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Custom naval engineering solutions

WHITEPAPER

Inclining guide

Securing safety and stability

Saltwater is taking you through the procedure of the inclining test one step at a time!

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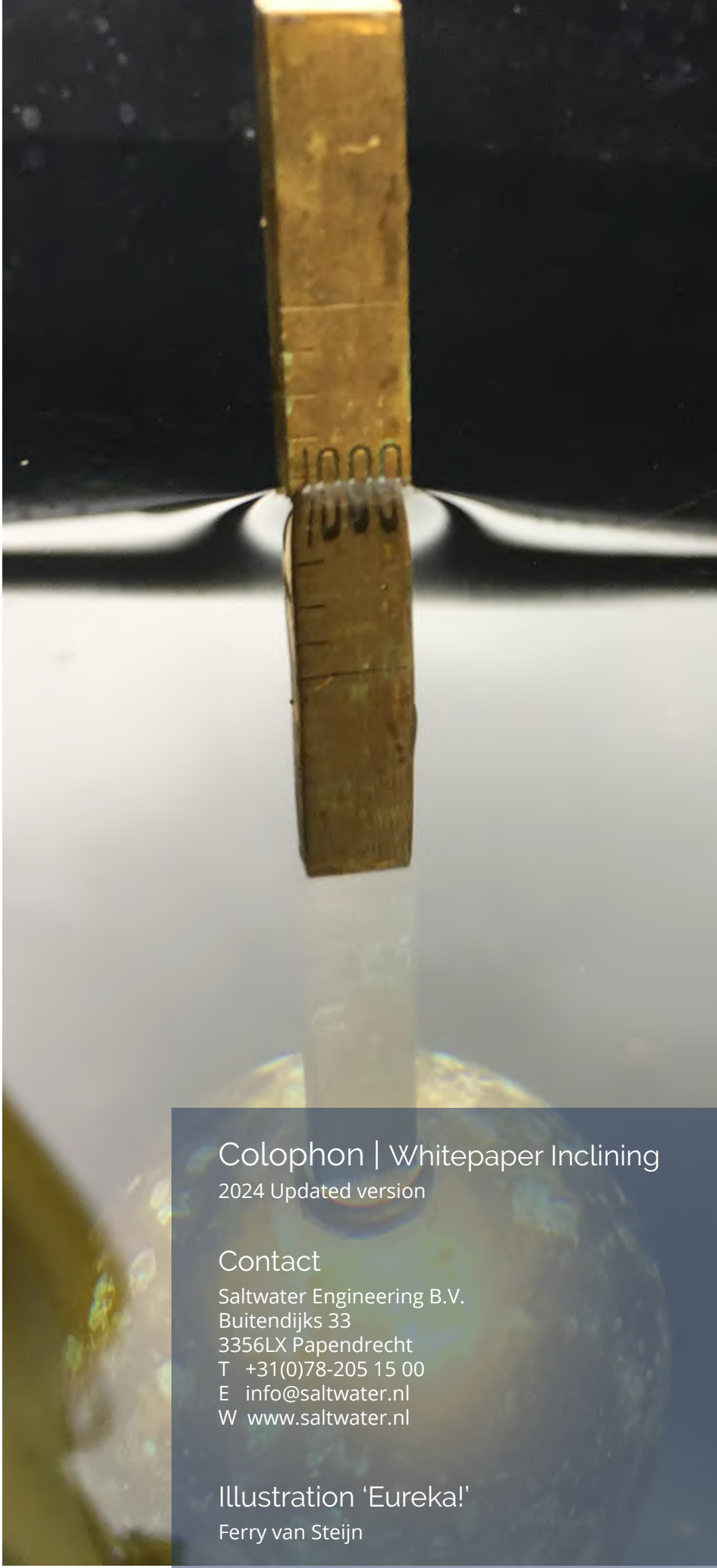

Colophon | Whitepaper Inclining

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Illustration 'Eureka!'

Ferry van Steijn

Why incline?

Every vessel will require in its lifetime of service one or more inclination tests. The main purpose of this test is to determine if the combination of the centre of gravity and lightweight is within the allowable limits for sufficient stability. Depending on the purpose and intended use of the vessel an inclination test is required only once, on a regular basis (f.e. Class renewal), or following an extensive refit or conversion. In any of the above examples, the execution (and preparation) of the actual test is identical.

This whitepaper is intended for vessel owners, operators or anyone with an interest in the theory to provide a better understanding why, how and when an inclination test is prepared and executed.

The importance of stability

One of the most crucial characteristics of a vessel is the stability, this represents the floating capability under deviating circumstances. The importance of a stable vessel is understood as one comprehends the potential consequences of an unstable vessel. A capsizing vessel, due to loss of stability is a risk to the health and safety of the personnel on board but also poses economic risks due to loss of cargo. Last but not least, a capsizing vessel could also have major environmental consequences.

Numerous accidents in history have demonstrated the importance of a proven stable vessel. Depending on the type of vessel, different rules and regulations regarding stability are required to be complied with. During the vessel's lifetime, stability is continuously monitored, to prove the stability of the vessel.

