Sjøfartsdirektoratet
Norwegian Maritime Directorate

Report

From the working group charged with considering the ship-technical aspects of the capsizing of

Rocknes – V2PU3 – Antigua and Barbuda

19 January 2004 in Vatlestraumen off Bergen, Norway

Submitted in Oslo on 24 June 2004 to the Director General of Shipping and Navigation

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1. Conclusions

After having considered the present information against existing regulations, the working group concludes as follows:

a) *Rocknes* was not loaded in accordance with the ship's approved stability calculations in respect of the quantity of cargo and ballast, which gave the ship too high a centre of gravity.
b) The cargo was not trimmed as described in Chapter VI, Part B, Regulation 7 of the International Convention for the Safety of Life at Sea (SOLAS).
c) If *Rocknes* had been loaded in accordance with approved stability calculations and the cargo had been trimmed, it would probably have capsized from the damage the ship suffered from running aground, but not as quickly.
d) The elapsed time under c) would have given the crew more time to undertake an evacuation, and lives might have been saved.

2. Facts and figures

Rocknes, signal letters V2PU3, IMO number 9229910, is a self-discharging bulk carrier of 17,357 gross tonnage. The owner is Reederei Hans-Jürgen Hartmann in Hamburg, Germany. The operator is Jebsen Beltship Pool AS, Bergen. AJ Ship Management GmbH is responsible for technical operation of the ship.

The ship has dual registry in Germany and Antigua Barbuda and is classed with Germanischer Lloyds. The ship was built in 2000 as a self-discharging bulk carrier and was then called *Kvitnes*. From November 2002 to March 2003 it was converted in the Netherlands to a gravel dumper for dumping stone onto pipelines to secure them, among other purposes, and its name was changed to *Rocknes*. The conversion took place in collaboration with the Dutch company Van Oord ACZ.

On 19 January 2004 at 08.55 hrs *Rocknes* left Eikefet outside of Bergen, Norway, loaded with 23,243 tonnes of gravel and stone. The ship bunkered near Skålevik and then headed for Emden, Germany. The ship had a crew of twenty-nine, of whom one was Norwegian, one German, three Dutch and twenty-four Filipino; in addition, there was a pilot on board.

Rocknes capsized in Vatlestraumen at approx. 16.32 hrs, and eighteen members of the crew lost their lives. The direct cause of the capsizing was running aground and subsequently capsizing, which happened in the course of a few minutes. The ship was later towed to Hanøytangen outside Bergen and uprighted there.

After the accident, a maritime inquiry was held at Bergen District Court. The transcript of witness testimony and exhibits are not appended to this report.

After the maritime inquiry, the Director General of Shipping and Navigation appointed a working group to examine the reason why the ship capsized so quickly. The Ministry of Trade and Industry allocated NOK 1 million for this work.

The working group comprised Sigurd Gude, Deputy Director General of Shipping and Navigation (chairman), Directors Turid Stemre and Per Magne Indreeide, and Bodil Rafner, Adviser (secretary). The working group had the following terms of reference:

"The working group shall assess the ship-technical aspects that may have played a part in the Rocknes *accident, with an emphasis on matters related to stability that may be important for the assessment of current regulations. The working group shall propose measures that in its opinion should be implemented to prevent similar accidents in the future. The group shall cooperate with the authorities in Antigua and Barbuda, Germany and the Philippines and the Maritime Investigator in Bergen. The working group's assessment and recommendations shall be submitted to the Director General of Shipping and Navigation by 15 June 2004."*

The working group's deadline was later extended to 10.00 a.m. on Thursday 24 June.

The flag state was informed about the formation of the working group and invited to participate and has been briefed on the group's work.

In accordance with its terms of reference, the working group has not considered the cause of the accident, but examined only the ship-technical aspects that may have contributed to the consequences after the ship ran aground. Any circumstances prior to the accident that were considered were those that may be assumed to have had direct relevance for the consequences after the ship ran aground.
The working group has gathered information from the shipping company and flag state. Key to the working group's assessment was data reconstructed from *Rocknes'* loading computer. The reconstruction was done by Ibas in Kongsvinger, Norway. The working group also performed an on-board inspection of *Rocknes* on 26 April 2004, after the ship had been righted and towed to a dock in Bergen.

