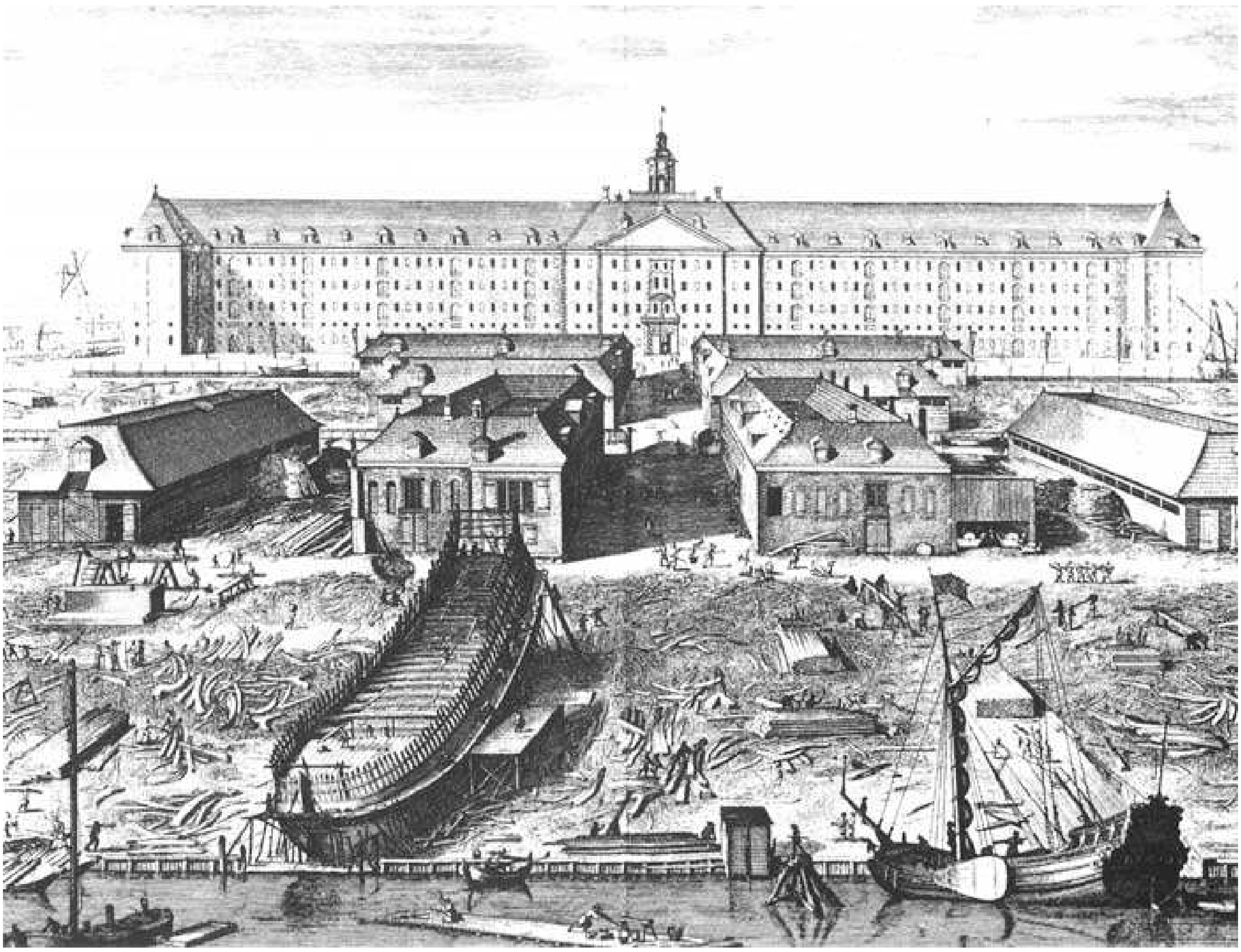
STANDVASTIGHEID
&
VERWACHTING

A historical and philosophical inquiry into standardization and innovation in design and production of the VOC *retourschip* during the 18th century



Johan de Jong (WWTS / s 0076759)

STANDVASTIGHEID (Tenacity / Constancy)

The VOC operated three ships by the name of *Standvastigheid*.

The first ship of this name was built in 1706 in Amsterdam, and was rated with a tonnage of 888. This vessel must have been built according to the standardized rules of 1697. After five return trips, it went down at the Cape on 13 June 1722 on its sixth outward journey.

The second ship of this name was built in 1742/1743 in Rotterdam, according to the new Bentam designs. It was of the second charter and was rated at 850 tons. It made six complete return trips, and after its seventh outward journey it stayed in the East and was sold locally in 1768.

The final ship of this name was a *hoeker,* bought in Rotterdam in 1785.

VERWACHTING (Expectation)

The VOC operated two ships by the name of *Verwachting*.

The first *Verwachting* was one of the very first ships built to the designs of Charles Bentam.
It was of the second charter and was rated at 850 tons. Having made one outward trip from the Republic to the East Indies, the ship foundered in 1744 on a trip from China to Seurat.

The second ship of this name was a *hoeker*, bought in Hoorn in 1787.

Details on these ships and their voyages can be found through
http://www.inghist.nl/Onderzoek/Projecten/DAS

The picture on the title page shows the VOC shipyard Oostenburg in Amsterdam, according to an engraving after an original oil painting by an anonymous artist (1725). The painting itself is in the collection of the "Nederlands Scheepvaartmuseum" in Amsterdam (catalogue number S0058). Retrieved through http://www.zaans-industrieel-erfgoed.nl/images_8/met_stoom_24_vocwerf.jpg

STANDVASTIGHEID & *VERWACHTING*

A historical and philosophical inquiry into standardization and innovation in design and production of the VOC "Retourschip" during the 18th century

Contents

Introduction

In June 2008, my wife and I boarded a small plane that took us towards the Houtman Abrolhos Archipelago, off the west coast of Australia. Looking from the air, we first saw the place where the VOC[1] retourschip Zeewijk perished in 1727, before we flew on to the reef where the infamous Batavia foundered in 1629.[2] It then really dawned on me which extraordinary demands were put on these ships, on their crews, on their navigation and on the shipwrights who had to design and construct these ships, in order that they could sail halfway across the globe to the East Indies, return heavily laden to the Dutch Republic and repeat such return voyages on average five to six times. A few months earlier, when discussing a possible subject for my thesis, Lissa Roberts had suggested looking into the introduction of technical design drawings in 18th century Dutch shipbuilding. That flight, the walk across one of the islands of the archipelago and visits to the museums in Geraldton and Fremantle caused this suggestion really to take hold. It was also the reason that I decided to concentrate on what had happened within the VOC regarding its *retourschepen*.[3]

The technological issues of ship design and shipbuilding were intricately linked with the commercial and colonial aspirations and development of the VOC, the largest commercial and technological enterprise in the Dutch Republic at the time. In addition, the VOC sometimes had a rather uneasy relation with the central and regional governments of the Dutch Republic, there was political turmoil in the Republic during the second half of the 18th century, and there were efforts – by the VOC as well as by Dutch admiralties - to increase control over developments in ship design and shipbuilding. Central to these issues was the complicated relation between innovation and standardization, whereby advances in technology needed to be squared with attempts to standardize and control the current and traditional systems of shipbuilding in the Republic.[4] Therefore, in my proposal I phrased the theme of the thesis as follows:

The central question is the interpretation of the complicated relation between innovation and standardization. In particular, I will explore and investigate whether the innovation in 18th century Dutch shipbuilding technology can be mainly attributed to the introduction of rational, standardized design- and building methods or rather to artisans (such as shipwrights) using their practical intelligence.

To give structure to the main theme, three sub-problems were distinguished:

How was the standardization and innovation of the constructed artefact retourschip actually given shape?

Which relation existed between the standardization of working procedures at the shipyards concerned and the way in which these yards were structured?

Clarification about the way local (master) shipwrights used their practical intelligence, on the one hand constructing the prescribed innovative and standardized vessels and on the other hand

[1] The acronym VOC stands for *Vereenigde Oostindische Compagnie*, i.e. the United (Dutch) East India Company.
[2] For the story of the *Batavia*, see Dash (2003) and Leys (2007). For the story of the *Zeewijk*, see http://www.museum.wa.gov.au/collections/maritime/march/shipwrecks/Wreckfinder/Zeewijk.htm and http://dspace.flinders.edu.au/dspace/bitstream/2328/342/1/1976005018033_FINAL.pdf
[3] For an explanation of the artefact *retourschip* (plural *retourschepen*) see chapter 1.
[4] The subject of the VOC is still of current interest, as is borne out by remarks made by the Dutch prime minister on 28 sept. 2006 and repeated since. Rhetorically he asked the Dutch to return to a "VOC-mentality". He made not clear at the time whether such a return would favour innovation or increased control. For the original quote, see http://www.nos.nl/nosjournaal/artikelen/2006/9/28/280906_beschouwingendag2.html

shaping anti-programs while they adapted existing, prescribed designs to demands put forward by different human actors and non-human actants.

When answering these questions, I opted for a historical/material approach, in which I tried to follow the actors and the actants.[5] This approach paved the way to philosophical considerations, relying on Latour's concept of hybrid networks. Such networks, in this case centred on the artefact *retourschip*, allow human actors and non-human actants to enter into negotiations and to play out their programs and anti-programs in a continually shifting equilibrium. The artefact *retourschip* not only takes up a central position, but it plays an active role in the expansion of its own hybrid network.[6] The use of the concept of the hybrid network means that historical, technological, social, political, geographical and meteorological considerations assume their place in the narrative in shifting alliances.

In the first chapter, I start with giving a historical account of the VOC, its shipbuilding operations and the way it used its ships to achieve its goals. This in turn leads to an analysis of the standardization aimed for by the VOC. The second chapter offers a change of perspective, as it concentrates on the situation within the Dutch navy and more specifically the Amsterdam admiralty. The reason for this is that the formal introduction of the innovation of technical design drawings took place at the Amsterdam admiralty, although one should realize that Dutch master shipwrights were already experimenting with similar technical drawings. The innovation is understood as an immutable (although flexible) mobile.[7] The reasons behind the introduction of the immutable mobile, its failed geographical spread to most other admiralties and an interpretation of its innovative character surround and inform the historical narrative.

In the third chapter, I return to the VOC, analyzing how a process of adaptive changes to the standardized design of the *retourschip* not only endangered the safety of the ships, but also the survival of the VOC. An intricate process of recruiting new allies eventually led to the introduction of an immutable mobile, similar to the one introduced at the Amsterdam admiralty; as a result, the master shipwrights of the VOC were linked together in a single constructive network, with the *Heeren XVII* able to increase the level of standardization, to increase their grip on the building process and to secure the survival of the VOC. This leads to an exploration of the relation between the introduced innovation and the increased standardization of the *retourschip*, signalling that a similar innovation displayed a different character within the context of the VOC, compared to what happened at the admiralties.

The master shipwrights of the VOC, after apparently having lost an important part of their independence, were able to regain their power assisted by the retourschip itself, as is described in the fourth chapter. They did so, not by using formal and theoretical considerations on ship design and shipbuilding (as was the case in France), but by enlisting human and non-human allies to adapt the standardized design to changes the ships encountered and by using expanding practical and experiential knowledge. They based the expansion of their knowledge partly on experiments, either on a small scale or with full-size *retourschepen*. The shipwrights' guild (the original source and distributor of knowledge and innovation in shipbuilding) was losing its grip on the technological process of shipbuilding, and started concentrating on socio-political matters. The actions of the VOC's shipwrights, centred on and emerging through the *retourschip*, show how they could continue to translate a changed environment into a changed artefact, while employing the hybrid network to good effect.

In the fifth chapter, I reflect on the role of the *retourschip*. First, it is interpreted as a technological artefact linking innovation and standardization, and next as a quasi-hybrid object

[5] Latour (1987), p. 258
[6] For more on the active role of artefacts, see Latour (1987) and Latour (1993)
[7] Latour (1987), p. 227

at the centre of a hybrid network, which connected innovation and standardization, or mediated between these two phenomena. Finally, the concept of the immutable mobile of the *retourschip* design is used to explain the transition of the VOC from being a large commercial enterprise into a large technological enterprise; an enterprise that was unique in 18th century-Europe in that it used technical design drawings in commercial shipbuilding. This leads to a final interpretation of the character of the knowledge of the master shipwrights concerned.

Finally, I make some suggestions for continued research, concerning a master shipwright, an appraisal of "tacit" knowledge and the transfer of "Western" technological knowledge to the "East".

This thesis shows that technoscientific developments in the Republic of the United Provinces were not confined to the 17th century (usually characterized as the "Golden Age" of the Republic) or the 19th century (when the Kingdom of the Netherlands turned into a colonial power of international importance). The 18th century can be characterized as an important chapter in the development of the process of technological design and of the early development of production organized as a (pre)industrial enterprise. The word "techno-scientific" is used to avoid positioning science (or "formal knowledge") opposite technology (or "practical knowledge"), or to interpret technology as "applied science". Master shipwrights contributed to the development of technoscience in a practical and experiential way. They used their practical intelligence to (re)design, construct and adapt standardized *retourschepen*, using the innovation of technical design drawings. They did so as part of a continually developing seamless hybrid network centred on the *retourschip*.

In the second half of the 18th century, at the time that the developments described in my thesis took place, the Scottish philosopher David Hume argued against the idea of intelligent design, using the metaphor of a ship. He wrote in part V of the Dialogues concerning Natural Religion:

> But were this world ever so perfect a production, it must still remain uncertain, whether all the excellences of the work can justly be ascribed to the workman. If we survey a ship, what an exalted idea must we form of the ingenuity of the carpenter who framed so complicated, useful, and beautiful a machine? And what surprise must we feel, when we find him a stupid mechanic, who imitated others, and copied an art, which, through a long succession of ages, after multiplied trials, mistakes, corrections, deliberations, and controversies, had been gradually improving? Many worlds might have been botched and bungled, throughout an eternity, ere this system was struck out; much labour lost, many fruitless trials made; and a slow, but continued improvement carried on during infinite ages in the art of world-making. In such subjects, who can determine, where the truth; nay, who can conjecture where the probability lies, amidst a great number of hypotheses which may be proposed, and a still greater which may be imagined? [8]

While Hume is quite right in his description of the long and complicated trajectory that led to the construction of the largest wooden artefacts of the 17th and 18th century - the merchantman and the man-o-war - he is definitely not right in characterizing shipwrights (or carpenters as he calls them) as stupid mechanics. They were the highly trained and articulated artisans responsible for the intelligent design and the materialization of these colossi.

[8] Retrieved through http://ebooks.adelaide.edu.au/h/hume/david/h92d/part5.html

1. The *retourschip*, material metaphor and standardized artefact

In dit hoofdstuk beschrijf ik het fenomeen retourschip, waarvan er in de 17de en 18de eeuw vele honderden gebouwd zijn op de zes eigen VOC-werven (par. 1.2), geplaatst binnen de context van de VOC zoals die onderneming op globale schaal opereerde (par. 1.1). Betreffende het retourschip beperk ik me niet alleen tot plaatsbepaling, ontwikkeling, ontwerp en bouw (par. 1.3) maar laat ik ook zien wat de rol is die het speelde binnen de VOC. In zekere zin geeft het artefact retourschip een beeld van de VOC als geheel (par. 1.4). Al in de 17de eeuw worden pogingen ondernomen om tot standaardisatie van de drie klassen retourschepen te komen, zoals uit contemporaine literatuur blijkt. Daaraan - en aan het fenomeen standaardisatie als zodanig - wordt in par. 1.5 aandacht besteed.

During the 17th and 18th century, every year dozens of large merchantmen slowly made their way from the Dutch Republic[9] towards the East Indies and back. On the way out each *retourschip* (East Indiaman) carried sailors, soldiers, precious metals and other building blocks for the construction of a private empire overseas and on their way back they carried spices, tea, coffee, textiles, porcelain and other building blocks for the construction and upkeep of the company that was in charge of this huge enterprise. These *retourschepen* (plural of retourschip) belonged to the *Vereenigde Oostindische Compagnie* (Dutch East India Company)[10]. Every *retourschip* was designed and designated to travel back and forth between the Republic and Asia, but it never existed as a single, well-defined entity, but was a more complicated phenomenon. In that respect, it mirrored the VOC, the company that operated these ships, and which cannot be seen as a single entity either. On the contrary, for the two centuries of its lifespan, the VOC consisted of a conglomerate of six rather independent, separate chambers. A short overview of the VOC's history will be given in section 1.1.

The concept of the *retourschip* manifested itself in a conglomerate of several different materializations. That is not to say that during the 17th and 18th century the VOC did not try to introduce innovation and standardization (both often at the same time) into the design and building of their *retourschepen* and into the organization of the way its fleets operated. In section 1.3, an attempt will be made to give a systematic overview of the various types of ships in use by the VOC until the company started a program of standardized ship design and shipbuilding. The *retourschepen* were – according to size – divided in three different classes or charters and standardized and innovative designs were introduced. The result of this program, the *retourschip*, will be described in section 1.4. In that section, it will be argued that the *retourschip* can be interpreted as an interactive metaphor for the VOC as a whole. Processes of innovation and standardization were complicated by the fact that each chamber of the VOC owned its own shipyard, and each shipyard had to negotiate its own network, often built out of a heady mix of politics, technology, geography, economics, artefacts and individuals. The way these shipyards operated (and more specifically the Amsterdam and Rotterdam yards) will be described and

[9] Formally called "The Republic of the Seven United Provinces", governed by provincial parliaments (the "States"), and a national parliament (the "States-General"), which consisted of representatives from the provincial States. Apart from the States and the States-General, headed or assisted by a "pensionary", the office of "stadholder" existed as well. The "stadholder" was originally the representative of the Habsburgian king of Spain but they assumed an independent role during and after the Eighty Years War of Independence, which ended with a peace treaty in 1648. Until 1795 when the Republic was dissolved, regular power struggles broke out between the States-General and its pensionary on the one hand and the stadholder on the other hand.

[10] Although in translation, *Vereenigde Oostindische Compagnie* means United East India Company, it is in English commonly referred to as Dutch East India Company. Throughout this paper, the acronym VOC will be used.

interpreted in section 1.2. Each *retourvloot*[11] *(*return fleet*)* needed to reflect the relative importance of the six chambers in the tonnage of its ships, and the same relative importance had to be translated into each chamber's share of the returns of the fleet. In the final section of this chapter, attention will be given to the way in which standardization was introduced within the VOC in the course of the 17th century, to the phenomenon of standardization itself and again to the artefactual result of this standardization, the *retourschip*.

1.1 The VOC: notes on its origins and organization

In the late 16th century, Dutch merchants started exploring shipping routes to Asia in an attempt to bypass the Iberian monopoly on spice-trading. While finding a route to the north of Europe failed, a successful expedition (as far as route finding was concerned) took place between 1595/1597[12]. The States-General supported the expedition, and this link between government and private enterprise turned out to be a recurring theme in the history of Dutch-Asiatic trading. After this *Eerste Scheepvaart* (First Shipping) several competing merchants from different provinces of the Republic fitted out more or less successful expeditions of their own, with the result that these merchants were not only trying to break a foreign monopoly, but were also competing against one another. Through intervention by the governments of some provinces (the States of Holland and the States of Zeeland) as well as by the federal government (the States-General), the *raadspensionaris* (pensionary of the States General) Johan van Oldebarneveldt[13] and the stadholder Maurits, an agreement was reached on March 20, 1602, which marked the beginning of the VOC. This agreement merged six different companies into one company, but the original companies (or chambers) remained in existence and their conglomerate formed the VOC. A central board governed the VOC as a whole, consisting of seventeen gentlemen, called *Heeren XVII*. The States-General granted the VOC an *octrooi* (monopoly) for all shipping east of the Cape of Good Hope and through the Straits of Magellan, an *octrooi* that had to be renegotiated on a regular basis.

One can argue that the VOC was an early example of a private-public enterprise. As far as the raising of capital was concerned, the VOC had to rely on private investors, usually merchants from the cities in which the chambers had their domicile. Its public character is shown by the fact that the VOC was given power by the States-General to act as a state in Asia, i.e. to enter into treaties with local rulers and states, to build fortifications, to employ an army, to wage war, and to rule its colonies. On the other hand, high-ranking officials had to swear allegiance to the States-General and upon return of the fleet, reports had to be presented to a committee of the States-General. Apart from having close relations with the States-General, the VOC also had a special relationship with the stadholder. This relationship emerged already in 1602 when stadholder Maurits intervened in the negotiations, which laid the foundation of the VOC. In 1674, the VOC decided that the stadholder should receive 3% of all dividends. In the 18th century, the stadholder could act as chairman of meetings of the Heeren XVII and of board meetings of the chambers, and he was given the right to appoint directors[14].

---

[11] A *retourvloot* consisted mostly of *retourschepen*, which were destined to return with merchandise from the East Indies, but each fleet also contained a number of (usually smaller) ships that were destined to stay in the East.

[12] For a more extensive overview of the early history of the VOC see Bruijn e.a. (1979-1987) Part 1, chapter 1 and Gaastra (2001/2007), hoofdstuk 1

[13] His position at the time might be compared with that of a modern day prime minister. He might not have been completely impartial, because his brother, his banker and many of his friends from Rotterdam had interests in the East Indian trade (Grimm (1994), p. 10).

[14] Bruijn e.a. (1979-1987) Part 1, p. 14

The organization of the VOC reflected its beginnings, in that it was based on the six chambers, Enkhuizen, Hoorn, Amsterdam, Delft, Rotterdam and Zeeland, of which Amsterdam was by far the most important. Activities such as the building and equipping of ships and the sale of goods were determined as follows: Amsterdam was responsible for one-half, Zeeland for a quarter and the remaining chambers for one-sixteenth each. Each chamber had its own number of directors, Amsterdam twenty, Zeeland twelve and each of the smaller chambers seven. These directors decided two or three times a year who would represent them in the meeting of the central board, the *Heeren XVII*, which means that being a member of the *Heeren XVII* was not a permanent post. One could argue that the organisational structure of the VOC mirrored the structure of the Republic, which was a conglomerate of seven semi-independent provinces. The number of seats in the central board reflected the relative importance of the chambers: Amsterdam appointed eight representatives to the board, Zeeland four and the remaining chambers each one. To prevent Amsterdam from obtaining total control a seventeenth representative was appointed in turn by either Zeeland or one of the smaller chambers. The *Heeren XVII* convened for a few weeks three times[15] each year, during six consecutive years in Amsterdam and for the next two years in Middelburg (Zeeland).

In 1614, a permanent post for an *advocaat (*counsel*)* was created[16] who acted as a secretary for the Heeren XVII. In this capacity, he had to read all incoming letters, to consider the most important points and to suggest an answer. He also was a member of several committees and he was employed by the chamber Amsterdam where he joined the directors' meetings. In 1621, the post of second *advocaat* was added to lighten the workload of the first *advocaat*. As these *advocaten* remained in their posts for decades, they had in effect a large influence on the day-to-day running of the VOC, as membership of the *Heeren XVII* was only a temporary post. Requested to do so by the *Heeren XVII*, Pieter van Dam, who was *advocaat* from 1652 until his death in 1706, wrote a history of the first century of the VOC's existence, called *Beschrijvinge van de Oostindische Compagnie* (Description of the East India Company), which he finished in 1701[17].

Furthermore, the *advocaat* was member of several committees, set up by the *Heeren XVII*. The directors of the individual chambers appointed the members[18] of these committees. The oldest committee was set up in 1606 and had to oversee and inspect the books of the chambers. A committee for secret affairs was entrusted with the task to determine the best sailing routes for the fleets, routes that, dependent on the time of year, became more or less standardized. The most important committee was the *Haags Besogne* (The Hague Affairs) which consisted of twelve members, ten directors - Amsterdam four, Zeeland two and the smaller chambers one each - plus two principal shareholders. This committee met in The Hague each spring for several weeks. It dealt with incoming letters from Asia, could consult with the States-General, kept a survey of all the company's ships and it had to see to any unfinished business of the *Heeren XVII* or it had to take preliminary decisions.

The most important meeting of the *Heeren XVII* took place in September, after the return of the fleet from Asia. In this meeting, the number of ships to be dispatched for the next season (i.e. from September of the next year until June of the year thereafter) had to be decided upon, the (provisional) amount of gold and silver to be shipped out had to be decided, as well as (provisionally) which goods and how much of these had to be brought back from Asia. Finally, the auction of the imported goods had to be organized. The next official meeting of the *Heeren XVII* took place in February/March, where the past auctions were discussed and the spring auction was organized. The definitive amount of goods to be brought back and the

---

[15] From the second half of the 18th century onwards they met only two times a year.
[16] Bruijn e.a. (1979-1987) Part 1, p. 15
[17] The original text is available at http://www.inghist.nl/retroboeken/vandam
[18] Bruijn e.a. (1979-1987) Part 1, p. 16-17

corresponding amount of gold and silver was decided upon. A decision was taken on the dividend that should be paid out as well as on the dates at which the *Haags Besogne* should meet. Any results of this committee were discussed at the summer meeting of the *Heeren XVII* and a provisional decision was taken about the number of ships that should sail in late autumn. From the middle of the 18th century onwards, this meeting was scrapped and responsibilities for any decisions that should be taken moved to the *Haags Besogne*.

The individual chambers had to put the decisions by the *Heeren XVII* into effect, each chamber according to its share. The directors of the larger chambers met several times a week, and within these chambers, committees (or departments) were set up. In Amsterdam, they consisted of an *equipage*-department (equipment department), responsible for the building, repairing and fitting out of ships and for supplying the ships with crews; a warehouse-department, which administered the merchandize; a reception-department, which was responsible for all financial affairs between the chamber and Asia, and finally the audit-department, which oversaw the accounts and controlled the cash office. Zeeland had a similar arrangement, although the two financial committees were combined. Not much is known about the smaller chambers because the resolutionbooks of these chambers have not survived.

The six chambers of the VOC each employed a large workforce, not only in the shipyards, but also as bookkeepers, clerks and other administrative workers, the greatest number of course being in the employment of the chamber Amsterdam. As far as shipbuilding was concerned, it should be noted that the individual chambers had to make sure that the numbers of ships, allocated to each chamber, were available for the outward fleets, which meant either repairing existing ships or building new ships on their own shipyards. As will be seen later, the chambers were increasingly restricted in the design and dimensions of the ships they had to build. The tension between the quasi-independence of each chamber and its operations on the one hand and the increasingly centralized way in which the VOC was run – most notably in its shipbuilding operations – on the other hand will become manifest in the remainder of this chapter and in the following chapters as well.

1.2 The VOC shipyards

"In the early days the Company partly built its ships itself and partly purchased them; it also got a few ships passed on from the State and the State sold a few to it"[19]. It took about twenty years after the inception of the Company (i.e. until after 1620)[20] before the VOC produced most of its ships on its own shipyards, each chamber having its own yard, although quite different in size and capacity. This meant that not every yard was capable of building all three types (or charters as they were called) of the large *retourschepen*. At least 1461 ships (and probably 120 more as well) were built on VOC's own shipyards between 1602 and 1795[21]. Of this number Amsterdam built almost 50%, Zeeland almost 21% and the four smaller yards (Rotterdam, Delft, Hoorn and Enkhuizen) each about 7%, Amsterdam and Zeeland building most of the ships of the first (i.e. largest) charter. Apart from the building of new ships (in Amsterdam about four ships every year, on the smaller yards approximately one ship every eighteen months) repair and maintenance were important as well. Upon return in patria the retourschepen were inspected and a decision was taken whether the wear and tear, caused by the trip to Asia and back and by the stay in tropical waters, could be repaired or whether the ship had to be scrapped. In fact,

[19] Van Dam (1701/1927), Cap. 17, Pag. 450. In Dutch: *"In de eerste tyden heeft de Compagnie hare schepen ten deele selfs gebouwt en ten deel gekoft; ook zijn haer nu en dan door den Staat eenige bygeset, ook verkoft"*
[20] Bruijn e.a. (1979-1987) Part 1, p. 37
[21] Bruijn e.a. (1979-1987) Part 1, chapter 3

quite a few *retourschepen* managed to complete up to six or even more return trips during their lifespan, meaning an average lifespan of about fifteen years[22].

The largest shipyard of the VOC was Oostenburg[23] in Amsterdam, where from 1660 until 1799 about 500 merchantmen were produced out of the total production of 728 ships for the VOC chamber Amsterdam. Oostenburg consisted of three islands, on one of which a storehouse was situated in which the imported goods from Asia were stored, and which also stored nails, ropes and cables for the ships. On a second island were several workshops, where parts for ships were produced and finally on the third island was the shipyard itself with three slipways, a forge, a steam kiln for bending timbers and some more workshops[24]. Organisation and logistics at Oostenburg were as large-scale and complex as the yard itself. During the 1750s, according to Lucassen[25], the yard employed 1100 workers and 180 staff, supervisors and commanders[26]. They were divided over six main departments: administration, artisan departments, storage, transport, vessels and a security system. Bruijn[27] mentions 156 staff and supervisors in 1762 and a number of 1319 workers shortly before 1791, of which 245 had been recently dismissed [28]. If one considers that –until the beginning of the 19th century - an enterprise, employing a few hundred workers, is seen as very large[29], this number of employees indicates that the Oostenburg yard ranks with the famous Venetian Arsenal as a huge industrial enterprise[30].

The organisation as a whole displayed a pyramidal structure, with three *boekhouders* (financial controllers) at the top and tapering out towards an intricately structured base with – amongst others – fifteen separate artisan production units. At the level of the factory floor, the shipyard can be interpreted as a system of horizontally organised, independent and specialized units. To quote the historian Gawronski[31], this organisation was "almost modern, in view of the standardized and efficient assemblage of mass-products in wood" in contrast to the oligarchic, hierarchical bureaucracy of the Heeren XVII. The use of the word modern by Gawronski probably refers to the way manufacturing became organised during the 19th century and it may even point to the use of interchangeable parts[32]. The way the yard operated points to a rather sophisticated system of division of labour[33], which was in operation quite some years before Adam Smith wrote The Wealth of Nations, promoting division of labour as a way to increase wealth.

Working conditions at the VOC-yard in Amsterdam were relatively favourable compared to those at the many private yards in the town. During the course of the 18th century, the number of

---

[22] The number of return trips is mentioned by Bruijn e.a. (1979-1987) Part 1, p. 95.
A lifespan of fifteen years is mentioned at the website of the VOC-Kenniscentrum, which is a project by the Koninklijk Instituut voor Taal-, Land- en Volkenkunde (KITLV), an institute of the Koninklijke Nederlandse Akademie van Wetenschappen (KNAW), http://www.voc-kenniscentrum.nl/vocschepen.html
[23] Gawronski (2003), pp. 133-135
[24] Bruijn e.a. (1979-1987) Part 1, p. 28
[25] Lucassen (2004), p. 19 and 29 where he is quoting Gawronski (1996)
[26] Gaastra (2001/2007), p. 163 mentions 600 employees for the shipyard in Middelburg (Zeeland) and 150-200 for the yards of the smaller chambers.
[27] Bruijn e.a. (1979-1987) Part 1, p. 29-30
[28] Bruijn e.a. (1979-1987) Part 1, p. 29, referring to ARA, VOC 6846, (Mei 1762) mentions "a list of qualified servants from 1762 giving an insight in the actual way labour was divided at Oostenburg".
[29] Lucassen (p. 12), quoting Sydney Pollard "The Genesis of Modern Management: a Study of the Industrial Revolution in Great Britain" London 1965
[30] Lucassen (2004), p. 12. In addition, Davis in "Shipbuilders of the Venetian Arsenal" (Baltimore, 1991), pp. 12-13 gives the combined number of shipwrights, caulkers and mastmakers at the Arsenal as between 1000 and 1200 towards the end of the 17th century.
[31] Gawronski (2003), p. 135. Gawronski goes on to say that "… the 19th century industrial technology of steam and steel would have fitted well with the 18th century production system of the VOC yard"
[32] These aspects will be discussed more extensively in the next chapters.
[33] For similar developments in the London dockyards, see Schaffer (2007)

private shipyards was between thirty and thirty-five, the number of breakers' yards about ten, the number of yards building small boats approximately fifteen and there existed about five yards specializing in the production of masts[34]. Although the basic salary for VOC-shipwrights was slightly lower[35] than for privately employed shipwrights, working for the VOC had the advantage of having a secured job. Workers at the VOC yard could not be dismissed without a good cause, they were entitled to a good redundancy pay and they were paid a good pension during old age. Furthermore, VOC shipwrights were admitted to the shipwrights' guild even if they had yet not reached the status of master shipwright, an admission that gave access to the social security provided by the guild[36].

About the smaller VOC-yards much less is known than about Oostenburg, because of the loss of the resolutionbooks of the four smaller chambers, but some details about the VOC's yard in Rotterdam are mentioned by the historians Van Kampen and Grimm [37]. In 1632, the chamber Rotterdam bought a shipyard at the Boompjes, an area where, until 1650, about twenty-three different shipyards were established. In 1663, the chamber Rotterdam had a large warehouse constructed at the site of the yard[38]. In 1685, the VOC started building a new shipyard further to the East - situated at the Boerengat, opposite the admiralty yard – which became operational in 1694[39]. Both the old and new yard in Rotterdam were capable of building ships up to 170 ft. in length, which was the largest size of ship until the 19th century. Therefore, the VOC-yard in Rotterdam, despite being owned by a small chamber, was able to build all charters of *retourschepen.* It is interesting to note that the shipyard in Rotterdam also used a system of division of labour[40], just like Oostenburg in Amsterdam, although on a smaller scale. Whereas the VOC-yard in Amsterdam usually built four retourschepen every year, the yard in Rotterdam produced about one retourschip every two years. The total production in Rotterdam ran to about 110 ships[41]. Despite this small number (both in total and on a yearly basis), the VOC-yard in Rotterdam was nevertheless responsible for ten percent of the total local output in shipbuilding.

About the size of the workforce at Rotterdam, little is known, but in spring 1791, it is listed as employing 209 people. In that respect, it was similar in size as the neighbouring VOC-yard in Delfshaven, which employed on average between 150 and 200 men. In Rotterdam, the management consisted of a senior *equipagemeester* and an ordinary *equipagemeester*, the master shipwright, the high bosun - who controlled the workforce - and two clerks (a senior clerk and an ordinary clerk). The workforce itself consisted of seventy shipwrights, who built the ships, sixteen apprentices, who were not allowed to do any work on the retourschepen but who built and repaired smaller ships, nine woodworkers, who were engaged in sawing wood to measure and in drilling holes, forty-two dockhands who pulled the wood from the water and transported it to where it was needed and did odd jobs as well and sixty hoisters, who prepared the rigging, rigged, tarred and painted the ships and could be employed in the loading and unloading of ships. Finally, there were six sailors who were crew on the yacht belonging to the chamber Rotterdam but who did odd jobs on the yard on a part-time basis.[42]

---

[34] Deurloo (1971), pp. 9-10
[35] According to Lucassen (2004), p. 29 "about 300 guilders a year"
[36] Lucassen (2004), p. 29
[37] Van Kampen (1953), p. 105. Van Kampen based these details on research in the Municipal Archives of Rotterdam (G.A.R.), especially in the so-called Gifteboeken and the Archief Fabrieksmeesteren. Grimm (1994), pp. 17-23.
[38] Van Kampen (1953), p. 36
[39] Grimm (1994), p. 18
[40] Van Kampen (1953), p. 48
[41] Grimm (1994), p. 18
[42] Grimm (1994), p. 20

Returning to the shipyard Oostenburg, this yard can not only be thought of as a production site, but it can also be interpreted as a junction of hundreds of supply lines, through which raw materials and goods were shipped in, appropriated and transformed into complete merchantmen. Oak for keels, inner- and outer hulls, frames and other structural purposes was bought in Deventer, having been brought in from Munster. Pinewood was used for masts, yards, decks and cheaper fir for the galley, cabins and other accommodation. Oak kegs were manufactured at the Zaan area. Iron nails either came from Liege in the Southern Netherlands, or were made locally from either Spanish or Swedish iron. Anchors were made from an alloy of Spanish and Swedish iron. Ropes were made from Dutch hemp, sails from Dutch or French sailcloth. Tar for treating parts of the hull was imported from Russia. Resin from France, mixed with sulphur from Sicily, was made into a coating as a remedy against shipworm[43]. In this process the VOC yards, and specifically Oostburg, formed the centre of a complicated international logistical and technological network, or, to put it in other words, Oostenburg acted as a centre of accumulation.[44]

In its construction, the *retourschip* was therefore an international phenomenon, built by Dutch shipwrights from predominantly foreign materials, imported by the VOC, at a specialized VOC shipyard. Whereas sailors and soldiers, employed by the VOC, came from all over northwestern Europe[45], the shipwrights, carpenters and other workers at the yards were recruited locally and the job often was often handed down from father to son[46]. The manufacture of a *retourschip* can be said to reflect, in miniature, the workings of the VOC within the Republic. The VOC purchased – through Dutch merchants - spices, coffee, tea, textiles and porcelain abroad, accumulated these goods in its *retourschepen* for shipping to the Republic, re-accumulated them at its storehouses in the Republic, calculated the most profitable way of selling these goods and in doing so constructed a single, complicated enterprise, relying on the labour of foreign workers. Similarly, the VOC purchased materials for the building of its ships locally and from abroad, accumulated these at its shipyards, calculated the dimensions of the parts that constituted the ships, and used a local workforce to construct a single, complicated artefact, which in turn was used to serve the commercial interests of the company abroad, mostly manned by foreign sailors and soldiers.