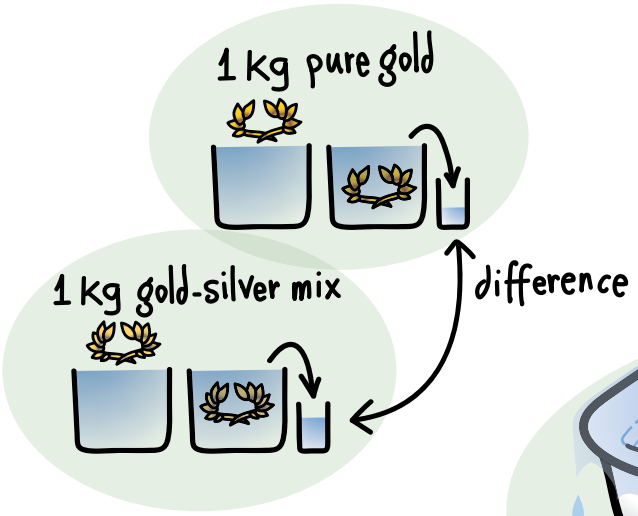
In doing so, one should start at the center of gravity. This originates from the theoretical design of the vessel (or the planned modification), throughout the build registered and prior to delivery verified. This verification is the starting point to prove that the vessel will have sufficient stability to safely navigate the intended waters. It is therefore essential to accurately determine the centre of gravity, this is done by the inclining test method.

Historically speaking, one of the most important mathematicians, related to the determination of a vessel's stability, is Archimedes. He discovered a mathematical theory to determine the floatability of a vessel, the so-called buoyancy effect.

Eureka!

In the first century BC the Roman architect Vitruvius related a story of how Archimedes uncovered a fraud in the manufacture of a golden crown commissioned by Hiero. Suspecting that the goldsmith might have replaced some of the gold given to him by an equal weight of silver, Archimedes discovered that an object displacing water is subjected to an upward force that is equal to the weight of the displaced water.

This investigation leads to the important discovery of buoyancy, the mathematical ability of a vessel to float. Archimedes is considered to be the greatest mathematician of ancient history, and one of the greatest of all time.



Rules & regulations

As stated by the International Maritime Organisation (IMO), all passenger vessels and every cargo ship with a length of 24 m and over are required to execute an inclination test. Cargo vessels below 24 m require an inclination test but are subjected to different stability requirements. These depend on the flag state which is selected by the vessel's owner. Refitted vessels whose original lightship weight has been adjusted by ≥ 2% or whose L.C.G. has been moved by ≥ 1% of L shall undergo a lightweight survey and an inclination test. Additionally, passenger vessels must undergo a lightweight survey at regular intervals not exceeding five years.

The requirements for the inclination test are given by the IMO and the International Association of Classification Societies (IACS). To regulate the inclination test, flag state as well as a classification society is involved.

Flag State

IMO INTERNATIONAL MARITIME ORGANIZATION

Every vessel is required to be registered to a flag state. The flag states are responsible for setting up the guidelines and maintaining the norms and rules as established by the IMO. Simply put, flag state societies carry out the defined rules and regulations by the IMO. The regulations as enhanced/adapted by the flag state generally involve the following domains:

- Compliance with International standards (IMO)
- Safety of seafarers (SOLAS)
- Prevention & protection of the marine environment (MARPOL)
- Collision Regulations
- Convention on Load Lines (ICLL)

Each flag state has its own adoption on the stated rules and regulations as defined by IMO. Differences for the rules and regulations are found between the domains per flag state which thereby create a competitive market. The vessel owner can select a flag state based on his/her own demands.

Classification societies

IACS International Association of Classification Societies

The IACS founded rules and regulations represent about 90% of the worldwide cargo carrying tonnage and exists of 12 classification societies.
On classification domains, IACS is the main technical advisor of the IMO. IACS establishes objectives in relation to the safety of maritime constructions and systems while standardizing the procedures.

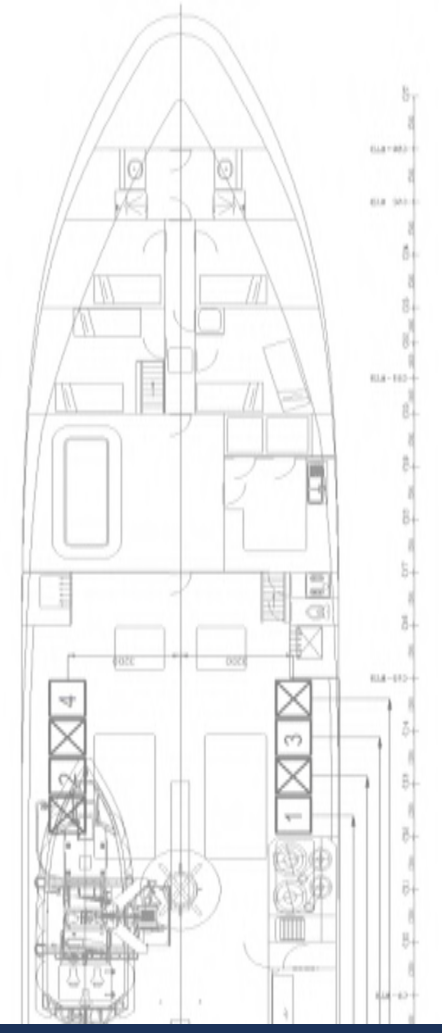
Classification societies are mainly focused on validating the constructed Maritime objects. The following list displays the tasks that are carried out by the classification societies:

- Setting up Rules and Regulations in relation to design, construction and maintenance.
- Executes verification upon the defined rules by the classification society.
- Once the vessel is operational, periodical assessments to validate the compliance with Rules and Regulations are executed.
- Surveys the building process.

