THE CONTRADICTIONS BETWEEN THE ORIGINAL THREE MASTER BELGICA AND PRESENT REGULATIONS

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SUMMARY

On 16 August 1897, the Belgian captain Adrien de Gerlache together with an international crew of 15 left Antwerp (Belgium) for the Antarctic on the three-master *Belgica*. This expedition was the first Antarctic expedition of a purely scientific nature and the first to spend a winter in the austral polar night. Trapped in ice in March 1898 she managed to escape in February the year after. She was initially built as a whaler with a length of 34.60m, beam of 7.28m and draught of 3.46m.

In 2007 a project was initiated to build a replica (or look alike) of this vessel at the workshops of De Steenschuit (Boom, Belgium), specialized in traditional shipbuilding techniques and maritime restoration.

After a short historic review and a description of the main goals of the present project, the paper will emphasize the contradictions between the attempt to reconstruct the original vessel on one hand, and the requirements imposed by present regulations that have to be fulfilled by a vessel capable of sailing against the polar ice on the other hand. Also the application of modern day techniques in combination with traditional materials will be discussed.

NOMENCLATURE

GM	[m]	*metacentric height*
GZ	[m]	*stability lever (righting arm)*
KG	[m]	*distance between keel and centre of gravity*
∇	[m³]	*displacement volume*
θ	[°, rad]	*angle of heel*
θ_f	[°, rad]	*flooding angle*

1. HISTORY OF THE BELGICA

1.1 BARON de GERLACHE

In the autumn of 1894, Baron Adrien de Gerlache de Gomery (Figure 1), Lieutenant in the Belgian Navy, mails to prominent scientific researchers and Maecenas to elaborate his idea for exploring the arctic waters and investigating the local weather, magnetic field, fauna and flora. The positive and enthusiastic reactions result in an official meeting in 1895 were the goals and financial targets are set. After some initial experience of sailing in arctic waters on the *Castor*, Adrien de Gerlache buys the (smaller) three-master *Patria* in 1896 and names her patriotically *Belgica*.

Figure 1 Portret of Baron Adrien de Gerlache [1]

1.2 THE THREE MASTER BELGICA

The naval architect Johan Chr. Jakobson designed the three master *Patria* for whale hunting in arctic areas. Due to this specific service area she is designed with an extra layer of greenheart at the stern and stem around the waterline and her ice breaking bow was even extra reinforced with plates of iron. At her launching in Svelvik (Norway) in 1884 she was equipped with a 35 BHP steam engine and bark sails. Each of the first two masts carried three cross rigged sails and staysails fore and aft the first mast. The second and third mast could carry a brig sail but the manoeuvrability of the central brig sail was limited due to the chimney of the steam engine. The sail plan is shown in Figure 2. With a length of 34.60m, beam of 7.28m and draught of 3.46m her displaced volume was 590m³.

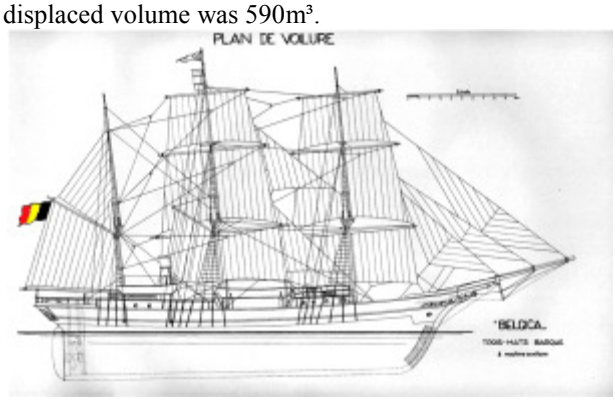

Figure 2 Sailplan of the original *Belgica*.[1]

De Gerlache repaired and modified his new ship. A laboratory was installed as well as more cabins at the stern. The ship was equipped with a new twin blade propeller. This propeller was retractable to avoid damage when sailing in icy waters or even when stuck in the ice.

On 16 August 1897 the *Belgica* left Antwerp (Belgium) for the Antarctic with an international crew of 15 under the command of Adrien de Gerlache. After a (too) long scientific campaign in South America the sailboat finally arrived at the Antarctic peninsula only on 23 January 1898. From there on she progressed with the necessary stopovers further south to 71°28'S. Perhaps planned by de Gerlache, but probably not, on 2 March the *Belgica* got dramatically trapped in the pack ice (Figure 3). The devastated crew realised this was the beginning of a long, cold, dark and wet winter. The unprepared crew feared for their lives and for the strength of their ship suffering from the constant ice pressure.