1.3 The VOC ships

It took the VOC almost a century to develop a form of standardized *retourschip*, but even then the VOC still used various others types of ships. Particularly during the 17th century, the VOC used many types of ships of a rather bewildering variety, so much so that even contemporary writers seem sometimes puzzled[47]. The *retourschepen*, however, formed the mainstay of the VOC's fleet, increasingly so during the 18th century, and their development during that century will be discussed in the next chapters. To put the *retourschepen* into perspective, and to show how these ships developed, an overview will be given of the types of ships in use until the early decades of the 18th century. In an attempt to systematize, these ships have been divided into three categories; first the *fluit* (fluyt) and its later developments, next some small ships designed for fast sailing and finally the family of ships of which the *retourschip* forms the culmination. By choosing this systematization, two developments that happened rather simultaneously, can each be shown in a chronological order. The first development is originated with the *fluit* and the

---

[43] Van Kampen (1953), pp. 50-51
[44] The role of Oostenburg as a centre of accumulation will be the subject of a forthcoming article.
[45] Gaastra (2001/2007), p. 81 gives the percentage of foreigners as 60% in the case of soldiers and 40% in the case of sailors. These numbers are an average over the lifespan of the VOC. These percentages tended to increase in the course of the 18th century, for 1770 the numbers are 80% and 50% respectively.
[46] Lucassen (2004), p. 19
[47] To illustrate this point Bruijn e.a. (1979-1987) quote Witsen (1671) (in Part 1, p. 40 - footnote 12) and Van Dam (1701/1927) (in Part 1, p. 42 - footnote 19)

other led to the *retourschip*. Because the small, fast ships, which were also used by the VOC, do not fit into any of the two main categories, they have been combined within a separate, independent, group. It should be noted that developments, regarding a certain type of ship, show an interactive relation between the design of the vessel and the VOC in action. This interactive process was aided by the fact that the VOC built its own ships on its own yards, even if its shipwrights were quite often independently minded as will be shown in the next chapters.

1.3.1 The *fluit* family[48]

Around 1595 the *fluit* was developed in the town of Hoorn, probably with the purpose of shipping and trading with the Baltic in mind. The *fluit* was a middle-sized ship, with a very narrow deck, designed specifically that way to prevent having to pay a heavy toll in the Danish Sont. This gave the ship a very characteristic, bulbous appearance. The ships were small enough to be run with a small crew and large enough to be quite seaworthy and were capable of carrying a relative large payload of 300-500 tons[49]. The *fluit* was designed in such a way that the carrying capacity per crewmember was maximalized[50]. They were lightly built, which made for a short lifespan, but which at the same time led to a cost price that was about 40% lower than elsewhere in Europe[51]. Richard W. Unger[52] writes "the importance of the two small provinces of Holland and Zeeland within Europe and beyond in the seventeenth century depended on the ability to offer shipping services for less, to exploit the wind more effectively".

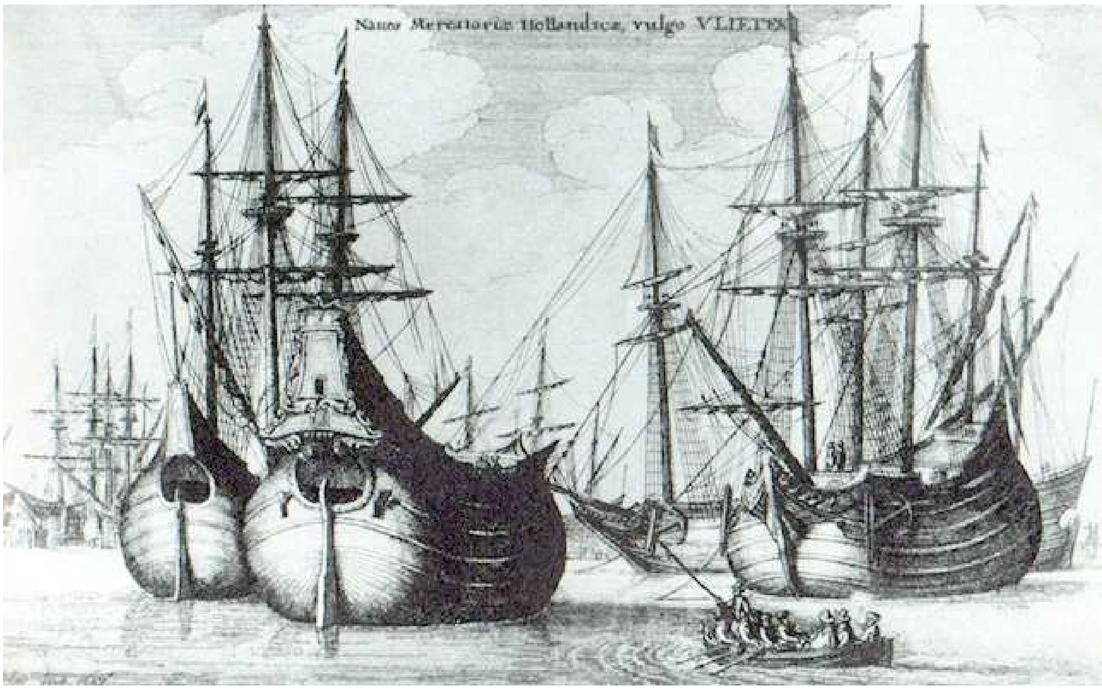


Fig. 1.1 Dutch *fluit* ships, engraving by Wenzel Hollar (1647). The porthole in the stern of the ships to the left shows that these ships were adapted for the transport of wood. Picture retrieved through http://en.wikipedia.org/wiki/File:Fleuten_1647.jpg

The design of the *fluit* was, according to Unger[53], vital to the success of Dutch shipping and contributed to low building and operating costs. The success of the *fluit* meant that it was used

48 A rounded stern characterized all ships in the fluit family
49 An approximate conversion into modern measures.
50 Unger (1978), p. 44
51 Unger (1978), p. 44
52 Unger (1978), p. 22
53 Unger (1978), p. 45

for many different purposes in its original form. In due course, the *fluit* was adapted to suit specific circumstances (e.g. the Baltic, the Nordic seas, the Mediterranean or the Atlantic coast of France and Spain) or a specific trade (e.g. whaling, wood transport, salt transport). In 1714 and again in 1718 the VOC had a series of four *fluits* of 130 ft. built, especially for the transport of sugar[54]. These sugar *fluits* had an upper deck without superstructures to enable them to be manned by a minimal crew (seventy-six on the outward voyage and sixty-six on the homeward voyage)[55]. Adaptations such as these led to the fact that by the middle of the 18th century there no longer existed one single type of *fluit*, but many different variations on the original basic design instead[56]. In the case of the VOC, the original *fluit* proved rather problematic in the tropics, because exposure of the curved hull to the sun caused the planks to dry out and the caulking to disintegrate. This problem was partly remedied by redesigning the *fluit* to give it a less narrow deck and by building the *fluit* more solidly than usual.

The *katschip* (catbark) was a fluit with details incorporated from the *boeier (*boyer*)*[57] (originally a vessel designed for inland waters, but later in a slightly enlarged form used for trips across open sea to France, England and even Iceland). They were rather small, about 100-120 ft. in length. As can be seen in figure 1.2, the stern displays typically rounded, boeier-like characteristics. The bottom was flat and the transition from bottom to sides was angular. The *katschip* had a rather squat appearance, and while being a slow ship, it could carry a large load and it only required a small crew.

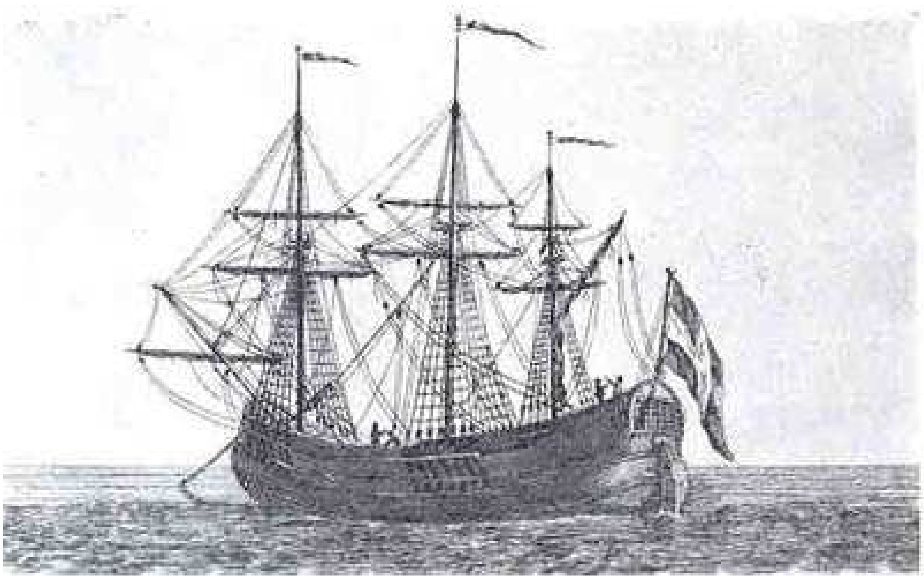


Fig. 1.2 A *katschip* (from the collection of "Hogskolen i Vestfold" – Biblioteket Norge). Picture retrieved through http://www.vaartips.nl/extra/kat.htm

The *hekboot* (sternship) was a mixture between a *fluit* and a *pinas (*pinnace*)*[58]. The lower hull was formed like that of a *fluit*, while the superstructure was designed after the *pinas*, and therefore much wider than the original *fluit* design. The result was an increased carrying capacity and more generous accommodation for the crew. Only a small number were built by the chamber Amsterdam. *Hekboten* and large *fluits* (like the sugar *fluit*) were used both for return journeys and trips within Asia, while small *fluits* and *katschepen* (these ships being smaller than

---

[54] ARA VOC 37 (9.3.1714)
[55] Bruijn e.a. (1979-1987) Part 1, pp. 44-45. For the reasons behind the difference in crewmembers on the outward and homebound voyages, see section 1.4.
[56] Unger (1978), p. 45
[57] Van Kampen (1953), p. 55
[58] Van Kampen (1953), p. 55. For more on the pinas see the section on the "retourschip family".

the smallest charter of *retourschepen*) usually stayed in Asia after their first outward journey. They were used for transport between the different factories of the VOC on the mainland of Asia and Batavia, and within the Indonesian archipelago.

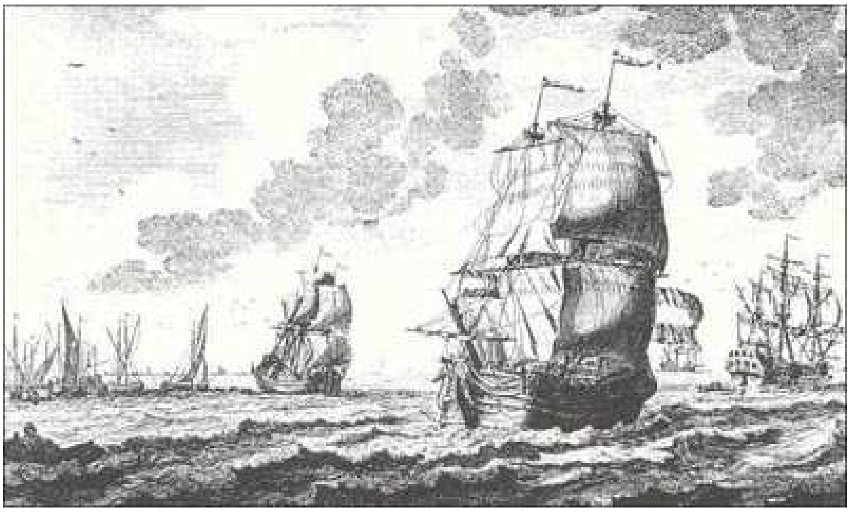


Fig. 1.3 "Een Hollandse Hekboot in zijn wenden Leggende". Etching by A. van der Laan, ca. 1720. In the background left a *fluit*, in the centre the *hekboot*; in the background far right possibly a *retourschip*. Picture retrieved through http://www.vaartips.nl/extra/hekboot.htm

1.3.2 Fast ships[59]

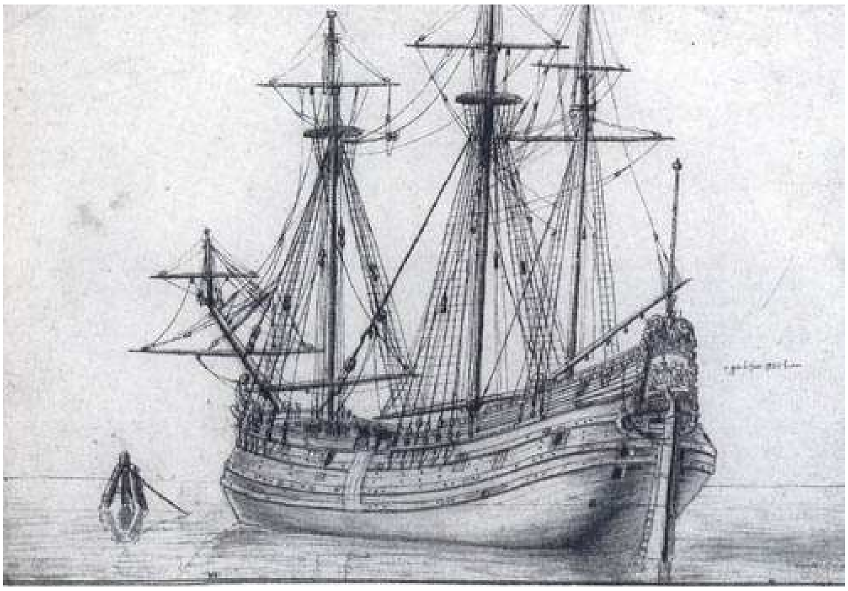


Fig. 1.4 The VOC *galjoot Zuilen*, drawing by G. Pompe. The *Zuilen* was built in Amsterdam in 1657, left Holland in October 1658 and arrived in Batavia in August 1659. In 1671 the ship was sold locally for breaking up[60]. Picture retrieved through http://www.vaartips.nl/extra/galjoot.htm

The *galjoot* (galliot) was originally a small, two-masted ship equipped with leeboards[61], a rounded bow and stern, and it carried fore-and-aft sails. Later the hull got a more slender design, which made it possible to operate the ship without leeboards. The length of the hull also increased, which led to a three-mast design with square sails, as is shown in fig. 1.4. The *galjoot*

[59] A category containing a number of different designs for small, fast ships
[60] See http://www.inghist.nl/Onderzoek/Projecten/DAS/detailVoyage/92016
[61] Van Kampen (1953), p. 55

was a rather fast ship, and was used for transport between the VOC factories in the Dutch East Indies.

Fig. 1.5 A two mast *hoeker*, etching by G. Groenewegen (1754-1826). Picture retrieved through http://www.vaartips.nl/extra/hoeker.htm

The *hoeker* (hooker) was a design, originating from the Rotterdam/Maassluis area, as shown in fig. 1.5. Originally designed for fishing, it was turned into a merchantman, and could be equipped with three masts[62]. The chamber Rotterdam built a series of this design in the late 1660s, which were used as wartime despatches and stayed in Asia afterwards. About a century later, a small series of a later development of the hoeker was built for fast and regular service between Holland and the Cape[63].

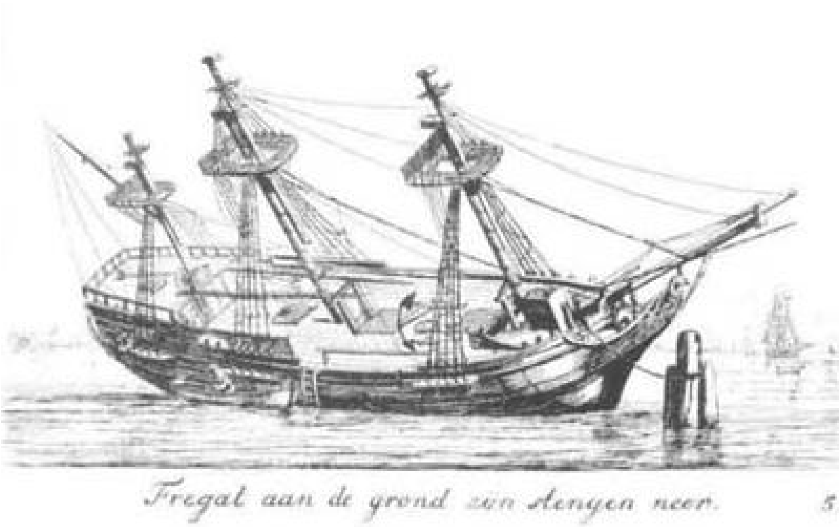


Fig. 1.6 A *fregat*, being careened to make repairs to the hull, with its topmasts removed. Drawing by G. Groenewegen (1754-1826), retrieved through http://www.vaartips.nl/extra/fregat.htm

In the late 17th century, a few ships of the type *fregat* (frigate) were built. These ships should not be confused with the naval frigate, but they were rather small ships (about 100 ft. in length, and they might therefore be called a *jacht* (yacht) or a *pinas*[64] as well) and, according to Van Dam, they were "made of light wood and designed for fast sailing".[65]

---

[62] Van Kampen (1953), p. 56
[63] Bruijn e.a. (1979-1987) Part 1, p. 41; see also section 4.4.1
[64] For more on the jacht and the pinas see the next section on the "retourschip family".
[65] Van Dam (1701/1927), p. 475. In Dutch: "*ligt van hout en te bouwen op de seylagie*".

1.3.3 The *retourschip* family[66]

The *jacht* was the result of a development of the medieval *kraak* (carrack), which in turn was a large version of the *karveel* (carvel). The rounded stern of the *kraak* was changed into a high, square stern, which sometimes was adorned with elaborate carvings, and this redesigned kraak was called *galjoen* (galleon). The *galjoen* usually had three masts and it was a reasonably fast sailer. A small version of this *galjoen* was called *jacht.* The VOC used the larger versions as well, and these were sometimes also called *jachten*. Therefore, a *jacht* could either be relatively small (80 - 100 ft.[67] in length) or relatively large (120 – 135 ft.). Both versions had not much in the way of superstructures fore and aft. After their first trip, they usually stayed in Asia. It seems that whether a ship was called a *jacht* or a *retourschip*

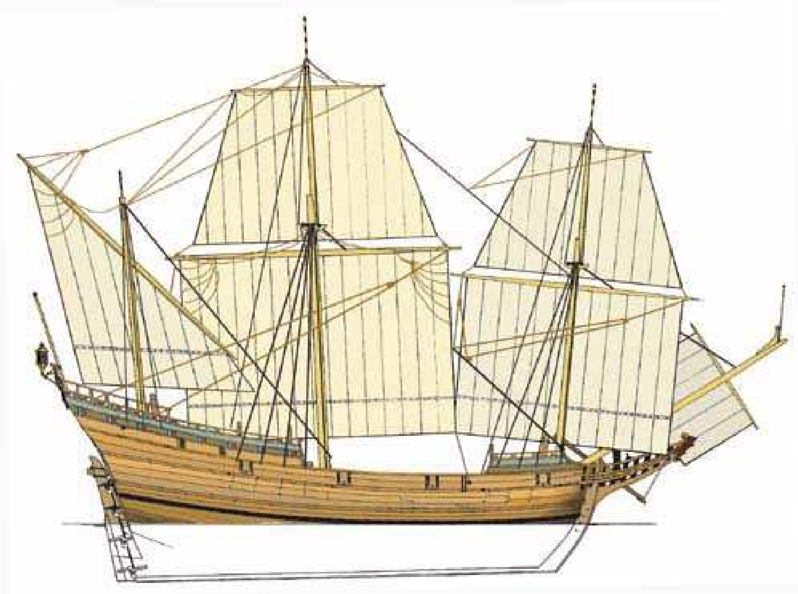


Fig. 1.7 Working drawing of the *jacht Duyfken,* created by Nick Burningham, maritime archaeologist and designer of the Australia built replica. Picture retrieved through http://www.duyfken.com/CurrentVoyage/GalleryEntry.asp?id=1668

depended more on the function of the ship than on its outward appearance[68]. During the second half of the 17th century, the name *jacht* disappeared and was replaced by the name *pinas*.[69] It can therefore be argued that jacht and pinas are one of a kind, a suggestion supported by Van Dam, who describes a few ships, built in 1662, as *jacht* as well as *pinas.* According to Unger, the *pinas* was a naval, heavily armed version of the *fluit*[70]. This suggestion is not convincing because the *pinas* has a square stern whereas the *fluit* has a rounded stern. The suggestion by Bruijn e.a.[71] that the *pinas* had much in common with the (square sterned) small *jacht* seems more plausible. Both writers agree in that the armed *pinas* was used as merchantman on routes with a high risk of piracy or where conflicts with other colonial powers were expected. Ultimately the *pinas* was developed into either the naval ship of the line or – as was the case with the VOC – into the *retourschip* (East Indiaman). In fact, as can be seen in Van Dam[72], the name *pinas* was often used to denote a *retourschip*, which is not surprising as the development of *pinas* into *retourschip* gradually took place at VOC's own shipyards[73]. Whereas originally the word retourschip was

[66] A square stern characterized all ships in this family, at least until 1741, when a new design introduced a rounded stern for all three charters of retourschepen
[67] A foot is the Amsterdam foot, which equals 28,3 centimeters; each foot was divided into 11 inches.
[68] Bruijn e.a. (1979-1987) Part 1, p. 39
[69] Van Dam (1701/1927), p. 470
[70] Unger (1978), p. 46
[71] Bruijn e.a. (1979-1987) Part 1, p. 39
[72] Van Dam (1701/1927), pp. 480-492 & 498-499
[73] Innovation and standardization of the retourschip will be discussed in more detail in chapters 3 and 4.

used to denote the use that was being made of a ship, during the 17th and 18th century standardized types of ships, derived from the *pinas*, were built specifically for use as *retourschip*. These (rather heavily armed) *retourschepen* formed the mainstay of the VOC fleet. They were built in three different sizes or charters, which were subject to change on a regular basis.

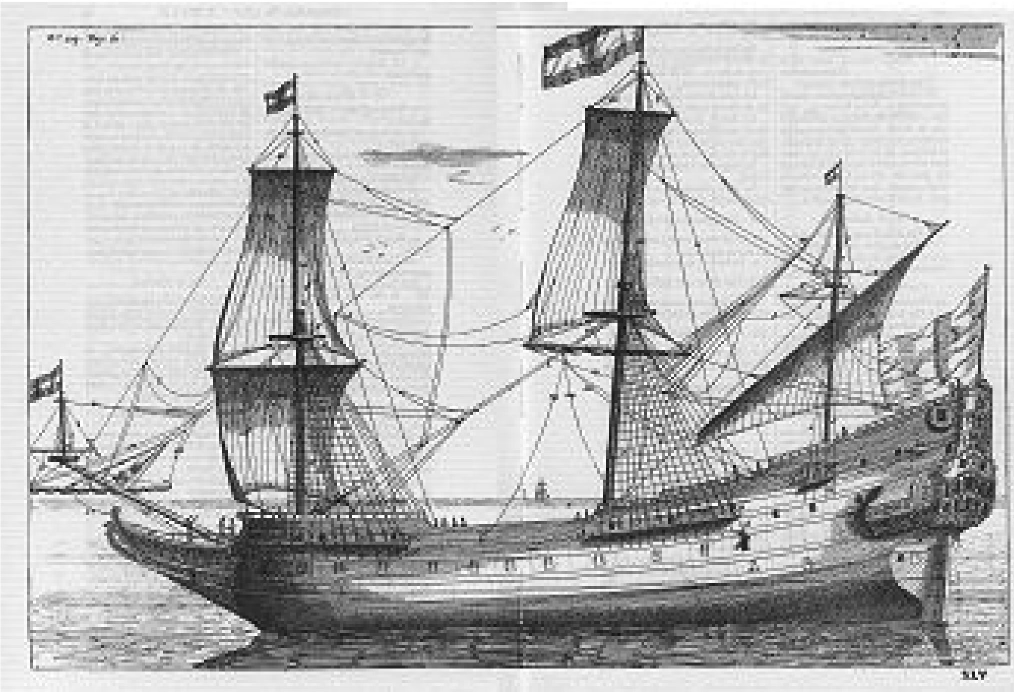


Fig. 1.8 A *pinas*, drawing in Nicolaes Witsen "Aeloude en Hedendaegsche Scheepsbouw en Bestier"(1671). Picture retrieved through http://www.vocsite.nl/schepen/scheepstypen.html

Quite remarkably, there was a north/south split in the way shipyards in the Republic, and therefore also the VOC-yards, built their ships. The northern yards (Amsterdam, Hoorn and Enkhuizen) employed a method of building *shell first*, meaning that the hull of the ship was constructed, partly with the help of preliminary frames, before the main frames were put in place. In contrast, the southern yards (Rotterdam, Delfshaven and Middelburg) favoured more of a *frame first* method whereby a few main frames were put in place before the hull was constructed[74]. This meant that the southern system of shipbuilding showed some similarities to the English and French way of shipbuilding, which used a proper frame first method, meaning that between ten and twenty main frames were put in place before the hull was built.[75] To be able to use such a frame first method it is necessary to work the design of a ship out in technical drawings prior to building, a system that had been developed in England from the 1580s onwards and in France from the last decades of the 17th century onwards[76]. Why and when the split in building methods in the Republic occurred is not clear. In his description of Dutch shipbuilding, Witsen (1671) only mentions the northern method; a quarter of a century later Van IJk (1697) just mentions the southern method. In the course of the 18th century, at the Amsterdam admiralty and later at the six VOC yards, English shipwrights introduced the English frame first system, together with the use of technical drawings. However, by that time some Dutch shipwrights were already developing technical drawings themselves and adapting their building methods to suit their designs. The introduction of the English method led to a

---

[74] These building methods (and later developments) will be discussed more extensively in chapter 3.
[75] For the similarities and differences between the English and the French methods, see section 2.2.2 and Hoving & Lemmers (2001), p. 40 "English/ British" and p. 69 "French". For illustrations putting the English and Dutch methods into perspective, see section 2.3.1 (fig. 2.6 & 2.7) and section 3.3 (fig. 3.4 & 3.5). Also Hoving & Parthesius (1991) pp. 5-11 and Hoving & Lemmers (2001), p. 23 "shell-first" (Witsen/North), p. 53 "frame-first" (Van IJk/South), p. 72 "Van Zwijndregt" (Rotterdam).
[76] McGee (1999), p. 222

significant controversy between English shipwrights and Dutch shipwrights, especially as far as the admiralties were concerned. In this controversy, shipwrights from Rotterdam and Middelburg, although having developed technical drawings and employing building methods rather similar to the English method, also opposed the English shipwrights and their methods. This dispute will be described and discussed in the next chapters.

1.4 The VOC retourschip: characteristics, role and metaphor

On its journey, every *retourschip* carried building blocks for the construction of an empire, both outward bound towards the East Indies and homebound back to the Republic. On the outward journeys, actual building blocks were transported, because on these trips the ballast was made up of large quantities of bricks, ordered by the VOC's officials in Batavia to build the company's premises overseas[77]. However, other materials, goods and persons can be interpreted as building blocks as well. Precious metals, soldiers and sailors carried on the way out, and spices, coffee, tea, textiles and porcelain carried on the way home, they all contributed to the building of the VOC's empire. This interactive role played by the *retourschip* within the VOC will be discussed in this section.

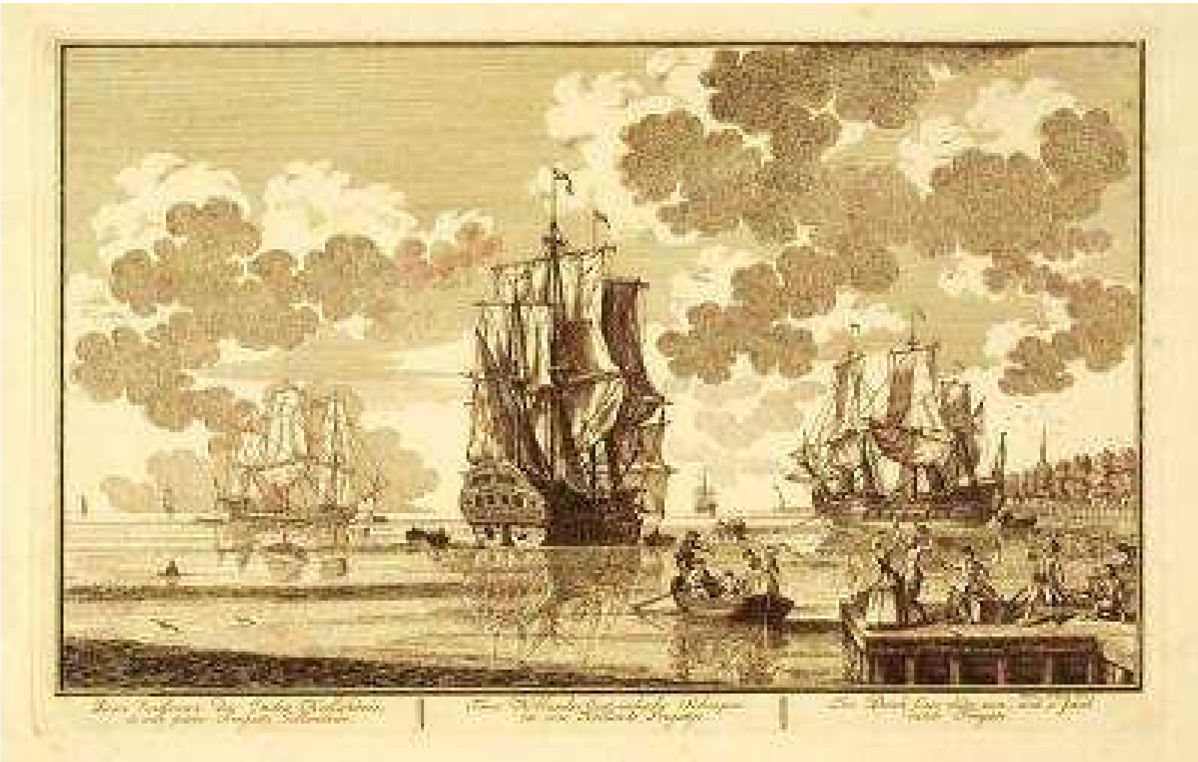


Fig. 1.9 "Two Dutch *retourschepen* and a Dutch *fregat* in quiet conditions in a roadstead. The ship in the middle is the *Castricum*[78]. On the jetty a jolly party with women, drinks and music" (P. Schenk, ca. 1750) © Nederlands Scheepvaartmuseum, Amsterdam

[77] Dash (2002), p. 69. In the local museum in Geraldton (Western Australia), the original prefabricated, classicistic gateway can be seen that was carried as ballast in the bilges of the retourschip Batavia. In the maritime museum in Fremantle (Western Australia), the reconstructed original stern of the retourschip Batavia sits on yellow cobblestones, also carried as ballast.

[78] The *Castricum* was the third ship of this name. It was built at the Oostenburg yard in Amsterdam for the chamber Amsterdam in 1722, its tonnage being 1150 tons. The ship made seven return trips to the East, stayed in Asia after its eighth outward voyage in 1736, and was laid up in Batavia in 1743. As can be seen in the picture

A *retourschip*, as was usual in the case of large ships, had two complete decks, the lower of which was called *overloop (*orlop or gun deck*)* and the higher *verdek*. The lower hold, below the *overloop*, was used for stowing goods and provisions, the space between *overloop* and *verdek* contained accommodation for sailors and soldiers. On top of the verdek, another deck was constructed in two parts, at the stem called *bakdek* and after the mainmast called *halfdek*. On this *halfdek*, the cabins for the officers, merchants and passengers were located near the stern of the ship. The lower part in between these decks was called the *kuil* (waist). In the late 18th century, this deck in two halves was developed into a complete deck, called *bovendek* (top deck)[79]. The sailing plan was made up of a three-mast configuration, the masts being high to take as much advantage of the light winds in the tropics as possible. Yards carried high and rather narrow sails. Only the foresails and the mizzen sail were of a fore-and-aft configuration, the main sails being square[80].During the course of the 17th and 18th century, the dimensions of the *retourschepen* continued to be adapted. Their length varied between 130 ft. and 160 ft., they tended to get wider and at the same time to get a more shallow effective draught and as a result, their carrying capacity increased from the original 400-500 tons to about 1200 tons for the largest charter. This increase in carrying capacity had originally a detrimental effect on the ship's speed[81], and on the seaworthiness of the ships[82], the effects of which will be described in the next chapters.

Once the artefact *retourschip* was completed – as described in section 1.2 - it was sent on its way to fulfil its role. On the outward voyage, it carried gold and silver, to be traded against spices[83], but it also transported dozens of soldiers and was manned by far more sailors than were actually needed on the voyage[84]. The soldiers materialized the powers that were bestowed on the VOC by the States-General to act as a state overseas, and they were obliged to stay for at least five years in Asia. The power embodied by the soldiers was vulnerable, though, through their high mortality in the East Indies, and therefore new soldiers had to be shipped out on a very regular basis. The surplus of sailors on any outward voyage made it possible that there were sufficient crewmembers for a competently manned return voyage, because sailors were vulnerable as well. As far as crewmembers were concerned, the inevitable death toll on the way out and the fact that some of them deserted during the outward journey, had to be taken into account[85]. Even more important was the fact that almost all sailors had to stay in Asia to serve their three-year contract by operating ships in the intra-Asian traffic, an occupation they might not survive[86]. Sailors therefore contributed to the building of VOC's commercial empire in the East Indies by operating *retourschepen*, and by operating the local Asian VOC-fleet as well.

During the voyage, both outward bound and homebound, the person ultimately in charge of the *retourschip* was not the skipper but the upper-merchant and his deputy, the under-merchant. While the skipper was still responsible for matters of navigation and sailing, the merchants

---

the ship has a square stern, which confirms that it was built before 1741. Details retrieved through http://www.inghist.nl/Onderzoek/Projecten/DAS/voyages?clear=1&field_voynameship=CASTRICUM

79 Van Bruggen (1976-1978), p. 32

80 Van Bruggen (1976-1978), p. 42-44

81 Unger (1978), p. 47

82 As mentioned by Kist (1985), p. 9.

83 In addition, during the 18th century textiles, tea, coffee and porcelain also made up an important part of the return cargo.

84 E.g., the Castricum pictured earlier usually carried up to 120 soldiers and about 160 sailors on its outward voyages. On the return voyages however, it hardly carried any soldiers and the number of sailors on board was reduced to less than 110. For details see http://www.inghist.nl/Onderzoek/Projecten/DAS/detailVoyage/93566 and further. In general, as far as individuals were concerned, the rate of return for soldiers was between 19 and 30%, rate of return for seamen between 40 and 60% (Lucassen (2004), p. 16)

85 Bruijn e.a. (1979-1987) Part 1, p. 161-167 gives a rate of mortality of between 7% and 15% on the journey from the Republic to Asia, well above the rate of mortality of 4% that was to be expected in the Republic.

86 Bruijn e.a. (1979-1987) Part 1, p. 169-172 estimates that between half and two-thirds of those staying in the East Indies to serve their contracts, died before they could return.

could order the skipper to stay in port or to make sail when the interests of the company required[87]. This arrangement mirrors the impression that profitable trade was the first and utmost consideration as far as the VOC was concerned.