Defining responsibilities

Prior to the inclination test, several responsibilities will have to be assigned to different parties. The owner is responsible for initiating the lightship weight survey and the inclination test. By contracting an external expert, the owner or the crew of the vessel gets a representative who acts on his behalf. During the inclinating test, the owner/crew is present on-site to support the ongoing operations and to act upon any emerging problems. For a better understanding of the responsibilities for each party, an overview is given below.

Owner/crew	Naval architect	Class surveyor
Contacts naval architect Cordinates with the crew	**Executes test**	**Validates test**
Initiates inclination test by contacting Class surveyor	Prepares the entire procedure prior to the arrival of the Class surveyor	Verifies the procedure as well as assessing the results
Contacts naval architect	Executes a weight estimation and investigates corresponding centre of gravity prior to the inclination test	Verifies the content of the report and approves it when content complies
Executes an overall vessel survey to prepare for the inclination test	Executes deadweight survey	
Empties tanks if required by Class surveyor	Investigates on tank conditions	
Arranges required inclination test weights	Calculation of free surface correction	
Moves vessel to predetermined test location	Draught mark reading	
Assures proper mooring arrangement for the test	Determines location of pendulums	
Provides a dinghy for draft reading	Translates the conducted results to a report	
Submits final report to Class surveyor		



Inclining theory

To get a proper understanding of an inclining test a basic introduction to vessel stability must be given.

A stationary vessel is held upright due to a certain amount of righting lever on both sides. Simply put, the righting lever is a force that wants to push the vessel back toward an upright state if a heel angle is introduced by external effects such as wind, waves or cargo placement. The amount of righting lever a vessel has is determined by the GM value. A vessel with a low GM value will have a low amount of righting lever and a vessel with a high GM value will have a high amount of righting lever. GM describes the distance between the center of gravity "G" and the metacentric height "M". The metacentric height can be determined analytically, but the center of gravity cannot.

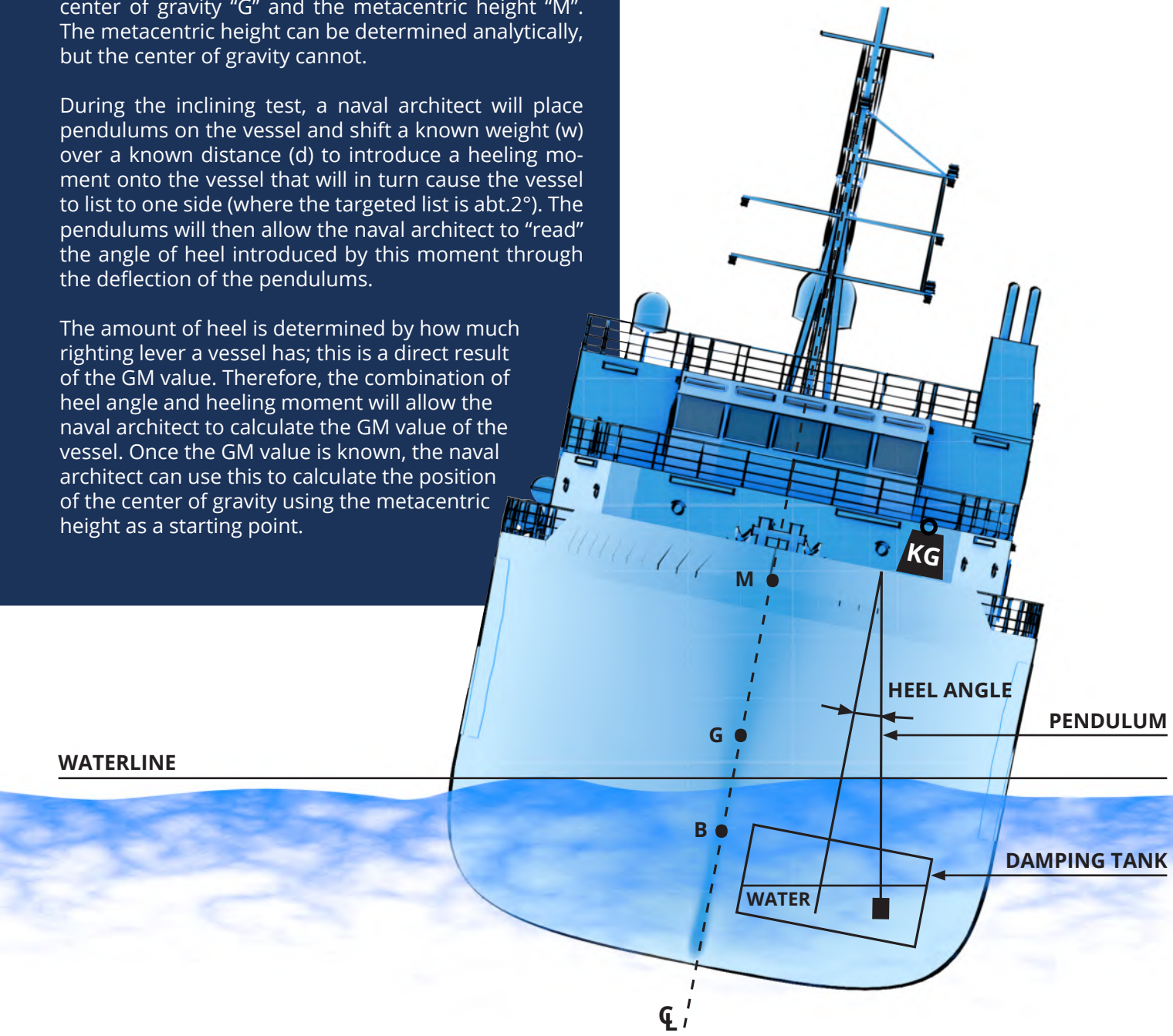
During the inclining test, a naval architect will place pendulums on the vessel and shift a known weight (w) over a known distance (d) to introduce a heeling moment onto the vessel that will in turn cause the vessel to list to one side (where the targeted list is abt.2°). The pendulums will then allow the naval architect to "read" the angle of heel introduced by this moment through the deflection of the pendulums.