Figure 3 The *Belgica* trapped in the polar ice [1].

During the winter the depressed crew suffered from scurvy and lost lieutenant and geophysicist Emile Danco in June 1898. After months of hesitations they started eating penguin which they named 'Antarctic steak'. Their new meal, described by doctor Frederick Cook as *"a combination of steak and heavily smelling cod boiled in a pot with cod-liver oil and blood"* gave them some hope for better times.

At the beginning of the Antarctic summer in January 1899 the crew tried to free the *Belgica* with ultimate effort. With saws, explosives and all imaginable tools a canal was created which froze over time after time until the lucky day of 15 February 1899 when the *Belgica* escaped from the ice and was free to sail to Belgium where she arrived in Antwerp at 5 November 1899 after a tough two year expedition. The journey cost the life of two men but those who lived were the first ever to spend a winter in the austral polar night.

From 1901 to 1904 the *Belgica* was chartered for hunting whales and seals in the Arctic regions but after the collapse of the price of these animals the *Belgica* was sold. With a new owner she undertook Arctic expeditions. In 1905 and 1909 she sailed from Spitsbergen to Greenland and back to Dunkirk. In 1907 she unsuccessfully tried to gauge the Kara Sea, got stuck in the ice and floated free in the spring of 1907.

In the middle of the First World War the vessel was sold again to be operated under the name *Isfjord* as a transport vessel for coal. Because of the high costs involved in the required revision and the high standards of Det Norske Veritas to allow the *Isfjord* for sailing in polar waters the owner decided to dismantle the ship and to sell the hull, steam engine and ropes in 1918 to Kristian Holst. He baptizes the *Isfjord* to *Belgica* again and used it during the interbellum period as a floating platform for the fishing industry.

Figure 4 The rudder and stern of the *Belgica* as she currently rests at the sea bottom in Harstad [2]

During the Second World War, when the allied troops of Norway, Poland, France and Great Britain forced back the German occupation of Sweden, the *Belgica* was used as a floating ammunition storage about 2km from Harstad (Norway). Although a German bomb attack in 1940 did not directly hit the *Belgica*, she sank because of a collision to a neighbour ship (Figure 4).

1.3 THE BELGICA SOCIETY

Although the presence of the wreck was known by the local community in Harstad, in Belgium the exact position of the *Belgica* was unknown until the publication [3] was read by Baron Gaston de Gerlache, Adrien's son, in September 2005. Via various media this paper came to a group of enthusiastic people who wanted to initiate a platform to attempt the conservation or even the salvage of this historic vessel. Therefore the non-profit organisation Belgica Society was founded and aims at "*contributing to the knowledge of Belgian maritime heritage and its maritime history whilst focusing on the renowned Belgica as a tangible relic. The Belgica Society hopes to increase public awareness and accessibility of maritime heritage through various educational projects."* [4].

2 NOVA BELGICA

2.1 BACKGROUND

During the International Polar Year 2007-2008 [5] the 110 year old exploration journey of Adrien de Gerlache and his men was remembered and celebrated. Together with the current interest in the wreck of the *Belgica* the time was ready for the yard "De Steenschuit", situated

along the banks of the river Rupel (a tributary of the river Scheldt) in Boom (Belgium), to initiate the plans to build a replica of the historic vessel. The non profit organisation "New Belgica" [6] was funded for realising this ambitious project.

Besides concern for the maritime heritage, other underlying motives are of interest. The organisation wants to focus on sustainable use of materials and energy sources, to stress the vulnerability of the polar regions and to draw the attention to the consequences of climate change. But in the first place a social project is envisaged. Indeed, De Steenschuit, founded in 1990, is not an ordinary yard but an unemployment relief works project. De Steenschuit aims to get long-time unemployed persons back on the labour market. This is achieved by teaching the participants, under expert guidance, a wide range of traditional and modern naval construction skills, which will benefit them in their future jobs.

Parts of the new vessel – which will unofficially be referred to as *Nova Belgica*– will be built by shipyards with a similar social vocation and experience. This type of yard has some repercussions on the building of the replica. The construction workers do not dispose of all required skills and experience in wooden boat building nor do they stay during the entire building process. This makes it even more important to aim for simple building and operating techniques. Despite these disadvantages De Steenschuit successfully completed many small boats, restoration projects and two newly built ships: the fore-and-aft schooner *Rupel* finalised in 1996 with a length of 22.50 m and the track boat *Gentse Barge* from 2004 with a length of 25.00m.