On the return voyage the *retourschepe*n were heavily loaded, if not overloaded with spices. Moreover, ships could be in a poor condition because of their stay in the tropics, especially if they had been used for traffic within Asia between their outward bound and homebound journey. Quite remarkably, no major repairs were carried out in Batavia or elsewhere in Asia, although hulls were cleaned and re-caulked locally. Masts and yards could be replaced, as is shown by the fact that the *Heeren XVII* considered building specialized ships for the transport of voluminous goods, such as masts, to Asia[88]. Any structural overhaul of the hull had to wait until the ships arrived back in the Republic. As mentioned earlier, the homebound crew was much smaller than the crew on the outbound trip. All these factors combined to make the homebound voyage much more dangerous: the number of ships that perished on the voyage home was at least twice the number of the ships being wrecked on the outward voyage[89]. However, upon arrival in patria, the value of the cargo was almost three times as valuable as the amount of precious metal and other goods shipped out[90]. Therefore, while on the outward voyage the *retourschip* acted as a building block for the construction of VOC's empire overseas, on the homeward voyage it was a floating, overloaded warehouse full of spices, generating large profits for the company and in that way again acting as a building block.

The way in which a *retourschip* operated thus reflects the workings of the VOC abroad, building a private-public commercial empire spanning the globe, created by an international labour force, and intent on making large profits on the sale of produce and goods from the East Indies and Asia[91]. As was discussed in section 1.2, the way in which the *retourschip* was built reflects the way the VOC operated within the Republic. Therefore, through its building process and its operations, the artefact *retourschip* can be interpreted as a metaphor for the VOC as a whole, not just as a passive metaphor but as a dynamically interactive metaphor as well.

1.5 The VOC retourschip: the early standardization of an artefact

As indicated in section 1.3, during the 17th and early 18th century the design of ships, such as the *fluit*, was continually adapted to changes in use. In addition, different designs were combined and crossovers, combining advantages of two designs, were built. Therefore, the suggestion[92] that the main characteristics of hull design and sailing plan of the (Dutch) merchantman were established - in the form of the original *fluit* - as early as the beginning of the 17th century seems not quite convincing. A consequence of this suggestion, namely that the rest of the 17th and the 18th century can be characterised as a period of small changes within an existing paradigm[93] of ship design and shipbuilding, can be questioned as well. If such a paradigm did exist, then a standardized design could make it more interesting for merchants and shippers to concentrate on aspects of price rather than on aspects of technological innovation[94]. The development of more specialized and efficient ships of different sizes seems to point in the opposite direction, showing adaptation to the different purposes these ships were used for, be it either for use on the high seas, in coastal waters or on inland waters or on the other hand for whaling, wood

[87] Dash (2002), pp. 3-4
[88] Bruijn e.a. (1979-1987), p. 90. On the building of specialized transport ships: cf. section 3.2
[89] For actual numbers, compare Bruijn e.a. (1979-1987), Table 13 (p. 75) with Table 22 (p. 91)
[90] Gaastra (2001/2007), Tabel 19 (p. 137) and Tabel 21 (p.147).
[91] Although, in the end, the returns were not sufficient to finance the operation of the VOC as a whole.
[92] Unger (1978), p. 59
[93] Unger (2008), pp. 31-32
[94] Unger (1978), p. 84

transport or salt transport. Moreover, as not all of these ships belonged to the extended *fluit* family of ships, and therefore several of these ships had either a different hull design or a different sailing plan, the conclusion might be drawn that the paradigm of the *fluit* as the single, standardized design of the merchantman in the 17th and 18th century is questionable. Especially in the case of the VOC, if one considers the many different types of specialized vessels used by this company, it is difficult to detect any form of standardized design.

However, a different development can be detected if one looks more specifically at the *retourschepen* of the VOC. From the early 17th century onwards, in resolutions drawn up by the *Heeren XVII*, the main dimensions (length, width and *holte,* i.e. height of the lower hold or draught[95]) of these vessels were established. In 1614, the standard lengths of the three charters were mentioned as 150 ft., 138 ft. and 130 ft.[96] Van Dam does not explain why these lengths were chosen, but a reasonable guess might be that in doing so the *Heeren XVII* tried to fit these charters in with the way ships were already being built. Such a (re)invention of a new class of ships, emerging from older types could be called a "conservative invention"[97]. However, chambers kept building larger ships than the charters permitted so that an increase in carrying capacity might get them a larger share of the returns[98] . In 1626, this led to a maximum length of 160 ft. being sanctioned. The fact that the dimensions were given in rather global figures meant that the individual master shipwrights at the six VOC-yards had quite some leeway to interpret these dimensions and to proportion the hull as they saw fit, as is shown by comments by Van Dam. He wrote about the situation in 1616: "In order to better comply with these rules, as soon as the hull is finished two representatives of neighbouring chambers should inspect it and two neutral shipwrights should accurately measure length, width and draught; and if any fault or excess should be discovered this should be paid for personally by the directors (of the chamber in question)…".[99] Although all of the Heeren XVII signed this resolution in person, it did not work out as expected. Van Dam keeps mentioning that chambers did not adhere to the rules, which the *Heeren XVII* themselves kept changing on a regular basis.

On April 4 1697, the *Heeren XXVII* tried to settle the design and dimensions of the three charters of retourschepen once again. After extensive consultations with the master shipwrights of the six yards, the charters were defined as [*160 ft x 40 ft x 17 ft*], [*145 ft x 36 ft 8³/₄ in x 15 ft 7³/₄ in*] and [*130 ft x 33 ft 6½ in x 14ft 4½ in*]. In addition, it was permitted to build ships of the 130 ft. charter in the shape of a hekboot or a fluit (i.e. with a rounded stern instead of with a square stern) and a smaller ship could be built for service within Asia[100]. Not only did the *Heeren XVII* define the main dimensions of the ships, they also standardized in detail the position of the masts, the dimensions of all sorts of parts, the size of the sails, the size of anchors and the amount of ropework, and even the type of wood that should be used for different parts[101]. This suggests that by the end of the 17th century, the VOC had turned the art of shipbuilding into an

[95] Hoving & Parthesius (1991), p. 8 and Parthesius (1994), p. 13. The *holte* was measured between the bottom and the top of the lower hold. The top of this hold more or less coincided with the supposed waterline of the vessel. However, due to the problems in predicting the carrying capacity and the amount of cargo and supplies that were actually carried, the effective draught might be larger or smaller than the *holte*. This problem was partly addressed by Hendrik Decquer (a member of the board of the VOC) in a book published in 1688 (see also section 4.1). Decquer suggests on page 30 of his book that the effective draught on the outward journey was usually about five feet more than the *holte*.
[96] Van Dam (1701/1927), p. 460
[97] In general, Hughes (1987), p. 57 and more specifically Fleischer (2007), pp. 155-158. For more on this type of inventions regarding ships and shipbuilding, see section 3.2
[98] Van Dam (1701/1927), p. 461
[99] Van Dam (1701/1927), p. 461. In Dutch "*opdat sulcx te beter soude mogen werden onderhouden, dat alle schepen wanneer het hol gemaakt is, door twee gecommitteerdens uyt de naastgelegen Cameren souden worden gevisiteert en by neutrale timmerlieden perfectelijk in lengte, wytte en diepte gemeeten; en daarinne enige faut of exces bevindende, gelaten werden tot particuliere laste en kosten van Bewindhebberen (…)*"
[100] Bruijn e.a. (1979-1987) Part 1, p. 38 & 42
[101] Van Dam (1701/1927), pp. 493-496 and 501-504

assemblage of prefabricated, exchangeable parts. As far as the form and the dimensions of the hull were concerned, a procedure was put in place to check at nine equidistant frames on five points each the prescribed width and draught[102]. At the same time, a more strict control on compliance with these rules was introduced, whereby the responsibility shifted from the directors to the master shipwrights themselves. Van Dam wrote: "the master shipwrights shall forfeit 500 guilders, if they are found to have violated the charters for the first time (…) and for the second time 1000 guilders (…) And when they violate the rules for the third time they will be dismissed" [103]. To put matters into perspective, at that time master shipwrights were paid about 1700 guilders per year[104]. It seems that the *Heeren XVII* were intent on settling the charters definitely, not as previously by holding the directors of the local chamber responsible but through sanctions on the level of the shop floor. The existence of three different classes or charters of these ships, coupled with the fact that these ships were built on six different yards, added to the complexity of the building process and resulted in an increase in management activities to control the way these ships were built.

To generalize, the VOC was trying to establish a regime for efficient and fast production of these ships, in an effort to manufacture large numbers of a reliable and predictable standard design. This development took place within the context of dynamic developments in its activities, and therefore this process of standardization cannot be seen as anything static or as leading to a predefined endresult. It is intricately linked to and co-constructed with the way the VOC developed as a whole.

Unger has suggested[105] that during the 16th and 17th century, an increasing volume of trade on certain routes triggered standardization in shipbuilding and design, whereas in the 18th century any tendency towards standardization was brought about by government intervention. This was – as supposed by Unger - shown in the way the Dutch admiralty operated. However, the Dutch admiralty consisted of five separate and rather independent admiralties, only one of which went through a process of standardization, as will be discussed in the next chapter. For a more convincing example of a centralistic intervention by a government, one has to turn to the case of the London dockyards during the late 18th century, as described by Schaffer[106]. In the Dutch Republic, the case of the VOC-retourschip in the late 17th and in the 18th century shows an interesting and complicated example of standardization, linked with innovation in design and building techniques, and interactively tied to the activities of the VOC. It could be said that the relation between the developments in shipbuilding and the ongoing process of VOC-building is one of co-construction [107].

In a paper, discussing different aspects of standards and standardization O'Connell describes how standards are socially constructed on two levels[108]. The first level of social construction is linked to interactions between different groups of humans concerning non-human entities, or - in other words - how humans translate definitions into practical measures. In the case of the VOC, examples of this level of construction are the agreement on the unit of length to be used or on the way the hull of a *retourschip* should be inspected, as can be recognized in the consultations leading to the decisions of 1697. The second level of social construction is concerned with the construction of a (hybrid) society of material collectives, on the one hand consisting of persons (and/or institutions consisting of humans) and on the other hand of

---

[102] Van Dam (1701/1927), pp. 497-500
[103] Van Dam (1701/1927), p. 476. In Dutch "*dat de meesters-scheepstimmerlieden, de (…) charters (…) overtredende, voor de eerste maal zullen verbeuren f 500; voor de tweede maal f 1000 (….). En voor de derdemaal worden gedeporteert*"
[104] Gawronski (1996), p. 81
[105] Unger (1978), p. 59
[106] Schaffer (2007)
[107] More on this in chapter 3 and 4.
[108] O'Connell (1993), from p.137 onwards and from p.147 onwards

material objects representing technological entities. In the case of the VOC, an example of such a society might be found in shipwrights employing the innovative use of technical drawings and standardized moulds and models to construct *retourschepen*. The construction of this hybrid society was a long process, which was in fact not completely realized before these innovations were introduced and adopted in the middle of the 18th century[109]. Until then, most objects within the hybrid society consisted only of texts and procedures and not of artefacts. However, this hybrid society did not exist on it own, but was intricately linked to the construction of the society of the VOC.

On standards and standardization O'Connell takes a rather pragmatic (and materialist) perspective: science and technology are not just matters of ideas, but these ideas have to be materialized at a certain place at a given time, be it in the form of texts (e.g. a list of specifications[110]), artefacts (e.g. a ship's model or a mould[111]) or procedures (e.g. such as those dating from 1614 or 1697, as mentioned by Van Dam). It is, however, a matter of debate whether ideas always lie at the root of materializations. It is quite possible that some material object leads to an idea, which is subsequently formalized. That could imply that standards may be negotiated and transferred in a not-too-material way as procedures or concepts. Materialized ideas or conceptualized objects are able to circulate through different communities, eventually leading to universal acknowledgement by all concerned. For this communication to be intelligible across different localities, a certain amount of standardization is needed, because not only should these localities speak the same technological language, but also any numbers used in this language should carry the same meaning for everyone. This means that there needs to be agreement on standards (e.g. the Amsterdam foot as the standard unit of length in VOC's shipbuilding). However, such an agreement on basic standards cannot be imposed, but needs to be achieved through a form of circulation as well. This suggests a two-tier system, a circulation producing an agreement on standards and a circulation of materialized ideas leading to a universally acknowledged and accepted standardized technology. However, these circulations are not independent of each other, as it seems hardly possible to have a discussion on standards without already taking into account the underlying technological content. Once a form of standardization is in place, it has to be implemented which means that there is some scope for local variation, depending on how strict the definition of the standard has been constructed. For instance, the standardized dimensions of the *retourschepen*, as per 1614, granted local shipwrights more room for variation than the standards of 1697.

Returning to O'Connell's first level of social construction, one could ask which humans or groups of humans were actually translating definitions into practical measures as far as ship design and shipbuilding is concerned. In the case of the VOC, one can look two ways, either towards the guilds of shipwrights or towards the management of shipyards. Until well into the 17th century, guilds of shipwrights circulated technological skills and knowledge between guild members and circulated equipment between guild members that was too expensive to be owned by a single guild member. According to Unger, during the 17th and 18th century guilds in most of Europe (e.g. England, France and Germany), became increasingly restrictive but less so in the Republic[112]. This can be linked with the Dutch economic prosperity in the 17th century, and with the unique political situation in the Republic. Political power was devolved at the level of the city, and regents, usually rich merchants and entrepreneurs exercised this political power. City councils assisted in the development of new shipyards[113], outside the city centre but they did not involve

[109] The way innovative artefacts were incorporated into the hybrid society will be discussed in chapter 3 and 4.
[110] Van Dam (1701/1927), Cap. 17. For more on this see chapter 3.
[111] Kist (1985) and Lemmers (1996), for more on this see chapter 3
[112] Unger (1978), pp. 64-65. See chapter 4 for more on this, where also remarks made by Epstein (1998, 2004 & 2006) will be discussed.
[113] E.g. the situation in Rotterdam, as mentioned in section 1.2 and in Amsterdam where the VOC moved to large premises at Oostenburg, situated outside the city centre (see also section 1.2 and chapter 2).

themselves in the processes of design and technological change. These aspects were left to the guilds, which in turn did not get involved in politics. During the late 17th and the 18th century, however, a shift can be noticed away from guilds as a union of independent owners of (small) shipyards towards a situation in which one guild member/entrepreneur entered into a contract with a (large) customer, employed other guild members and at the same time governed the guild[114]. This meant that most guild members were turned into employees instead of being small entrepreneurs themselves. Consequently, the guilds had less impact on technological and organizational aspects of shipbuilding, and shifted their focus of attention towards the regulation of pay and the organization of funds providing for sickness, accident and retirement[115]. This shift towards centralization was even more outspoken in the case of the VOC with its building of increasingly standardized ships in its own shipyards. The way in which shipbuilding was organized became more centralized, a centralization leading to an increased emphasis on administrative and political rules, and the responsibility for technological developments shifted away from workers on the shop floor to the master shipwrights or even the *Heeren XVII.* In chapter 4, the role of guilds and the link between guilds and the VOC will be discussed in more detail, including the role guilds started to play in politics. The centralization at the VOC therefore implies that the first level of social construction took place between the management of its six shipyards and the *Heeren XVII* instead of within the guilds. However – as will be shown in chapter 3 and 4 – a degree of localized independence still existed, which was probably dependent on the relation between the local VOC-chamber and its master shipwright.

A similar emergence of centralization can be found in the description of the 18th century Naval Dockyards in London[116]. Schaffer describes these dockyards as large enterprises with on the one hand specialization between separate shipyards and on the other hand a sophisticated system of division of labour within each yard. On an organizational level, this description mirrors what has been written about the Oostenburg yard of the VOC[117]. Schaffer[118] characterizes the military arsenals and dockyards along the Thames as laboratories on a huge scale and as localities where both theoretical and practical knowledge met. However, when the management of these laboratories tried to introduce innovations in the way labour was organized, by increasing the division of labour and by putting more emphasis on economical and financial criteria, the shipwrights saw such innovations as an infringement on what they considered to be their moral rights and their traditions. Similar sentiments can be noticed in the Republic as well, both at the admiralty yards and at the VOC yards, as will be shown in the next chapters.

According to Schaffer[119], this management project was supported by a second, intellectual, project to divide the design and the actual behaviour of (naval) ships into parts that were manageable by mathematical research. Such a division might in turn lead to a redefinition of skills and a redistribution of tasks that would link this second project to the centralization that was mentioned earlier, meaning that these projects were co-constructed. However, the VOC never seems to have entered into such mathematical research although the company was standardizing and innovating its ships and its shipbuilding. The only documented use of (albeit rather practical) mathematics occurred when the *Heeren XVII* tried to solve the problem of predicting the cargo capacity of newly built retourschepen. This (theoretical) cargo capacity was important for the attribution of profits to the individual chambers and for the toll a ship had to pay when it was ferried across the Zuyderzee. The actual carrying capacity was important when the return cargo had to be stowed at the start of the homeward run from Batavia. In 1688, Hendrik Decquer, a director of the chamber Amsterdam, devised a method to ascertain “in a

114 For more on this, see chapter 4.
115 Unger (1978), p. 97
116 Schaffer (2007)
117 Gawronski (2003) and Lucassen (2004) as discussed in section 1.2
118 Schaffer (2007), p. 282
119 Schaffer (2007), p. 290

mathematical way" the cargo capacity, by using the three main dimensions of the *retourschepen*[120]. He described his method in an illustrated book Middelen om uit te vinden de ware ladinge der schepen na hare grootte[121]. In chapter 2 and 4, the lack of (formal) mathematical research in Dutch shipbuilding will be discussed – not only as far as the VOC was concerned, but also in the case of the admiralties.

In chapter 3 and 4 it will be shown that non-human actants (be it storms at the Cape of Good Hope or the silting of Dutch estuaries or increasing trade volumes) and human actors (such as the States General questioning the monopoly of the VOC, shipwrights appropriating designs and the *Heeren XVII* getting a grip on the design process) were actively interacting and transforming the hybrid society that was being constructed. These interactions make it doubtful whether standards were really standardized once and for all. If one considers standards to be part of a (hybrid) society, it cannot be assumed that matters are settled, once definitive standards have been circulated as paperwork, procedures and equipment. Because of the impact of human and non-human actants, a society is never static, and therefore a hybrid society of standards within a greater society cannot be static either. This point is also illustrated by Raj[122] who shows that standards and equipment not only have to be, but also are in fact adapted to new situations with which they are confronted, implying an ongoing process of circulation, appropriation and adaptation.

Summary

In this chapter, the origins and the organisation of the VOC and its shipyards have been discussed. The organisational model of the VOC resembled the way the Republic was governed, a confederational model with a non-permanent central committee in which an important role could be played by some permanent employees. In the course of VOC's history, important matters tended to be devolved to a committee called Haags Besogne with close links to the government of the Republic. The VOC shipyards were organized in a pyramidal, hierarchical way and operated through an early form of division of labour.

The governing body of the VOC turned the eclectic mix of ships, used by the early VOC, towards the increasingly standardized design of the three charters of retourschepen. The design moved from an early definition, consisting of determining the three main dimensions only, via the standardization of more dimensions and proportions to the rather sophisticated system of 1697. This system described the main dimensions and the form of the hull, the position and size of masts and yards, the size of the sails, and the dimensions of all sorts of different parts, including the materials these parts should be made of. Responsibility for compliance with the new design shifted from the directors of the local VOC-chambers to the master shipwrights of the local shipyards. The art of shipbuilding changed over time into an assemblage or manufacture of ships, using prefabricated parts, of an increasingly standardized design. This change in working practice also influenced the way guilds operated, from an non-political organization of independent shipwrights concerned with the exchange of technological developments to a more politically oriented organization providing financial and social security – as will be discussed in chapter 4. The artefact retourschip was produced by a local workforce, using an accumulation of materials from all over Europe. The retourschip, used to accumulate merchandise in the East, and run by a crew consisting of Dutch officers and merchants and of predominantly foreign sailors and soldiers, has been interpreted as a material metaphor for the VOC, both in the way it was built and in the way it operated.

[120] Bruijn e.a. I (1979-1987), pp. 42-44
[121] In translation "Means to establish the true carrying capacity of ships in relation to their size"
[122] Raj (2002), p. 22

A more general discussion on standards and standardization was linked to the actual process mentioned before. In this discussion, a distinction was made between two levels of social construction. One of these is concerned with the translations of definitions into practical measures (e.g. the specification of the Amsterdam foot as the standard unit of length within the VOC), the other with the building of a hybrid society of material collectives (e.g. the – continually shifting - society consisting of shipwrights, materials, retourschepen, shipyards, directors of local VOC-chambers and the Heeren XVII). The ongoing building and rebuilding of this society will be discussed in the next chapters, linked with the introduction of innovative techniques and procedures in shipbuilding. It will be shown that English shipwrights were instrumental in introducing the use of technical drawings at the admiralty of Amsterdam in 1727, an innovation that – in due course - spread to all shipyards of the VOC, but not to other admiralties. Intriguingly, some Dutch shipbuilders were developing systems of technical drawings at the time, but their systems did not become generally known before the middle of the 18th century. The introduction of these drawings (as will be described in chapter 2) took place in an effort by the directors of the Amsterdam admiralty to react to criticism of its naval officers and to standardize naval shipbuilding. Shipping disasters, partially caused by ongoing changes in the design of retourschepen, and discussions about the way the VOC operated and about the continuation of its trading monopoly were intricately linked with the introduction and early adaptation of this innovative technology by the VOC, as will be shown in chapter 3. The way in which the VOC, its shipwrights and the guilds were interactively connected with innovative and standardized artefacts and procedures and how they kept recreating and expanding a hybrid society will be discussed in chapter 4.

2. Drawing up plans

In dit hoofdstuk verschuift de aandacht van de VOC naar de admiraliteit van Amsterdam. Gebeurtenissen binnen de marine als geheel en meer specifiek rond die admiraliteit leidden in 1727 tot het aanstellen van Engelse scheepsbouwmeesters daar en tot de innovatie van het gebruik van technische tekeningen bij het ontwerpen van schepen. In par. 2.1 komen de conflicterende doelen aan de orde die de marine van de Republiek moest realiseren, de gecompliceerde opbouw van die marine, problemen met het rekruteren van natuurkrachten en klachten van kapiteins van de (Amsterdamse) admiraliteit over de schepen die ze onder hun commando kregen. Zij vroegen om betere en snellere schepen die bovendien een voorspelbaarder gedrag zouden moeten vertonen. Inmiddels door-gevoerde innovaties waren blijkbaar niet afdoende geweest. De genoemde klachten leidden ertoe (par. 2.2) dat met hulp van kapitein (later luitenant-admiraal) Schrijver, Engelse scheepsbouwers in dienst werden genomen bij de admiraliteit van Amsterdam. Deze scheepsbouwers introduceerden het fenomeen van de technische scheepsbouwtekening en een bijbehorende bouwwijze. Deze technische scheepsbouwtekening wordt – naar Bruno Latour - geïnterpreteerd als een "immutable (and flexible) mobile". De Engelse scheepsbouwers en hun ontwerpmethoden werden met scepsis bejegend door de scheepsbouwmeesters van de overige admiraliteitswerven. Om te zien of de "Engelse" schepen inderdaad beter waren werden zeilwedstrijden georganiseerd, niet alleen in 1729, kort na de komst van de Engelsen, maar ook nog in 1753. Uit die laatste wedstrijd blijkt dat meer dan 25 jaar na de komst van de Engelsen hun aanpak en positie nog steeds omstreden was. Dat was eerder al duidelijk geworden uit het mislukte overleg dat er in 1747 toe had moeten leidden dat er uniformiteit binnen de verschillende klassen oorlogsschepen zou komen – een proces dat inmiddels binnen de VOC wél zijn beslag had gekregen en waarbij op alle werven van de VOC de nieuwe, innovatieve manier van ontwerpen werd ingevoerd (par. 2.3). In par. 2.4 wordt de innovatie van het invoeren van de technische scheepsbouwtekening en de nieuwe bouwwijze geïnterpreteerd als een radicale innovatie voor de Amsterdamse admiraliteit.

During the 18th century, Amsterdam possessed two large industrial enterprises. The local VOC-chamber Amsterdam owned and operated one of these in the form of its shipyard Oostenburg. The second large industrial enterprise was the admiralty shipyard[123]. This yard was situated on Kattenburg, the most westerly of three artificial islands, constructed in the 1660s[124]. The VOC occupied the most easterly of these islands, Oostenburg. The island between the VOC and the admiralty, Wittenburg, was home to a number of private shipyards and housed several shipwrights. Not only were the admiralty and the VOC close neighbours as far as their shipyards were concerned, there also existed direct and indirect connections on a personal level: directors of the VOC were councillors at the board of the Amsterdam admiralty (and vice versa) and there were connections through marriages between important families, members of which held posts in both the admiralty and the VOC. The similarities did not end there: the Dutch navy struggled with problems of standardization and innovation in much the same way as the VOC did at the time.

In this chapter, the focus shifts from the VOC to the Amsterdam admiralty. We need this change of perspective to describe how the innovation of technical design drawings was officially introduced and partly implemented in the Republic in the year 1727. Although we might be tempted to leave this part of the story aside and just mention the presence of English shipwrights and their drawings at the Amsterdam admiralty, doing so would make it impossible to comment on the quite different degree to which this innovation was accepted and appropriated within the network of the admiralties compared to the VOC-network. Whereas

[123] In 1744, the Amsterdam admiralty employed 440 workers, 174 of which were shipwrights. In 1781, at the height of the fourth Anglo-Dutch war, the number of workers totalled 1200, of which 728 were shipwrights. (Deurloo (1971), pp. 7-8)

[124] http://www.bma.amsterdam.nl/monumenten/beschrijvingen/werkspoorhallen?ActItmIdt=114532

other Dutch admiralties did not accept the innovation, one of the English shipwrights who played a prominent role in its introduction was asked to produce technical design drawings for a new design of the VOC's *retourschepen*, which was accepted across the VOC. This shows that there might be some truth in Bruno Latour's first principle which reads that "the fate of facts and machines is in later users' hands; their qualities are thus a consequence, not a cause, of a collective action"- provided of course that we interpret the artefact of design drawings as a fact or a machine (or as an immutable mobile, as will be shown later).[125] Already before 1727, however, naval shipwrights in the Republic were experimenting locally with producing and using technical design drawings. In Rotterdam and Middelburg, these experiments led to the development of sophisticated, local systems of technical design drawings, systems that were initially kept secret by their inventors and only became public in the mid-1750s.

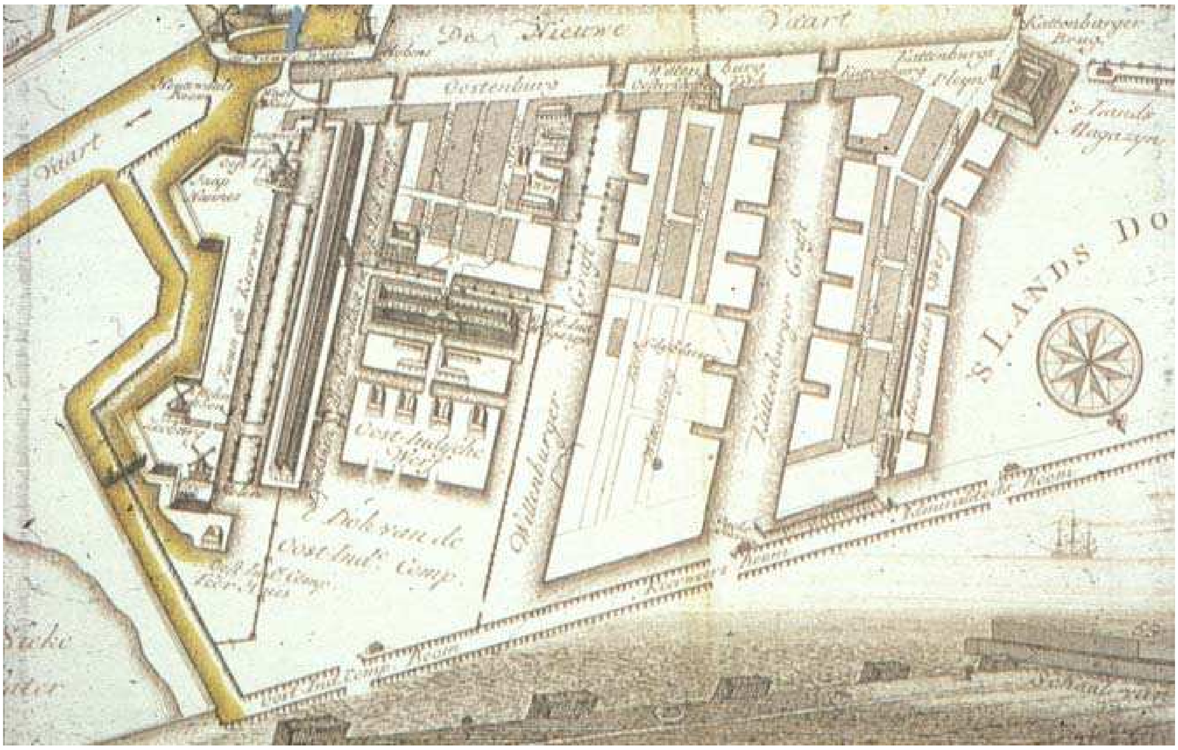


Fig. 2.1 Detail of an Amsterdam town plan (by C.P. Jacobs, 1766) showing the close proximity of the VOC-yard at Oostenburg and the Admiralty yard at Kattenburg. From left to right: Oostenburg (inscribed Oost-Indische Werf), Wittenburg and Kattenburg (inscribed Admiraliteits Werf). Retrieved through http://www.bma.amsterdam.nl/contents/pages/67250/aar18oost3.pdf

In the 17th and 18th century, the Dutch navy consisted of five rather independent admiralties, a configuration which resembles the way both the Republic and the VOC were organized. During the late 17th and the early 18th century, several high-ranking officers of the Dutch navy complained about the ships they were given to command, one of the most outspoken of these being captain (later fleet admiral) Cornelis Schrijver. Their criticism was directed at the fact that ships were not suited to the tasks they had to perform and that ships were of a variable and unpredictable quality. These complaints and their underlying causes – one of these a failed innovation – as well as contemporary suggestions for change will be discussed in the first section of this chapter.

In an effort to master these problems, the Amsterdam admiralty adopted an innovative way of ship design by using technical drawings. To that end, English shipwrights were appointed as master shipwright at the admiralty yard from 1727 onwards. No use was made of the (secret)

[125] Latour (1987), p. 259

emerging expertise of Dutch master shipwrights regarding technical design drawings. Captain Cornelis Schrijver played an important role in employing the English shipwrights. The reason behind the choice for shipwrights from England was that most naval officers considered them to be at the forefront of naval ship design. This conviction was probably brought about by the close cooperation between the English and the Dutch navy, as - from 1688 onwards - the two navies were combined into a single naval force for several decades[126]. To materialize the detailed ("English") technical drawings meticulously into an artefact, new building practices were introduced as well. The design drawings increased the control of the master shipwright over the design phase, and the new building practices increased his control over the building process. In the second section of this chapter, we will describe the introduction of the new procedures and give an anatomy of technical drawings. Following Latour, we will characterize the set of design drawings as an immutable mobile. [127] In discussing this characterization of the innovation, we will argue that the mobile set of technical design drawings – although in a sense immutable – also displays an inherent degree of flexibility, a flexibility that is not restricted to this case but seems to have a more general validity.

The introduction of the new design and building methods caused quite a stir. At the Amsterdam admiralty, there were rumours of ships being sabotaged while they were being built according to the new plans and procedures. Other admiralties of the Dutch navy refused to be enlisted into the Amsterdam network, and did not implement the innovation. To put the new designs to the test a regatta was organized between the fastest ship in the English fleet and one of the ships designed for the Amsterdam admiralty by the English shipwright Thomas Davis. This regatta took place in 1729 but the outcome was rather inconclusive. In 1747, a final attempt to introduce the "English" method of designing and building ships at all admiralties ended in an acrimonious debate in The Hague, the only actual effect being two more regattas between naval ships, which – when they finally took place in 1753 - again turned out to be rather inconclusive. The extension of the design-network to include the corresponding building process in Amsterdam and the failed extension of the network to include other admiralties will be discussed in the third section of this chapter.

This chapter concludes with an appraisal of the innovation that remained confined to the Amsterdam admiralty. In contrast to what happened at other admiralties, the innovative use of technical drawings and corresponding building techniques was introduced at all shipyards of the VOC from 1742 onwards, as will be described in chapter 3. In that chapter, it will be argued that the VOC and the Amsterdam admiralty were not only linked in a geographical sense and on a personal level but more importantly, were linked by the immutable mobile of design drawings of ships.

2.1 Complexity, conflict, complaints and calls for change

Events surrounding a small squadron of the Dutch navy will be used to illustrate how the navy was organized, which different and conflicting demands the navy had to meet during the late 17th and early 18th century, and which problems the navy encountered when building ships that had to recruit the forces of nature efficiently. First, the way the squadron was formed mirrors the complicated structure of the Dutch navy during the 17th and 18th century and the way it was financed. Secondly, the two conflicting roles the Dutch navy was supposed to play and choices made in that respect led to the fact that not all ships available for the squadron's mission were suited to their tasks. This highlights problems and challenges regarding ships' design. Thirdly, the recurring problems about how Dutch naval ships were able to recruit nature are highlighted

[126] Bruijn (1989)
[127] Latour (1987), pp. 227 et seq

by the way the squadron operated. Related to the choices made regarding the roles of the Dutch navy, naval captains – to their embarrassment - discovered that the ships of privateers were almost always superior in turning the forces of wind, water and waves into speed and manoeuvrability. Finally, it will be shown how these interwoven aspects, reinforced by continuing complaints by the users of the ships, led to the quest for a ship design that might better reconcile the various demands placed upon the navy.

In 1724, a small squadron of the Dutch navy, consisting of five ships under the command of rear admiral Carel Godin, cruised in the Mediterranean in an attempt to pacify privateers operating from the Barbary Coast. These privateers had taken advantage of the fact that after 1713 (i.e. after the Treaty of Utrecht, which ended the War of the Spanish Succession), no Dutch warships had been operating in the Mediterranean to protect merchant vessels, and they had started taking Dutch merchantmen from 1715 onwards. At that time, the Republic was engaged – in cooperation with the English, the Danish and the Russian navy – in a conflict in the Baltic against Sweden. The finances of the Republic were depleted because of earlier wars[128], and no ships or finances were available to fight two conflicts at the same time. It was not until 1718 that some attempts were undertaken to redress the situation in the Mediterranean. In that year, a small squadron (consisting of three ships) failed to take any privateers, and the same occurred when a large squadron (consisting of eight ships) operated in the area in 1721. The reason for these failures was apparently the lack of speed and manoeuvrability of the Dutch naval vessels. In 1722, a third squadron (consisting of six ships) operated in the area, and apart from taking two small privateers near the north-western tip of Spain, in the Mediterranean not a single privateer was sighted, let alone taken[129]. In May 1724, Godin's squadron arrived in the Mediterranean and on 11 June, the smallest ship in the squadron, the 36 gun-frigate *Wageningen*, commanded by captain Cornelis Schrijver, engaged an Algerian privateer, armed with 40 guns. The next day, Schrijver took this privateer, and on 4 and 5 October he forced the stranding of another privateer that was consequently destroyed by its own crew. It turned out that the speed of the *Wageningen* was far superior to the other Dutch vessels in the squadron and that the ship was as least as fast as the ships of privateers. It therefore proved to be the only vessel in the squadron that was a match for these ships [130].

2.1.1 Complexity

Godin's squadron existed of a 42 gun-ship (the *Sandenburg*) of the Zeeland admiralty, which operated as flagship, a 44 gun-ship of the Maze/Rotterdam admiralty (the *Matenesse*), two ships supplied by the Amsterdam admiralty (the *Damiaten* armed with 44 guns and the *Wageningen*, mentioned earlier) and a ship from the Noorderkwartier (Enkhuizen/Hoorn) admiralty, the *'t Huys te Neck*, carrying 44 guns. The admiralty of Friesland could not supply a ship, as it no longer possessed any ships[131]. The way the squadron was made up mirrors the organization of the Dutch navy as a whole. During the 17th and 18th century, the navy consisted of five quasi-independent admiralties, one in Amsterdam (the largest and the most important), one in Rotterdam (the second in size and the oldest), one in Middelburg (Zeeland), one in the Noorderkwartier (Enkhuizen and Hoorn) and the fifth in Harlingen (Friesland) [132]. The organizational model of the Dutch navy was very similar to that of the VOC, which also was a conglomerate of semi-independent chambers. Almost all admiralty towns also accommodated VOC-chambers. The only exceptions were Harlingen, which had an admiralty but no VOC-

[128] The Nine Years' War (1688-1697) and the War of the Spanish Succession (1701-1713)
[129] De Jonge IV (1861), pp. 113-124. De Jonge's books are important because they relied on primary sources, of which quite a few were lost or badly damaged after a fire that gutted the Navy Department in 1844.
[130] ARA Fagel (1.10.29) 1099 / Schrijver (1753), pp. 1-2; De Jonge IV (1861), pp. 124-129; Bruijn (1970), p. 28
[131] De Jonge IV (1861), p. 124 (footnote 2) and Bruijn (1970), p. 27. According to Bruijn, who compiled a list of all ships owned by Amsterdam admiralty between 1713 and 1751, the *Damiaten* was a 52 gun-vessel (Bruijn (1970), p. 170)
[132] The description of the organizational model of the Dutch navy draws on Bruijn (1989), pp. 122-124

chamber and Delfshaven (near Rotterdam), which had a VOC-chamber, but did not have an admiralty. The board of each admiralty consisted not only of local representatives, but also of representatives from other provinces in the Republic[133]. To coordinate naval activities when necessary, members of the boards of the five admiralties met in a committee called Haags Besogne, a committee that should not be confused with the VOC-committee of the same name. At times when the security of the Republic as a whole was at stake, combined squadrons or fleets were formed, in which every admiralty had to participate. During such times, the States-General could provide the admiralties with extra funds for the building and equipment of naval ships. The depletion of the Republic's finances, both on a central and on provincial level, was the reason that - after 1713 - the only building of naval ships of any significance occurred at the yards of the Amsterdam admiralty[134]. This also explains why the Friesland admiralty had no ships available in the 1720s. Final decisions on national strategy, command structure and the provision of extra money were taken by a Committee for Naval Affairs of the States-General. This decision-making could be a protracted affair, as each province had to agree separately. The role of this committee was rather similar to the role played by the Heeren XVII within the VOC, whose decision-making process also had to take into account the opinions of all chambers.