The amount of heel is determined by how much righting lever a vessel has; this is a direct result of the GM value. Therefore, the combination of heel angle and heeling moment will allow the naval architect to calculate the GM value of the vessel. Once the GM value is known, the naval architect can use this to calculate the position of the center of gravity using the metacentric height as a starting point.

Heeling moment

$$GM = \frac{w \times d}{W \tan\Theta}$$

The mass of the ship — Heeling angle



Based on the occurring heeling angles during the test and the deviations of the pendulum, the GM of the vessel can be calculated.

Inclining - step by step

1. Drafting the protocol

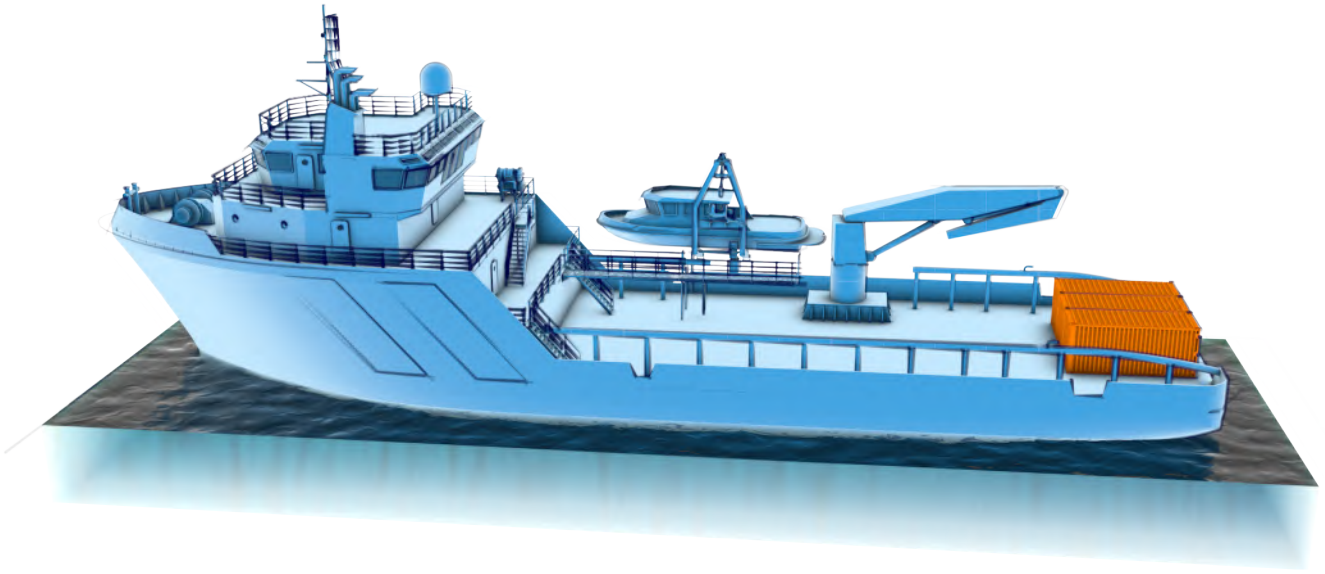
The first step before executing an inclining test is drafting the inclining test protocol, this document outlines a couple of key aspects to ensure there are no surprises during the test and is presented to the owner and attending classification society for approval. In a standard protocol, at least the following items will be mentioned:

- Planned location and number of pendulums
- Required testweight, testweight placement and planned weight shifts
- Pre inclination calculation verifying pendulum length and testweight
- Harbour location of the vessel
- Limiting environmental conditions
- Responsibilities during test

This step can be done remotely, based on existing plans of the vessel, therefore it is not required to visit the vessel to prepare for the test.

2. Deadweight survey

To derive an accurate inclining test result it is required to complete a deadweight survey, during this survey all the weights on board will be reviewed to determine whether these form part of the lightship or not. If an item is deemed to be no part of the lightship, the item will be logged with its weight and the center of gravity and excluded from the calculation. The maximum amount that can be deducted from the lightship weight is limited to 4% of the lightship weight.



Inclining - step by step

3. Placing pendulums

A minimum of 2 pendulums will be used to measure the deflection of the pendulum during the test. To achieve adequate accuracy in the results, the pendulums should be of sufficient length such that the deflection is a minimum of 15 cm to each side. A dampening tank will be placed under each pendulum and a weight will be fitted to the pendulum wire, this weight will be lowered into the fluid to reduce irregular oscillations from external sources other than the heeling moment.