To tackle all technical complexities involved in the building of the *Nova Belgica* a Technical Workgroup was initiated in 2008. The workgroup consists of naval architects, yard supervisors and seafarers. The first task of this workgroup was to investigate the feasibility of creating a seaworthy replica of the *Belgica* capable of sailing safely under contemporary rules and regulations.

2.2 THE GOALS FOR THE NOVA BELGICA

The, to be built, *Nova Belgica* will be a modern day ship looking alike the original *Belgica*. This means that the lines of the hull, deck layout, position of the masts, sails and rigging should be similar to those of the original *Belgica*. However, the main purpose will be completely different, as the *Belgica* was designed and built for hunting whales and seals in polar areas. The *Nova Belgica*, on the other hand, should be capable of performing just one journey to the Antarctic without direct support, not to carry out research neither for staying a long period (a whole winter), but rather for promotional reasons to bring a green message to the world. After this one and – probably – only polar voyage she can be used for several purposes, to be decided: as a trainee ship for the Belgian Navy, as an exclusive cruise ship for up to twelve passengers or as a promotion platform capable of hosting a reception combined with a sailing trip of a few hours.

As a consequence of all these different aims for the vessel, it is not possible to build a ship which is an exact copy of the original *Belgica*. A balance should be found between modern day regulations and the characteristics of the original ship. This will have an impact on the equipment (sailing and non-sailing), strength and stability of the ship. Furthermore the organisation New Belgica wanted significant changes to inner layout of the ship, the used woods, the method of production as well as changes to the sailing gear. These changes are requested for ease of production, for the reduction in costs and for easier handling of the sails. Other significant changes apply to the engine and machinery throughout the ship. As the term 'replica' is for some only valid when building an exact copy, a 'look-alike' might be more correct in this context.

3 CLASSIFICATION AND CLASS

3.1 FLAGSTATE

The *Nova Belgica* will – almost naturally – carry the Belgian flag. The flagstate is in principle the responsible authority in regard of the safety and security of the ship, her crew and her passengers, and also the protection of the marine environment. To fly the flag of a country, a vessel should comply with all requirements set by the national authority for the type of vessel. In Belgium, the Maritime Inspectorate, belonging to the Federal Public Services Mobility and Transport, is responsible for the implementation of this legislation, and has the duty to verify compliance with the mentioned requirements at all times. In most cases, however, the inspections are fully or partially delegated to classification societies. Through a bilateral agreement, the private company will be empowered to fully or partially act on behalf of the flagstate. The ship owner is free to choose a classification society, insofar it is recognised by the Inspectorate.

3.2 CLASSIFICATION SOCIETY

Several classification societies are of interest for this specific ship. In the first place, Det Norske Veritas (DNV) plays a historical role, as it was the classification society of the original *Belgica*. Register Holland is a Dutch society specialised in traditional (and modern) rigged sailing passenger vessels. However, this organisation is unfortunately not recognised by the Belgian Maritime Inspectorate; nevertheless, some of its specific rules may be used. Bureau Veritas (BV), founded in Antwerp in 1828, is originally a Belgian, but nowadays a French society, whose rules and regulations are freely accessible online [7]. Together with a sponsor

agreement with the yard, this makes Bureau Veritas a very interesting partner for the certification process.

3.2 CLASS NOTATION

After selecting a classification society, it has to be determined which class notation should be assigned to the ship. The class notation is a direct indicator of the seaworthiness of a ship. Most of the common classes (e.g. passenger vessel) do not allow a full wooden deck superstructure. The two classes allowing a wooden ship are “charter yacht” and “Special Purpose Ship (SPS)”.

The notation “charter yacht” is meant for seagoing sailing vessels within the range of dimensions of the *Belgica*., and does take into account the specific needs for this type of ship without excessive requirements. The results of the rules are not formulated for steel ships only.

The SPS is a very specific notation which does not follow very strict rules. The ship can be built as desired as long as the safety of the vessel can be proven to the Classification Society and the Inspectorate. This proof can be achieved by using other rules such as these from Register Holland,, wooden fishing vessels, charter yacht or specific elaborate calculation. The disadvantage of this freedom is that all have to be proved without having one path to follow. The *Nova Belgica* will be built under this SPS Class.