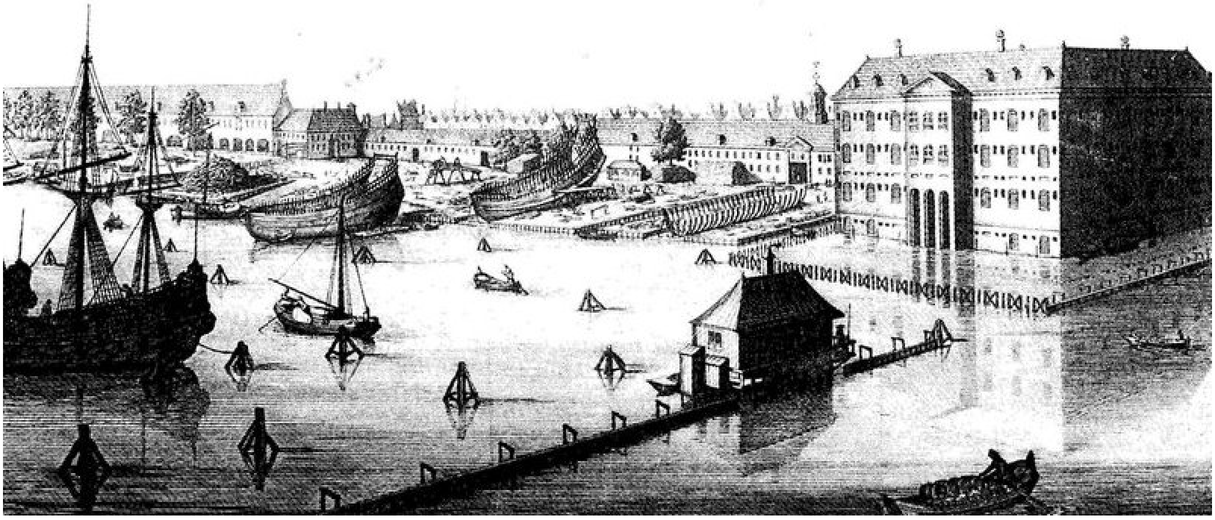


Fig. 2.2 The admiralty dockyard and *'s Lands Zeemagazijn* at Amsterdam (Kattenburg) [135]. Illustration taken from C. Commelin's Beschrijvinge van Amsterdam (1693)

Each of the five admiralties had to build, equip, manage and pay for its own share of the Dutch naval fleet. This meant that each admiralty possessed a shipyard with supporting industries, complete with buildings for administration and storehouses. Income for the admiralties was generated through their responsibility, among other things, for the collection and administration of import and export duties on transport over sea and (quite remarkably) on transport over land as well. The income of the Amsterdam admiralty was as large as that of the other admiralties combined. This was because Amsterdam was the most important port of the Republic, which in turn was caused by the huge amount of commercial activities connected with the local VOC-chamber. This means that the Amsterdam admiralty and the VOC were not only closely linked geographically, on a personal level and through standardization and innovation of shipbuilding, but in addition, the admiralty depended financially for a large part on the prosperity of the VOC. Their (financial) dependence on commercial activities at sea, in either the Baltic, the Mediterranean or the East Indies, meant that it was in the interest of the admiralties to protect

---

[133] For instance, in section 2.2 the nobleman Torck van Rosendaal will be encountered. He represented the province of Gelderland on the board of the Amsterdam admiralty, and played an important role until he was ousted from the board.
[134] Bruijn (1993), pp. 145-149
[135] The building is still in use, currently as the "Nederlands Scheepvaartmuseum" (Dutch Maritime Museum).

local ship-owners against the risk of privateers. This in turn might influence decisions by the admiralties relating to the type of ships they preferred to build, a choice that could be at odds with demands made by the States-General.

2.1.2 Conflict

The fact that almost all vessels within Godin's squadron were too slow to be a match for ships of local privateers – a problem that had manifested itself also in the case of the previous squadrons – shows that the Dutch navy placed more emphasis on roles other than combating privateers. The navy was – at least in name – commanded by the stadholders of the Republic who carried the title *Admiraal-Generaal* (i.e. supreme commander of the united fleet), but the stadholders never actually took up that post. They left this to naval commanders such as De Ruyter, Tromp, Van Wassenaar Obdam and others. They sometimes appointed a trusted political figure or a courtier as their representative at the boards of all admiralties. Stadholder Willem III (1672-1702), who personally commanded the army, was represented at the navy by De Ruyter and later on (in formal affairs) by the secretary of the Amsterdam admiralty. Soon after Willem III ascended to the English throne as William III in 1688, he started a close cooperation between the English and the Dutch navy against the common enemy, France[136]. In May 1689, a treaty was concluded whereby the English and the Dutch navies were combined. The main purpose of William III was to counteract the French hegemony in Europe. To this end, a fleet of eighty large ships of the line was to combat the French navy in the English Channel and in the Mediterranean, and the English/Dutch navy proved successful in doing so after some early defeats. A result of combining the fleets and of the role the navy had to play was that the relatively scarce resources, available for the Dutch navy (as most of the resources went to the army) were invested in large ships of the line.

An example of the emphasis on large ships was the – rather unsuccessful - introduction of three-deckers in the Dutch navy, which had already started before 1689 and which was continued after 1689. Between 1682 and 1700, fifteen of these large ships were constructed, each carrying up to 96 guns[137]. They were introduced as a response to the introduction of larger ships in the English and French navy, which made the smaller Dutch ships "obsolete in battle"[138]. However, Dutch shipbuilders encountered quite some problems in combining the large length and width of these ships with the shallow draught that was required to safely navigate the shallow coastal waters and inlets of the Republic[139]. The need for a shallow draught, combined with the heavy armament of these ships, necessitated that the ships were built even wider which compromised speed, manoeuvrability and seaworthiness even more. Therefore, a conflict emerged between the dimensions of these large naval warships (as the materialized translation of the new role of the Dutch navy) and the shallow coastal waters of the Republic[140]. At the same time, apart from classic naval battles, an increasingly important role had to be played by naval ships in escorting commercial vessels and in combating privateers. Important strongholds of these privateers were Dunkirk and the North African Barbary Coast. The privateers from Dunkirk constituted a serious threat to commercial and fishing vessels in the English Channel and the North Sea. Privateers from the Barbary Coast operated mainly in the Mediterranean but ventured as far north as the English Channel. Their ships, be it either from Dunkirk or from the Barbary Coast, were built locally or taken as spoils. They were small, fast, highly manoeuvrable and efficiently armed, and far superior in those respects to Dutch naval ships. To counteract the threat of privateers the Dutch navy needed a different type of ship, possessing characteristics similar to those of the

[136] For more on this cooperation, see the article by Bruijn (1989)
[137] De Jonge III (1860), pp. 158-160
[138] According to Bruijn (1989), p. 124.
[139] Bruijn (1989), p. 124
[140] A similar conflict will be encountered in the next chapter when the ongoing development of VOC's *retourschepen* is described.

privateers, characteristics that were at odds with those of ships of the line[141]. Therefore, a conflict emerged between the sailing capacities materialized in the existing large ships and the capacities needed to combat privateers efficiently. It was only in 1695 that the Admiralty of Zeeland built the *Mercurius* (42 guns), specifically designed for fast sailing and bought the *Aurora* (28 guns), a former privateer from Dunkirk that was grounded during a storm and was captured. These ships finally equalled the capacities of the ships of the Dunkirk privateers, as far as fast sailing and manoeuvrability were concerned[142]. However, the next ship that could cope with privateers was the *Wageningen*, built in 1723, signifying a gap of almost thirty years[143].

2.1.3 Complaints

If we look at the way Godin's squadron operated, it becomes clear that the *Wageningen* was the only vessel that could be relied upon to engage effectively with privateers. The other ships in the squadron might have been able to operate in a supporting role but they could not take any initiative[144]. The reason for this asymmetry is highlighted by the way the *Wageningen* came to be built. The building of the vessel can be seen as a material response to complaints, voiced by naval officers, regarding ships of the Dutch navy in the early 18th century.

In 1721 – probably in a response to earlier failed expeditions to the Mediterranean - fleet admiral Van Wassenaer, together with fleet admiral Pieterson, vice-admiral Van Aersen van Sommelsdijck and rear admiral Bodaan complained that "the ships of the State could not sail fast enough to overtake the Barbary privateers and fight them (…)"[145]. They apparently realized that different demands placed on the Dutch navy called for an innovation in ship design, different from the innovation tried during the last decades of the 17th century. They suggested to the States-General to have a number of fast and manoeuvrable frigates built, each by a different master shipwright. The shipwright of the Amsterdam admiralty and shipwrights of private yards in Amsterdam and Zaandam with "the best reputation in (building) fast sailing frigates" should be invited to do so[146]. The builder of the best frigate would be rewarded with a few thousand guilders and would receive more commissions. The States-General decided to have six of these frigates built, but the admiralties (partly due to financial problems) did not comply, and the result was that only one frigate was built. This frigate, the *Wageningen*, was designed and built by the (then) private shipwright Gerbrand Slegt who, after winning the prize was appointed as master shipwright at the Amsterdam admiralty in 1723, as successor to Jan van Rheenen who had died in 1722.[147]

Interestingly, (technical) drawings of the frigate *Wageningen* still exist, as is shown in fig. 2.3. It is not quite clear whether these drawings are actual design drawings or whether they were made by copying the lines from a three-dimensional model. The mentioning (in the bottom righthand corner) "that a mistake has been made concerning the last frame" might support the last interpretation. That being so, the existence of these drawings points to the fact that

[141] The English navy encountered the same problems. Therefore, in the mid 1670s, they built some fast galley-frigates designed by Anthony Deane Jr but based on a French design (Lavery (1981), p. 19). In 1690, his father, the famous naval shipwright Anthony Deane Sr, remarked that building large ships of the line had been a mistake (Lavery (1981), p. 14).
[142] De Jonge III (1860), p. 157 and 463. It is interesting to note that between 1690 and 1710 an efficient fleet of Dutch privateers operated from the province of Zeeland (De Jonge III (1860) pp. 463-531)
[143] Both the *Mercurius* and the *Wageningen* were also equipped with oars, for use in calm conditions.
[144] As is borne out by the accounts given in De Jonge IV (1861), pp. 124-129
[145] De Jonge IV (1861), pp. 259-260. In Dutch: "*de schepen van den Staat niet hard genoeg zeilden, om de Barbarijsche roovers te achterhalen en bevechten (….)*"
[146] De Jonge IV (1861), pp. 259-260 and Bruijn (1970), pp. 27-28. In Dutch: "*de gereputeerdste meesters van welbezeylde fregatten*"
[147] Bruijn (1970) pp. 9-11 (footnote 12) and 27-28; Hoving & Lemmers (2001), p. 16

Gerbrand Slegt was experimenting with technical drawings, an impression that is reinforced by surviving drawings of the *Damiaten* and the *Pallas*, ships that he also designed and built[148].

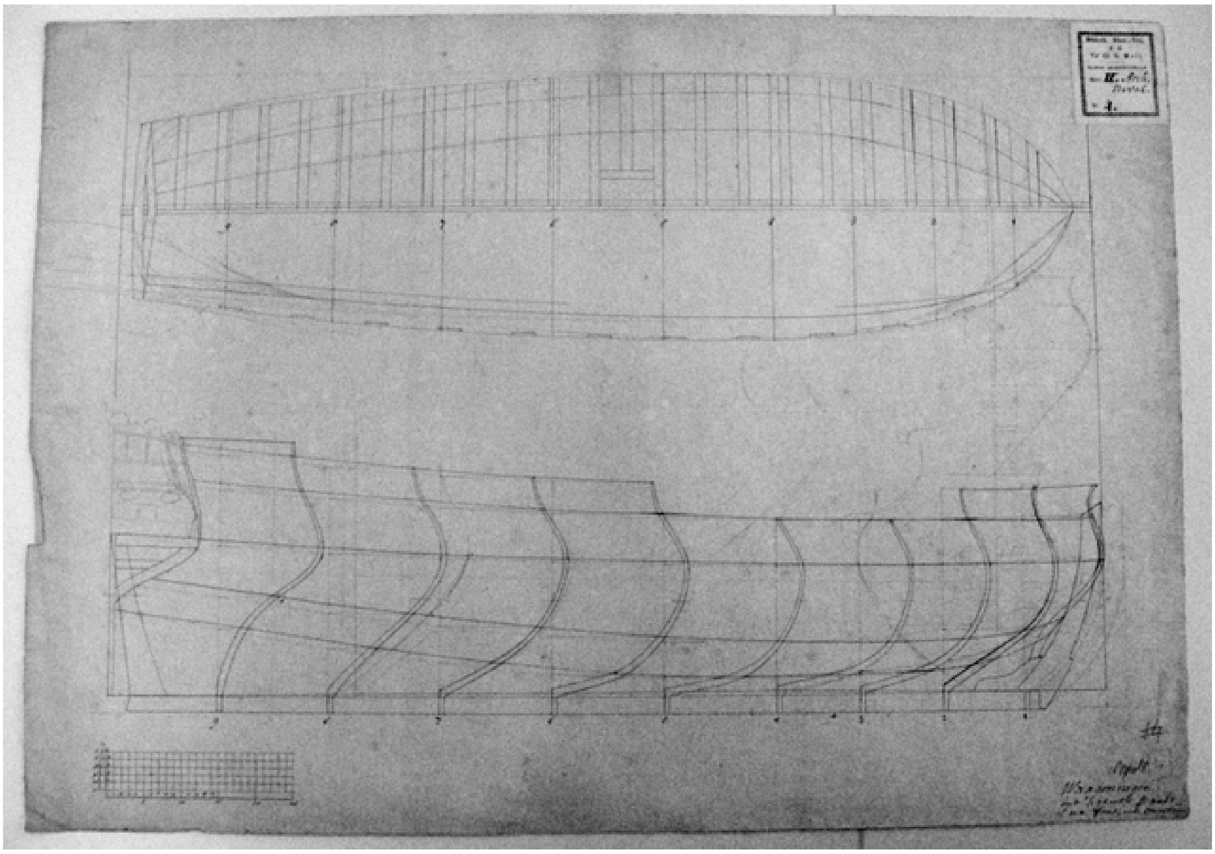


Fig. 2.3 Early (technical) drawings of the frigate *Wageningen*, designed and drawn by Gerbrand Slegt (1722/1723). Photo of the original drawing in the Moll collection at the library of the University of Utrecht, taken by Johan de Jong (28 July 2009).

However, new ships as such did not always succeed in answering to the changing role of the Dutch navy. For instance, the flagship of Godin's squadron, the *Sandenburg*, had been recently built at the yard of the Zeeland admiralty. During the building process, much had been made of the capacities of this ship, but it did not live up to the expectations. Its sailing capacities were disappointing and upon return from the Mediterranean, it foundered on the roadstead near Middelburg[149]. The fate of the *Sandenburg* reinforces the impression that Dutch shipwrights at the time were apparently not able to predict sufficiently the sailing capacities of the ships they designed and built.

Earlier, the conflict was mentioned between the dimensions of ships and the way nature sculpted the Dutch coastal waters. However, this was not the only problem Dutch naval ships encountered in their recruitment of nature. In 1692, rear admiral Philips van der Goes wrote a letter to the Rotterdam admiralty praising the sailing capacities of the new ship *Admiraal-Generaal*, but in the same year vice-admiral Carel van der Putte wrote to the Zeeland admiralty complaining bitterly about the poor qualities of the new ship *Koning William*. He wrote about this ship (one of the new class of three-deckers) that it could not cope with more than a gentle breeze and that its lower gun ports could not be used in those circumstances. Not only was it continually leaking (this, apparently, was a minor problem compared to the other defects he mentioned), it took in more than a foot of water through the lower gun ports if there was any

[148] These drawings are also in the Moll collection at the library of the University of Utrecht. See also Hoving & Lemmers (2001), pp. 32-33.
[149] Bruijn (1970), p. 28

wind at all and it could not make its way off a lee shore. He blamed "prejudice or stupidity of the shipwrights" for this[150]. The introduction of these ships may be seen as an innovation for the Dutch navy, although considering the complaints, the innovation seems not to have been very effective in improving the quality of naval ships. Regarding smaller Dutch ships, there it was no plain sailing either: in 1696 vice-admiral Callenburgh complained to the Amsterdam admiralty about the 52-gun ship *Gaesterland* that the lower gun ports could not be used if there was any wind at all[151]. In 1753, vice admiral Schrijver summarized these and other complaints in a lengthy letter to the States-General[152]. The building of large ships of the line suggests that - at the end of the 17th century and during the first years of the 18th century - Dutch naval shipbuilding still concentrated on ships for the large naval battles that were introduced in the middle of the 17th century. In these long drawn out battles, lasting over several days, stable floating gun platforms were required. Ships of the line needed to have firepower, stability and a sturdy construction, and matters like speed and manoeuvrability were considered to be of secondary importance[153]. This impression is reinforced if one realizes that as late as 1690 the States-General ordered 18 ships to be built according to specifications and models of 1666, although the building of ships according to old specifications did not guarantee that these specifications were always met[154].

Apart from the introduction of three-deckers, the only other change in the organization of shipbuilding had been – from 1682 onwards - a more strict interpretation of different charters of ships, four of which were introduced and which led to some semblance of standardization as far as the size and armament of ships was concerned. One gets the impression that the main concern regarding shipbuilding was how to reconcile large dimensions with shallow depths, at the same time ignoring the efficient recruitment of the powers of wind and water to turn these into speed and manoeuvrability.

2.1.4 Calls for change

In the early decades of the 18th century, there continued to be disquiet about the state of affairs in shipbuilding, and the perceived lack of expertise among shipwrights. This commotion concerned both naval ships as well as merchant ships, operated by the VOC[155]. As far as the navy was concerned, the most outspoken critics were the naval officers Johan Gerrit van Wassenaer, François van Aerssen and Cornelis Schrijver[156]. Just as their colleagues had done at the end of the17th century, they complained about the variable and unpredictable quality of their ships, about the lack of speed of the ships, and they blamed naval shipwrights for not expanding their expertise[157]. The cooperation between the English and the Dutch navy lasted for several decades and it offered officers of both navies ample scope to compare their ships. It may have been a major reason why Dutch naval officers looked towards the way the English designed and built their ships when they considered improvements in Dutch naval shipbuilding. Not only naval officers did so: in 1695, the Rotterdam admiralty proposed appointing an English master shipwright as "General Director and Inspector of Naval Shipbuilding"[158]. A decision on this proposal was postponed and in the end, it never came to anything. This suggests, however, that

---

[150] In Dutch: "*opiniatriteyt ofte dommicheit van de timmerlieden*", as quoted in De Jonge III (1860), p. 155. *Timmerlieden* is the generic term for carpenters, but in this context it points to *scheepstimmerlieden* (ships' carpenters or shipwrights).
[151] De Jonge III (1860), p. 155
[152] ARA Fagel (1.10.29) 1099 / Schrijver (1753)
[153] De Jonge III (1860), p. 150
[154] De Jonge III (1860), p. 151
[155] For complaints and problems regarding VOC-ships, see chapter 3.
[156] Bruijn (1970), p. 9 and Hoving & Lemmers (2001), p. 158-159
[157] Lemmers (1996), from p. 48 onwards, Hoving & Lemmers (2001), from p. 27 onwards, Bruijn (1970), pp. 27-28, Bruijn (1972), p. 18 and Van Bruggen (1974 / issue 28), pp. 33-34.
[158] De Jonge III (1860), p. 152 and Van Bruggen (1974 / issue 28), p. 37

on the board of the Rotterdam admiralty there was also some concern about the expertise of Dutch shipwrights and about the fact that Dutch shipbuilding might be lagging behind developments abroad.

When Godin's squadron returned to the Republic in October 1724, captain Schrijver wrote a letter to the Amsterdam admiralty, arguing that two or three more frigates similar to the *Wageningen* should be built, in order to pacify the privateers of the Barbary Coast once and for all [159]. However, it was not until 1748 that a similar ship was built and by that time the *Wageningen* had been scrapped[160]. In the meantime, ships of larger charters were still being built. This again points to the problems regarding the types, the quality and the availability of ships that made up the Dutch navy in this period, and – possibly even more importantly – the uncertainty about the main purpose of the Dutch navy. The emphasis on taking part in large naval battles was increasingly at odds with the realities encountered when protecting merchantmen. On the one hand, the problematic innovation of the three-decker can be considered as a failure. Not only were these ships not suited to the tasks they had to perform, but they also offered no solution for a new post-war reality. On the other hand, promising inventions such as the design, production and further development of fast frigates were not implemented at the time, against the wishes and judgement of experienced users.

The complaining officers put increasing pressure on the board of the admiralty to adopt technological change in order to develop naval vessels that possessed characteristics suited to changing ways of naval warfare and suited to the geographical and meteorological conditions they had to contend with. This meant that new ships needed to have greater speed and better manoeuvrability than the classical large ships of the line, and that these characteristics should at least be equal to those of the ships of privateers. In addition, the new ships should be able to negotiate the shallows of the Dutch coastal waters and the entrance to the Dutch harbours even under unfavourable circumstances, so that they could be recruited at short notice. Moreover, the officers thought it necessary that these new ships should be produced in sufficiently large numbers and with sufficiently predictable characteristics. In their perception, this meant that the design and the building of these new ships could not be left to the accidental good fortune of a shipwright, whereby one ship could turn out to be quite good and the next rather poor. They assumed that a more systematic approach was needed, which they tried to achieve by adopting the way naval vessels were built at the English Royal Dockyards.

If we look more closely at the suggestions for innovation at the Amsterdam admiralty and the considerations regarding the proposed introduction of the "English" way[161] of ship design and shipbuilding, we see an intricate connection between aspects of technology, naval organization, naval policies and geographical considerations. This points to a (shifting) hybrid network incorporating the design and building of naval vessels[162]. This network was made up of heterogeneous participants, both human actors (shipwrights, captains, councillors, members of the States-General and privateers) and non-human actants[163] (naval policies, naval vessels, technical drawings, estuaries, depleted finances). As was mentioned in section 2.1.2, the central naval policy concentrated on the building of increasingly larger ships of the line and a conflict had emerged between the dimensions of these large naval warships and the shallow coastal waters of the Republic. In addition, the scarcity of resources prevented simultaneously smaller and faster ships from being built for purposes like combating privateers. One gets the impression that during the negotiations within this network, the complaining captains

---

[159] De Jonge IV (1861), p. 129

[160] We will encounter this new 36-gun vessel, the *Haarlemmerhout*, later as evidence of the failed expansion of the network of the Amsterdam admiralty.

[161] More on this in the next section

[162] Callon (1987), p. 100

[163] Callon (1987), p. 93

predominantly blamed the master shipwrights for not being able to square the circle of conflicting demands. The captains might have noticed the better qualities of the ships of their English counterparts (which is not surprising as English ships – not encumbered by shallow coastal waters - could be built with a smaller width and a larger draught, thus enabling higher speeds and better manoeuvrability) and they concluded that the expertise of Dutch shipbuilders was lagging behind. The obvious way in which Dutch shipbuilders differed from the English (naval) shipbuilders was that most of them did not use technical drawings[164]. This may have been important considering the lack of predictable characteristics, but it cannot be blamed for the lack of response to the other aspects. A possible introduction of technical drawings might lead to more standardized designs and it might open up the possibility that artefacts with similar characteristics might be produced at different times and - as will be seen in the case of the VOC - at different localities. It could, however, only be partly successful in remedying other existing conflicts and controversies within the Dutch navy and Dutch naval shipbuilding. The opportunity for change arose within two years after the return of Godin's squadron, when the master shipwright of the Amsterdam admiralty yard came under scrutiny regarding his competence and his honesty.

2.2 Secretive dealings and innovative drawings

In March 1726, Gerbrand Slegt, the master shipwright at the Amsterdam admiralty, offered his resignation after the board accused him of incompetence and dishonesty. It is questionable whether he was really incompetent, as he was responsible for the design of the successful frigate *Wageningen* and was expanding his expertise by developing a system of technical drawings of ship designs[165]. Probably the accusation of dishonesty did carry more weight than the accusation of incompetence: Slegt still owned his private shipyard whilst being employed by the admiralty[166]. Whatever the exact circumstances surrounding his resignation, it opened up the possibility of introducing English shipwrights with their "English" design and building methods at the Amsterdam admiralty. The enlisting of English shipwrights will be described in the first part of this section. In the second part an anatomy of technical ships' drawings will be given, together with an interpretation of their "English"-ness. In the final part of this section, the technical design drawings will be interpreted as immutable, flexible and combinable mobiles.

2.2.1 English shipwrights introduced

In the aftermath of Slegt's resignation, captain Schrijver travelled to the naval dockyard at Portsmouth. He was commissioned by the board of the Amsterdam admiralty to employ English shipwrights for its shipyard, because the board could not find an acceptable candidate in Holland[167]. According to Schrijver, he had convinced councillor Torck van Rosendaal to employ an English shipwright[168]. A few years later, he mentioned the involvement not only of Torck van Rosendaal, but also of Van Lockhorst[169]. In 1717, Torck had been appointed at the Amsterdam

---

[164] For the early use of technical design drawings by the English, see Lavery (1981), Mc Gee (1999 and 2003), Epstein (2006), Schaffer (2007).
[165] See also section 2.1.3. It has been suggested that Torck van Rosendaal paid for the building and equipment of the frigate *Wageningen* out of his own pocket: http://nl.wikipedia.org/wiki/Lubbert_Adolph_Torck . As yet, I have not been able to find corroboration of this suggestion.
[166] Bruijn (1970), p. 11 footnote 12. However, in contrast to what Bruijn suggests, it seems rather unlikely that Slegt operated a private yard on the premises of the admiralty yard, the more so as he had operated his own yard already before he was appointed. It is therefore more likely that he still operated his private yard at Wittenburg, between the VOC-yard at Oostenburg and the admiralty yard at Kattenburg.
[167] De Jonge IV (1861), p. 260
[168] ARA Fagel (1.10.29) 1099 / Schrijver (1753), p. 6
[169] Schrijver mentions Torck's and Lockhorst's involvement in his Plan (Hoving & Lemmers (2001), p. 157).

admiralty as representative for the province of Gelderland. He served until 1741 when he was ousted, possibly because of the fact that he was considered too influential, although he formally kept his seat until 1744[170]. From 1723 onwards, he was a member of the committee responsible for the shipyard and the storehouses. In 1722, he married Petronella van Hoorn, the wealthy widow of Jan Trip Jr, a former governor-general of the VOC in the East Indies[171]. Van Lockhorst, a nobleman from the province of Utrecht, had been a member at the board of the Zeeland admiralty, before he moved to the board of the Amsterdam admiralty in 1710. He served on this board until his death in 1740, and – while being member on the admiralty board - he served some terms as director of the VOC-chamber Amsterdam[172]. Other sources point to the fact that vice admiral Van Aersen van Sommelsdijk, rear admiral Grave and captain Lijnslager also played an important role in this matter[173].

Fig. 2.4 (Left) Cornelis Schrijver (1687-1768), naval captain and flag officer of the Amsterdam admiralty; painting by J.M. Quinkhard (1736) Westfries Museum Hoorn / (Right) Lubbert Adolf Torck van Rosendaal (1687-1758), nobleman from Gelderland and councillor at the Amsterdam admiralty from 1717 – 1741(1744); painting after A. Boonen (ca. 1723)

Schrijver was to operate "as cautiously and secretly as possible"[174] and at first, he seemed to have been successful. At the naval dockyard at Portsmouth, he managed to employ an experienced assistant master shipwright (Thomas Bucknall) together with two other shipwrights (Charles Bentam[175] and Francis Whitea) on behalf of the Amsterdam admiralty. Bucknall was to become master shipwright, with Bentam and Whitea as his assistants. However, the scheme was discovered prematurely, probably by the English, who – in 1720 - had passed a law "banning the emigration of resident technicians"[176]. Although Schrijver returned empty-handed to Amsterdam, the Amsterdam admiralty managed to secure the services of the

[170] Bruijn (1970), pp. 40-42 and pp. 55-59
[171] Bruijn (1970), p. 42, http://www.inghist.nl/Onderzoek/Projecten/BWN/lemmata/bwn3/torck and http://nl.wikipedia.org/wiki/Lubbert_Adolph_Torck . The father and grandfather of Petronella van Hoorn had been governor-general of the VOC as well.
[172] Bruijn (1970), p. 41
[173] De Jonge IV (1861), pp. 258-260. This is partly corroborated by a letter written by these officers and captain Schrijver on 30 May 1727 (see also section 2.2.2)
[174] Bruijn (1972), p. 18. In Dutch: "*soo omsigtig en secreet mogelijk*"
[175] In (contemporary) literature, the name Bentam is sometimes written as Bentham or as Bentem. Throughout this paper the spelling Bentam will be used, as this is the spelling used by Charles Bentam himself.
[176] Epstein (2004), p. 385

shipwright Thomas Davis in April 1727. Of Davis little is known, originally he had been a shipwright in Portsmouth, he had worked in Amsterdam for some time and from 1715 onwards he was employed as a shipwright on admiralty yards belonging to the Habsburg Empire, both along the Danube and at Naples[177]. A few months later, the shipwright John May came to Amsterdam. He was originally from Chatham, had left for France in 1714 where he had been working as a shipwright at the naval shipyard in Lorient and from 1720 onwards at Toulon[178]. In August 1727, Charles Bentam suddenly turned up in Amsterdam. He had left Portsmouth secretly and without offering his resignation, he had not asked for any outstanding wages and he had not settled his debts[179]. His brother William arrived in Amsterdam as well. Thomas Davis was appointed master shipwright, Charles Bentam became his first assistant and Thomas May his second assistant. William Bentam was appointed commander of the admiralty's sawmill [180]. In fact, Charles Bentam may be considered as the only proper English shipwright, as he had been working in England all the time before he deserted to the Republic. Nevertheless, because of their English origins and training all three can be labelled as English shipwrights.

In the preceding paragraphs, the word *English* has been used with and without quotation marks. The reason for this is that the word can be interpreted in a few different ways in relation to the introduction of the foreign shipwrights and their methods. On the one hand, there is the (not so simple) matter of nationality whereby somebody (or something) originating from England can be labelled English[181]. In that sense the three newly appointed shipwrights at the Amsterdam admiralty and their design and building methods can be called English, denoting the geographical, historical and technological origins of these new actors within the admiralty network.

2.2.2 "English" methods implemented

On the other hand, the word "English" (especially in connection with the word method) can be used to point to an (innovative) method of ship design and shipbuilding different from the systems used at the time in the Republic.

Using technical (or measured) drawings in designing naval ships means that a set of three technical drawings is made, as shown in fig. 2.5. The first drawing represents the side-view (elevation or "sheer plan"), which shows most recognizably the way the ship would eventually look. This representation displays the keel, the stem and stern, the gunports, supports for the rigging and so on. The position of the main (or station) frames (although these are of course not visible from the outside) is also indicated. Quite often, the (invisible) decks are added in a different colour. A second drawing is used to present a top (or "half breadth") view of the ship, showing just half of the submersed part of the hull, starting from the widest part of the hull downwards. A third drawing shows the main frames (the "body plan"); in one half of the drawing these frames are depicted from the stern towards the widest main frame and in the other half of the drawing the frames are depicted from the stem towards the widest main frame. These architectural drawings represent three different two-dimensional aspects of a three-dimensional design, the implication of which is that changing some detail of the design in one of the drawings (e.g. narrowing the hull) inevitably leads to changes in one or both of the

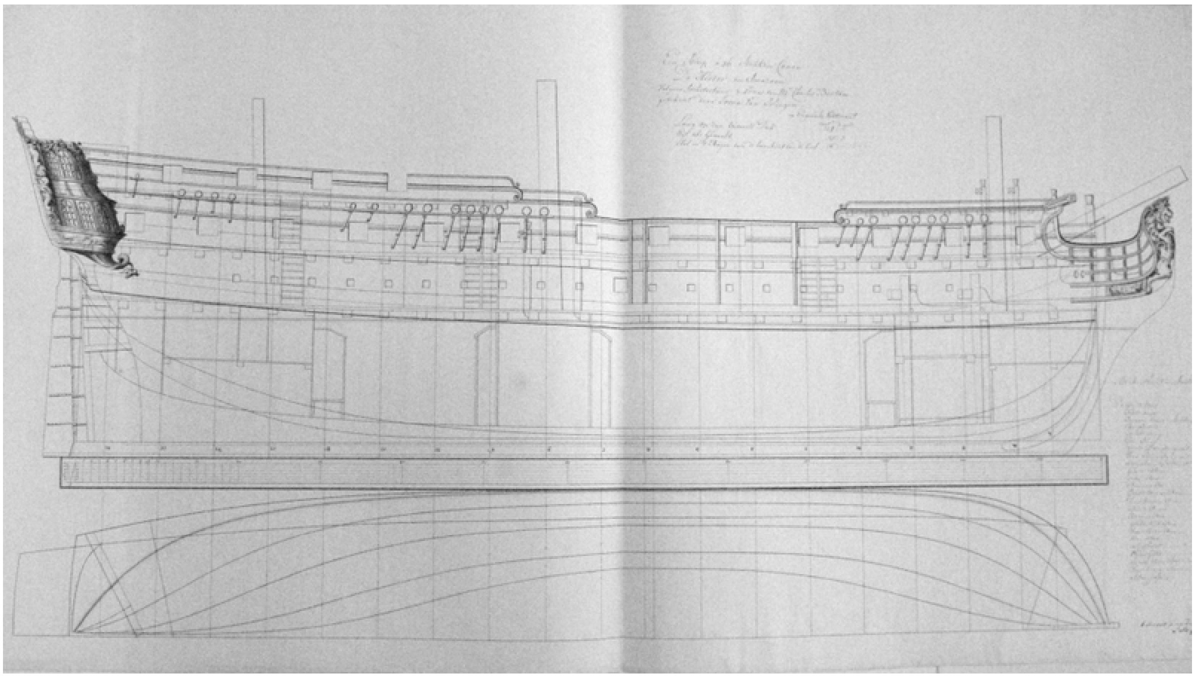
177 Bruijn (1970), p. 11, Bruijn (1972), p. 18 and Van Bruggen (1974 / issue 28), p. 29

178 Bruijn (1970), p. 11, Bruijn (1972), p. 18 and Hoving & Lemmers (2001), p. 16. Considering that May (1694-1779) was twenty years of age when he left for France it seems reasonable to assume that his initial training as a shipwright had taken place in England.

179 Bruijn (1970), p. 11 and Bruijn (1972), p. 18

180 Bruijn (1972), p. 18

181 In doing so, we are ignoring matters of the creation of nation states and sidestepping the discussion whether the word English can be used as a national adjective at a time when - through the union of Scotland and England - the concept of Great Britain was being introduced.