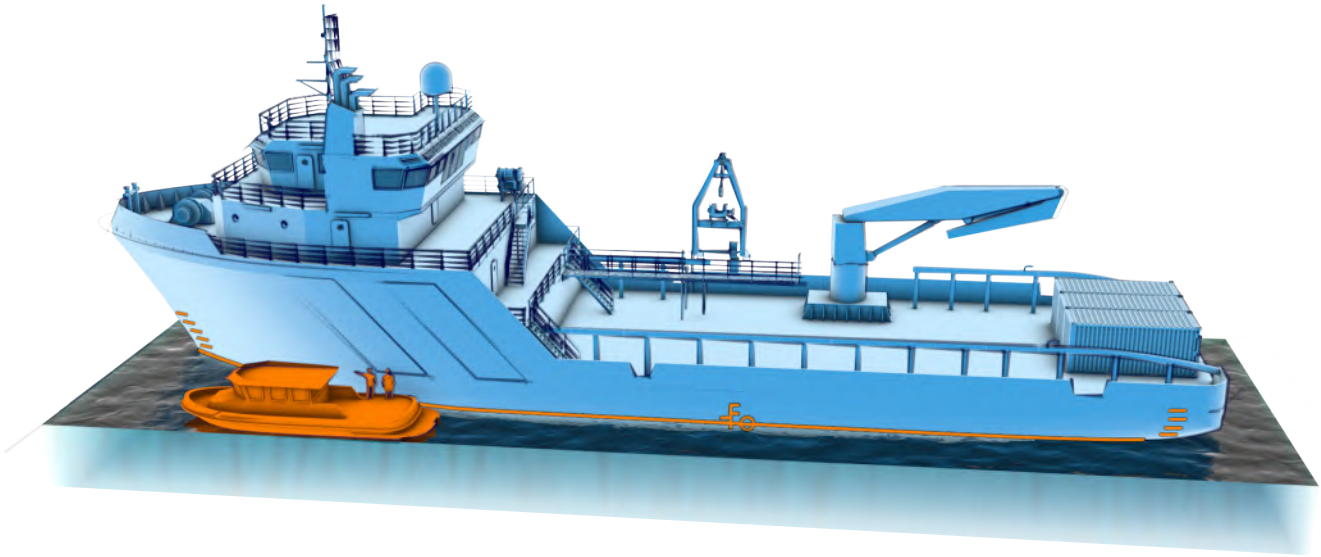
4. Tank inspection

Ideally, all tanks should be empty and clean during an inclining test. For vessels in service, it is usually not possible or too costly to empty and clean all tanks. Therefore, the empty tanks should be inspected, and tanks that are full or partially full should be sounded. Preferably the number of tanks containing liquids should be kept to a minimum to reduce free surface effects, and if possible, the tanks should be filled to the overflow pipes.