3. International requirements and amendments and/or revisions

3.1 Relevant regulations concerning watertight subdivision, stability and loading:

- Chapter II-1, Parts B and B-1 of SOLAS contains mandatory international requirements for watertight subdivision and damage stability.
- Chapter VI, Part B of SOLAS contains mandatory international requirements for the loading, unloading and stowing of cargo.
- There are no mandatory international requirements for intact stability. Requirements for stability in the intact condition are laid down by each Administration.

Since international regulations in general have a "grandfather clause", which means that amendments to IMO regulations usually do not apply to ships in existence when the amendments come into force, the requirements for complying with the individual regulations will vary depending on the ship's year of build.

It may be noted that the IMO subcommittee "Stability Load Line and Fishing Vessel Safety" (SLF) is currently working on a revision of Chapter II-1, Parts A, B and B-1. This work is scheduled for completion in September 2004. The probable date the revised chapter enters into force is 1 July 2006. Since this revision is on the coming SLF's work schedule, this makes it easier to for us to make suggestions for changes as a result of experiences from the *Rocknes* accident.

In particular, the group has concentrated on the following regulations:

<u>Chapter II-1 Part B</u>

Regulation 12-1	Double bottoms in cargo ships other than tankers
Regulation 22	Stability information for passenger ships and cargo ships

Regulation 12-1 applies to cargo ships constructed or significantly reconstructed on or after 1 February 1992 and consequently to *Rocknes*. Regulation 22 applies to all cargo ships 24 metres or more in length and consequently to *Rocknes*.

Chapter II-1, Part B-1

Regulation 25-3	Required subdivision index "R"
Regulation 25-4	Attained subdivision index "A"
Regulation 25-8	Stability information

Chapter II-1, Part B-1 applies to cargo ships over 100 m in length (L_s) constructed or significantly reconstructed on or after 1 February 1992 and cargo ships over 80 m in length (L_s) constructed or significantly reconstructed on or after 1 July 1998, and consequently to *Rocknes*.

Chapter VI, Parts A and B

Part A, Regulation 2	Cargo information
Part B, Regulation 7	Loading, unloading and stowage of bulk cargoes

Up until 1991 Chapter VI dealt with only the carriage of grain. In 1991 it was amended also to deal with other cargoes (except cargoes in liquid form and gases). The requirements apply to all cargo ships covered by SOLAS. Part B applies to carriage of bulk cargoes other than grain and therefore to *Rocknes*.

3.2 Double bottom

Chapter II-1, Regulation 12-1, first paragraph requires a double bottom extending from the collision bulkhead to the afterpeak bulkhead *as far as this is practicable and compatible with the design and proper working of the ship.*
Regulation 12-1, second and third paragraph provide some detail about this requirement, but no specific requirements are set for the arrangement beyond requiring that the inner bottom be continued out to the ship's side in such a manner that it protects the bottom to the turn of the bilge.
Regulation 12-1 fourth paragraph specifically states that a double bottom need not be fitted in way of watertight compartments used exclusively for the carriage of liquids, *provided the safety of the ship in the event of bottom damage is not, in the opinion of the Administration, thereby impaired.*

This wording allows for different interpretations and practices. It is also likely that the wording is such that Administrations should not construe permission not to fit a ship with a double bottom as an exemption to be reported to the IMO.

Conclusion: No direct violation of Chapter II-1, Regulation 12-1 can be ascertained.

Comments: The IMO has not prepared guidelines for how this regulation is to be practised. *Rocknes* had a double bottom only in the centre of the hold, i.e. not out to the ship's side. The working group does not have documentation on whether any special assessment was performed of the extent to which this impaired the ship's safety in the event of bottom damage, as the fourth paragraph requires. However, the first paragraph may be understood to imply that such an assessment is not required. The working group has difficulty seeing that a double bottom out to the ship's side would not have been practicable and compatible with the design and proper working of the ship. The working group is further of the opinion that the safety of Rocknes was impaired because a double bottom was not required out to the ship's side.

On 4 June 2004, Norway, jointly with Germany, submitted a proposal to the IMO's sub-committee "Stability Load Line and Fishing Vessel Safety" (SLF) with specific recommendations for the text of amended requirements for double bottom. Among other recommendations are specific types of bottom damage to be analysed if permission is granted to omit a double bottom.