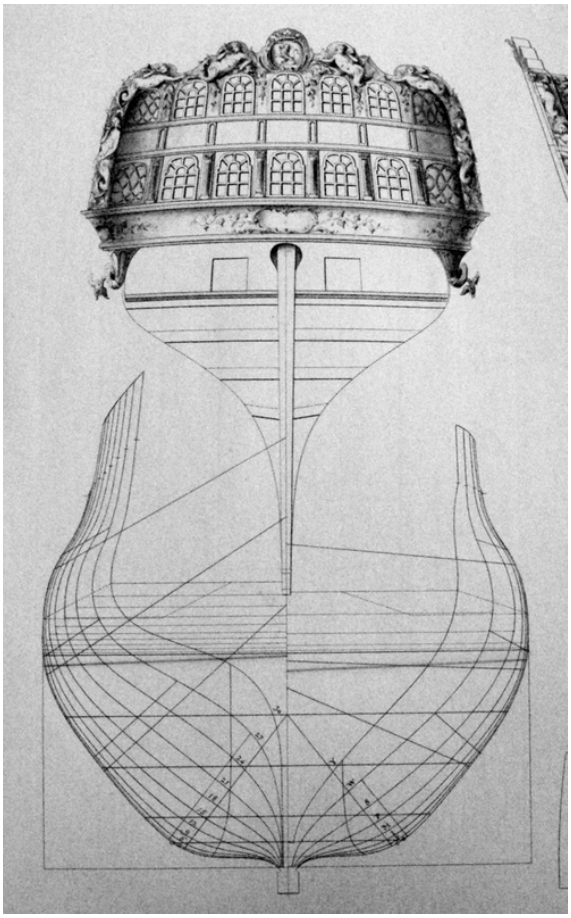


Fig. 2.5 Technical drawings of the naval vessel *De Hector en Amazoon*. This ship of 36 guns was designed by Charles Bentam and drawn by Josua van Solingen. The top picture shows the side view (“sheer plan”) and top view (“half breadth”), the bottom picture shows the stern and the front/back view (the “body plan”, displaying the numbered main frames). Photos of the original drawing in the Moll collection at the library of the University of Utrecht, taken by Johan de Jong (28 July 2009).

other drawings as well (e.g. a narrower hulls means that the main frames have to be drawn narrower as well). Especially for the drawing of the frames intricate mathematical procedures were developed, whereby the designer used circle segments with a different radius and/or (parts of) sinusoidal functions[182]. Although the English, French or Dutch methods – which developed over time - of producing drawings might differ in some (minor) details, the basic system (which is still used in naval architecture) was identical. The next step was that, based on the drawings, wooden templates were made to the actual size and these in turn were used to construct the main frames themselves[183]. The frames then dictated the materialization of the hull, as will be shown in section 2.3.

The use of such a set of three technical (or measured) drawings in designing (naval) ships can be traced back to the English shipwright Matthew Baker, who produced the first known of these drawings in a manuscript Fragments of English Shipwrightery (1586). This meant not only the introduction of technical drawings in English shipbuilding, but in shipbuilding in northwestern Europe as a whole[184]. Within a century, this system of drawings had developed into a quite sophisticated system as becomes apparent from Anthony Deane's manuscript Doctrine of Naval Architecture (1670), which was presented to Samuel Pepys FRS, chief secretary to the Royal Admiralty. Deane had formalized this mode of working when he was shipbuilder for the Royal (English) Navy[185]. For the construction of the mainframes Deane made use of several different circle-segments, while a satisfactory relation between the three different views had to be established by working to and fro between these drawings. Following Epstein, the introduction of technical design drawings may have had mainly to do with the "cultural and functional separation between designers and builders"[186] and with a predilection for classification and standardization within the English navy. It is debatable whether "any cognitive advance in the making of premodern ships"[187] was the main objective. Looking at the Dutch complaints about unpredictable characteristics of vessels, one is inclined to believe that for the Dutch aspects of standardization were also more important than advance in ship design as such.

During the reign of Louis XIV and under the guidance of father and son Colbert[188], in France a system of technical drawings was adopted for designing naval vessels in an attempt to upgrade the French navy. The French system (possibly partly developed on the basis of espionage) was set apart from the English system in that it used a different system for numbering the mainframes and that it used more complex geometric formulae to construct these mainframes and that it relied on mathematical methods to work out the relationship between the three views[189]. In addition (as will be discussed in section 4.1), the French were much more concerned with cognitive advances in ship design than the English and the Dutch. This more theoretical approach of naval shipbuilding by the French became evident by the fact that several mathematicians (amongst others Paul Hoste and Pierre Bouguer) published on theoretical aspects of shipbuilding and that the French *Académie des Sciences* organized several competitions relating to mathematical aspects of ship design. This approach stood in contrast to the experiential approach to ship design and shipbuilding as practised in England and the Republic.

---

[182] For more details on this, see Lavery (1981), pp. 52-71 and Hoving & Lemmers (2001), pp. 59-68
[183] McGee (1997), pp. 223-225
[184] There is some evidence that a form of measured drawings may have been used at the Venetian Arsenal. See the article "A Venetian ship drawing of 1619" by Richard Barker in Nowacki & Valleriani (2003), pp. 67-77
[185] Hoving & Lemmers (2001), pp. 35-36 and McGee (2003), pp. 29-30. Deane never published his manuscript although he may have originally intended to do so (Lavery (1981), p. 21). Deane also devised a method by which he was able to predict the draught of a ship before it was launched (Lavery (1981) pp. 71-73).
[186] Epstein (2006), p. 20
[187] Epstein (2006), p. 20
[188] Jean-Baptiste Colbert (1661-1683) and Jean-Baptiste Colbert (1683-1690)
[189] Hoving & Lemmers (2001), pp. 65-67 and Epstein (2006), p. 19

Apparently unknown to the boards of the admiralties, some Dutch shipbuilders had been developing and using technical drawings for a number of years, and had adapted their building methods accordingly. As mentioned in section 2.1.3, during the 1720s the shipwright Gerbrand Slegt was already experimenting with an early form of technical drawings in Amsterdam. At the Rotterdam admiralty, the master shipwright Paulus van Zwijndregt developed a method of technical drawings that must have originated before 1725. In that year he built the vessel *Twikkelo* for the Rotterdam admiralty and a set of sophisticated technical drawings of this ship survive, as do drawings of later designs by Van Zwijndregt[190]. His method was different from the English system of technical drawings, but there were some similarities with early French methods. However, how exactly Van Zwijndregt developed his method remains unclear.[191] His sons Leendert and Pieter, master shipwrights at the admiralty and the VOC respectively, further developed his system of drawing.[192] At the same time, other shipwrights in Rotterdam, such as the private shipwright Cornelis de Ruiter, also employed technical drawings during the design and building process.[193] During the 1740s and 1750s, in Zeeland the shipwright Willem Udemans Jr. developed a system of technical drawings. His method was different from the English method and it may have been influenced by the French or by Van Zwijndregt, but it is nevertheless also different from these methods. As already mentioned, the English system of constructing technical drawings (and of shipbuilding) differed from the French system, and the independently emerging Dutch systems of technical drawings were different again. They differed from the English and French, in that the Dutch draw a smaller number of mainframes, used different mathematical systems to relate the three views to one another and used a different system of numbering[194].

Because the English (and French) systems can be seen as centralized systems, it makes sense to label these systems with a national adjective, as has been done before. The Dutch systems were much more localized and it makes therefore little sense to refer to a single Dutch system of drawing[195]. It was not before 1757, that Leendert van Zwijndregt, Pieter van Zwijndregt and Willem Udemans published details of their design and building methods. They did so in a reaction to a pamphlet, published in 1755, in which Cornelis Schrijver questioned the competence of Dutch shipwrights[196]. Why the Dutch shipwrights did not reveal their own, local, method of technical drawings earlier remains unclear. It may be that making and using these drawings was considered a trick of the trade and that therefore it was kept a closely guarded secret. This supposition is confirmed if one reads the remarks of the French shipwright and spy Blaise Ollivier, who visited the Rotterdam admiralty yard in 1737[197]. Although Paulus van Zwijndregt was quite open about his system of shipbuilding[198], he did not mention his method of producing technical drawings. Another reason for the secrecy of the shipwrights might have been that they wanted to retain a degree of control vis-à-vis the board of their admiralty, while at the same time increasing their control over the outcome of the building process, just as occurred in Amsterdam, although independently from these events. On the other hand, there was probably little to gain for them by publicizing their methods, until the accusations by Cornelis Schrijver came out into the open. That the French did publish was probably connected to government initiatives and the competitions organized by the *Académie des Sciences.* For

---

[190] For more on Paulus van Zwijndregt's drawing technique, see Hoving & Lemmers (2001), pp. 54-65. Surviving drawings are in the collection of the Maritime Museum at Rotterdam and in the Moll collection at the University of Utrecht.
[191] Hoving & Lemmers (2001), pp. 64-65
[192] For more on Pieter van Zwijndregt's methods and experiments, see chapter 4.
[193] Hoving & Lemmers (2001), pp. 95-97
[194] Hoving & Lemmers (2001), pp. 54-64 and 116-126
[195] Apart from the question whether it is appropriate to use a national label at a time when that nation itself did actually not exist.
[196] Schrijver's Plan voor Zee-Wetten, published in 1755 (see section 2.3.2)
[197] Roberts (1992), pp. 197-229
[198] For more on his system, see section 3.3

English (naval) shipwrights there was little point in being secretive as the use of technical drawings was a standard procedure in designing ships.

The English shipwrights imported their system of technical drawings representing the design of the ship that was to be built, and incorporated this system into the Amsterdam admiralty network. It makes therefore sense to label the new methods at the Amsterdam admiralty with the adjective "English" (instead of just "new"). Quotation marks are used here to emphasize that the system, although developed in England, was transferred to the Republic, was modified and became embedded in at least some of the shipbuilding practices in the Republic – although not without some significant controversies (more on which in section 2.3). Therefore, the adjective "English" used in this way, operates as an analytical indication, pointing to a new – imported – concept of ship design and shipbuilding which was no longer strictly geographically linked to England, but still possessed the (standardizing) characteristics as used by the English. In a way, though, the fact that this "English" system was imported is somewhat accidental. Had alliances been different at the time, it may well have been the "French" system that was implemented.

We should note that the systems of drawings (whether of English, French or Dutch origin) were not static, but kept developing, both on a technological and organizational level. On a technological level, in all systems – but especially in France and in the Republic - the mathematical procedures used to link the different views became more sophisticated[199]. On an organizational level, it became obligatory within the English navy (from 1715 onwards) that copies of the technical design drawings were sent to the Navy Board to be assessed. Relevant dimensions, such as length, draught and width had to conform to the *Establishment of Dimensions*, which were in force at the time[200]. The result of this was that ships, built according to an established design, displayed rather predictable properties. Another result was that the Navy Board was able to establish control over individual shipwrights, even more so as from 1755 onwards the design process of naval ships was taken out of the hands of individual shipwrights and transferred to civil servants, who were subordinate to the surveyor of the navy[201].

In Amsterdam, however, the "English" method did not lead to the strict centralization implemented in England. The design process was not transferred to somebody detached from the actual yard; the master shipwright himself remained the designer of the ships he had to build. This meant that at the Amsterdam admiralty, the effect of the drawings was therefore not so much an increased control over individual shipwrights by the admiralty board, but implied an increased control by the master shipwright over the lower ranking shipwrights, who built the ships according to his designs. This control was materialized through the introduction of the "English" building method (section 2.3.1). Attempts to introduce increased centralization across all admiralties (which might have led to a proper "English" approach) failed (section 2.3.2).

2.2.3 Innovative drawings as immutable – and flexible - mobiles

The "English" system for the construction of architectural technical (or measured) drawings formed the basis through which designs could be inscribed on paper. We might say that the English shipwrights connected the Amsterdam admiralty network with the English naval designing and shipbuilding network, adding their expertise and experience to what had already been accumulated within the Amsterdam network and – importantly – adding a layer of calculation that they used to work out the frames of their designs. The English shipwrights

---

[199] Hoving & Lemmers (2001), p. 62 and 67
[200] Hoving & Lemmers (2001), p. 36
[201] Hoving & Lemmers (2001), p. 36

added to an existing network the fundamentals for what can be interpreted as an *immutable and combinable mobile,* a concept introduced by Bruno Latour in Science in Action[202].

In the centre of a network (in the case of the Amsterdam admiralty a network concerned with designing ships that possessed qualities that were both predictable and suitable for the different tasks these ships had to perform) several aspects related to a ship design were accumulated, such as existing experiential and theoretical knowledge, knowledge about nature in the areas the ships had to operate in, considerations of naval strategy and tactics, knowledge about the purpose of the ship to be designed, financial constraints and requirements put forward by the Dutch navy as a whole. This took place in addition to the material accumulation at shipyards already mentioned in the first chapter. Through combination, calculation and manipulation these aspects were integrated into the design for a specific vessel. Through the set of three interrelated design drawings, inscribed onto paper, the design was transformed into an immutable mobile, generated in the centre of the network, able to be spread outwards again. Therefore, it was at the same time immutable (at least temporarily) and mobile. Immutable in the sense that the design stayed intact while being moved and mobile because of its ability to be moved through time and space. In the case of the Amsterdam admiralty, this meant a move to the boardroom where the councillors of the admiralty met, and – when the board agreed – a move to the lofts where the templates were generated and then a move (accompanied by the templates) to the actual yard where the design was materialized into an artefact such as a warship[203], using "English" procedures. The network in which the design was inscribed turned into a constructive network, partially disciplined by the immutable mobile, as will be described in the next section.

The immutable set of technical drawings allowed the design of the ship to be moved through time and/or through space, giving opportunities for adaptations to the design. This may seem at odds with the adjective "immutable" but a degree of flexibility can already be detected within Latour's own introduction of the concept, and within the examples he gives. For instance, he characterizes the inscription of the coordinates of Sakhalin and a first map of this island as an immutable mobile, which was sent by courier to Paris. When the inscriptions reached Paris, the combination of the mobility of the paper and the immutability of its contents meant that the information arrived unchanged, after having been taken halfway across the globe. This did not preclude that subsequent explorers added information to an existing map, redrew the map, replaced coordinates and – through employing new experiences – modified the map, adapting it to a changed perspective or to a different purpose[204]. The same can be said about other examples of immutable mobiles mentioned by Latour, such as the periodic table of elements. The conclusion must be that an inscription on paper is indeed immutable, but is not set in stone. The presence of technical design drawings of ships, dating from the 18th century, in a library in the 21st century signifies both their mobility and their immutability. However, this does not imply that designs are immune to modification. On the contrary, precisely the fact that the design has been inscribed makes it possible to change details as a result of changing requirements or experiences of users, leading to a (re)new(ed) immutable mobile, which in due course may again show that it is open to flexibility[205]. As long as we remember that flexibility is inherent when

---

202 Latour (1987), p. 227. The phrase "immutable and combinable mobile" is abbreviated by Latour to "immutable mobile" in the rest of the chapter.

203 Interestingly, McGee writes that "the use of plans did not spread to merchant shipbuilding until the mid-nineteenth century, so that the term "naval architecture" prior to 1800 really only refers to the building of warships" (McGee (1997) p. 222. In a later article, he rephrases this slightly: "Interestingly, the use of plans did not become the norm in merchant shipbuilding until far into the nineteenth century. Until then, plans were used almost solely for the construction of warships" (McGee (2003), p. 35). He seems to overlook the large number of ships built by the VOC according to "naval architectural" plans during the second half of the 18th century.

204 Latour (1987), pp. 226-227. His example of the pre-printed observation forms, supposedly used by Tycho Brahe, has been challenged by Gorman (2001) http://www.stanford.edu/group/STS/immutablemobile.htm

205 In another context, the term "fluid mobile" has been coined by De Laet & Mol (2000)

moving from one immutable mobile to the next, it feels appropriate to use the word immutable to describe that within a given set of inscriptions the content is indeed unassailable. As far as the adjective "combinable" is concerned, Latour points to the combination of several separate immutable mobiles but in the case of technical drawings for a ship design combinability is an essential part of the design itself. The three two-dimensional drawings that made up each design had to be combined to produce the three-dimensional artefact[206].

In Amsterdam, the English master shipwrights immediately introduced changes in the design of the naval vessels, and specified these through a complete set of technical drawings[207]. The hulls got sharper and more slender lines, the length and the width of the hulls increased and the ratio length/width increased, which meant that the ships became relatively narrower. The draught increased only slightly because the upper part of the hull was of a lighter construction. These changes suggest that complaints about naval ships being too slow were taken seriously: the new characteristics should allow for a greater speed. Looking from the outside, the most conspicuous change was the rounded stern that superseded the former square stern. Internally there were some changes too, such as the galley being moved from the hold to the *bakdek* (the covered front part of the upper deck). Regarding sailing characteristics, an important change was that the masts could be moved over the steps upon which the foot of the mast was resting. This made it possibly to reposition the masts slightly, in order to fine-tune sailing characteristics, even after the ship had been completed[208]. The planks, used in building the hull, were narrower than before. These and other details are to be found in a letter by Van Aersen van Sommelsdijk and others[209] in which they mention that they have closely studied design drawings for two different warships (which suggests they must have been able to read these) and agree with twelve changes in design, layout, equipment and construction details. The "English" design and (as we will see) the "English" building methods were instrumental in giving the new ships a more English appearance.

In the next section of this chapter, the ongoing development of the constructive Amsterdam network will be followed, concentrating on innovations in the building process, the consequences of this new approach and the opposition against it. The "English" systems (relating to design as well as to building) did not spread beyond the Amsterdam admiralty towards other admiralties. Neither the local master shipwrights at other admiralties – some of them independently developing drawing methods - nor the boards of these admiralties wanted to be enlisted into the Amsterdam network. These opponents of the new methods (and their instigators and proponents) seem to have used the word English as a derogative term, used to denote that the "English" procedures, practices and the resulting new ships were alien and inferior to Dutch traditions of shipbuilding. It is remarkable that such derogative remarks can be mainly positioned within the ranks of admiralties outside of Amsterdam, and not within the VOC, where "English" methods were introduced some fifteen years later, at a time when the controversies at the admiralties were still very much alive.

---

[206] As far as the ships are concerned – especially those of the VOC – these might be interpreted as "mutable mobiles": mutable in the sense that what was accumulated in its hold and in terms of its crew differed on the way out and the way back and in the sense that it served different purposes going and coming. This idea will be elaborated in a forthcoming article.

[207] Bruijn (1972), pp. 18-19

[208] According to Lemmers (1996), p. 57, this requires the use of a double step - in between which the mast was mounted. This practice seems to have been originally invented by Van Zwijndregt in Rotterdam and not by English shipbuilders.

[209] Letter by vice-admiral Van Aersen van Sommelsdijck, rear admiral Grave and the captains Schrijver and Lijnslager , dated 30 May 1727, in ARA VOC 4944 (30/5/1727)

2.3 Ships, wagers, sabotage and acrimony: internal and external expansion of networks

The English shipwrights relied on skills, empirical methods, practical knowledge and trial and error which they embedded in technical design drawings before the design was materialized in the artefact ship. In that way, their initial approach more or less resembled the Dutch approach to shipbuilding, which relied on descriptions, rules of thumb and sometimes on moulds derived from previous ships. The outcome of this process was – as we have seen –different in the sense that it generated a set of measured design drawings. To materialize the design faithfully into an artefact, the building process at the admiralty yard had to change as well. If other admiralties were to adapt the "English" procedures, a similar change would be needed there. In this section, attention will first be paid to the development of the constructive network in Amsterdam itself, how a shift of power was built into the network and in what way solutions were sought for emerging controversies. Next, the (failed) external expansion of the network will be described, through which other admiralties were to be linked with the design and building network of the Amsterdam admiralty.

2.3.1 The building of a constructive network

To materialize the new designs into vessels, a new building process was introduced. The crux of the new design was that the form of between sixteen and twenty-four main frames (depending on the size of the ship) was worked out in a very detailed and meticulous way. It would have been pointless to work out in detail how the form of the main frames was to be, and then use building procedures that made no use of these detailed drawings. Therefore, instead of the old shell first method, the English method needed to be adopted in which these main frames were faithfully copied from the designs by means of templates, erected on the keel and then the hull was constructed following the lines dictated by the frames. Blaise Ollivier, who visited the Amsterdam admiralty yard during 1737, confirmed this change in building practices. He wrote that at this yard the English shipwright Bentam had been practising the English manner of shipbuilding for about ten years[210]. The building process therefore had become subordinate to the design process, just as in England[211]. As a result, innovation promised to lead to increased standardization, but it also led to a decrease in the independence of shipwrights engaged in the actual building process. They became subordinate to the drawings and had less scope for adapting the design during the actual building[212]. The combination of new design procedures and new building procedures led therefore to a shift in power within the hybrid network, away from shipwrights working on the slipway towards the master shipwright who was responsible for the process of designing, inscribing and prescribing. As soon as the first English shipwrights were employed, the Amsterdam admiralty stipulated that drawings should be presented of each ship that was going to be built, with the intention of being able to reproduce this design exactly. However, according to Schrijver, writing in 1753, this obligation had been cancelled[213]. Schrijver's suggestion is supported by the fact that no drawings survive of any of the ships, designed by John May, master shipwright in Amsterdam after 1758[214]. It seems therefore that originally the board of the admiralty tried to increase control over the design (and the designer) of its ships, but eventually left the balance of power within the network in the hands of the master shipwright.

[210] Roberts (1992), p. 203.
[211] Schaffer (2007)
[212] Lemmers (1996), p. 23. In the case of the VOC, the implementation of the English way of design entailed even more changes in building practices. In section 3.3 an overview will be given of changes relating to the VOC.
[213] ARA Fagel (1.10.29) 1099 / Schrijver (1753), p. 7
[214] Hoving & Lemmers (2001), p. 35

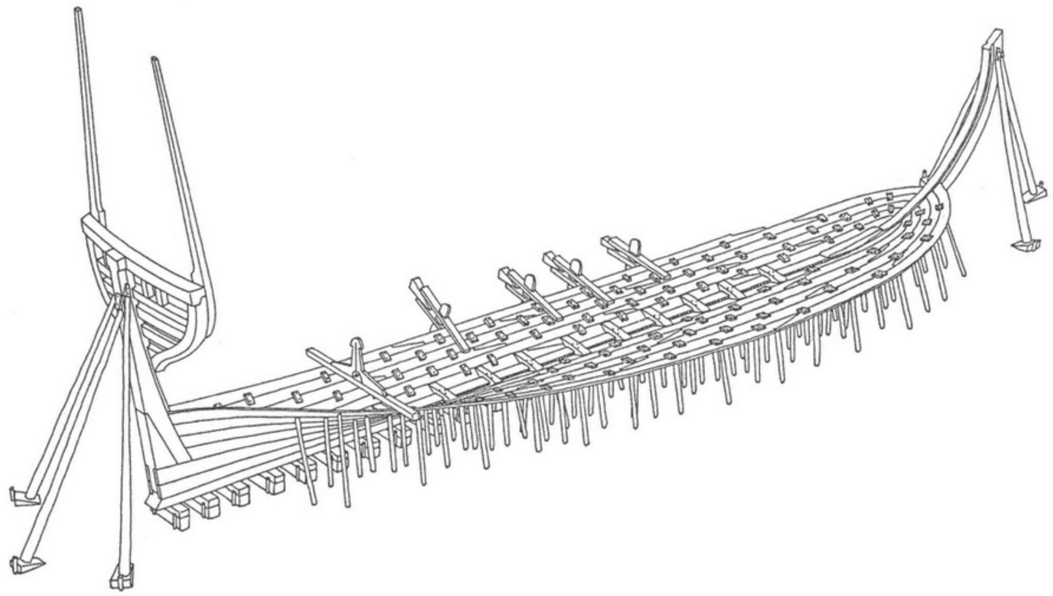


Fig. 2.6 The construction of the bottom of a vessel according to the shell first practice in Amsterdam and the North of the Republic; picture derived from Hoving & Parthesius (1991), p. 6

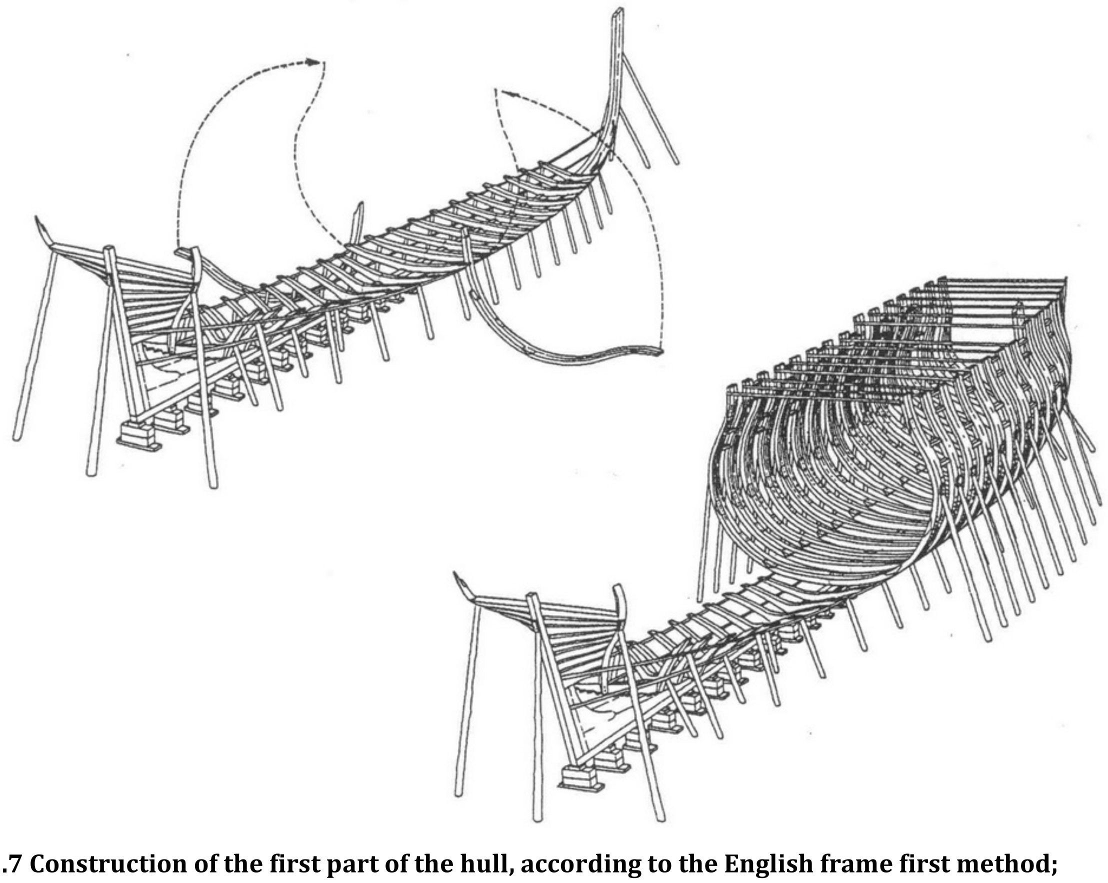


Fig. 2.7 Construction of the first part of the hull, according to the English frame first method; picture derived from Hoving & Lemmers (2001), p. 40

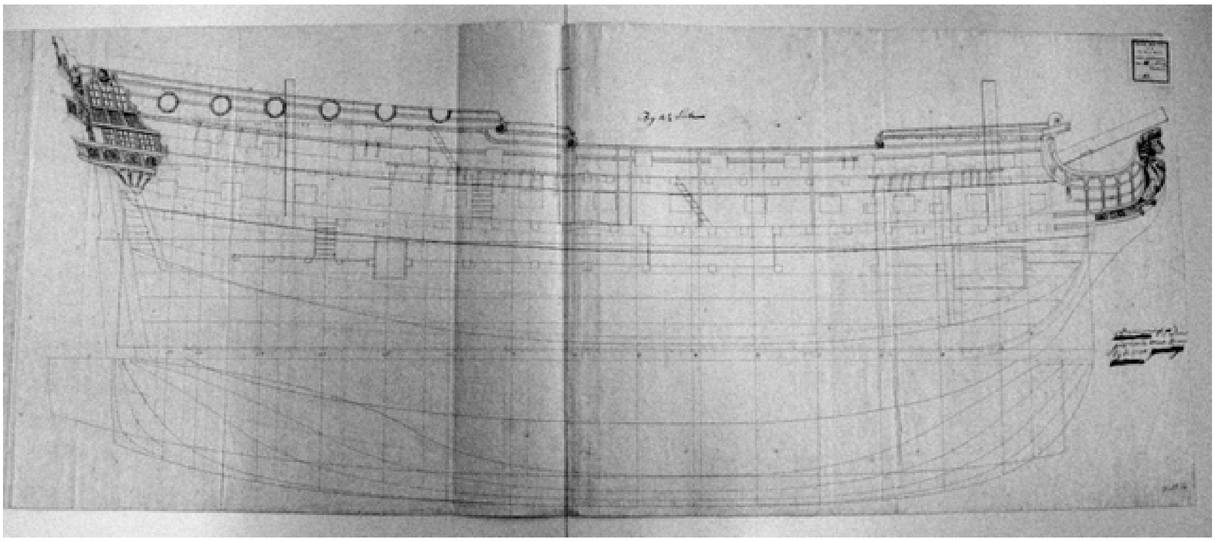
The original method used at the Amsterdam admiralty was the shell first method, described by Witsen in Aeloude en hedendaegse scheepsbouw en bestier (published in 1671/1691). It implied that first the keel was laid down and the stem and stern put into position. The next step consisted of fitting a number of timbers that were to form the bottom floor of the ship (as shown in fig. 2.6). The third step consisted of positioning a few low moulds on to floor to assist in constructing the transition from the bottom of the vessel to the bilges of the vessel. When that stage had been completed, preliminary frames were positioned on the bottom floor and between the bilges, outlining the vertical lines of the hull. Horizontally across these moulds, the planks forming the hull were fitted. Once the hull had been completed, the definitive frames were put in place, the form of which had to fit in with the hull as it had been created. These procedures offered the shipwrights, engaged in the building process, ample scope to (re)design a ship while building it.

Within the new "English" system of shipbuilding, after the laying of the keel, the "floors" of the frames were put in place. These floors had a form that confirmed to the form of the frames. On top of these floors, the main frames (also called station frames) were put in place, in two halves. The two halves were linked and locked between the keel and a so-called "chock" on top of the bottom of the frame (as shown in fig. 2.7). The floors and the main (or station-) frames had been constructed beforehand according to templates, derived from the technical drawings. That stage being completed, a few ribbands (small flexible planks) were mounted horizontally across the frames and then auxiliary frames were placed between the main frames; finally the planking of the hull was completed. In a sense, one could say that – within the building network - the main frames exercised control over the definitive form of the hull, and over the shipwrights as well. Working under the master shipwright, shipwrights were obliged to closely follow the new designs and to use the prescribed form of all main frames (depending on the size of the vessel, between sixteen and twenty-four) exactly as they were inscribed into the design, which led to a decrease in their independence, as already was indicated in section 2.2.2. This shows that the English system of designing and building not only made it possible to control the building of the ship itself right down to the smallest details but also to "control the shipwrights right down to the smallest details"[215]. The hybrid network encompassed the constructors, the construction method relating to the artefact under construction and, most importantly, the artefact itself. In the original system of shipbuilding, with no drawings available to record accurately what happened (or should happen) during the building process, the building of a second ship of the same dimensions and for the same purpose invariably led to variations in the materialization. This problem was (to a large extent) solved by the introduction of the new system.

In 1728, Davis launched his first two ships, the *Westerdijkshorn*, a vessel of the fifth charter, armed with 44 guns and the *Provincie van Utregt*, of the third charter and armed with 64 guns[216]. This implies that the new way of building ships must have been mastered quickly by the shipwrights at the admiralty yard, which says quite something about the professionalism and versatility of these artisans. By the end of 1728, the *Westerdijkshorn* left on convoy-duty for the Mediterranean. In several ports, the ship was the centre of attention by local dignitaries and shipbuilders. According to captain Lijnslager, who commanded the *Westerdijkshorn* on its maiden voyage, the sailing characteristics of the ship, especially its speed and manoeuvrability, were excellent. Later commanders confirmed his judgement[217], which gives the impression that the new ship performed better than its predecessors did. However, others argued that the new ships had too large a draught to be able to cross the Zuyderzee to the roadstead at Texel without running into difficulties, thus enlisting the local shallows again in the discussion.

[215] Hoving & Lemmers (2001), p. 33
[216] Approval of these designs is to be found in the letter by Van Aersen van Sommelsdijck e.a. (ARA VOC 4944 (30/5/1727))
[217] Bruijn (1972), p. 19

In the summer of 1729, Schrijver commanded the *Provincie van Utregt* on its maiden trip to Portsmouth, where it formed part of a combined English/Dutch squadron that was waiting to be called into action against Spain in the Mediterranean. Before he set sail from Amsterdam, Schrijver apparently discovered an attempt to sabotage the ship. In a letter to the Amsterdam admiralty, accompanied by a statement by his officers (dated 27 November 1736) he wrote "that the malice at the yard had been such that baskets full of rubbish had been placed near the drains, hoping to prevent water from reaching the pumps, so that in stormy conditions an English built ship would flounder so that it could be said that this was the result of building ships according to the English method".[218] If this allegation is true, then the opposition at the shipyard against the new English master shipwright must have been very serious indeed, and the attempt to sabotage must have been carried out by experienced artisans, possibly shipwrights, who knew where to inflict the most damage without incriminating themselves. On the other hand, Schrijver wrote the letter more than seven years after the alleged incident, so he may have exaggerated events to discredit his opponents. One way or another, this episode shows that there existed considerable (actual or perceived) opposition against the new system, an opposition that was the more important because it seemed to reside within the network.



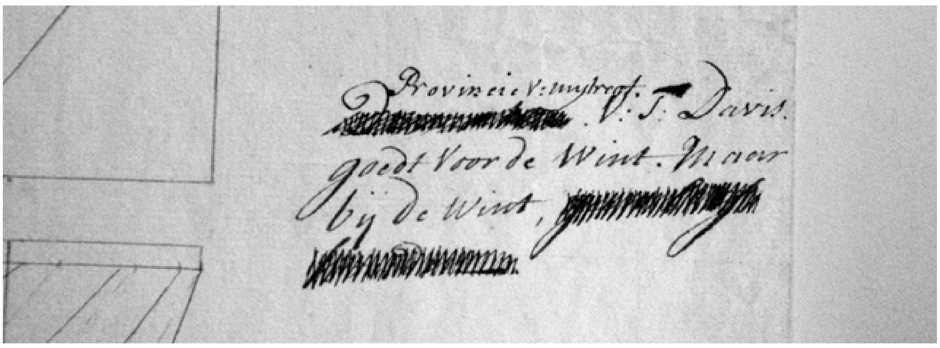


Fig. 2.8 The top picture shows the technical drawings (side view and top view) of the *Provincie van Utregt*, designed by Thomas Davis. The bottom picture shows a note (probably in Schrijver's handwriting) on the sailing capacities of the Provincie van Utregt, to be found in the right hand margin of the technical drawing. Photos of the original drawing in the Moll collection at the library of the University of Utrecht, taken by Johan de Jong (28 July 2009).

---

[218] His letter is partly quoted by De Jonge IV (1861), p. 263, footnote 1. Schrijver wrote: "*dat de quadaardigheid aan de werf zoo groot was dat men manden met vuilnis (…) voor de lockgaaten hadden gestopt, in de hoop (…) om te beletten dat het water na de pompen zoude zakken, om alzoo bij storm (…) een Engelsz gebout schip (…) te doen vergaan (…) om (…) te kunne zeggen dat zulks het effect is van de Engelsze gebouwde scheepen.*"

While the Dutch and English squadron were moored at the roadstead off Spithead, near Portsmouth, Schrijver, commanding the *Provincie van Utregt* had his ship measured and inspected by English and Dutch naval officers and shipwrights of the Portsmouth naval shipyard[219]. Upon comparison with a similar English and a similar (but older) Dutch vessel it emerged that, for the same length, it was slightly wider and that its draught was somewhat less. Overall, it was considered a good and very solidly built ship. To test its sailing capacities it competed in a regatta with the (English) *Monmouth*, which was considered to have the best sailing capacities of the ships in her 70 gun-class. This regatta took five days, under a fresh gale. The outcome was inconclusive, as the *Provincie van Utregt* was superior when sailing with a tailwind, or when sailing large, while the *Monmouth* was superior when sailing to windward. The wagers that had been placed upon the outcome could therefore not be paid out[220]. It is interesting to note that this regatta was organised more or less on the spot, although Schrijver might have had a hidden agenda in that he hoped to show the superiority of his new vessel, recently built at Amsterdam. It is curious to note that another English ship, the *Drake* (a sloop, rigged like a brigantine, which was also equipped with seventy oars, and therefore of an altogether different design) joined the regatta and was superior throughout. Even more curious is the fact that no other Dutch vessel took part in the regatta, although a Dutch designed ship of the same size was available as is shown by the fact that its measurements were taken. The discussion about the perceived superiority of the new "English" designed Dutch naval vessels was apparently conducted with the wrong partner. The purpose of the regatta remains something of a mystery. Two years earlier, the Amsterdam admiralty had engaged a number of English shipwrights. Therefore, there was presumably no need to show the superiority of their designs. Either, it may be interpreted as a rearguard battle against the opposition that had surfaced by the alleged attempt to sabotage the *Provincie van Utregt*, trying to pacify the shipwrights that might have been to blame by showing them the superiority of the new ships they were building. Alternatively, it may have been a shot across the bows of the other admiralties, by showing them that the new designs were at least a match for the (superior) English warships and thus paving the way for the introduction of the "English" methods at the other admiralties.