Inclining - step by step

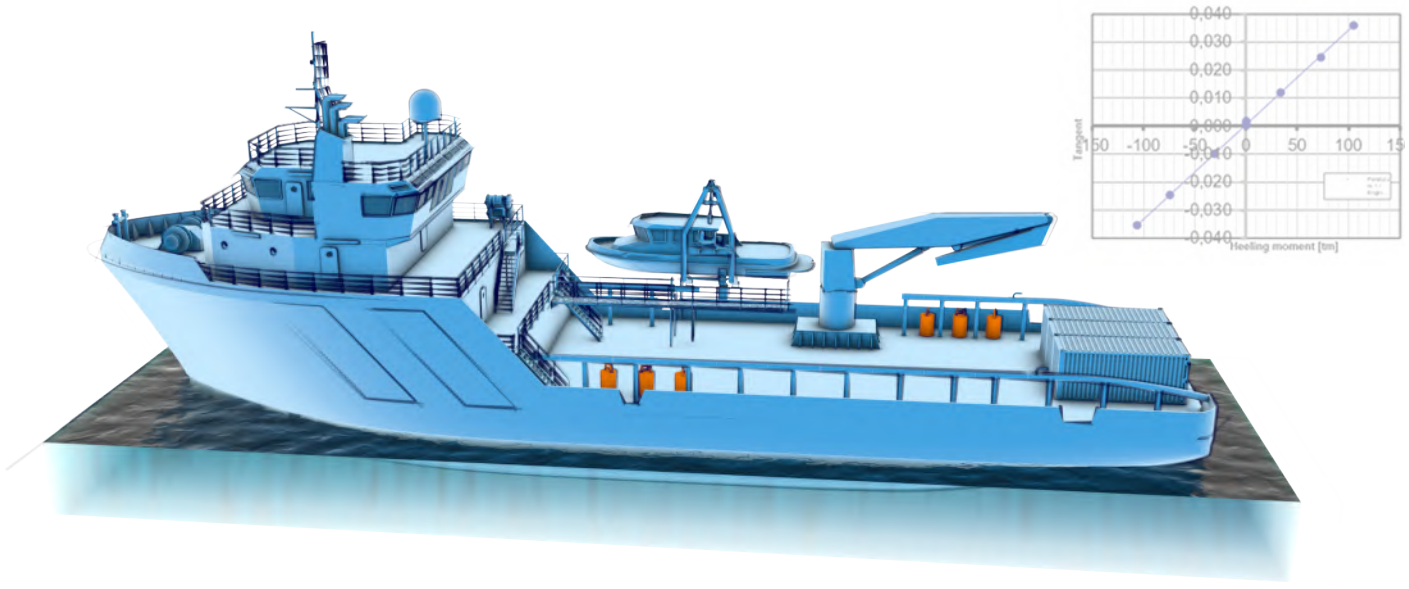
5. Draft and freeboard reading

Prior to the inclining test, the draft marks will be recorded. This is done to determine the displacement of the vessel but is also required to retrieve the actual trim/heel of the vessel. The displacement value is used to determine the new lightship weight by subtracting the weights recorded in the deadweight survey, the inclining test weights and the tank fillings. When the inclining test is completed, the drafts will be taken again to ensure the conditions have not changed during the test.

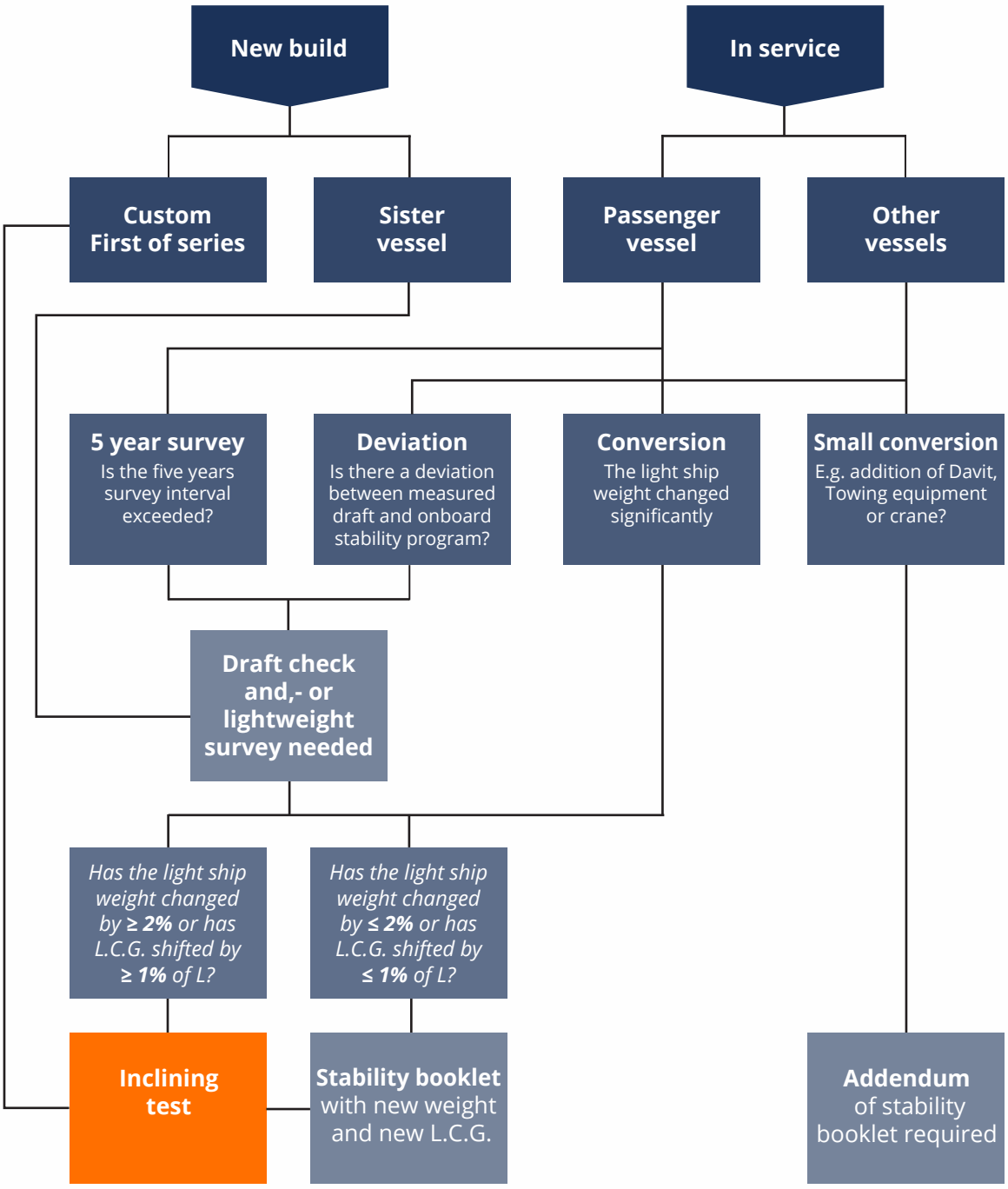


6. Execution of inclination test

After executing all the above-mentioned tasks, a total of eight tests, which consists of the additional test weights from their starting position to starboard and portside a heeling moment is introduced to the vessel, this heeling moment will produce a heel angle that can be marked at each pendulum. By shifting the weights in multiple steps the accuracy of the test is increased, usually, eight steps are sufficient to achieve the required accuracy. Upon completion of the test, the heeling moment in relation to the heeling angle shown by the pendulums will be plotted on a graph on-site and presented to the surveyor. If this graph shows a straight line, the test can be deemed as successful.



Do the check, take the test!