Working group's recommendation: Norway should work actively to get these proposals adopted.

3.3 Inclining test

Chapter II-1, Regulation 22 of SOLAS requires that an inclining test be performed on newbuildings or after major alterations. Exemptions may be granted under certain conditions.

Conclusion: *Rocknes* was not granted an exemption, and the ship underwent an inclining test on 30 March 2003 at the Keppel-Verolme shipyard (the Netherlands) after its conversion was completed. The inclining test report was approved by GL, see Appendix 5.

3.4 Damage stability

Required subdivision index "R"

Chapter II-1, Regulation 25-3 of SOLAS sets a minimum standard for subdivision index "R" for cargo ships. For cargo ships of over 100 m in length (L_s) the requirement is:

$$R = (0.002 + 0.0009\ L_s)^{1/3}$$

"R" is a chosen value that member states of the IMO have jointly arrived at as acceptable.

For Rocknes, the required subdivision index "R" = 0.533

Attained subdivision index "A"

Chapter II-1, Regulation 25-4 requires that the attained subdivision index "A" be greater or equal to "R".

The attained subdivision index "A" is a measurement of the probability that a ship will not capsize or sink if it is subjected to random collision damage.

"A" is found by summing the "sub-probabilities", which in turn are measures of the probability that that particular damage occurs and that the ship survives that particular damage.

In practice, these sub-probabilities are converted to a numerical value that may contribute to the subdivision index. These contributions are calculated for damage to a single watertight compartment and to a combination of more than one watertight compartment. If there is a high probability that the damage can occur and a high probability that the ship will survive, the contribution to the subdivision index will be relatively larger than if there is a low probability that a breach will occur or a low probability that the ship will survive the breach. Although the main contribution to the subdivision index will come from damage to single compartments and some damage to two adjacent compartments, this is no guarantee that "weak" areas are not found in the ship where even a small damage would result in the ship not surviving.

For Rocknes, the average attained subdivision index "A" was calculated at 0.539

The contributions to the calculated subdivision index "A" were distributed as follows:

Index at the summer load line, damage to the starboard side: 0.179

Index at the summer load line, damage to the port side: 0.386
Index at the partial load line, damage to the starboard side: 0.721
Index at the partial load line, damage to the port side: 0.871

$$\text{"A"} = \frac{0.179 + 0.386 + 0.721 + 0.871}{4} = 0.539$$

The approved damage stability calculations are based on the following GM values:
For a fully-loaded draught GM = 0.52
For a partial load line GM = 1.873

(All values above are taken from the ship's approved damage stability calculations)

Regulations 25-5 and 25-6 describe how "A" is to be calculated. The regulations say nothing about the more unfavourable side being allowed for in the event of asymmetry. Regulation 25-6.1.3 specifies that the index calculated at the summer load line and the index calculated at the partial load line are to be weighted equally. In other words, an average value.

Conclusion: *Rocknes* complied with the subdivision index requirements contained in Chapter II-1, Part B-1 of SOLAS.

Comments: It gives cause for concern that in the event of asymmetry, calculations allowing for the more unfavourable side are not required. For example, *Rocknes* would not have complied with the subdivision index requirements if this had been mandatory. It also gives cause for concern that partial and fully loaded conditions are weighted equally, when it turns out over and over that the subdivision index is primarily attained with the aid of contributions from the partial load line.

However, a summation of contributors to "A" is of little relevance for assessing the stability and capsize risk in a defined instance of damage. For *Rocknes* the damage is defined, and the relevant residual stability can be calculated.

Weighting contributions from different draughts is an issue being addressed in the ongoing effort to revise Chapter II-1 of SOLAS. Proposals during the SLF's most recent session to have a form of weighting of the attained index at the various draughts have garnered broad support, but evaluations of how the indexes are to be weighted were left to the correspondence group that was appointed. This group has now performed validation calculations that show for cargo ships that on average the contribution to the attained subdivision index "A" from a fully loaded draught is only 30%. This is unacceptable.

The working group's recommendation: Norway needs to work for the highest possible weighting of contributions from the summer load line. Norway should also propose a requirement that the more unfavourable side be allowed for in the event of asymmetry.