After his first two ships, Davis built several more until his resignation in 1735. The role of the English shipwrights within the Amsterdam admiralty continued to be questioned and in 1733, another attempt at sabotage was apparently discovered in the *Termeer*. Iron nails had been stuck inside the hawseholes through which the anchor ropes passed, causing damage to these ropes, which could have had serious consequences. Again, according to Schrijver, this had been done "not by ignorance, but with premeditated malice".[221] It seems that Schrijver's efforts to have the "English" method of shipbuilding introduced at Amsterdam still met with some opposition. After the resignation of Davis, Bentam continued with the building program. Linked with the shifting tasks of the Dutch navy, which had to concentrate more on convoy tasks and on engaging privateers from the Barbary Coast in their fast vessels, the emphasis was on building smaller vessels, such as frigates. However, in the closing years of the War on the Austrian Succession (1747-1748) a small number of large ships were constructed, which points to a re-emphasis on the classic role of large ships in sea battles. Considering the ships built by Davis and Bentam, one gets the impression that the standardization of the design process and the building process led to ships that were – at least as far as their dimensions are concerned - more standardized than used to be the case before the English shipwrights arrived[222]. However, as late

[219] Apparently, there were no hard feelings in Portsmouth regarding Schrijver, although it must have been known locally that he had been trying to convince shipwrights to leave for Amsterdam. For instance, the commander of the English squadron knew that an English shipwright had built the *Provincie van Utregt*.
[220] Bruijn (1972), pp. 19-20
[221] Schrijver is quoted in De Jonge IV (1861), p. 263, footnote 1: "*die aldaar niet door onkunde konden geslagen zijn, maar met voorbedachte kwaadaardigheid*"
[222] Bruijn (1970), Bijlage I, pp. 169-172

as the 1750s, Bentam felt that his position in Amsterdam was still being questioned. In October 1752, he published a printed pamphlet in which he tried to defend himself against "slanderous remarks concerning his shipbuilding, and to maintain his honour and reputation"[223]. In this pamphlet, various naval officers (some anonymously) were quoted, praising the sailing capacities of ships designed by Bentam. Whether the pamphlet is directed against criticism from within or from without the Amsterdam admiralty is not clear. Looking at the events that took place between the years 1747 and 1753 (as described below) it may well be that both external criticism (voiced by master shipwrights from other admiralties) and internal criticism (a conflict between Bentam and his assistant May) were at the root of the apology.

2.3.2 The spatial expansion failes

Admiralties outside Amsterdam refused to conform to the "English" methods introduced at Amsterdam. The board of these admiralties seemed to value their independence more than the assumption that the "English" system of shipbuilding made it possible to "control the shipwrights right down to the smallest details". In 1747, an attempt organized by the stadholder and *admiraal-generaal* Willem IV – on the instigation of fleet admiral Schrijver - to introduce the "English" method of ship design at all admiralties ended in an acrimonious debate in The Hague. By that time, the main task for the navy had moved towards convoy duties and combating the Barbary privateers. For that purpose, a number of fast frigates had been built. In 1746, the States-General had ordered the additional building of twenty-five (later decreased to twelve) ships of small charters, each carrying twenty to forty guns and needed for convoy duties during the War of the Austrian Succession (1740-1748). At that occasion, Willem IV suggested that naval vessels, belonging to the same charter, should be built using the same methods on all admiralty yards and that the master shipwrights of all yards should produce plans and drawings for these new ships. This suggests that the master shipwrights of the other admiralty yards were apparently considered to be able to produce technical drawings. In addition to using the same designs at all admiralties, a shipwright-general was to be appointed to supervise all master shipwrights at the admiralty yards. Charles Bentam, who by that time was master shipwright in Amsterdam, was to take up that post[224]. This suggests that the stadholder (and Schrijver) tried to expand the Amsterdam network to include the other admiralties as well, with the Amsterdam/English method of design as the standardized procedure within the network. This would have meant the introduction of the English system of shipbuilding as well, because of the – already indicated - intricate connection between design methods and building procedures. Looking at the numbers of ships involved, one might suppose that it made sense to follow a standard design. However, the master shipwrights of the admiralty yards at Rotterdam, Middelburg and Enkhuizen/Hoorn reacted by producing a memorandum in which they pointed out that ships of Dutch design were more appropriate for the circumstances encountered by the Dutch navy. They recruited nature as an ally by pointing to the ongoing silting up of entrances to harbours and the associated risk of grounding. This asked for a small draught to reduce the risk of grounding and for a sturdy construction to withstand grounding when it occurred. "Foreign" designs were deemed to be not suitable, as these were supposedly not strong enough structurally and had too much of a draught[225]. One gets the impression that the master shipwrights did not object to the building of specific types of vessel (such as convoy ships) as such, but that they objected to centrally prescribed designs and building methods. In their view, being part of the Amsterdam network would jeopardize their independence and the building methods they considered appropriate. In August 1747, several meetings were held at the lodgings of the Amsterdam admiralty at The Hague, in an effort to reach a solution. Against

[223] ARA Collectie Fagel (1.10.29 / 1099) Pamphlet by C. Bentam. In Dutch it says "*(…) vind zig gedwongen om veele Reedenen, van dagelyks alle lasteringen die hy moet ondergaan, ten opsigte van zyn Scheepsbouw, en alzoo ten principale tot maintien van desselvs Eer en Réputatie (…)*"
[224] De Jonge IV (1861), pp. 285-286; Bruijn (1970) pp. 20-21 and Hoving & Lemmers (2001), p. 18
[225] Hoving & Lemmers (2001), p. 18; Bruijn (1970) pp. 20-21

Bentam, the other shipwrights stuck to their guns and they did not budge, and neither did Bentam. Each party accused the other of incompetence. Bentam travelled twice to Hellevoetsluis to inspect ships built by Van Zwijndregt and to get acquainted with his building practices, but no solution was reached. This suggests that building practices were seen as crucial. This suggests that the master shipwrights were in agreement with the boards of the admiralties, although the developments in Amsterdam suggest that they had the most to gain from a change in designing and working practices. In September, the stadholder told the boards of all admiralties at an audience that they could go ahead with their own building practices, only the system of rigging had to confirm to the way it was practised in Amsterdam.[226]

The expansion of the design and constructive network beyond Amsterdam therefore had failed and consequently, the innovation – as far as the Dutch navy was concerned - did not spread geographically beyond Kattenburg. That is to say, apart from Friesland; as the admiralty in Harlingen was the smallest of all admiralties, it could not afford a master shipwright of its own and it usually relied on master shipwrights from Amsterdam to supervise the design and building of the few ships that were constructed on its yard. In 1728, Davis travelled during four holiday breaks to Harlingen to supervise the building of the *Prins Friso* (52 guns). Davis must have introduced the "English" methods locally at the time, as it is highly unlikely that he would have returned to the earlier Dutch shell first method. His designs would of course have travelled with him across the Zuyderzee, demonstrating again the mobility of the drawings. Later, in 1740, the admiralty of Friesland bought the (sabotaged) *Termeer*. From the late 1750s until the early 1770s, a (Dutch) pupil of Davis and Bentam was in charge of the design and building in Harlingen, undoubtedly continuing with the "English" methods[227].

The failed geographical spread of what has been called the immutable mobile of innovative technical drawings, points to the fact that its mobility was impaired by the weakness of the network that incorporated the drawings. In hindsight, one may suppose that the complaining captains had enlisted too few master shipwrights (and admiralty boards) as allies. Just a single network had been changed (albeit the largest), on the instigation of a few captains and councillors, consisting (amongst others) of one shipyard with its workforce, its slipways and its working practices, one board of governors, three imported shipwrights together with their technical drawings, material representations, new practices and the material products of these practices, specific tactical and strategic naval considerations and selected political allies. Relations with and the responses and reactions of other shipwrights and other admiralties were not translated into the network: the process of building allies all but stopped at the boundaries of Amsterdam. Procedures and working practices outside Amsterdam proved to be immutable. Instead of trying to enlist other localities, a material contest was played out, through regattas between ships in which there was supposed to be one winner, and through the publication of manifestos that only preached to the converted. In the ensuing political powerplay, the tables were turned when the stadholder died.

In relation to the failure of the spatial spread of the innovative method of ship design and building, and its adaptation at other localities, it might be useful to remember the geographical perspective, mentioned by Inkster. He suggested that a "diffusing item (….) may be at once a stimulus to further innovations and itself subject to *adaptation* as it spreads from its physical point of origin"[228]. One gets the impression that local adaptation was not in the cards in the discussions in 1747. It seems that the other admiralties were asked to accept the "English" methods exactly as they had been implemented in Amsterdam. In the next chapters we will see that the VOC allowed its master shipwrights more room to manoeuvre, which may have

[226] Lemmers (1996), p. 58, Bruijn (1972), p. 20 and Van Bruggen (1974 / issue 29) pp. 13-14
[227] Hoving & Lemmers (2001), pp. 137-138
[228] Inkster (1991), p. 16, quoting Brown and Moore Diffusion Research in Geography: A Perspective . Italics appear in the original text.

contributed to the successful spread of the "English" methods within the VOC. Speaking about local adaptation, Inkster pointed out that the success of innovative technology imported from abroad is dependent on the ability of local artisans to modify and reconstruct this technology; otherwise, the new technology will not spread beyond its original niche[229]. To this ability should be added the willingness of both local artisans (and local councillors) to engage with an innovation from abroad, as is shown by the events in 1747 and later.

In 1748, the position of assistant master shipwright at Hellevoetsluis became vacant. This shipyard belonged to the Rotterdam admiralty and specialized in maintenance and repairs. Interventions by the stadholder led to the appointment of a shipwright from Amsterdam, who had been apprenticed to Davis and Bentam. When the post of master shipwright in Rotterdam itself became vacant, Schrijver suggested that Leendert van Zwijndregt, the candidate preferred by the Rotterdam admiralty, and John May, from Amsterdam, who had also applied for that post, should each build a frigate to test which of the two was the most accomplished shipwright[230]. However, by the time both ships (Van Zwijndregt's *Oranjezaal* and May's *Triton*) were ready, Willem IV had died and Schrijver's influence waned. Van Zwijndregt got his appointment without the proposed regatta between the two frigates being held.[231]

In 1753, the governess Anna, widow of the deceased stadholder Willem IV and acting regent for her minor son Willem V, decreed that the regatta should go ahead at a time when a navy squadron was cruising in the North Sea, waiting to escort the returning VOC-fleet from the East Indies back home. Meanwhile in Amsterdam a conflict had emerged between Bentam and May. Supporters of May grasped the opportunity to arrange a regatta between the *Haarlemmerhout*, built by Bentam, and the *Triton*. After much wrangling[232] about who should be supervising the regatta and about the fairness of the regatta itself (the *Haarlemmerhout* had been used for quite some time and was heavily fouled, whereas the *Triton* had never been to sea), the regatta between these two ships went underway, ending inconclusively. The next regatta between the *Triton* and the *Oranjezaal* seemed to show that (in the light conditions at the time) the *Triton* was the superior ship, but whenever there was more wind the *Oranjezaal* seemed to have had the upper hand. In the end, it was decided that both ships were "quick and fast".[233] These inconclusive outcomes were possibly quite convenient, as they allowed both Van Zwijndregt and Bentam to stay in their posts. Eventually, May succeeded Bentam after he died in 1758.

In January 1755, Schrijver undertook a final attempt to secure the innovation and standardization of Dutch shipbuilding that he wished to realize. He did so by publishing a pamphlet, called <u>Plan voor Zee-Wetten</u>[234] in the series <u>Boekzaal der Geleerde Waerelt</u>. By this time, he had moved beyond naval shipbuilding and in his pamphlet he addressed commercial shipbuilding and the education of naval officers as well. It is significant that Schrijver at that time started mentioning the French approach to shipbuilding, as he obviously did not take much notice of French methods when he introduced English shipbuilders and their methods at the Amsterdam admiralty in 1727. In contrast to the Dutch and English shipbuilding tradition, at the French navy a more mathematical/theoretical approach was introduced from the end of the 17th century onwards[235]. In his pamphlet, Schrijver denounced Dutch shipbuilders as not having a

---

229 Inkster (1991), pp. 55-59
230 ARA Collectie Fagel 1753 / Letter from Schrijver to Mr. Fagel, clerk of the States General regarding the state of the Dutch shipbuilding.
231 Bruijn (1972), p. 21-22
232 Schrijver suggested (without proof) that the design of the *Triton* and the *Oranjezaal* was based on a French frigate, taken by the English in the War of the Austrian Succession. At that time, French warships were considered far superior to other warships.
233 Bruijn (1972), pp. 22-24
234 This is the <u>Plan</u> mentioned in previous sections. In translation: "Plan for Sea-laws", published in "Library of the Learned World"
235 Some more remarks on the French mathematical/theoretical approach will be made in chapter 4.

sufficient theoretical background, and he wrote "that the Dutch master shipwrights did not understand theory and plans, which is also the reason why Dutch master shipwrights did not proceed beyond their expertise of over a hundred years ago, whereas other nations did. They surpass them very much in this respect"[236]. To redress the – supposed - lack of theoretical knowledge he suggested that French and English literature on shipbuilding should be translated into Dutch[237]. The first (and the only) book in the proposed series that was translated was Élémens de l'Architecture Navale by Duhamel du Monceau. In 1757, a Dutch translation was published as Grondbeginselen van den scheepsbouw, of werkdadige verhandeling der scheepstimmerkunst[238]. The fact that their competence as well as their theoretical and practical knowledge was publicly being questioned caused renewed disquiet amongst shipwrights outside of Amsterdam[239]. Master shipwright Udemans from Middelburg (at that time assistant master shipwright at the local VOC-yard) and Leendert and Pieter Van Zwijndregt, shipwrights at Rotterdam (Leendert being master shipwright at the local admiralty yard and Pieter holding the same position at the local VOC-yard) each a reacted to Schrijver's proposals. Two of these reactions were published at the time. Leendert's essay Verhandeling van den Hollandschen Scheepsbouw raakende aan de verschillende Charters der Oorlogsschepen[240] was the second (and last) publication in the series proposed by Schrijver, and the essay by Udemans was published independently. The essay by Pieter van Zwijndregt only survives as a manuscript[241]. In this essay, he tried to refute the notion of Schrijver that Dutch shipbuilders lacked theoretical knowledge regarding shipbuilding and shipdesign. In addition, he discussed the results of a series of experiments, which he had undertaken and from which he tried to deduct some rules for the design of ships.

By the mid 1750s, the use of technical design drawings and new building practices had spread to most large shipyards in the Republic. As far as the admiralties were concerned, Amsterdam and Friesland used the "English" methods, Rotterdam used the local method developed by the Van Zwijndregt dynasty, and Zeeland used the local Udemans system. The situation at the Noorderkwartier admiralty is unclear; probably the existing methods remained in use. From 1742 onwards, the "English" system was also used at the shipyards of the VOC. In the next chapters, it will be shown how this system operated at these yards and how local shipwrights were able to negotiate changes to the system.

2.4 A radical innovation leading to standardization: an interpretation

The innovation introduced at the Amsterdam admiralty by English shipwrights through their "English" methods displayed a radical character. At the same time, the innovative aspects of the use of technical drawings and of new building techniques led to an increased degree of standardization.

The innovative aspect of the use of detailed technical drawings during the phase of design meant that the actual shape of a new ship was determined before the building process got under way,

[236] In Dutch: "*dat de Hollandse Bazen die Theorie en plaanen geenszins verstaan, dat dan ook de reden is dat niet regt gezegd kan worden dat de hollandse Bazen in de kunst van het Oorlogsschepen te bouwen niet verder zijn gevorderd als zij voor honderd en meerder jaren kundig waren; daar andere Natien zijn geavanceerd. Hun in deze zeer verre overtreffen*"
[237] Schrijver's Plan in Hoving & Lemmers (2001), pp. 159-162
[238] The translation was made by "*een liefhebber der vrije kunsten, onder opzigt van twee beroemde scheepsbouwers, P. de Hondt en H. Scheurleer*" (i.e.: "an amateur and lover of the free arts, supervised by two famous shipwrights, P. de Hondt and H. Scheurleer").
[239] For the Dutch situation, see Deurloo (1971), for the English situation see Schaffer (2007).
[240] In translation: "Essay on Dutch shipbuilding, concerning the different charters of naval vessels".
[241] This manuscript was published in Hoving & Lemmers (2001), pp. 181-296

and that no longer the building process itself determined the final shape of the ship. This shape was inscribed into drawings, which showed in great detail how the ship would look, once completed. The representational technical drawings therefore had "enormous (…) rhetorical power" because it spoke convincingly about the new artefact. [242] No longer was the board of the admiralty dependent on descriptions and specifications to get an impression of a new ship, but by looking at the drawings they might be able to see how the vessel would look even before the artefact itself was completed. This of course supposes that board members were able to read the set of drawings, and combine and visualize these into the artefact-to-be. Their learning process was assisted by the master shipwright producing halfmodels (or even complete models) of the new design and these three-dimensional representation being brought into the boardroom, creating another immutable mobile of technical design. As far as the Republic is concerned, the first halfmodels of ships actually date from the time that English shipwrights were introduced at the Amsterdam admiralty; one of these models can with certainty be attributed to Charles Bentam[243].

Another innovative aspect was the use of technical drawings not only at the design stage, but also during the building of the ship. Although - through lack of (mathematical and theoretical) knowledge about the behaviour of ships at sea - it still was not possible to predict how a ship would behave once it was built, this innovation at least opened up the possibility to faithfully reproduce ships. This meant that it might be reasonably expected that a second ship, built to the same design, would possess the same characteristics (such as size, dimensions, shape of hull and, most importantly, sailing characteristics) as an earlier ship, as long as it was built according to the same drawings. The design, once agreed upon, was "immutably" inscribed onto paper and displayed its mobile character by being moved (over and over again) to the lofts and to the slipway. Before the introduction of drawings, Dutch building practices were generally not capable of faithfully reproduce sister-ships with predictable, similar characteristics[244]. Now, probably for the first time in the history of Dutch shipbuilding, if a series of similar ships was to be built, one could be reasonably certain that these ships might be called sisterships, meaning that these ships were more standardized than before[245].

By inscribing onto paper the details of the design, it also became possible – by using the flexibility built into the drawings - to modify those parts of the design that turned out to be unsatisfactory in practice while maintaining other details. This meant that a process of adapting existing designs to variations in uses and circumstances became possible without having to go through a completely new design process[246]. In a break with existing practices, changes within a design had no longer to rely on adaptation on sight [247]. While the original "hands on" flexibility during the materialization of designs may be considered as positive, as it allowed for an "on the spot" adaptation of the design to changing demands, on the other hand this could easily lead to an uncontrollable flexibility. In contrast, the flexibility, inherent to the immutable mobile, made interaction between users and designers easier to translate into the design while retaining the stability of the design as such. In turn, this increased the level of standardization.

As a result, ships no longer got their definitive form during the building process, but already at an earlier stage through descriptions, technical drawings and sometimes models. The design process itself changed from being partly a material design process at the slipway of the yard to a

---

[242] Lubar (1995), p. S63
[243] Lemmers (1996), pp. 33-37
[244] Complaints about the unpredictability of the behaviour of similar ships can be traced back to the 1660s (Lemmers (1996), p. 22)
[245] As mentioned in section 1.5, a process of standardization had been introduced at the yards of the VOC from the end of the 17th century onwards. Although the hulls of the ships might be not completely standardized, parts used in building the VOC-ships were already interchangeable.
[246] A documented example of such an adaptation in the case of the VOC will be given in chapter 4.
[247] Van Bruggen (1974 / issue 29), pp. 10 and 17

paper-based process at a drawing board within an office, an office that in due course might even no longer be situated at the yard itself[248]. Through the strict implementation of the design, the master shipwright increased his grip on the materialization of the design, leading to an increase in standardization, but also leading to a decrease in the independence of shipwrights engaged in the actual building process. They became subordinate to drawings and had less scope for adapting the design during the actual building. This illustrates what Stephen Lubar wrote: "Designers and engineers capture the essence of technology in representations, and technological institutions use those representations to subdivide work and produce and control technological artefacts and systems" [249].

Considering these aspects, the innovation in designing and building within the technological enterprise of the Amsterdam admiralty can be interpreted as a radical and system-changing one, because it created an intended break with previous procedures and practices, affecting not only the design process but also building practices. [250] In an essay on large technological systems, Hughes distinguishes between radical and conservative inventions. He positions *radical* inventions against *conservative* inventions that appear in existing systems during competition and system growth; conservative inventions are very similar to what Misa calls *system-stabilizing* inventions[251]. Hughes suggests that large technological systems are the culmination of radical inventions, when these are turned into an innovation[252]. If one follows Hughes to the letter, he seems to suggest that large technological systems appear because of a radical innovation, apparently overlooking the possibility that an existing large technological system might change through the introduction of a radical innovation.

According to Hughes, when a (radical) invention is developed into an innovation "the social construction of technology becomes clear" and the inventor embodies in the invention "the economic, political and social characteristics that it needs for survival in the use world".[253] However, this interpretation suggests that only at the stage when an invention is turned into an innovation, certain characteristics are added to something that is already technologically complete, which ignores the seamless character of a hybrid network. Arguing for a more integrated approach, Law wrote "(that) *the stability and form of artefacts should be seen as a function of the interaction of heterogeneous elements as these are shaped and assimilated into a network.* In this view then, an explanation of technological form rests on a study of both the *conditions* and the *tactics* of system building"[254]. Such a heterogeneous (or hybrid) network approach, acknowledges the importance of non-human actants (such as the shallows along the Dutch coast, the purpose of the Dutch navy and the lack of availability of financial funds), and recognizes the existence (and importance) of conflicts and conflicting interests. The recognition of the role of conflict makes this approach especially appropriate when considering the success and failure of the introduction of ships' technical drawings and different building techniques in the Republic.

The introduction of "English" methods failed at most admiralties outside Amsterdam, probably because of the fact that too few allies were recruited and that local developments, such as at Rotterdam were not recognized. To use a modern term, the "top-down" approach that became manifest in 1747 failed to enlist a sufficient number of other master shipwrights. In contrast to

[248] As was the case with naval shipbuilding in England (see Schaffer (2007))
[249] Lubar (1995), p. S63
[250] This change in practice was confirmed by Blaise Ollivier (cf. section 2.3.1)
[251] Hughes (1987), p. 57 and Misa (2004), chapter 5. However, whereas Hughes seems to imply that conservative inventions do not lead to innovation, Misa recognizes the existence of "system-stabilizing modes of innovation". It will be argued in the next chapter that the introduction of technical drawings at the VOC displays aspects of such of a conservative/system-stabilizing character.
[252] Hughes (1987), p. 62 and 64
[253] Hughes (1987), p. 62
[254] Law (1987), p. 113, italics appear in the original text

this failure, in 1742, a similar introduction succeeded at all yards of the VOC. In chapter 3, it will be shown that the way in which local master shipwrights were made allies within the renewed VOC-network differed from what happened at the admiralties. It will also be argued that within the VOC the innovation displayed more of a system-stabilizing character, but that it also strengthened the standardization that the VOC had been implementing since the end of the 17th century. Master shipwrights of the VOC proved to be able to critically assess the innovation and standardization, and to adapt and appropriate the immutable mobiles they had been given, which will be described in chapter 4.

Summary

In this chapter, the introduction of innovative design and shipbuilding methods at the Amsterdam admiralty was interpreted through the concept of a local hybrid network, and the design drawings themselves have been read as immutable mobiles of an inherently flexible character.

During the early decades of the 18th century, the quality of Dutch ships and shipbuilding was repeatedly being questioned, both regarding the navy and regarding the VOC. High-ranking naval officers complained about the quality of the ships they were given to command and about the lack of appropriateness for the tasks these ships had to perform; the goals of the Dutch navy (as part of the combined English-Dutch navy) being sometimes at odds with local interests. In an attempt to improve the quality of ship design and shipbuilding, English shipwrights were appointed at the yard of the Amsterdam admiralty. Flag-officer Cornelis Schrijver played an important role in this process. The English shipwrights took with them a system for the production of technical drawings, leading to the immutable (although flexible) mobiles of design drawings. Apparently unknown to the boards of the admiralties, at the same time some Dutch shipwrights were developing similar systems for technical drawings.

The innovation of using technical drawings at the Amsterdam admiralty can be seen as having occurred through the (re)construction of a local hybrid network, consisting of human actors (shipwrights and master shipwrights, captains, councillors) and of non-human entities (naval policies, naval vessels, drawings, building methods, estuaries and shifting shallows, depleted finances). The introduction of the new design process also implied the introduction of a new building process, which meant a radical break with earlier procedures and which introduced an increased control by the master shipwright over other shipwrights. The innovation introduced in Amsterdam was not without controversy, as was borne out by attempts to sabotage ships. A (quasi)objective way of assessing the quality of new ships through a regatta ended inconclusively. Meanwhile, local shallows kept re-appearing in discussions about the appropriateness of the new designs.

The new network turned out to be not strong enough to be stretched over the whole of the Republic, as the imported innovation in naval ship design and shipbuilding did not spread to the yards of other admiralties. This became clear through events from 1747 onwards. The independence of other yards (and their master shipwrights) and of local building methods turned out to be insurmountable obstacles to the building of one large constructive network. Even in Amsterdam itself, the innovation continued to be questioned as is shown by a pamphlet, written by Bentam (the second of the English master shipwrights) and a lengthy letter by Schrijver to the States-General. Bentam, who was master shipwright in Amsterdam between 1735 and 1758, even had to contend with a regatta being held between a ship of his design and a ship designed by his assistant. A final attempt by Schrijver to improve the quality of Dutch shipbuilding through the publication of a pamphlet provoked the publication of a few books by Dutch shipbuilders, arguing their case against his ideas. Some of these publications (and a non-published manuscript) will be discussed more extensively in the next chapters.

The introduction of technical design drawings at the Amsterdam admiralty and their implementation in the building process has been interpreted as a radical innovation, which at the same time opened the possibility for increased standardization.

Meanwhile, from the early 1740s onwards, the VOC was embarking on its own program for change. A complicated restructuring process regarding ship design and shipbuilding ended with Bentam being asked to produce new designs for retourschepen in three different charters. His "English" designs were turned into the standard designs at all yards of the VOC. Eventually, the new VOC-network incorporated not only the "English" innovation of designing and building ships, assisted by technical drawings but also the standardization that had been an important aspect in the shipbuilding of the VOC from the late 17th century onwards. Just as was the case at the Amsterdam admiralty, standardization was intricately linked to the innovation of technical drawings and to a changing way of shipbuilding at the (industrialized) yards of the VOC. In addition, it formed the culmination of a process of standardization that had been going on for a considerable time[255]. In chapter 3, it will be argued that in the case of the VOC, the radical innovation of the use of ships' technical drawings and new building practices can be interpreted as displaying a system-stabilizing character. The construction of this network was a rather fluid affair as will be shown in chapter 4; for instance, the practical experiments of Pieter van Zwijndregt secured themselves a place within the VOC-network when he appropriated the immutable flexible mobiles handed down to him.

[255] As was described in section 1.5; the continuation of that process will be described in section 3.1.

3. Changing ships

Dit hoofdstuk speelt zich af in het Amsterdam van de jaren 1740-1742, maar eerst wordt teruggeblikt op gebeurtenissen uit de jaren daarvoor. Is de VOC aanvankelijk te kenschetsen als een “large enterprise”, geleidelijk aan kan ze steeds meer gezien worden als een “large technological enterprise” door haar uitgebreide, gestandaardiseerde en adaptieve scheepsbouwprogramma. In het begin van de 18de eeuw waren op een adaptieve manier veranderin-gen aangebracht in de bestaande charters, maar het bleek uit stormen bij Kaap de Goede Hoop en in de Indische Oceaan dat deze veranderingen niet over de hele linie verbeteringen waren geweest. Na stormachtige reacties in de Republiek kwam het tot een proces waarbij – opnieuw op adaptieve wijze - een herzien ontwerp voor de retourschepen werd vastgesteld (par. 3.1). Al voordat deze adaptieve oplossing in de praktijk kon worden ingevoerd werd een meer radicale oplossing voorgesteld door tussenkomst van een teruggekeerde (beoogde) gouverneur-generaal. Het bestaande, herziene ontwerp werd vervangen door een radicaal nieuw ontwerp, gebaseerd op ontwerptekeningen van Charles Bentam, Engels scheepsbouwmeester bij de admiraliteit van Amsterdam. Na raadpleging van direct betrokkenen (scheepsbouwmeesters van de VOC-werven te Amsterdam en Middelburg, van particuliere werven en ervaren schippers) werd dit nieuwe ontwerp ingevoerd. In aanvulling op eerdere procedures (bestaande uit het vastleggen van hoofdafmetingen en uit besteklijsten) werden nu ook technische scheepstekeningen en modellen verstrekt aan de scheepsbouwmeesters van de VOC. Zij kregen de opdracht zich strikt aan de nieuwe ontwerpen te houden De ontwerptekeningen kunnen gelezen worden als *immutable mobiles* (par. 3.2). Het invoeren van deze technische ontwerptekeningen had ook gevolgen voor de wijze waarop de schepen gebouwd werden; een nieuwe, beter controleerbare bouwwijze droeg bij aan een nauwgezette materialisatie van het ontwerp. Daarbij zou men kunnen stellen dat de scheepstekening niet alleen het scheepsontwerp definieerde, maar er ook toe diende om de werkwijze op de VOC-werf te tekenen en te legitimeren. De wijze waarop de schepen van de VOC rond het midden van de 18de eeuw vorm kregen vertoonde enerzijds kenmerken van een onderhandelde innovatie en standaardisatie, en was anderzijds verbonden met een centralistische managementcultuur. De nieuwe manier van ontwerpen en bouwen leidde ertoe dat de VOC geïnterpreteerd kan worden als een “large technological enterprise”, en een uitgebreid nieuwbouwprogramma bevestigde dat de VOC ook de grootste technologische onderneming in de Republiek was. Door middel van de tekeningen en de nieuwe bouwwijze worden de scheepsbouwmeesters van alle werven samengeweven in één hybride construerend netwerk; hun positie binnen het netwerk is verschoven van die van ontwerper en bouwer van (deels door hen zelf ontwikkelde) ontwerpen naar die van bouwer van het ontwerp van een buitenstaander (par. 3.3). Met dit al lijkt de positie van de scheepsbouwmeesters tamelijk ingrijpend veranderd te zijn, maar kritiek op de nieuwe ontwerpen opent voor hen de mogelijkheid om zich opnieuw als deskundigen te profileren, zoals in hoofdstuk 4 beschreven zal worden.

The large commercial conglomerate of six separate chambers acting as the VOC was transformed over the years into a single large technological system through the continuous development of its shipbuilding operations. Originally, the technological character of the VOC was not built on any radical invention, but relied on existing Dutch shipbuilding expertise that became increasingly standardized over the course of several decades.[256] In 1697, about seventy years after the start of its shipbuilding operations, the VOC started on the path towards becoming a large technological system that was more impressive than that of the Amsterdam admiralty. Whereas the admiralty can be considered as a local or regional technological enterprise, branching out through its ships from the North Atlantic to the Mediterranean and the West African coast, the VOC operated on a much wider geographical scale, with outposts halfway across the globe, linked by an intricate shipping pattern, both from the Republic to the East Indies, China and Japan and within the Far East. It was not only concerned with building a huge commercial empire, both at home and overseas (as has been shown in chapter 1) but – as a

[256] See section 1.5

technological enterprise – it became the largest single producer of ships (or indeed technological enterprise) in the Republic during the 17th and 18th century.[257] This process reached its culmination through the introduction of new design and building practices during the 1740s.

With the controversy about "English" innovations at the admiralties in Amsterdam and beyond still making some waves, the VOC was in even more stormy waters. During the first decades of the 18th century, an ongoing process of negotiations took place within the VOC-network, leading to a repeated adaptation of the standardized design of the *retourschip*, in answer to changing needs of both local VOC-chambers and of local estuaries. Storms at the Cape and in the Indian Ocean however made it clear that – while the changed design might have succeeded in satisfying directors and enlisting local estuaries - it had failed in recruiting natural phenomena between the Republic and the East Indies. The ensuing stormy exchanges with the States of Holland and the States-General brought into the open serious problems in the design of the *retourschepen* and – more generally - in the way the VOC operated. Within the VOC-network, several attempts were made to address these issues, and more specifically, the design of the retourschepen was adapted in a more rigorous way than before. This adaptation was brought about by negotiations within the VOC-network, in which the States of Holland and the States-General made themselves heard – albeit from outside the network. These processes of change, the way in which they were negotiated and their consequences will be described in the first section of this chapter.

The latest adaptation of the designs was discarded before it had been implemented, in favour of a more radical solution, instigated by the high-ranking VOC-official Van Imhoff. After his sudden arrival in the Republic, the *Heeren XVII* asked him to suggest proposals for commercial, organizational, personal and technological change within the VOC. He managed to enlarge the VOC-network with allies from outside the network and asked an outsider, Charles Bentam (master shipwright at the Amsterdam admiralty), to produce designs and technical drawings for three new charters of *retourschepen*. At the same time, he did not neglect actors from inside the network and only after extensive consultations with experienced shipwrights and skippers from within and from outside the VOC, these new designs were adopted, as an inscribed extension to the network. The innovation of designing and building ships according to technical drawings used a similar immutable mobile as was being used at the Amsterdam admiralty. Through a description of Van Imhoff's proposals, the way he extended the network and his explicit incorporation of the knowledge of artisans and specialists from within and from outside the VOC, it will be shown that his rather radical solution was used to stabilize the system of the VOC.

The use of technical design drawings led to a change in building procedures at all VOC-yards, to make it possible that the new design drawings could be materialized into the prescribed artefact as exactly as possible. In contrast to what was about to happen at the admiralty yards, all VOC-yards adopted the new procedures, and an impressive building program got underway, as will be described in the third section. The changed design and building procedures assisted the VOC to develop into an increasingly large technological enterprise. Within this enterprise, the role of master shipwrights at the local yards changed and they lost part of their independence because they had to supervise the building of ships strictly to somebody else's design and were no longer responsible for designs of their own. Finally, it will be shown that the introduction of innovative design methods and building techniques did not prevent an ongoing discussion about the designs themselves. A first indication of this discussion will be given, in anticipation of a more extensive discussion in the next chapter, where it will be shown how some local master shipwrights regained some of their independence vis-à-vis the prescribed and prescribing design drawings.

---

[257] This in contrast to the British East India Company that hired ships owned by private ship-owners, although specifically built for the East India trade (Bruijn e.a. (1979-1987) Part 1, pp. 93-94).