How can Saltwater help?

Understanding your challenges enables us to deliver practical, quality products and clever solutions. Our team of professional, multi-disciplined engineers helps you to deliver, no matter what the challenge, delivery time or budget. Saltwater is the flexible partner that complements your business with knowledge, experience and innovative engineering.

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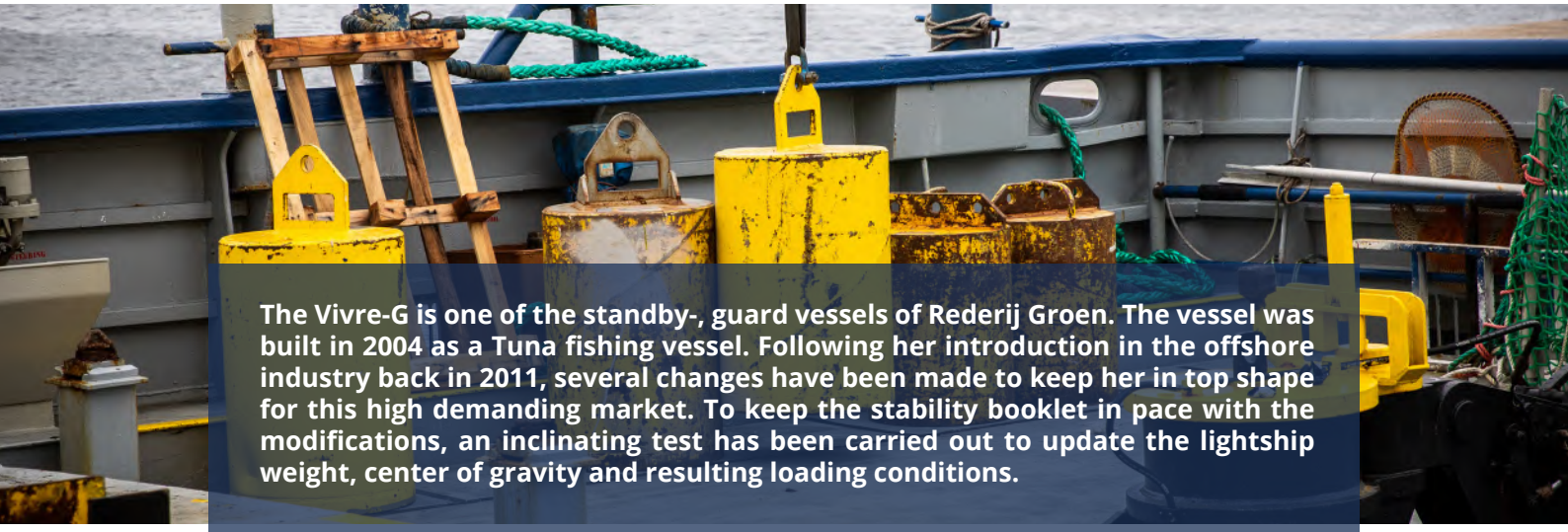
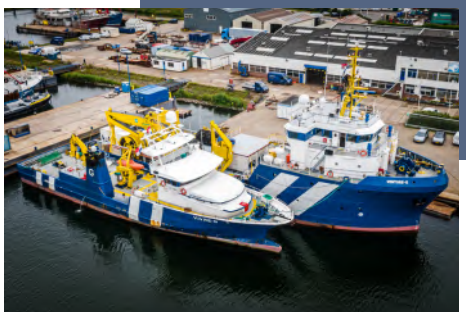
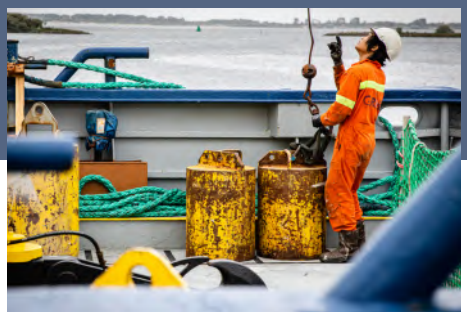
On-site works



The Vivre-G is one of the standby-, guard vessels of Rederij Groen. The vessel was built in 2004 as a Tuna fishing vessel. Following her introduction in the offshore industry back in 2011, several changes have been made to keep her in top shape for this high demanding market. To keep the stability booklet in pace with the modifications, an inclinating test has been carried out to update the lightship weight, center of gravity and resulting loading conditions.





Flexibility

Due to the busy and unpredictable work schedule, it was difficult to determine a date when the inclination test was to be performed. The estimated time of arrival at the port changed several times due to few extensions of the vessel's contract. Our team of professionals easily adapted to these ever-changing situations and re-scheduled at each request. Coping with an ever-changing situation is in our DNA, being flexible in these types of work is the best service one can provide to its customers.
The inclination test was carried out during a short-planned maintenance visit to Maaskant Shipyard.

On-site works

The inclinating test entails shifting a series of known weights transverse across the deck when the ship is free to heel. The resulting change in the angle of the heel is measured by the shift of a pendulum and/or an inclinometer. This angle is used to determine the center of gravity. A deadweight survey is executed, drafts are measured following a survey with the assistance of a small boat. Combined with the specific gravity, the temperature of the water and the hydrostatic data (derived from the shape of the vessel), the mass of the vessel in the water can be determined. Both are procedures that require an eye for detail for all measurements. Any inaccuracy will influence the test and can greatly affect the outcome of the test which obviously must always be avoided.