3.5 Intact stability

Rocknes' intact stability was considered in accordance with IMO Res. A.749 (18), the so-called Intact Stability Code. This is a recognised standard on intact stability requirements. This approval also included an assessment of the ship's stability according to the so-called weather criteria. This is an assessment of the ship's stability in heavy winds and rolling.

Conclusion: *Rocknes* complied with the flag state's requirements for intact stability and weather criteria.

Comments: The code is currently being revised by the IMO with a view to making it mandatory through SOLAS or the International Convention on Load Lines. It may be noted that Norway also uses the stability criteria in the Intact Stability Code when considering intact stability.

The working group's recommendation: Norway should work actively to make the Intact Stability Code mandatory.

3.6 Stability information

Chapter II-1, Regulation 25-8 requires that the Master be supplied with such reliable information as is necessary to enable him by rapid and simple means to obtain accurate guidance as to the stability of the ship under varying conditions of service.

Specifically, a single curve is required that shows the minimum GM at different draughts. This curve shall ensure compliance with all relevant intact stability requirements and with all requirements of Regulations 25-1 through 25-6. An equivalent curve showing a minimum GM, such as from a loading computer, may be used as an alternative.
Instructions for the operation of cross-flooding arrangements as well as all other data and aids that might be necessary to maintain stability after damage are also required.
The regulation also specifies how the curve for the minimum GM is to be derived if the subdivision index requirements limit the load.

An approved curve for the minimum GM is available for *Rocknes*. In addition, the ship was equipped with a loading computer system supplied by Lodic AS. The system's software has been validated by Det Norske Veritas, cf. the maritime inquiry's exhibit 14, which concludes that it provides a correct picture of the ship's trim and stability in the loading conditions that were checked. The ship's stability calculations also accord well with calculations performed on software taken from *Rocknes'* own loading computer.

Conclusion: *Rocknes* had the required aids for assessing the stability on board, but nevertheless everything points to the ship not having been loaded in accordance with the limitations present.

Comments: Although specific loading conditions will be discussed under 4, everything points to *Rocknes* not having a satisfactory GM on the date of the accident. The information displayed on the loading computer as it has been recreated shows that the GM in an intact condition is satisfactory, but that the GM relative to damage stability is "critical".

The working group is critical of the fact that the loading computer's screen image shows values from two limit curves, one for intact stability and one for stability in a damaged condition. This is not in compliance with SOLAS Chapter II-1, Regulation 25-8, which requires a single resulting limit curve. Depending on the user's training in the use of loading computers and understanding of how the ship's stability in an intact and damaged condition is connected, such a screen image may make personal and faulty interpretations possible.

Although there are currently no mandatory international requirements for loading computers to be approved, there are some type approvals from classification societies. The loading computer on board *Rocknes* had such an approval. In the ongoing revision of the Intact Stability Code, a proposal has been made to require the approval of loading computers, a proposal that has been widely endorsed. If this becomes mandatory, approval guidelines will be drawn up. In the view of the working group, the information that appears on the user's screen and training in the use of loading computers will be issues that will have to be addressed in this process.

The working group's recommendation: Norway should work actively to get a mandatory requirement for the approval of loading computers into SOLAS. Input to the IMO on what the guidelines for approval should contain will have to be formulated. Requirements or guidelines will also have to be prepared for training in the use of loading computers and reporting to the shipping company.

3.7 Trimming of the cargo

Cargo information
Chapter VI, Regulation 2 of SOLAS sets requirements for the information about the cargo to be provided to the master in connection with loading, including information on the stowage factor, *trimming procedures* and angle of repose.

Loading, unloading and stowage of bulk cargoes
Chapter VI, Regulation 7, second paragraph of SOLAS provides specific minimum requirements for what a cargo operations booklet is to contain. This booklet is to be in a language with which the master is familiar.

Chapter VI, Regulation 7, fourth paragraph of SOLAS requires that bulk cargoes be trimmed reasonably level, as necessary, to the boundaries of the cargo space *so as to minimize the risk of shifting and to ensure that adequate stability will be maintained throughout the voyage.*

The cargo aboard *Rocknes* had not been trimmed at departure. Owing to limitations in the loading equipment at Eikefet, all the cargo holds had a void on the starboard side, see Appendix 7. Facing these empty spaces, the cargo lay at its natural angle of repose so that even a slight heeling to starboard would lead to some sliding of the cargo.