4 NEW SPECIFICATIONS

A short overview of the influence of the class notation on three topics will be given. The properties for sailing and non-sailing equipment, the strength of the main construction and the overall ship stability.

4.1 EQUIPMENT

For equipment and safety of seagoing vessels the national regulations are applicable For vessels sailing under Belgian flag these regulations are published in a Royal Decree [8]. In attachment to this Royal Decree an extensive list of all equipment with their standards of type approval (with references to SOLAS and MARPOL) is included. This list also contains the installation instructions, instruction for the parts and the type approval.

Most of the personal life saving appliances can arranged in such a way that they are easy accessible but discretely hidden except for the lifeboats. The original *Belgica* carried two whaleboats and two gigs. From esthetic point of view, it would be convenient if replicas of these open tenders could be operated as lifeboats, but this appears not to be in accordance with the regulations. Indeed, Resolution A.534 of SPS states in chapter 8.3 that the *Nova Belgica* should carry at least one totally enclosed lifeboat at each side of the vessel. This resolution, however, is only applicable to SPS vessels with a gross tonnage of at least 500GT, while the (Nova) Belgica will only have a gross tonnage of about 265GT. This offers an opportunity for the Belgian Maritime Inspectorate to allow a departure from the general rule.

To avoid pollution at sea the ship should carry different tanks and filtering equipment which can be easily placed in the hold. Other compulsary equipment such as navigation equipment, radio communication and COLREG 72 equipment can be installed in a discreet way without major problems. Only the fire protection is a stringent and complex issue on a wooden ship. All watertight bulkheads and fire fighting equipment should be installed according to the regulations.

Besides the safety equipment, the *Nova Belgica* will carry on board a number of modern day equipment such as an installed mess, washing machines, bathrooms, etc.

4.2 STRENGTH

For assessing the overall strength of the vessel three sources are used: the Bureau Veritas rules for charter yachts [7], the BV rules for fishing vessels up to 30m of length [9] and the Lloyds Register of Shipping rules for wooden and composite yachts [10].

The BV rules for charter yachts are also applicable for vessels constructed of composite materials. While the rules and regulations for steel ships result into minimum scantlings, the rules for charter yachts impose loads the construction must be able to withstand.

Although the Belgica is slightly longer than 30m, the BV rules for wooden fishing vessels up to 30m of length can still be applied without the need for extrapolation. Based upon a number of principal dimensions these rules define the scantlings of most main construction elements.

For several construction details the rules of Lloyds Register of Shipping for wooden and composite yacht are used. Although these rules only apply for vessels up to 30m and with a maximal displacement of 150m³ - none of these conditions being fulfilled in the case of the *Nova Belgica,* - the results are applicable for construction details, junction methods and criteria for the wood used for the construction.

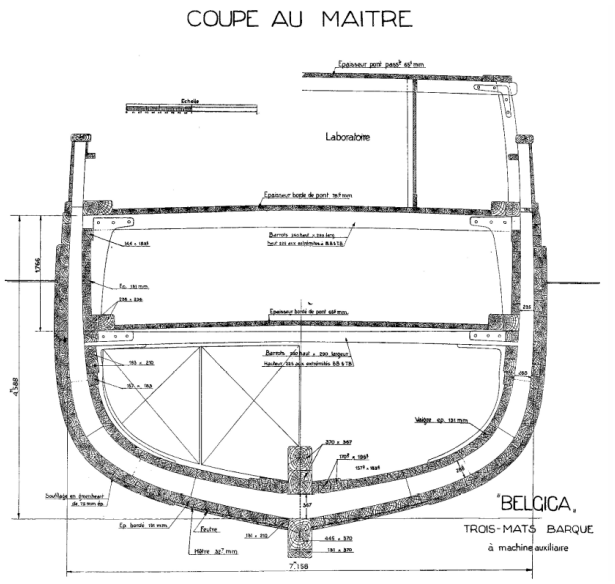

Figure 5 The main frame of the *Belgica* [1]

The design of the main frame for the replica is based upon the original one as shown in Figure 7. The BV rules for composite yachts are used for the longitudinal strength.

To check the strength of the *Nova Belgica* the hull transverse section, the framing and the shrouds were subjected to a more detailed calculation. The hull transverse section was adapted to her new requirements. The most important changes are the uniform thickness of hull planking, frames and inner planking and the use of a steel keel. The frames will be built in a Douglas-resorcinol composite. The properties of this composite are defined by a destructive bending test (Figure 6).