3.1 Stormy weather…

3.1.1 … at the Cape of Good Hope

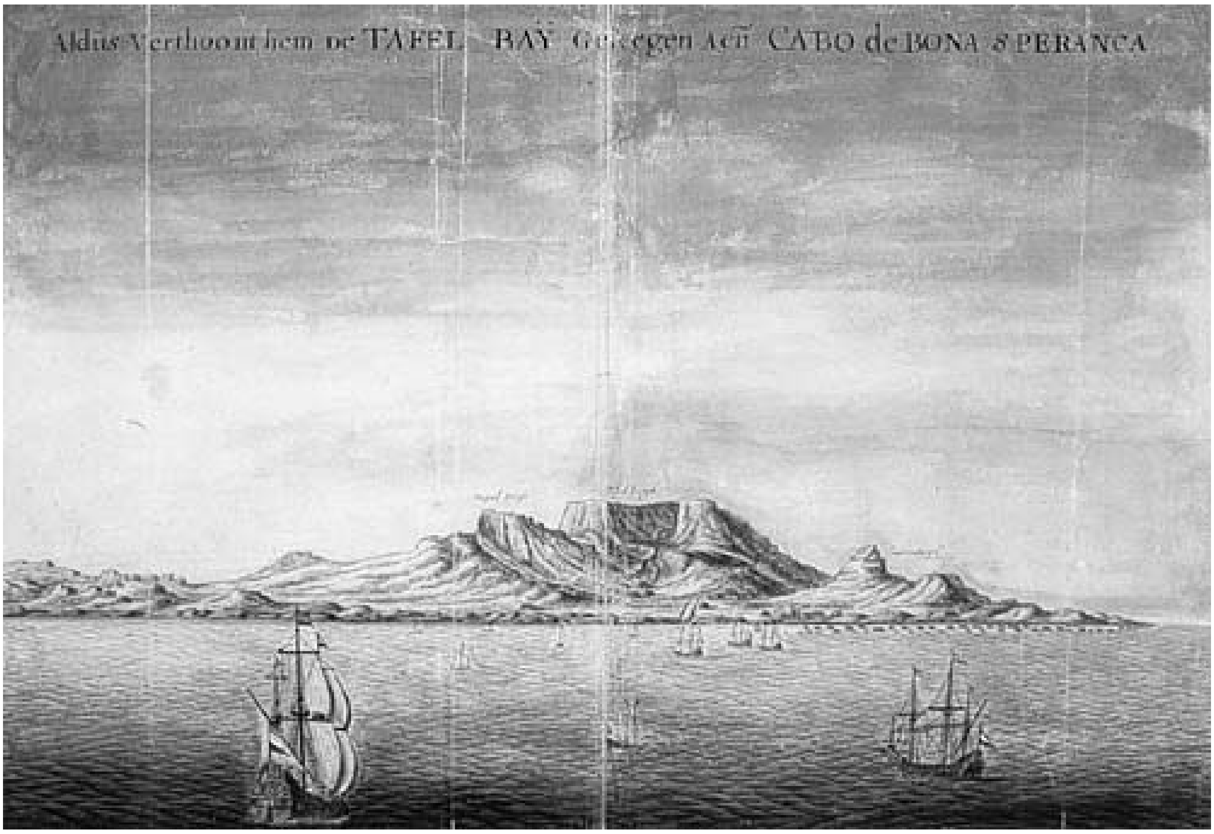


Fig. 3.1 Table Bay at the Cape of Good Hope at the time of the VOC, retrieved through http://voc-kenniscentrum.nl/images/vest-kaap.jpg

In June 1722, disaster struck at the Cape of Good Hope. A heavy north-westerly storm surprised ships of the outward VOC-fleet, lying at anchor in Table Bay. Five *retourschepen* of the fleet, as well as a *hoeker* and a small *jacht,* were completely wrecked with a large loss of lives. In a letter, dated 15 July 1722, the Governor and Council of the Cape wrote "(….) it is with utter sadness and crying that we have to say (…) that it has pleased God (…) through his chastising and visiting hand to punish heavily not only all the mentioned Company's Ships, but also the *hoeker Gouda*, the small yacht *d'Amy* and three visiting English ships (…)"[258]. Earlier that year, in January 1722, six *retourschepen* of the homebound fleet had perished because of hurricanes near Mauritius in the Indian Ocean. In July 1728, again two ships perished at Table Bay during a storm. In an effort to avoid these winterstorms at Table Bay, alternative anchor sites were being researched. Meanwhile, the *Heeren XVII* had given permission to use the more northerly Saldanha Bay as an alternative to Table Bay in winter, but even as late as 1737, no official alternative had been decided upon. Then, in May 1737, eight *retourschepen* of the homebound fleet went down when they were surprised by a storm while anchoring at Table Bay. On 24 May 1737, the Governor of the Cape wrote that "especially the Sea, in a terrible way" had been "rolling as whole mountains

[258] ARA VOC 4744 (24.8.1740), pp 14-15 (Extract of letter dd. 15 July 1722) In Dutch: " *(…) wy ook met de uyterste droefheid en weenende nogtans seggen (…) dat het God behaagt heeft (…) door sijne kastijdende en besoekende hand alle de gemelde Compagnies Scheepen niet alleen, maar ook den Hoeker Gouda, het Jagtje d'Amy, en de drie hier vertoevende Engelsche Scheepen(…) op het alderswaarste te straffen*". The *hoeker* was built in 1719 in Amsterdam and probably stationed at the Cape. Regarding the small *jacht*, only its name *d'Amy* is mentioned, no further details are known.

into the Bay"[259]. However, in the Republic rumours started spreading that the recent redesigning of *retour-schepen* and incompetence of skippers might be partly to blame for what had happened.

The seemingly strict standardization of 1697 of the *retourschepen* - as described in section 1.5 – had been subject to a more or less continuous process of interaction and renegotiation. Continuous adaptations of the 1697 designs of *retourschepen* made it possible to respond to questions posed by local VOC-chambers, to the silting of harbour entrances (both in the Republic and in the East Indies) and to new commercial ventures. Through the Heeren XVII, changing trade patterns and new ventures made themselves felt within the VOC-network; through local master shipwrights, the marine geography of the Republic and of the Dutch East Indies got a voice, and through the directors of local chambers, an increasing demand for cargo capacity entered the network. The events during the first decades of the 18th century showed the continuous interaction between the VOC-network (or society) and the standardization in the design and building of ships. What happened during these years was possibly not as structured as the original standardization, but it can be characterized as an ongoing process of adaptive reconstruction, through which the hybrid network of the VOC tried to implement adequate reactions to change and to enlist as many allies for these changes as possible.

On 9 March 1714, the Heeren XVII agreed on two changes in the original charters[260]. The most important of these changes resulted from a formal suggestion by three master shipwrights of the VOC (those from Zeeland, Rotterdam and Delfshaven) to increase the width of the retourschepen. They suggested adapting the existing design to suit both the needs of their local chambers and the needs of local estuaries (both in the Republic and in the East Indies). It is remarkable that the chamber Zeeland helped to introduce ships with a lesser draught as it was the only chamber that had direct access to the North Sea, without it ships having to negotiate cumbersome shallows. The local chambers wanted a larger carrying capacity and the local estuaries asked for a smaller draught. Some have suggested that the master shipwrights in Zeeland, Rotterdam and Delfshaven had already adopted these changes well before 1714[261], which would imply that master shipwrights were not controlled as strictly as was foreseen in the resolutions of 1697 and had therefore more room to manoeuvre. When the *Heeren XVII* took their decision, at least one naval captain warned against these changes, arguing that the seaworthiness of the *retourschepen* would be compromised [262]. The width of the first charter was redefined as 42 ft., of the second charter as 39 ft., and of the third charter as 36 ft[263]. The *holte* of the first (160 ft.) charter did not increase in ships without a between-deck but it did increase with 1¾ (Amsterdam) inches for ships with a between-deck. The *holte* for the second (145 ft.) charter increased with 3¼ inches, no figures were given regarding the new *holte* of the third (130 ft.) charter[264]. Therefore, there must have been a discrepancy between the effective draught, which was supposed to decrease and the designed *holte*, which increased slightly[265].

[259] Bruijn e.a. (1979-1987) Part 1, p. 69; ARA VOC 4744 (24.8.1740), p. 15 (Extract of letter dd. 24 May 1737) In Dutch: "*(…) en wel voornamentlijk de Zee, op een terrible wijse (…) als geheele bergen deeze Baai quam inrollen*"
[260] ARA VOC 37 / 9.3.1714
[261] Bruijn e.a. (1979-1987) Part 1, p. 45 and Ketting (2006), p. 122
[262] Bruijn e.a. (1979-1987) Part 1, p. 45 & 105 and ARA VOC 37 / Letter by Christoffel Middagten
[263] Although ships of the second charter, built in Delfshaven, could not exceed 38 ft. because the lockgates did not permit a greater width. Building ships of the first charter was completely impossible in Delfshaven.
[264] Ketting (2006), p. 122
[265] This discrepancy is already mentioned in section 1.5. Anyway, the charters were redefined as [*160 ft x 42 ft x 17 ft* or *18 ft 7 ¼ in*], [*145 ft x 39 ft x 16 ft*] and [*130 ft x 36 ft x 14ft 4½ in*].

The second change was the decision to build a series of four specialized 130 ft.-*fluits*, equipped for the transport of sugar[266], a change that shows the interaction between new commercial activities of the VOC and the design of its ships: the upper deck had no superstructures and that made it possible to run the vessel with a minimal crew. In 1718, a second series of four sugar *fluits* was built, but with a heavier armament compared to the first series[267]. In these cases, the *Heeren XVII* took the initiative, and the outcome of their negotiations had to be renegotiated by the master shipwrights on the yard into a materialized artefact. When the sugar trade became less profitable, the *fluits* were used for other roles, showing the flexibility with which they fitted in the network. For instance, they carried voluminous cargo, such as masts, to the East Indies, which could be easily done because of the lack of superstructure. These *fluits*, as was the case with all *fluits* from 1697 onwards*,* were built according to the main dimensions of the 130 ft. *retourschepen*. This implied that there was hardly anything left of the characteristic bulbous stern of the original *fluit*-design, which can – as already mentioned in section 1.3 – also be seen as a way of adapting the *fluit* to the tropical conditions into the network[268].

The re-opening of the black box of the standardized design did not stop there. Another, rather unofficial, change took place when the Amsterdam and the Zeeland yards all but stopped building the first charter. From the 1720's onwards, Amsterdam only built one 160-footer in 1724 and one in 1733, and at the same time, the shipwrights at the Middelburg yard also started concentrating on smaller charters. The actual discontinuation of the first (i.e. largest) charter - which could only be built in Amsterdam and Zeeland because the other yards were too small - points to a *de facto* change in the number of charters, implemented by the two chambers concerned and not on a central level. This independent behaviour was possible, because within the hybrid society of the VOC as such, local chambers could act as sub-societies. The chambers were allowed to take their own decisions about the number and type of ships to be built on their yards, after the allocation of their share in the next *retourvloot* by the *Heeren XVII*. The *Heeren XVII* apparently withheld a formal validation of this discontinuation as can be inferred from their rejection of the proposal made by the chamber Zeeland (in 1731) to build 150-footers instead of both the 160-footer and the 145-footer[269]. In that respect, it is interesting to note (as will be seen in section 3.2) that about ten years later a 150 ft. vessel was officially defined as the largest charter. That the first charter became obsolete is quite remarkable, considering that one of the arguments for widening the existing charters was the need for increased carrying capacity. In addition, in 1727, another change was made regarding all charters. This change, made on the instigation of the shipwrights at the Amsterdam yard, consisted in moving some (internal) bulkheads in order to enlarge the size of the hold of all charters; through this operation the volume available for cargo increased by about ten percent[270].

The official standards therefore provided a basic guideline that could be adapted – following a process of re-negotiations on a human or non-human level – to suit changing demands and shifting local circumstances, pointing to an inherent flexibility in the standardized designs. The flexibility went even further when the chamber Zeeland wanted to capitalize on its advantageous geographical position. The local geography was recruited in an attempt to build a fast sailing retourschip. The widening of the charters, introduced in 1714 must, if anything, have resulted in a lower speed of the *retourschepen.* In 1736, the chamber Zeeland requested permission to build a ship with a length of 130 ft., specifically designed for fast sailing. This permission was granted on the condition that the payload would remain the same as that of the standard ships of that charter. To be able to reach higher speeds the new design must have had a larger length/width ratio, meaning that it was of a narrower build and it must have had a deeper

[266] See section 1.3.1
[267] Ketting (2006), p. 129
[268] Ketting (2006), pp. 121-123
[269] Bruijn e.a. (1979-1987) Part 1, p. 45 and ARA VOC 43 / 27.3.1731
[270] ARA VOC 118 (25.2.1727 & 4.4.1727)

hold and a larger draught to compensate for the smaller width. Such a design would have been impracticable for the other five chambers to operate. The experimental ship was called the *Arnestijn*. Without explicit permission of the Heeren XVII, three more ships of this type were built until 1740 (the *Loverendaal*, the *Ouwerkerk* and the *Huis Ter Duine*). This again suggests that the system of control, introduced in 1697, was not implemented as strictly as it was supposed to be. In 1739, members of the Haags Besogne declared the experiment a failure after a visual inspection. In September 1738, the *Arnestijn* had left for its second outward journey, from which it would in fact not return before 1741. Therefore, the inspection was carried out on the second ship of the series (the *Loverendaal*) which – at that time - had just finished its first return voyage. The inspectors decided that the vessel undoubtedly had a smaller hold, and they considered the value of the cargo to be very low[271]. The chamber Zeeland was rebuked for its actions. In fact, however, the *Loverendaal* carried goods to the value of 121,000 guilders and the *Arnestijn* had earlier returned with a cargo worth more than 329,000 guilders. Compared to other vessels of the third charter it turns out that, on average, these "illegally" built ships carried goods at least to the same value as ships of the standard design. The vessels stayed in service and did so for a considerable time[272].

Although ultimately the *Heeren XVII* were in control of the shipbuilding of the VOC, the events described above indicate that by recruiting human or non-human localities, master shipwrights were able to adapt the standard design externally or internally – or even come up with a completely different design. In doing so, the master shipwrights could claim a form of control vis-à-vis the *Heeren XVII*. However, the storms at Table Bay and the hurricanes near Mauritius demonstrated with painful clarity that it had not been possible to pacify the forces of nature sufficiently and to incorporate these into the network. For this pacification to be successful, it seemed that ships, shelters and skippers needed a thorough overhaul.

3.1.2 ... and in the Republic

The rumours about unseaworthy designs and incompetent skippers whipped up heavy storms in *patria* as well. The disasters caused disquiet amongst the ruling classes in the Republic and as the *octrooi* of the VOC was up for renewal by the end of 1740, both the States of Holland[273] and the States-General jumped to the occasion to discuss not only the policies and the economics of the VOC, but its technology as well. Questions were raised about diminishing returns, about corruption by (high ranking) servants of the VOC and abuse in the way offices were distributed, but also about the design of the ships of the VOC and the way the ships were being operated. In a resolution, drawn up on 23 July 1740, the States of Holland made a number of rather pointed remarks, which also contained suggestions about the state of the VOC's shipping and the possible causes of several disasters[274]. Considering the questions raised by the States of Holland, it is possible to detect in them almost all aspects that characterize the VOC as a developing large technological system.

The artefact *retourschip* marks the VOC out as a large technological system. Through this ship and the use that was made of it, the VOC seems to fit into the description given by Hughes of such a system:

---

[271] Bruijn e.a.(1979-1987), pp. 45-46.
[272] Details on these ships have been derived through http://www.inghist.nl/Onderzoek/Projecten/DAS
[273] In full: "the States of Holland and West Friesland". These States were the most important and influential in the case of the VOC, as five out of the six chambers (Amsterdam, Hoorn, Enkhuizen, Delfshaven and Rotterdam) had their seat in Holland. Only the chamber Zeeland fell within the jurisdiction of the States of Zeeland. Usually, the States-General followed the opinion of the States of Holland in matters concerning the VOC.
[274] ARA VOC 7237 / 23.7.1740

> These systems contain messy, complex, problem-solving components. They are both socially constructed and society shaping. Among the components in technological systems are physical artefacts (*VOC's retourschepen*). Technological systems also include organizations, such as manufacturing firms (*VOC's shipyards*) (…) and investment banks (*VOC's complex system of financial transactions between the Republic and the East Indies*) and they incorporate components usually labelled scientific such as books, articles (…) and research programs (*VOC's designs of ships*). Legislative artefacts (*VOC's rules and regulations*) (…) can also be part of technological systems. Because they are socially constructed and adapted in order to function in systems, natural resources (*VOC's materials and merchandise, such as wood, iron, hemp, tar, resin and sulphur for the building and equipment of ships, and spices, tea, coffee and other exotic produce as commercial goods*) also qualify as system artefacts.[275]

A point of debate might be the inclusion of scientific components, but against that it could be said that the label "scientific" as used by Hughes in the post-19th century interpretation did not exist in that sense during the 17th and 18th century.[276] Another point of debate might be that Hughes seems to take the presence and the availability of staff and workforce (both sufficient in numbers and sufficient as far as qualifications are concerned) for granted. As has been mentioned in section 1.4 this was a point of recurring concern for the VOC, and one could argue that it made the system even more complicated than already would follow from the description above. The increase in traffic during the 18th century put increased demands on the labour market. Apart from shipbuilding which was a typical national and even local affair (as mentioned in section 1.2), the labour market in the western provinces of the Republic relied for about fifty percent on foreign labour during the 18th century[277]. Sailors and soldiers employed by the VOC came from all over northwest Europe. This should come as no surprise if one realizes that (according to their own estimate in 1740) the VOC had to ship out between 24000 and 26000 personnel every year.[278] Of this number about 7000 were seafarers, the rest was made up by soldiers, clerks, artisans and higher-ranking servants. During its years of operation, the VOC may have sent over near to one million individuals to the East Indies, of which a large number did not survive their stay.[279] This number could not possibly be supplied by the national labour market, partly because of the sheer numbers involved, but most importantly because of the low wages paid out to the lower ranking sailors and soldiers. As the economy in the Republic as a whole prospered during the 18th century, local labourers could afford to leave the lowly paid and risky business of sailing or soldiering with the VOC to foreigners.[280]

Artefacts, shipbuilding activities, financial affairs, rules and regulations, commercial activities and the expertise of staff came all under the scrutiny of the States of Holland and of the States-General. One gets the impression that the *Heeren XVII* had overlooked the importance of enlisting the States as allies within the network of the VOC. Instead of being able to take the cooperation of the States for granted, the *Heeren XVII* were now forced into a defensive position and had to react to well-informed questions voiced by the States. This meant that the VOC – before a prolongation of the *octrooi* would be considered - needed to convince the States to join the VOC network again. A necessary first step was to come up with an adequate response, and the first approach of the VOC was to continue on the path of adaptation, as it had done before.

The States of Holland mentioned that whereas the number of ships in the *retourvloot* had increased, the cargo had not increased proportionally; that three VOC ships were needed to

---

[275] Hughes (1987), p. 51
[276] A more extensive appraisal of the VOC as large technological enterprise will be presented in chapter 5.
[277] Lucassen (2004), p. 18
[278] ARA VOC 4744 / 24.8.1740
[279] Following an estimate given by Lucassen (2004), p. 17. For the death toll, see section 1.4
[280] According to J.L. van Zanden (presentation and oral communication at the conference "Writing the History of the Global" in London on 21 & 22 May 2009) the per capita income in the Republic kept increasing during the 18th century.

carry the same payload that a single English or French ship could carry[281] and that sufficiently large numbers of competent skippers could not be found, which led to shipping disasters. They stated that the costs of building and equipping ships was very high and varied considerably between chambers, that considerable delays were encountered when the fleets left for the Indies and that a planning should be made to avoid arriving at the Cape during the monsoon season. Furthermore, they pointed out that there were rumours that returning ships were too heavily loaded and that the bows of the ships were too wide and too blunt to ride out a storm while lying at anchor. Writing about shipping disasters in general, they referred to rumours that gross incompetence of skippers had often been the cause of these disasters[282]. All in all, there seemed to be more at stake than just the design of the *retourschepen*. It was therefore not only a matter of retourschepen not sufficiently recruiting the forces of nature in the Indian Ocean but also a matter of the Heeren XVII not recruiting sufficiently experienced skippers in sufficient numbers.

In their response[283] the *Heeren XVII* wrote that the number of ships in the *retourvloot* had varied between 1715 and 1738, that the amount of cargo had increased more than proportionally with the number of ships but that the value of the cargo had fallen, due to increased competition by the English, the French, the Danes and the Swedes and - in the case of coffee - through competition from the West Indies. In addition, they had implemented a policy of spreading risks, which implied that the cargo on any one ship should not exceed a value of 250.000 guilders, later increased to 400.000 guilders. Although this policy could be interpreted as recognition of the fact that it might not be possible to pacify some forces of nature, reading between the lines it might also be interpreted as signalling doubts about the seaworthiness of the company's ships. Regarding the competence of officers, they wrote that on occasions extra officers had been appointed on board of some ships for training purposes and that if skippers have been found at fault they had been severely punished. Thereby they suggested that the number of competent officers within the network was being enlarged. However, the matter of expensive shipbuilding was ignored; only the higher cost of purchasing equipment and goods outside of Amsterdam was acknowledged.

The *Heeren XVII* announced that forthwith ships were not supposed to arrive at the Cape during the months of May until July, i.e. during the heavy monsoon season. They also announced that discussions were being held about how to develop Saldanha Bay as a safe anchorage, and that skippers were already allowed to use their own judgment if they wanted to anchor there. This was in fact a departure from the very strict way in which the route to the East Indies was prescribed to the skippers[284]. Considering that the first disaster had taken place eighteen years ago, one gets the impression that it had taken the *Heeren XVII* a very long time to decide on an alternative anchorage, a decision that they suddenly managed to take in their efforts to enlist the States of Holland. Moreover, they said, these storms had been sent by God, and neither anchors, nor ropes, nor the narrowness or bluntness of the bows had been a major factor in the disasters, as ships from other nations had perished as well[285]. They added that the ships had been made wider to be able to carry a larger payload. According to the *Heeren XVII*, in matters of design they had followed the advice of *equipagemeesters*[286] and shipwrights because "the Directors had to believe the Artists in their art", and there had been no complaints regarding the seaworthiness of the ships thus far.[287] Remarkably, they did not reply to the accusation of the ships being too heavily loaded, which they might have easily done by referring to the earlier complaint that the *retourschepen* carried a smaller payload that the English or French ships. This suggests that the

[281] It is not clear whether the States were referring to the volume or to the value of the payload.
[282] ARA VOC 7327 / 23.7.1740 and Brunt (1997), chapter 3
[283] ARA VOC 4744 / 24.8.1740 and Brunt (1997), chapter 3
[284] Voorbeijtel Cannenburg (1953)
[285] Some English ships had foundered at the Cape as well.
[286] The *equipagemeester* was responsible for the production and fitting out of ships, both old and new.
[287] It says in the original response "*dat Bewindhebberen moetende de Konstenaars gelooven in haar konst*".

accusation of ships being too heavily loaded did carry some weight, and that again the States of Holland were well informed. At the very end of 1740, the VOC's *octrooi* was provisionally prolonged by a year. This must have sent a strong message to the VOC that the States could not yet be considered as allies within the VOC-network. In March 1741, the *Heeren XVII* announced that they would look into matters of ship design. An investigation was launched to consider whether the bows of the ships were indeed too wide and too blunt, whether the ships should have a smaller rigging, whether the ships should be made less top heavy and whether the ships could be redesigned internally to increase the payload[288]. This last point sounds rather remarkable as the VOC was also being accused of overloading its ships. However, as the States had remarked that the ships of the VOC carried too little payload compared to foreign ships and that it might be advantageous to send out fewer ships, one gets the impression that a possible redesign of retourschepen was entering the network, not only based on considerations of increased seaworthiness, but also on considerations of an increased payload. To this end, in May 1741, a meeting was called of all VOC's master shipwrights, all *equipagemeesters* and some experienced former skippers to reconsider the existing three charters.

The committee suggested changes in the current charters of the two smaller retourschepen, and it made no mention anymore of the large 160 ft.-charter[289]. On June 15 1741, the *Heeren XVII* decided to adopt the changes proposed by the committee and to lengthen the 145 ft. and the 130 ft. charter by 5 feet each[290]. In fact, this implied that the length/width ratio returned more or less to that of 1697. One of the considerations was that the sailing capacities of the existing charters (especially those of the 130 ft. charter) left much to be desired. The committee was of the opinion that the existing charters were relatively too wide and that a lengthening of the ships would improve sailing capacities, would also improve the behaviour of ships while at anchor, and would increase the payload[291]. The rigging was to remain as it was, so effectively the rigging became relatively smaller, which might lead to a greater stability but also to a lower speed[292]. Looking at the considerations for change, one is inclined to believe that the members of the committee were of the opinion that the seaworthiness of the retourschepen, as built since 1714, had deteriorated compared to the situation before 1714. It seems that the States of Holland had been asking the right questions. The adapted designs might therefore – apart from being able to better recruit the forces of nature in the Indian Ocean – also be able to enlist the States of Holland and the States-General.

In addition, the *Heeren XVII* decided to build a few cheap[293] 125 ft. vessels - without superstructure - for the transport of voluminous goods (such as masts); these ships were to be equipped with an awning against the sun[294]. Possibly these vessels were meant as successors to the original sugar *fluits*. Apart from being cheap to build, these ships were supposed to be cheap to operate as well. This might have been a reaction to the remark by the States of Holland that the building and operation of ships was too expensive.

---

[288] ARA VOC 7237 / March 1741 (Reply by the Directors of the Chambers Delfshaven and Rotterdam to the States of Holland) & March 1741 (Reply by the *Heeren XVII* to the States General) and Kist (1985), p. 10

[289] As stated before, at the time effectively only two charters existed, as the largest (160 ft) charter had not been built for a considerable time.

[290] The 150 ft.-charter was to measure [*150 x 39 x 16 ft*] and the 135 ft. charter [*135 x 36 x 15 ft*].

[291] The payload of the proposed new 150 ft. charter increased with 20 *lasten* and that of the 135 ft. with 15 *lasten*. Interpreted as a volume one *last* equals three cubic metres, interpreted as a weight it equals 2000 kilogrammes.

[292] ARA VOC 7418 / 12.6.1741 & ARA VOC 123 / 12.6. 1741 & 15.6.1741

[293] In Dutch "*min kostbaar*"

[294] ARA VOC 123 / 15.6.1741. A few months later, it was decided that Amsterdam should build two of these vessels and Zeeland the third (ARA VOC 7418 / 6.10.1741). The proposed 125 ft.-charter was to measure [*125 x 33 x 14 ft*] (cf. ARA VOC 123 / 15. 6.1741)

In a lengthy paper by the States General regarding the *redres* (improvement) of the VOC, drawn up on 13 April 1741 by the committee responsible for the affairs of the VOC, no mention is made of matters concerning ships and ship design[295]. One gets the impression that the States-General left matters of shipbuilding to the States of Holland. In their reply to the States of Holland, of 15 June 1741, the *Heeren XVII* announced the changes in the design and rigging of its ships and added that from now on heavy cargo would be loaded at the lowest deck, that cargo stowed between decks was to be light[296], thus preventing the ships becoming top heavy.[297] In the same meeting of the *Heeren XVII*, a proposal by the chamber Rotterdam for a change in the charters was rejected.[298] And so by June 1741 the *Heeren XVII*, following the opinion of shipwrights and others and in accordance with the wishes of the States, agreed on the next adaptation of the definition of standardized ships. They may have thought that by changing designs and by promising to look into accusations of mismanagement, they had succeeded in adding the States to their network. In a reply, the States of Holland let it be known that – amongst others matters – the *Heeren XVII* ought to pay careful attention to the proposed change in the charters of their ships, and that they should see to it that ships were being built and operated with due attention to their seaworthiness[299]. This reply – which constituted not yet an extension of the *octrooi* - was sent on 28 September 1741, but before the adaptive solution was implemented, a more radical chapter in the reconstruction of the VOC and its *retourschepen* was being opened.

3.2 Innovation introduced: a high-ranking prisoner expands the network

As we have seen, storms at the Cape of Good Hope and stormy exchanges in the Republic had laid bare the vulnerability of the adapted designs of *retourschepen*. Unknown to anybody in the Republic, grave troubles had manifested themselves also in the way the East Indies were governed during the year 1740. When some of the key figures in these troubles were forcibly sent back to the Republic, a chain of events was set in motion that led to – amongst other things – a more radical solution to the problems concerning *retourschepen*.

In September 1741, three *retourschepen* arrived at the roadstead off Texel, each carrying a former official of the *Hoge Regering van Indië* (the governing body of the VOC in the East Indies) who had been arrested by governor-general Valckenier at Batavia in December 1740 in the wake of the *Chinezenmoord.*[300] In January 1741, these officials had been sent back to the Republic under arrest on separate ships. The second of the ships to arrive carried Gustaaf Willem van Imhoff who – almost on the day he was arrested - had been appointed by the *Heeren XVII* as the new governor-general of the East Indies, as successor of Valckenier who had offered his resignation about two years earlier. Due to the slow lines of communication between Amsterdam and Batavia, of course, nothing was known about the appointment of Van Imhoff in Batavia at the time.

On September 17, Van Imhoff landed at Den Helder and on September 25, he and his colleague De Hase were formally acquitted in a meeting of the *Heeren XVII*. A warrant for the arrest of Valckenier had been issued two days earlier[301]. On October 12, the third counsel member, Van Schinne, was also acquitted and in this meeting Van Imhoff, Hase and Van Schinne were asked to

---

295 The chairman of this committee was Frederik Willem Torck, a younger brother of Lubbert Adolf Torck van Rosendaal.
296 In case there was no light cargo available, no cargo should be stowed there whatsoever.
297 ARA VOC 7237 / 15.6.1741
298 ARA VOC 123 / 15.6.1741
299 ARA VOC 7237 / No. 37 / 28.9.1741
300 A notorious massacre of thousands of Chinese in Batavia in the last months of 1740.
301 Hase arrived on September 9 and Van Schinne on September 26. The whole chain of events shows the hurry the Heeren XVII apparently were in.

prepare themselves for an early return to the East Indies and in the meantime to write a report on the current state of the VOC and on possible measures for *redres*. On 24 November 1741, they delivered their report to the *Heeren XVII* [302]. Three reasons for concern were summed up. The first problem was that the expansion of the VOC in the East Indies made it difficult to manage the company – the VOC was no longer just a commercial enterprise, but had to take on a governmental role as well. The second cause for concern was a general downturn in commerce; increasing competition from abroad had driven down prices in Europe, but prices in the East had remained stable, causing diminishing profits. Finally, they said, the VOC was no longer as faithfully served by its employees as it used to be[303].

Fig 3.2 Gustaaf Willem van Imhoff, writer of a report on the improvement of the VOC (1741), promotor of the Bentam designs (1741/42) and governor-general of the East Indies (1743-1750). Painting by J.M. Quinkhard through **http://commons.wikimedia.org/wiki/File:Gustaaf_Willem_baron_van_Imhoff2.jpg**

In order to turn the tide, Van Imhoff c.s. suggested four points that should be addressed, regarding shipping, commerce, possessions of the VOC and administration[304]; in hindsight, these aspects point to characteristics of a large technological enterprise. As a result of this report, in their meeting on 28 November the Heeren XVII postponed the decision to build the three inexpensive 125-footers and asked Van Imhoff and director Hasselaer to give advice on how the company's ships might be built *methodice en op eguale voet* (in a methodical and proportional way). They were also asked to advise on the equipment and the rigging of the ships, on departure times, routes and wind patterns, both outward bound and homebound and on anything else relating to shipbuilding and shipping.[305] Adaptation of existing technological

[302] Steur (1984) p. 42. It should be noted that Steur gives the year as 1740. For some reason Steur predates all events relating to Van Imhoff by one year, although the original papers in ARA agree with the dates given in all other literature and in this paper as well.
[303] Krom (1941), p. 84 and Steur (1984), p. 44
[304] Krom (1941) p. 86, Steur (1984), pp. 44-45 and Kist (1985), pp. 11-13
[305] ARA VOC 7418 / 28.11.1741 and ARA VOC 123 / 28.11.1741 respectively. See also Kist (1985) p. 12.

patterns (as described in section 3.1) was abandoned in favour of a possibly more radical technological innovation. This meant a shift away from the current VOC-policy that consisted – as far a ship design and shipbuilding was concerned - in the adaptation, redesign and reconstruction of the current charters of *retourschepen*. Now, one was looking towards a more radical solution for the problems with the *retourschepen*, while at the same trying to stabilize the system of the VOC as a whole. Often positioned against radical inventions and innovations, conservative inventions and system-stabilizing modes of innovation[306] are usually characterized by a renewed interpretation of existing ideas and techniques; system-stabilizing innovations occur – in the case of large companies – predominantly during periods of competition and system growth, and they contribute to the improvement of existing systems. In this case, however, it was hoped that a radical innovation might not only give rise to the emergence of new and better ships, but that it would also act in consolidating the existing system[307]. The possible innovation was intricately linked to the commercial and organizational survival of the VOC as a large enterprise. This shift can therefore be interpreted as having a dual character, on the one hand generating a radical break with current technological practices within the hybrid network and on the other hand stabilizing the hybrid network as a whole. In order to successfully implement these changes to and within the existing network, allies had to be recruited from inside and from outside the network.

The search for allies outside the VOC-network can be seen in the contacts Van Imhoff maintained with influential persons who were not directly connected with the VOC. During his stay in the Republic, Van Imhoff frequently resided at the country estate *Waterland*, with his cousin Jacob Boreel, *fiscaal* (a high-ranking judicial official) at the Amsterdam admiralty[308]. The neighbouring estate *Beeckesteijn* was owned by Torck van Rosendaal, who had been partly responsible for the introduction of English shipwrights at the Amsterdam admiralty and whose younger brother was a prominent member of the States-General and chairman of the committee for the VOC[309]. At *Waterland* and *Beeckesteijn*, a circle of influential people from Amsterdam met on a regular basis, discussing current affairs during meals[310]. Van Imhoff, and probably Hasselaer as well, attended this circle.[311] It is likely that Van Imhoff through these connections with the Amsterdam admiralty was able to approach Charles Bentam, master shipwright at the admiralty, with a request to design three new charters for the VOC[312]. In their effort to enlist allies from within the network, Van Imhoff and Hasselaer held talks with a committee consisting of shipwrights and skippers to discuss the designs drawn by Charles Bentam. These talks took place during December 1741 and January 1742. The committee consisted of the master shipwright of the VOC Amsterdam yard (Blok), the master shipwright of the VOC Zeeland yard (Raas) and his assistant (Bakker), two private shipwrights (Goudrok and Van Dalen), three skippers (Van Thiel, De Boer and Belleveau) and two retired skippers (Reebok and Oterlijk)[313]. Bentam's designs were for *retourschepen* of 150, 136 and120 feet in length[314]. If we compare his designs with the plans agreed upon in June 1741, we can notice that the Bentam designs are slightly wider, but at the

[306] Misa (2004), chapter 5 and Fleischer (2007)
[307] Misa (q.v.) apparently makes no sharp distinction between "innovation" and "invention".
[308] Kist (1985), p. 14
[309] As is shown by ARA VOC 11153
[310] This group was called the *Saturdagse Krans* (the Saturday Circle). For details, see De Ridder (1966).
[311] It is quite possible that through these contacts Van Imhoff met Cornelis Schrijver (see chapter 2) as is suggested in Bruijn e.a. (1979-1987) Part 1, p. 46
[312] In September 1742, the VOC-chamber Amsterdam paid Bentam the sum of 300 golden ducats for these designs (Kist (1985), p. 14)
[313] Brunt (1997), chapter 5. Reebok is alternatively written as Rieboek and Belleveau as Billiveau. In October 1742, Belleveau became the skipper on the *Herstelder* that took Van Imhoff back to Batavia. Details regarding the skippers were retrieved through http://www.inghist.nl/Onderzoek/Projecten/DAS/search and through http://vocopvarenden.nationaalarchief.nl/list.aspx .
[314] The 150 ft.-charter was to measure [*150 x 41 x 19 ft*], the 136 ft.-charter [*136 x 39 x 17 ft*] and the 120 ft.-charter [*120 x 33 x 13 ft*] (cf. Brunt (1997) appendix)

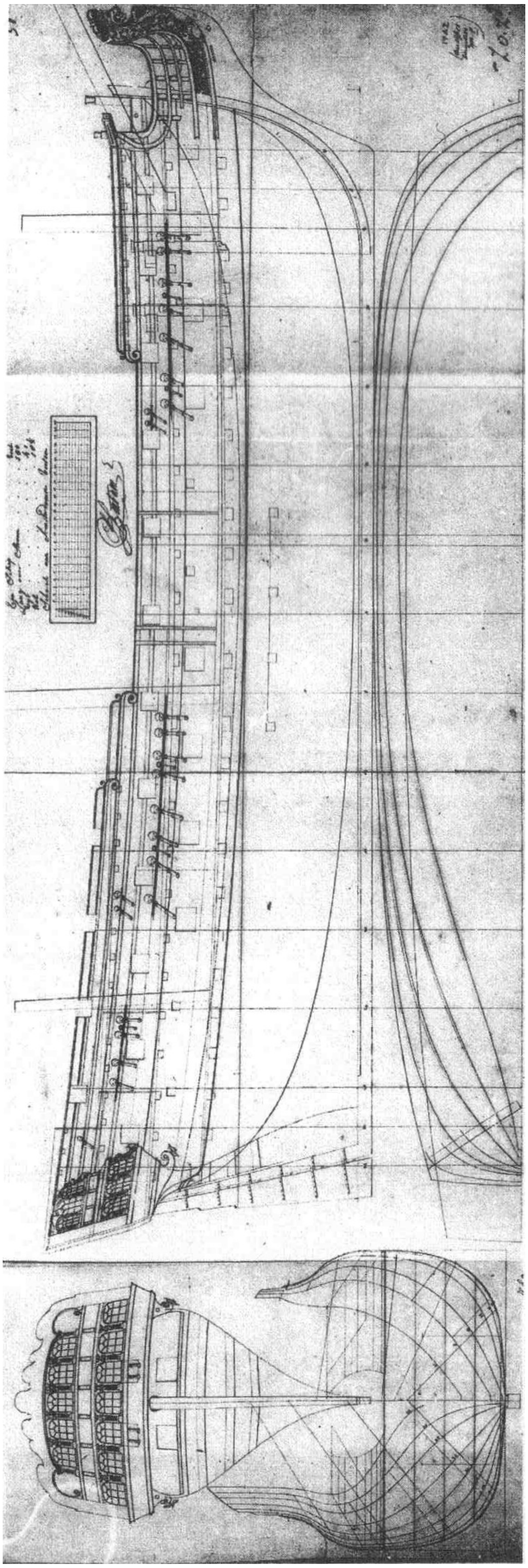


Fig. 3.3 Technical drawings of the 150-ft. *retourschip.* According to Kist (1992), these are probably the slightly modified plans dating from 2 February 1742. Copy of the original drawings by Charles Bentam, courtesy of the Nederlands Scheepvaartmuseum Amsterdam

same time the *holte* has increased relatively even more, which probably meant a larger effective draught as well. However, the use of lighter constructions meant that the draught in unloaded conditions probably hardly differed from that of the old ships. Bruijn's comment that the "English" designs were "slimmer and sharper in build"[315] can only refer to the underwater part of the hull as the dimensions of the new VOC charters show that their greatest width exceeded that of the redesigned charters of 1741. The most visible change in the design was the introduction of a rounded stern instead of the square stern.[316] The committee suggested that the decks at the stern of the ship should be built a foot higher and they suggested some changes regarding construction details. One should note that the committee must have been able to read the technical drawings presented to them. Some form of expertise in the interpretation of technical drawings had apparently diffused to some groups within the Republic, such as shipwrights and skippers on the one hand and councillors of admiralties and directors of the VOC on the other hand. This was probably partly caused through the (albeit still controversial) introduction of technical drawings at the Amsterdam admiralty, and partly through the ongoing local development of technical drawings. On 2 February 1742, the committee agreed with the slightly modified plans and Van Imhoff and Hasselaer informed the *Heeren XVII* about the outcome by letter.[317] Added to this letter were the slightly changed drawings (see fig. 3.3) and lists containing the sizes of masts, spars, sails, rigging and all sorts of equipment.[318] In the meantime, on 11 December 1741, the Heeren XVII decided to ask the Amsterdam admiralty whether it might be willing to sell a naval vessel, armed with about fifty guns, for the return of the Governor-General Van Imhoff back to the East Indies[319]. Eventually, the newly built *Edam* was purchased. This ship, designed and built by Charles Bentam in 1741, was renamed *Herstelder* (Restorer)[320]. On 30 November 1741, the States of Holland proposed to prolong the *octrooi* by three years, only to reconsider their position by 2 December 1741 when they suggested a period of one year, a suggestion that was followed up by the States general on 25 December 1741.