Conclusion: The cargo had not been trimmed in accordance with current regulations. This led to an almost immediate shift of the cargo when the ship began to heel after incurring damage. Along with a too high centre of gravity of the loaded ship, this was a contributing cause to the ship capsizing so quickly.

Comments: The cargo in question had a natural angle of repose of 32-38 degrees. With this cargo trimmed level, the ship would have been able to heel over 30 degrees before the cargo would begin to slide. Since the cargo had not been trimmed, but lay at its natural angle of repose, there are grounds to assume that the cargo had "settled" somewhat during the time from the departure from Eikefet until the time of the accident. Testimony about the ship's behaviour given at the maritime inquiry also indicates this. How much is difficult to say, but it nevertheless had little importance for the outcome of the accident.

The working group underscores the importance of procedures for trimming cargoes being formulated and followed.

4. Evaluation of loading conditions

4.1 The loading condition from the ship's loading computer (Appendix 1 a) showed the following values:

Draught	10.39 m
Heel	14.65^{o}
GM	0.42 m
Cargo	23,903 tonnes

Water ballast	41 tonnes

Comments:
According to this loading condition, the ship was overloaded and had a substantial heel. No other documentation was presented indicating that *Rocknes* was overloaded or that it was listing when it departed. Furthermore, the GM was lower than permitted according to the ships' approved stability calculations. We know that the latter was the case, since the ship cannot accommodate that much cargo without this affecting the amount of water ballast required in the fully loaded condition.

However, there are so many uncertainty factors connected with this loading condition, that it cannot be used to support concrete assessments:

- There is more cargo in the holds than what emerged at the maritime inquiry.
- The cargo's centre of gravity was not corrected for lopsided cargoes and the vertical centre of gravity for the cargo is obviously wrong.
- No water ballast was recorded being on board, which there must have been to prevent listing.
- The specific gravity of the cargo is not as stated at the maritime inquiry.
- Correction weights were added to the light ship which the working group has not succeeded in obtaining an explanation for.

Conclusion: This loading condition cannot be the actual departure condition after loading and bunkering. However, some of the data have been used in loading condition 1 c.

4.2 The shipping company's reconstructed loading condition after bunkering presented at the maritime inquiry (Appendix 1 b) showed the following values:

Draught	10.29	m
Heel	0.51^{o}	
GM	0.40	m
Cargo	23,243	tonnes
Water ballast	776	tonnes

Conclusion: The required minimum GM for this waterline is 0.62 m.
In this loading condition the GM does not satisfy the minimum GM requirements.
The GM in question in this loading condition corresponds to approx. 65% of the requirement.

With damage to deep tanks 2 and 3 starboard, no equilibrium is attained after damage and the ship capsizes even if the cargo is trimmed.
The aft damage is not included in the evaluation, since there the penetrations were small and the inflow of water limited.

Comments: This condition is based on the Bill of Lading and bunkering plan presented at the maritime inquiry. The amount of ballast is based on the shipping company's assumptions, which in turn are probably based on the assumption that the ship was not overloaded at departure. Equipment weights were also changed compared with the data from the recreated loading condition, cf. Appendix 1 a. The shipping company's loading condition shows an approx. 2 cm overload compared with the ship's maximum permitted winter draught. This provides room for a little more water ballast, but in this context the "overload" is negligible.

This condition is probably the most favourable condition *Rocknes* could have had at departure. Appendix 1c represents the assumed least favourable loading condition *Rocknes* could have had at departure. It must be assumed that the actual departure condition lay somewhere between the two.

4.3 The working group's possible departure condition (Appendix 1 c) show the following values:

Draught	10.26 m
Heel	0.29°
GM	0.25 m
Cargo	23,243 tonnes
Water ballast	542 tonnes

Conclusion: The required minimum GM at this waterline is 0.62 m.
In this condition the GM does not satisfy the minimum GM requirement.
The GM in question corresponds to approx. 40% of the requirements.

With damage to deep tanks 2 and 3 starboard, no equilibrium condition is attained after damage and the ship capsizes even if the cargo is trimmed.
The aft damage is not included in the evaluation, since the penetrations there were small and the ingress of water limited.

