally conducted or what assumptions were applied therefore, we can draw no conclusions as to cause of the discrepancy between reference (b) and our results.

We were asked if reference (c) adequately addressed the stability of the vessel following the addition of the bulbous bow. Again, as with our review of reference (b) we found the addition of the bulbous resulted in some loading conditions failing when using our model. When we used the GHS model provided by the author of reference (c), KraftMar, we found that all loading conditions passed stability criteria. In that scenario, where a naval architect evaluation found that all previously established loading conditions remained in compliance with stability criteria, reference (c) would represent an appropriate response to a vessel owner. However, it is unclear if a full evaluation was done; reference (c) only specifically discusses the negligible impact the bulbous bow addition would have on the metacentric height (GM). In our independent analysis, it was confirmed that the vessel far exceeded the initial GM requirement of 46 CFR 28.570(a)(1) in all loading conditions. However, after a modification such as this, the entire range of stability should be analyzed as GM is only an indicator of initial stability, not a good predictor of overall stability through larger angles of heel.

MSC independently verified that the lightship characteristics applied in reference (b) appear to be accurate and reasonable.

MSC analyzed the required freeing ports on the vessel, and, assuming that the nine freeing ports on each side of the vessel each had an area of 120 in^2, the vessel failed to meeting the minimum freeing port area required by 46 CFR 28.555.

Reference (e) was provided to present the assumed departure loading condition prior to the vessel's sinking. It is a variation of reference (b) loading condition number 3, with heavier pots stacked to five tiers instead of four and 6.1 LT of additional bait. Using our hull geometry model further modified by the addition of a bulbous bow, MSC analyzed the presumed conditions and found that the vessel failed the applicable stability requirements with or without any additional ice loading or ingress of seawater.

MSC analyzed the DESTINATION applying incremental icing loads up to 8 inches. Our analysis showed that none of the icing load conditions passed the intact stability criteria, with the exception of the initial GM criteria. Ice loads greater than eight inches resulted in negative initial GM. In general, icing weight would impair stability as icing equates to weight addition up high on the vessel.

We analyzed the DESTINATION applying incremental levels of salt water in the No. 3 RSW Hold up to 6 feet. Again, our analysis of these incremental levels of salt water in the

Hold No. 3 using the assumed departure condition as a baseline, shows that the DESTINATION failing to meet any of the intact stability requirements in 46 CFR 28.570, with the exception of the initial GM criteria.

We did not estimate or evaluate the heeling forces produced by wind or wave action on the vessel. However it can assumed that the vessel was significantly impacted by the severe weather conditions at the time of the casualty; the MBI indicates that winds at approximately 26.4mph, with gusts of 39mph, and waves at 12-14ft. For any vessel of this size, these weather conditions would be significant. As discussed above, the vessel had limited freeing port area, which would likely result in water entrapment and downflooding if the 3# Hold was left open as suspected. Also as discussed, any amount of icing would further degrade the stability of the vessel.

Given the uncertainty in our model and lack of detail as to the evaluation methods of the naval architects that produced references (b) and (c), MSC cannot definitely conclude that the vessel failed to meet applicable stability requirements. However, we have determined that the assumed loading condition greatly reduced the vessel's intact stability. The vessel had operated for many years with the guidance provided in reference (b) and (c), retained enough stability to operate for an extended period of time before encountering a particular situation where the combination of forces acting on the vessel were sufficient to overcome the vessel's righting energy and cause the vessel to capsize.