Figure 6 Destructive bending test of the Douglas-resorcinol composite

Other minor changes concern the knees and stringers. For this new cross section it was verified that it can withstand the bending moments and shear forces prescribed by BV. The induced forces where checked against the maximum stress criteria and the Tsaï Wu combined stress criteria. It was found that all parts can withstand the forces given by the rules and that most parts can withstand 5 times higher stresses.

The dimensions of the frames and frame spacing were calculated to approach the safe working stress under the design forces. The frame was modeled as a beam fixed at the keel, connected to a spring at the decks and free at the gunwale. Induced stresses from the lamination process in the heavily bended areas are taken into account. A frame spacing of 450 mm was found for a 170 × 200 mm cross section. The shrouds needed to be calculated to estimate the bending moment for the transverse section. Following the guidelines in [11] the shrouds are designed to counter a force at the hommer in magnitude equal to the maximum static stability moment. Only the lower shrouds are taken into account since with heavy weather only the lower sails are used.

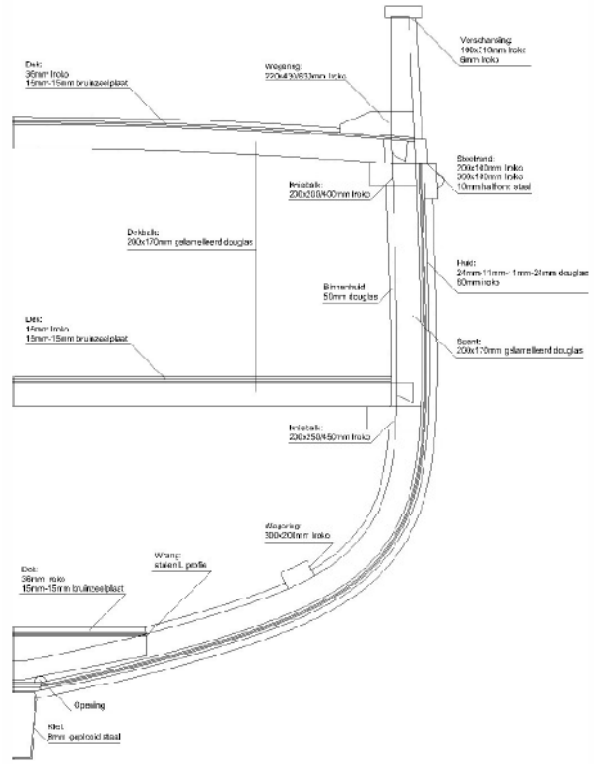

Figure 7 The main frame of the *Nova Belgica* [12]

4.3 SHIP STABILITY

The rules for the stability of ships are formulated by the International Maritime Organization (IMO) [13]. It is the choice for inspectorates and classification societies to adopt them or make them even more stringent. BV adopt all IMO rules and issues some supplementary restrictions for seagoing vessels under sail. Different rules of Register Holland are compared with the BV rules because of the specific type of ship.

The main stability rules are the same for IMO, BV and Register Holland [11]:

$$\int_{0°}^{30°} GZd\theta > 0.055\, m\, rad \qquad (1)$$

$$\int_{0°}^{\theta} GZ\, d\theta > 0.090\, m\, rad \qquad (2)$$

$$\int_{30°}^{\theta} GZd\theta > 0.030\, m\, rad \qquad (3)$$

where θ is 40° or the flooding angle θ_f, whichever is the less. Furthermore the stability lever GZ should be greater than 0.20m for a heeling angle of 30° and more:

$$GZ(\theta = 30°) > 0.20\, m \qquad (4)$$

The peak in the GZ-curve should be reached for an angle higher than 25° and preferably more than 30°.

According to IMO and BV the initial metacentric height GM_0 has to be greater than 0.15m. According to Register Holland the minimum value should be 0.50m.

$$GM_0 > 0.50\, m \qquad (5)$$

Because the lines of the ship are based upon the original vessel the height of the metacentre above the keel, KM, cannot be adapted. The vertical position of the centre of gravity KG is defined by the weight distribution of the ship's structure but can be varied within certain limits by adding extra mass.

Figure 8 shows KG in function of the displaced volume of the vessel according to the five criteria, the flooding angle is presumed to be 37°. At this angle the first non watertight opening is at 1.80m of the ships' side at the deck. KG has to be lower than the lowest curve which is criteria 5.