Comments: This loading condition is based on the loading condition recreated from the loading computer on board *Rocknes*. The amount of bunkers in the recreated loading condition corresponds to documentation presented at the maritime inquiry. The quantities of fresh water, diesel and lubricating oil have been retained for lack of other documentation. The light ship correction of 350 tonnes has been removed. The weight and centre of gravity of the cargo has been corrected in accordance with the documentation presented at the maritime inquiry. The equipment weights are the same as in the recreated loading condition, since this probably represents the least favourable amount and distribution of equipment.

4.4 The working group's possible departure condition with GM adjusted upward in 0.62 m (Appendix 1 d)

This is a hypothetical loading condition for calculating residual stability after damage for a loading condition that satisfies the minimum GM requirements. Equivalent calculations have been performed by GL, see Appendix 4. To perform damage calculations of this type it is not necessary to know the exact quantity and placement of cargo, bunkers etc., but according to the approved stability calculations, *Rocknes* would have to have had 1,461 tonnes of ballast on board to satisfy the minimum GM requirement when the ship was loaded to the summer load line. This limits the amount of the cargo to 22,395 tonnes in the fully loaded departure condition.

With damage to deep tanks 2 and 3 starboard, calculations performed at Lodic show the following:

Trim prior to damage	0.66 m
Heel after damage (equilibrium angle)	30.17°
Max GZ (righting lever)	0.10 m
Positive extent of the GZ curve	29.83 °

Corresponding calculations performed by Germanischer Lloyd show the following:

Trim prior to damage	0.00 m

Heel after damage (equilibrium angle)	29.80^{o}
Max GZ (righting lever)	0.09 m
Positive extent of the GZ curve	22.00^{o}

The difference in the results is due to the calculation using Lodic's software taking into account the fact that the ship probably had a stern trim, which with the ship's design has a positive effect on residual stability.

Pursuant to international regulations, the probability for the ship to survive is considered to be equal to 0 if the angle of heel is 30^{o} or greater. This is a chosen margin of safety. The ship can nonetheless stay afloat without capsizing at greater angles, provided that it has positive stability in excess of the equilibrium angle, which *Rocknes* had. Here the cargo's natural angle of repose as opposed to the equilibrium angle will be decisive.

According to the calculations, the angle of heel after damage is less than the cargo's natural angle of repose.

If Rocknes had been loaded and/or the cargo trimmed in accordance with current regulations, the cargo would theoretically not have shifted, and the ship would have attained equilibrium at an angle of approx. 30^{o}. However, dynamic forces also come into play that may affect the probability of the cargo shifting.

Even if the ship is not subjected to external influences from the wind and waves, it will have a certain kinetic energy resulting in its heeling somewhat in excess of the equilibrium angle before stabilising. However, the speed at which the ship lists and thus its kinetic energy gradually drops off, since the damaged tanks are filling up.

The cargo will also have a certain amount of inertia before "slipping".

In addition to this is the damage to the stern. Since the penetration of the stern is so slight, the filling of this tank takes time. It is also a fact that in the initial phase, the filling of this tank has a positive impact on stability, since it causes a reduction in the fore trim, which is beneficial for a ship designed with a copious stern. However, the positive impact is marginal and temporary, and we know that the filling of the tank will lead to capsizing, which will be accelerated by the shifting of the cargo as the angle of heel increases.

If the cargo does not slide, the ship will be able to remain afloat until the filling of the damage tank aft yields a list in excess of the cargo's angle of repose. Because the penetrations in the stern were small, in the view of the working group, this would have provided enough time to limit the consequences of the accident.

If the cargo slides, the ship capsizes, but the time it takes from the occurrence of the damage until the angle of repose is reached will increase with the ship's GM in the intact conditions.

Summary

The working group's investigations have uncovered two clear violations of operational requirements of international regulations:

1. The ship was not loaded in accordance with the approved minimum GM values. This would have led to capsizing with the damage the ship incurred, regardless of whether or not the cargo was trimmed.

2. The cargo was not trimmed. This would have led to capsizing with the damage the ship incurred, regardless of whether or not the ship had been loaded in accordance with minimum GM values.

Theoretically, if these operational requirements had been complied with, the ship could have survived.

Oslo, 24 June 2004

Sigurd Gude
Chairman

Per Magne Indreeide | Turid Stemre

Bodil Rafner