Stability booklet

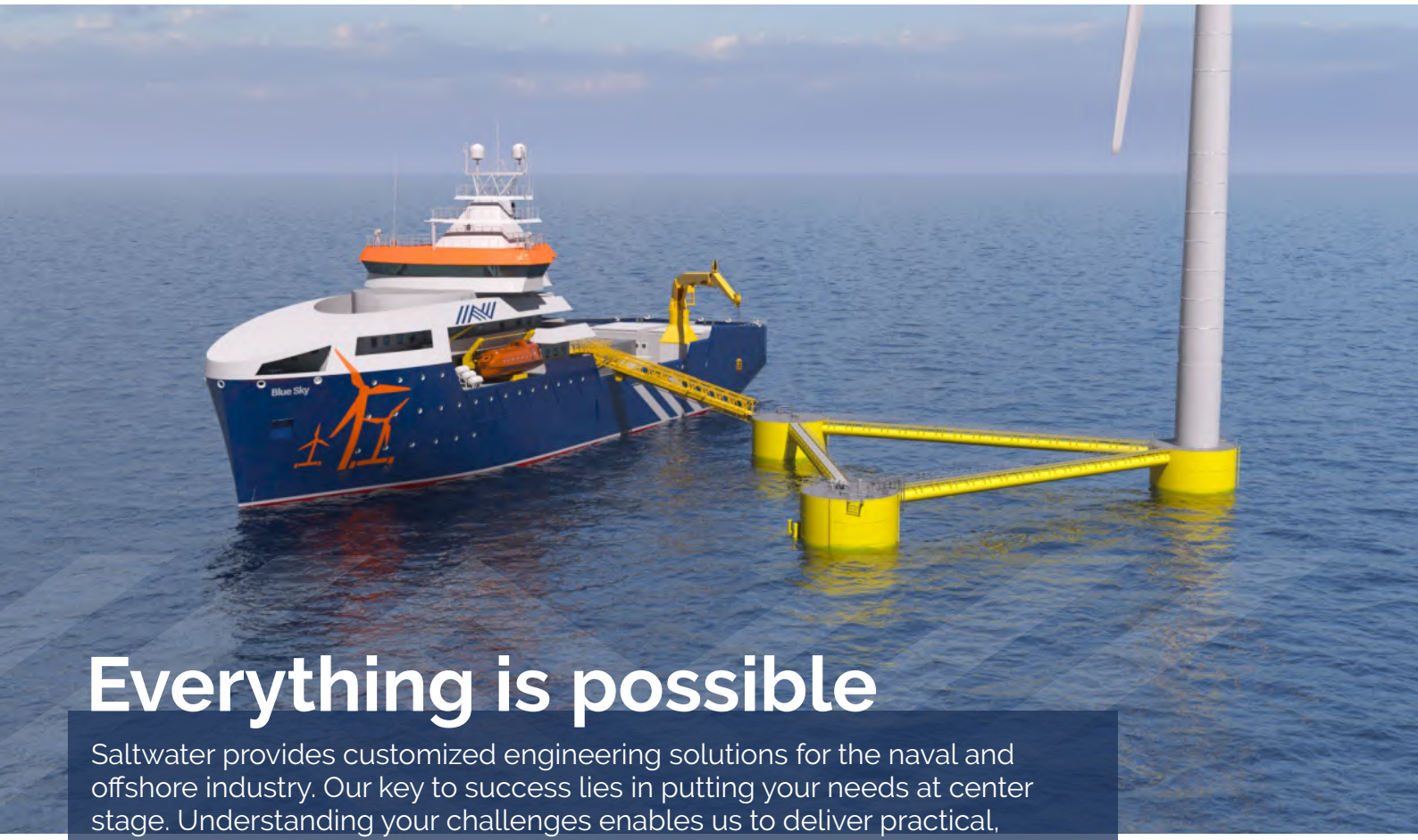
The results of the above tests are used to calculate the new lightship weight and corresponding centre of gravity of the vessel. This data is then used to create a new / updated stability booklet. Various loading conditions are determined to assure stability under the operating conditions all according to the applicable rules and regulations. With the approval of the stability booklet from the classification society, the captain can operate the vessel safely under the conditions described.

PROJECT INFORMATION

Scope of work
- Deadweight survey
- Inclination test
- New stability booklet

Dimensions Vivre-G:
- Length 42,0 m
- Breadth 9,0 m
- Draught 3.5 m

About us



Everything is possible

Saltwater provides customized engineering solutions for the naval and offshore industry. Our key to success lies in putting your needs at center stage. Understanding your challenges enables us to deliver practical, quality products and clever solutions and making everything possible.

Mission

Our mission at Saltwater is to engineer and develop maritime solutions that reduce the environmental impact and support a low carbon footprint. We are committed to provide innovative and efficient engineering services that meet the needs of our clients while guaranteeing safety and quality.

Vision

At Saltwater, our vision is to be a leading force in the maritime engineering industry, striving for positive change through socially responsible practices. We envision a future where our engineering solutions help to create a healthier and more sustainable world. We are committed to ship conversions and new vessel designs, encouraging a culture of young innovators and collaborating with our partners and clients to achieve our shared goals.

Sander Broekmeulen - CEO

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