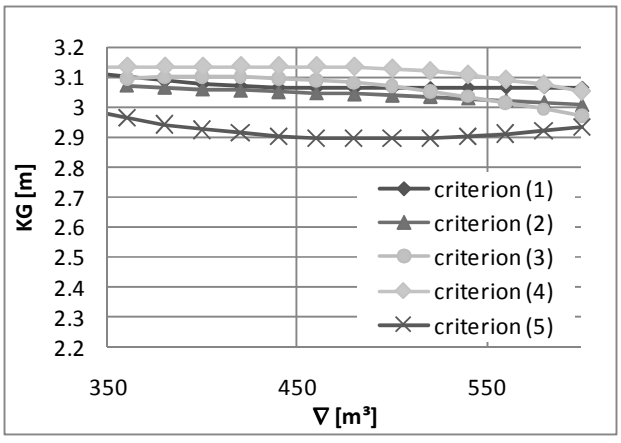

Figure 8 The maximal KG according to different stability criteria

The lateral area of the topsides and sails have to been known to calculate the influence of the wind on the ship's stability. These areas are calculated based on the sailplan of Figure 2. To calculate the maximal vertical position of the centre of gravity the Register Holland rules [11] are used because of their very specific application. For different sail combinations different wind speeds are calculated such that the resulting pressure is the same as prescribed by Register Holland. This results in 4 Bf under full sail and 6 Bf under reduced sail.

The allowed heel angle according to the first criteria is the lowest of 16° and 80% of the angle for which the deck is flooded at one side. Recalculating from this limitation results in a maximum KG as shown in Figure 9. There is a discrepancy between the BV rules and Register Holland rules for sailing solely under engine. According to BV the vessel should fulfill the requirements mentioned before at a pressure of 123 N/m² (6 Bf) while Register Holland takes as much as 504N/m² (10 Bf).

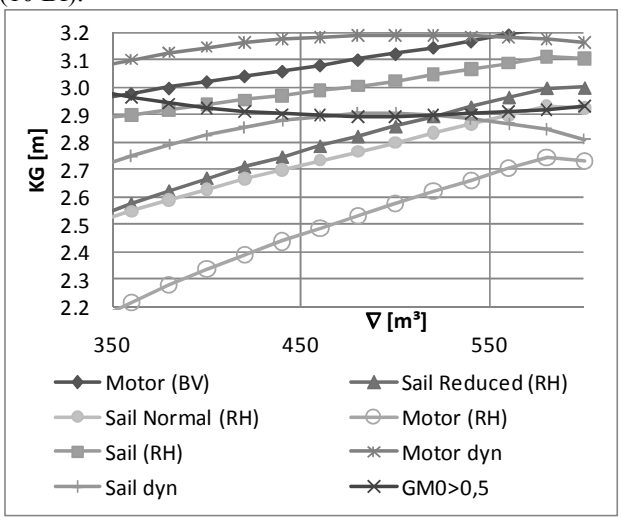

Figure 9 Maximal KG allowed according to first and second wind criteria

The second criteria states that the vessel should be dynamically stable after a roll of θ_1 for a wind pressure of 150% of the wind pressure according to criteria 1. The maximal roll angle allowed is the smallest of 50° and θ_f (heel angle at flooding). The maximal KG allowed for different displacements is shown in Figure 9.

The most limiting condition for the maximal distance KG is the Register Holland rule for sailing under main engine with a 10 Bf wind. These are very common winds between Cape Horn and the Antarctic. A solution to lower the vertical centre of gravity beneath this criteria is to enlarge the ship's keelbox and to add ballast to this new created volume. Enlarging the keel provides a higher resistance to drift and enables to carry ballast at the lowest position of the ship. Furthermore it is assumed that the *Nova Belgica* will be constructed much lighter than her ancestor because of the modern day techniques. This allows for a significant amount of ballast without jeopardizing her freeboard.

5 FUTURE PLANS

In the first months of 2010 De Steenschuit will begin the building of the *Nova Belgica*. They will start with the lamination and building of the frames. The dimensions of these frames are determined as explained in section 4.2. At the same period the building of the steel keel will commence at a building site of Forem. The height of this keel will be higher than the original (wooden) keel of the Belgica to be able to carry ballast to optimize the vertical position of the centre of gravity, KG, as made clear in section 4.3.

The Belgica Society is currently busy to determine the exact condition of the sunken vessel and they are gathering all necessary funds to salvage the de Gerlache's *Belgica*.

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7. ACKNOWLEDGMENT

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