One gets the impression that the States wanted to know what might be the result of the new plans for *redres*, drawn up by Van Imhoff, before taking any far-reaching decisions. Shipwrights, captains and directors made up part of the hybrid society that constituted the large technological enterprise of the VOC; also part of the society were non-human entities, such as commercial vessels, estuaries, climatological and geographical conditions. The design drawings and its resulting artefact linked these two parts. Within the society, the heterogeneous elements interacted in negotiations, trying to resolve the conflict about the future of the VOC and to rethink the way the VOC operated, on a commercial, organizational and technological level. In these negotiations, the artefact *retourschip* and its design played a silent but important role. In fact, it might have been the decisive factor in prolonging the *octrooi* of the VOC, and in enlisting the States of Holland and the States-General as allies. Whereas the introduction of technical drawings at the Amsterdam admiralty was seen as radical, the introduction of the same innovation at the yards of the VOC (radical as it might have been) also displayed aspects of a system-stabilizing character.

On 14 March 1742, the *Heeren XVII* formally agreed to introduce the new charters, and decided on an experimental period of four years, during which time all ships should be built according to the "drawings of each charter"[321]. They made a small change to the new charters by decreeing

[315] Bruijn e.a. (1979-1987) Part 1, p. 46
[316] Or re-introduction, as the *fluit* already possessed a rounded stern from the early 1600s onwards.
[317] Although on 20 February 1742, the master shipwright at the Zeeland admiralty, Bout, suggested to narrow the two largest charters by one foot, and to widen the 120 ft.-charter by one foot (Brunt (1997), chapter 5).
[318] Kist (1985), p. 14 and in more detail Kist (1992), pp. 46-53.
[319] ARA VOC 7418 / 11.12.1741
[320] The dimensions of the *Edam* were [*150 x 41$^{6}/_{11}$ x 18 ft.*]. The epithet *Herstelder* was also given to Van Imhoff.
[321] In Dutch "*volgend de teekeningen van yder charter*"

that the *holte* of the 120 ft.-charter should be increased by one foot. It was decided that *mallen* (models[322]) of all three charters should be given to the yards in Amsterdam and Zeeland, and that *mallen* of the two smaller charters should be given to the yards of the other chambers. In addition, they stipulated that the master shipwrights and the *equipagemeesters* should strictly comply with the charters and with the extensive specifications, concerning building, equipment and rigging.[323] One ship of the 150 ft.-charter was to be built in Amsterdam, two ships of the 136 ft.-charter in Zeeland and one 136-footer in Delfshaven. With the material aspect of the innovation of ship design in place, the States General finally (on 4 January 1743) prolonged the *octrooi* with twelve years, without making any remarks on shipbuilding, although they remarked that other points of *redres* remained points of concern.

Fig. 3.4 Model of a 150ft. retourschip in "camels[324]", made by Charles Bentam in the 1740s; currently in the collection of the Amsterdam Historisch Museum. Photo taken by Johan de Jong on 11 Feb 2010

The new designs of *retourschepen* still needed to be materialized into actual vessels and – keeping in mind the remarks the States of Holland had made in September 1741 – it must have been clear to the *Heeren XVII* that any delay in building ships according to the new designs would not have gone down well with the governing bodies of the Republic. This may have been a

[322] The original resolution mentions "*mallen*". Two translations are possible, "moulds" or "models". I agree with Kist (1985) and Gawronski (1996) that "models" is the appropriate translation. First, the use of technical drawings made it possible to independently produce identical moulds of frames at each yard. In addition, it would have been rather cumbersome to transport complete sets of full-size moulds to each yard. Second, the cost of these *mallen* (3390 guilders acc. to Kist (1985), p. 15) suggests that a huge amount of work went into producing these objects, which points rather to models than to moulds. Third, models could be used to show shipwrights construction details not visible in the drawings, and could also be shown to directors, assisting them in understanding the drawings. Two models - made by Bentam, according to Kist (1985), p. 14 - survive in the collection of the Rijksmuseum, one of a 150-ft. charter in "camels" (MC 502) and one of a 120 ft.-charter (MC 503) (Hoving & Lemmers (2001), pp. 41-42). Ferreiro (2007), p. 39 points out that one of the reasons English shipwrights were employed on the continent was their ability to use models to show their construction techniques.

[323] ARA VOC 7418 / 14.3.1742 & ARA VOC 123 / 14.3.1742, Bruijn e.a.(1979-1987), pp. 44-46 and Kist (1985), p. 14

[324] For the use of "camels" across the Zuyderzee, see section 4.3.1

principal reason why an impressive building program, using new techniques, was implemented almost immediately. The new construction techniques, coupled with their underlying design drawings, contributed to the development of the VOC as a single large technological enterprise as will be shown in the next section.

3.3 Innovation materialized: the VOC as a single large technological enterprise

The chamber Amsterdam apparently had decided to lose no time and started building the 150 ft. vessel on 22 February already, a month before the official decision was taken to go ahead with the new designs. This ship, the *Eendragt* (Unity), was ready to be measured on 28 August, as were two of the new 136-footers, the *Cleverskerke* built in Zeeland and the *Hoop* (Hope) built in Delfshaven. The speed with which these ships were built suggests that the transition to the new building methods, linked to the use of technical drawings must have been rather smooth[325]. The other 136-footer built in Zeeland, the *Verwagting* (Expectation) was not ready yet. Apart from the regional inspired name *Cleverskerke*, the naming of the new ships suggested hope for harmonious new beginnings coupled with high expectations. The results of the measurement of the *Eendragt*, the *Cleverskerke* and the *Hoop* were added to the list of dimensions that should be adhered to by the VOC-yards. The extension of existing procedures with technical drawings, models, results of measurements and the introduction of new building procedures point to the fact that the management of the VOC could intensify its grip on the design and building of its *retourschepen*: the innovation of technical drawings acted as a catalyst towards increased standardization.

The first retourschepen produced according to the new designs were put to use immediately. The *Eendragt* embarked on a journey to the East Indies in a small fleet together with the *Herstelder* and the *d'Anna,* the ships that took Van Imhoff to his post of governor-general. On 27 October 1742, this fleet, consisting of five ships, sailed from the roadstead at Texel, and arrived at Batavia on 28 May 1743. The *Cleverskerke* left Rammekens on 12 December 1742 and arrived at Batavia on 15 October 1743. The *Hoop* left Goeree on 10 May 1743 and arrived at Batavia on 12 February 1744, and finally the *Verwagting* left Rammekens on 29 August 1743 to arrive at Batavia on 13 May 1744; this ship was unfortunately wrecked the same year on a trip from China to Surat.

From March 1742 onwards, the master shipwright at all yards of the VOC had to construct the retourschepen using prescribed and predetermined frames. Although this was an innovation compared to the current building practice, we should remember that the standardized specifications of 1697 already determined the material outcome of the building process at a number of points at nine equidistant frames. In a sense, therefore, the innovation could build on an existing pattern of standardization. This existing pattern meant that shipwrights were controlled on the basis of the finished artefact. The new designs and the new building practice, however, controlled the shipwrights during the building process itself. They were obliged to follow the new designs exactly, and this meant that they had to use the prescribed form of all sixteen main frames, exactly as they were inscribed into the design. The result was that the master shipwrights of all VOC-yards who were already actors within a single hybrid network, became connected even more to this network by prescribed dimensions, standardized parts and design drawings that they had to follow, and also through prescribed and standardized construction techniques.

[325] The transition from the northern shell first system to the "English" frame first system has already been described in section 2.3; the transition from the southern frame first system to the new system is described below.

The new artefacts displayed a combination of innovation and standardization. On the one hand, through the new way of designing and building ships, innovation was introduced at the yards of the VOC. The use of technical drawings, added to the existing use of extensive specifications of dimensions and parts, combined with the availability of *mallen* and the new building method, made standardization, if anything, easier to achieve. It also enabled the management of the VOC to increase its grip on its shipbuilding activities as it enabled a tighter control on a standardized materialization of standardized *retourschepen*. In addition to the way the yards were already organized (as described in section 1.2) the new procedures, tended to move the role of the master shipwrights away from the actual design process and towards being responsible for producing artefacts to designs made by others, using procedures and techniques also prescribed by others. This had to some extent already been the case since 1697, but the changes introduced in 1742 went an important step farther and intensified the ongoing developments, not only because of the innovation of the completely inscribed design, but also because of the innovations in the way the design had to be materialized into the artefact *retourschip.* In section 2.3, it was observed that the master shipwright at the Amsterdam admiralty was able to "control the (other) shipwrights right down to the smallest details". He did so by controlling the materialization of his own design. At the VOC-yards, the situation was different: the role of the master shipwrights seemed reduced to controlling the other shipwrights who were reproducing designs made by somebody else than the master shipwright himself.

The new method of shipbuilding was based on the "English" *frame first* way of building, as already described in section 2.3. The three VOC-yards in the north of the Republic (Amsterdam, Enkhuizen and Hoorn) originally made use of the *shell first* method, described by Witsen (1671). In addition to what already has been written about the transition from this method to the new method, it has been suggested that – within the VOC - the transition was realized by moulding the preliminary frames according to the frames prescribed in the new designs.[326] However, this seems hardly likely, as the bottom of the vessel then still would have to be made in the "old" way, which was bound to lead to problems with the exact fitting of the main frames later on. Besides, it would have been rather time consuming first to have to produce preliminary frames, fitting in exactly with the definitive main frames, and then later on to have to fit the main frames in between the preliminary frames. Moreover, as the admiralty had been capable of changing over to the new way of building ships within a very short time, it seems likely that the VOC-yards in the North of the Republic must have been able to do the same. Finally, it should be noted that no new ships were being built at the Amsterdam admiralty between 1742 and 1746, which means that (master) shipwrights of the admiralty yard - situated quite near to the VOC-yard – might have had some opportunity to be of assistance.[327] It is quite possible that – because of guild regulations[328] – redundant admiralty shipwrights had to be employed at the VOC-yard.

The shipyards in the southern part of the Republic used a different method compared to the yards in the North, a method that was described by Van IJk in <u>De Nederlandse Scheeps-bouw-kunst open gestelt</u> (1697). After the keel had been laid and the stem and stern had been erected, the next step consisted in the positioning of two identical main frames, one approximately halfway[329] between stem and stern and a second frame before the first, at approximately a quarter of the distance between that frame and the stem. The next step consisted of fitting a ribband from stem to stern along the frames, providing the outline of the hull. If the shipwright was satisfied with the shape, then a third frame was put in place on the point where the stem met the keel. This frame was similar in shape to the two main frames but slightly narrower. Where the stern met the keel a fourth frame was put in place; this frame defined the shape of the hull at the stern. Working from these four frames the rest of the horizontal planking was fitted,

---

326 Hoving & Lemmers (2001), p. 48-49. They refer to a painting, dating from 1699 to make their point.
327 Bruijn (1970), pp. 169-172
328 See chapter 4
329 A formula was used to find the exact spot; in the formula, the fall of the stem was also taken into account.

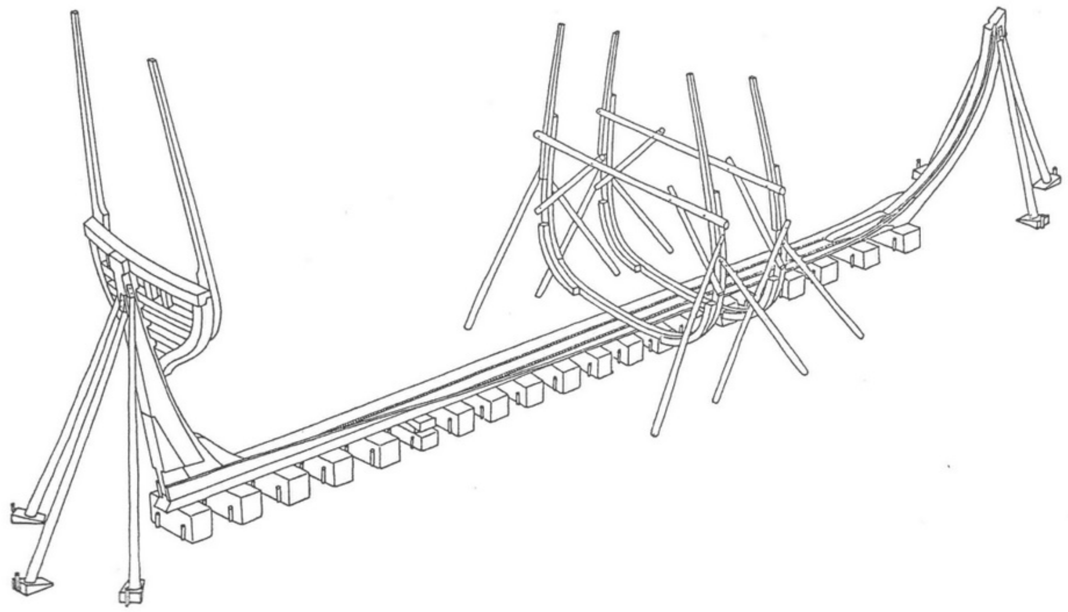


Fig. 3.5 First stages of construction according to the procedure followed in the South of the Republic; picture derived from Hoving & Parthesius (1991), p. 9

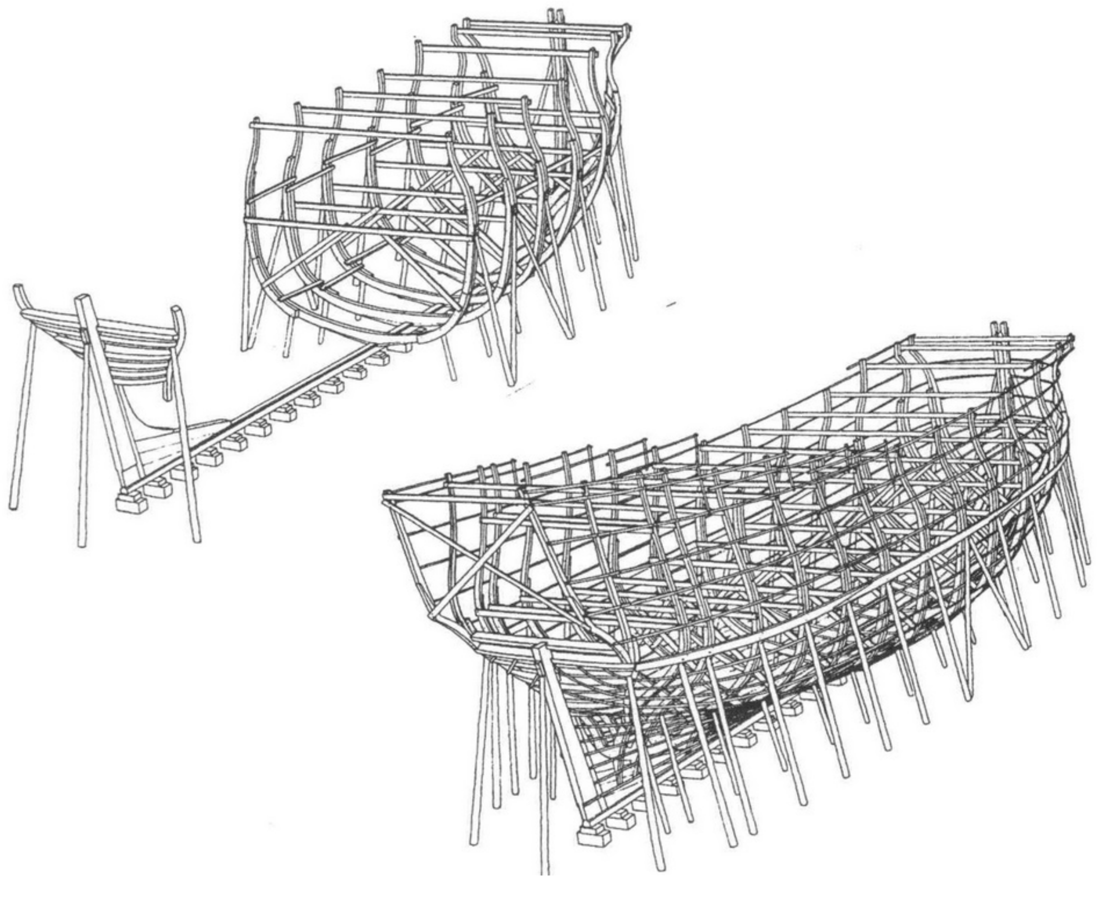


Fig. 3.6 First stages of construction according to the procedure followed by the Van Zwijndregt dynasty in Rotterdam; picture derived from Hoving & Lemmers (2001), p. 72

which gave the shipwright still quite some leeway to change the form of the hull. After completion of the hull, the remaining frames were put in place, which had to fit in with the hull as it stood; a process quite similar in character with the northern method. The main difference between the southern building method and the "English" system was the pre-fabrication and consequent erection of a much larger number of prescribed frames, which in turn dictated to a much larger extent the ultimate form of the hull.

Paulus van Zwijndregt, who was appointed master shipwright at the Rotterdam admiralty in 1725, developed a more extensive variation on the southern method. Connected to his system of technical drawing (as described in section 2.3) he developed a variation on the southern building method[330]. Using his method, eleven main frames were constructed according to the drawings, and these frames were erected on their appropriate places on the keel at the beginning of the construction process. After these eleven frames had been erected, a few horizontal ribbands were fastened to the frames. These ribbands in turn dictated the form of the frames that filled in the spaces between the main frames. After the fitting of these frames, the rest of the hull was completed. Although the Rotterdam admiralty did not adopt the "English" way of building ships, the VOC-yard in Rotterdam (headed by Paulus's son Pieter) had to introduce the "English" system, just as all other VOC-yards. The similarity of the Van Zwijndregt system to the "English" system implies that a change must have been even less complicated then the shift from the original southern method, as both systems only differed in details, which can be noticed when comparing fig. 3.6 with fig. 2.7.

The transition to the new "English" building methods can be interpreted as legitimizing and expanding current practices within the VOC. From the end of the 17th century onwards (as already mentioned in chapter 1), the VOC used largely prefabricated and interchangeable parts for the production of its *retourschepen*. The new system of designs drawings and building methods produced pre-drawn, prescribed and prefabricated mainframes. The system of using prescribed and prefabricated artefacts such as masts, yards, sails, ropes, guns etc. was therefore extended with the prescription and the prefabrication of mainframes. This addition might even have made an early form of serial production possible, constructing interchangeable ships, irrespectively on which yard they had been built. Because of the introduction of technical drawings, for the first time really similar ships might be produced. At the Amsterdam admiralty, similar warships could be produced consecutively, but even more impressively, similar *retourschepen* could be produced at different times and at different localities. Using the set of drawings, the design of a ship could be moved in time (as was the case with both the Amsterdam admiralty and the VOC) or in space (as was the case between the six different yards of the VOC), before it actually became materialized. Uniform building techniques implicated by the new system of design meant that the master shipwrights, and through them the directors and the *Heeren XVII*, could increase their control over the building process. Therefore, compared to the way the shipbuilding of the VOC operated before, the introduction of technical drawings – which made the master shipwrights subordinate to the design - and the new building techniques – which made the shipwrights subordinate to the master shipwright and the design - can be seen as a radical innovation regarding shipbuilding, decisively intensifying current practices of regulated shipbuilding and in that way reinforcing and stabilizing the single large technological enterprise VOC as a whole.

In March 1744, Van Imhoff wrote a letter to the *Heeren XVII*, in which he praised the qualities of the new ships. According to his letter, the ships sailed better to windward, were easier to keep on course, could take much more cargo and their construction was more sturdy, which would make for a longer lifespan. He added that a few matters still needed improvement[331]. His letter suggested that – in general - the new ships were better in recruiting the forces of nature into the

---

[330] This method was described by Blaise Ollivier, see Roberts (1992), pp. 197-229
[331] Brunt (1997), chapter 6, Kist (1992), p. 66 and ARA VOC 2612 / 13.3.1744.

VOC-network, that they were better in answering to the commercial demands of the network and finally they were technically better because of their sturdier construction. On 28 August 1744, the *Heeren XVII* changed some details in the design and decided on a different armament. On 30 August 1745, a year earlier than originally planned, the *Heeren XVII* decided "to continue with the new charters for the greater benefit and profit of the company, because of their sailing qualities, handling at sea and carrying capacity", thereby echoing Van Imhoff's comments.[332] The "few matters needing improvement" (although not specifically mentioned by Van Imhoff in his letter) entailed some problems on his journey on board the *Herstelder*. The ship rolled and pitched so much that it lost two topmasts and one topgallant. It took some time, of course, for experiences with the new *retourschepen* to filter back to the Republic, and then it turned out that similar problems occurred with the 150 ft-*retourschepen*[333]. The criticism regarding the design, based on practical experience with the ships, was – in hindsight - shared by the master shipwrights, who were also of the opinion that the ships pitched too much, and could not sail sufficiently to windward in rough seas. In addition, apparently also in hindsight, they did not like the narrow, rounded stern that had replaced the old wide, square stern[334]. Writing from his post in Batavia in 1746/1747, Van Imhoff started again commenting on the ships and shipping of the VOC, arguing that the VOC should concentrate on building the first (i.e. 150 ft) charter, because this charter could cope with the Dutch coastal waters and harbours, was the most profitable, sailed better and could defend itself better against attacks[335].

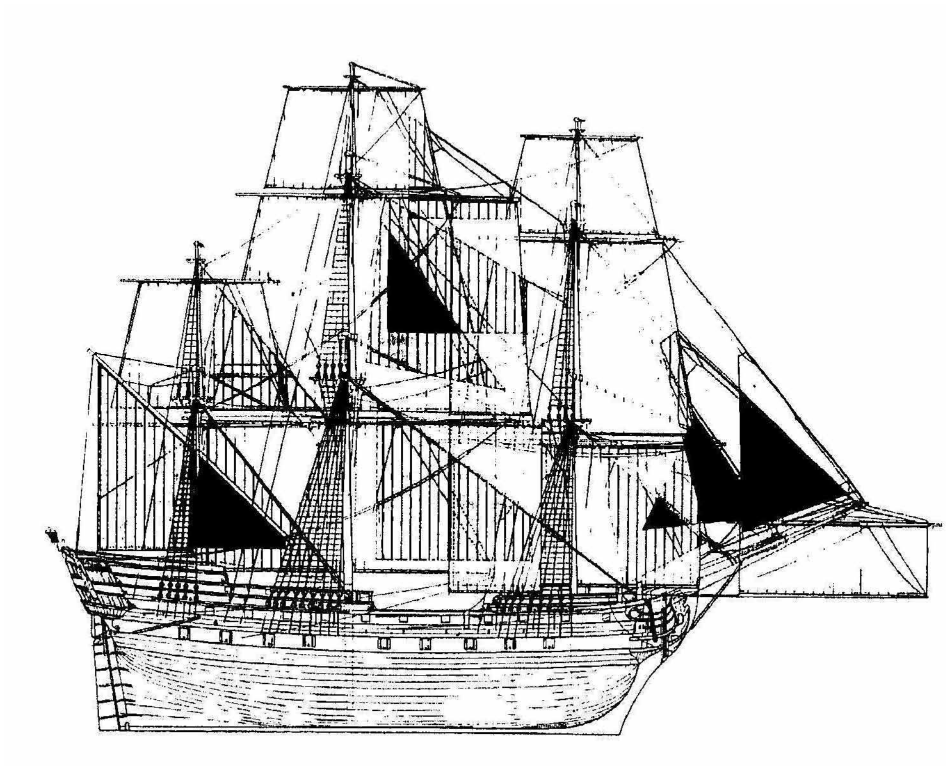


Fig. 3.7 Artist's impression of the innovative, standardized *retourschip* of the VOC/Dutch East India Company, a ship of the 150 ft. charter, after the design by Charles Bentam (appr. 1742). This illustration is derived from Kist (1985) © Drawing Herman Ketting Rijksmuseum Amsterdam 1985

[332] In Dutch it says that "*wegens de bezeyldheyd, gemaniertheyd als stuagie der gemelde scheepen van de nieuwe charters, dat daarbij ten meesten nutte en profijte van de compagnie behoorde te worden gepersisteert*". Kist (1985), p. 15. Also Kist (1992), p. 66, ARA VOC 7374 / 28.8.1744 and ARA VOC 7375 / 30.8.1745
[333] Kist (1992), pp. 65
[334] Bruijn e.a. (1979-1987) Part 1, p. 47.
[335] Kist (1992), pp. 68 and ARA Aanwinsten 1973 III-1

Other comments (again by Van Imhoff and by shipwrights) emerged in the years to follow, and the innovation was therefore not without some criticism. This shows that the enlisting of shipwrights did not mean that they followed the new design without questioning it, even after some of them had been consulted about the design and all of them had been more intensively linked to the network by the new design and building practices They used the experiences of users and their own expertise and insights for a continuous adaptation and development of the new standardized design. The black box of the design was therefore regularly reopened, the design renegotiated and adapted and, as a result, the immutable mobiles of both the 150 ft.- and the 136 ft.-*retourschepen* were mutated. The chamber Rotterdam (which was not consulted during the introduction of the Bentam designs) played an important part in the critical appraisal of the innovation, introducing some important changes. These and other reactions by master shipwrights regarding the innovation and standardization were partly inspired by theoretical and practical developments from abroad, partly by local experiments and partly by responding to shifting circumstances. All of this will be discussed in the next chapter, showing how the VOC-network and the *retourschepen* that belonged to it, kept changing and how the master shipwrights regained something of their former independence.

The VOC caught up with the radical invention of the technical drawing of ship designs, turned it into an innovation for its own use, partly changing its character into a system-stabilizing one, while embarking on a large program of shipbuilding. The introduction of the new designs, combined with the new building techniques turned the 1740s into an impressively productive period for the VOC, especially concerning its shipbuilding operations. Between 1740 and 1749, ninety-four ships were built[336]; in some more detail: between 1742 and 1745, fourteen retourschepen of the 150 ft.-charter were built against twenty-five of the 136 ft.-charter and none of the 120 ft.-charter; in 1746, sixteen ships were built, four of which were of the 150 ft.-charter, eleven of the 136 ft.-charter and one of the 120 ft.-charter. These numbers suggest that the 120 ft.-charter never really came into use.[337] In 1746 alone, the Oostenburg yard produced seven ships. These numbers point to three things. First, they suggest that the VOC was rapidly trying to modernize its fleet. Second, they confirm a trend towards the building of larger ships. This fits in with the observation made by Bruijn e.a. that in the course of the 18th century smaller ships tended to be used less and that the average tonnage of the retourschepen increased, especially after 1740[338]. This meant that for the shipping of the same tonnage of merchandise a smaller number of ships was needed, which may have constituted a material response to remarks about numbers of ships and small payloads made by the States of Holland and the States-General in 1740. More than two-thirds of the return trips from the East Indies to the Republic took place in the 18th century[339], and added to the increased tonnage of the ships, this implies that the amount of cargo shipped back to the Republic increased even more. Finally, they suggest an increasing emphasis on the technological aspects of the large enterprise VOC.

Summary

Departing from the standardized specifications, drawn up in 1697, a continuous process of interactive adaptation of the retourschip took place during the first decades of the 18th century. In addition to these changes, some specialized vessels were introduced and a few faster vessels were built on an experimental basis. While the largest charter of retourschepen was effectively discontinued, in the remaining two charters the objectives of increased cargo space and less

336 Bruijn e.a. (1979-1987) Part 1, p. 93
337 The payload of the 150 ft.-charter was 1150 tons, of the 136 ft.-charter 850 tons and that of the 120 ft.-charter 600 tons. Details were retrieved through http://www.inghist.nl/Onderzoek/Projecten/DAS/search
338 Bruijn e.a. (1979-1987) Part 1, p. 96
339 Bruijn e.a. (1979-1987) Part 1, p. 96

draught were realized. However, a series of shipping disasters in the 1720s and 1730s made it clear that the seaworthiness of these classes of ships had been compromised. This came out into the open when the octrooi of the VOC had to be renewed in 1740. By then, it emerged that neither the forces of nature had been sufficiently recruited into the VOC-network, nor that political forces had been sufficiently enlisted as allies.

The States of Holland and the States General made it clear that several changes were needed in the way the VOC operated, which included the design and the operation of the retourschepen. After an initial reluctant response by the VOC, changes were proposed by the master shipwrights of the VOC and accepted by the Heeren XVII. These changes consisted of adaptations in the current designs, and therefore followed the same pattern that had characterized earlier changes. However, before these changes could be implemented, the Heeren XVII asked a recently appointed governor general of the East Indies to suggest wide ranging plans for change. As far as shipbuilding was concerned, this led to a series of new designs for retourschepen, drawn by Charles Bentam, master shipwright at the Amsterdam admiralty, introducing the immutable mobile of technical drawings within the VOC network. After consultations with a number of shipwrights and skippers, the innovation of building ships according to technical drawings was introduced at all shipyards of the VOC. Building ships according to drawn out plans also implied a change in building practices. Instead of the existing regional differences in the way ships were built, a universal system was implemented across all VOC-yards, thus forcing an even stronger link between shipwrights and network. It also enabled the VOC to turn itself into a single large technological system, instead of the conglomerate that formed the commercial network of the VOC. The radical innovation of introducing design drawings and a universal mode of production, leading to interchangeable ships built out of interchangeable parts, acted for the VOC as a system-stabilizing innovation. The result was a large building program, leading to the construction of about a hundred ships in less than ten years, confirming the status of the VOC as the single largest producer of ships in the Republic. On a commercial level, this assisted the VOC in reaching the peak of its activities during the second half of the 18th century. This did not mean that any further developments were stifled. Criticism regarding the behaviour at sea of the new vessels, changing demands, further developments in shipbuilding and -design, both from abroad and locally generated, worked together in letting the master shipwrights reopen the black box of the design of retourschepen. This happened in a situation where it might have looked that the master shipwrights were completely tied up within the VOC-network. However, the master shipwrights were able to regain a form of independence within the network that tied them together with the VOC, by proposing and implementing changes to ships and ship designs. The continuing process of development, the reintroduction of adaptation and the introduction of more radical changes will be described in the next chapter.

4. The resilience of shipwrights and the versatility of artefacts

> De invoering van de ontwerptekening in 1742 verminderde bij de VOC de onafhankelijkheid van de ambachtelijke scheepsbouwer. Althans op het eerste oog, want het blijkt dat het getekende ontwerp regelmatig opnieuw gedefinieerd werd door deze scheepsbouwers. In dit hoofdstuk beschrijf ik wie (of wat) betrokken waren bij het muteren van de *immutable mobile* van de technische tekening en wat hun innovatieve en/of standaardiserende bijdrage was. In de loop van de 18de eeuw werden scheepsbouw, scheepsontwerp en het gedrag van schepen in toenemende mate vanuit theoretisch gezichtspunt beschouwd. In hoeverre die theorie zijn weg vond binnen het hybride netwerk rond het retourschip wordt beschreven in par. 4.1. Aanvankelijk werd een belangrijke technologische rol bij scheepsbouwkundige ontwikkelingen gespeeld door het scheepstimmermangilde, als drager, overdrager en – in tegenstelling tot wat vaak gedacht wordt – als vernieuwer van technologische kennis. In de loop van de 18de eeuw ziet men dat de rol van dit gilde verschuift naar die van een sociaal vangnet en dat nieuwe technologie een meer individuele aangelegenheid lijkt te worden. De tweede helft van de 18de eeuw was een periode van politieke en sociale onrust, zowel binnen de Republiek als op het vlak van de buitenlandse politiek. Dat wordt – met de rol die het Amsterdamse scheepstimmermangilde daarbij speelde – besproken in par. 4.2. In par. 4.3 wordt beschreven hoe, rond het midden van de 18de eeuw, individuele Nederlandse scheepsbouwers experimenteerden op het gebied van scheepstechnologie. Dit gebeurde vooral op de locale werven in Rotterdam en Middelburg. In Rotterdam eisten experimenten op schaal, zeearmen en riviermondingen een plaats op in het hybride netwerk rond het retourschip, met als gevolg zowel een algemene als een locale aanpassing van het ontwerp. Geopolitieke overwegingen om meer troepen naar de wingewesten te kunnen vervoeren, betere stormbestendigheid en gezondheidsoverwegingen werden door de VOC-scheepsbouwer in Middelburg ingeschakeld om het ontwerp van het retourschip aan te passen tot een gesloten driedekker. In par. 4.4 wordt beschreven hoe er in de laatste decennia van de 18de eeuw enkele innovaties buiten het retourschip om en een (laatste) aanpassing aan het standaard retourschip zelf werden doorgevoerd, op een moment dat de VOC financieel gezien in zwaar weer verkeerde. Ook daar kan men zien dat "externe" fenomenen gerekruteerd worden om het netwerk te versterken, en onder andere scheepsworm en aangroei (bij het "koperen" van de romp) worden ingelijfd om op het laatste moment innovaties en aanpassingen door te voeren.

In 1742, the independence of master shipwrights at the VOC had taken a blow. The introduction of the immutable mobile of ship's technical drawings and of new building techniques had reduced their role to supervising the materialization of somebody else's design. At least, that was how the situation appeared in the first years after its introduction. On closer inspection, however, the black box of ship design was re-opened repeatedly by shipwrights, implying that they regained at least some – if not all – of their independence by mutating the immutable mobile. In this chapter, the cooperation between shipwrights and *retourschepen* will be investigated, and it will be shown how the interactive relation between humans and artefacts was instrumental in an ongoing development of the artefact and also essential in regaining independence by the shipwrights. This relationship was part of an already existing hybrid society that kept expanding; an expansion that incorporated elements such as the development of technoscientific[340] knowledge regarding the properties of ships, the shifting position of the shipwrights' guilds, local technological experiments, shifting shallows, geopolitical considerations, political turmoil in the Republic and desperate endeavours to keep the VOC afloat.

In the first section, principles and practicalities of ship design are discussed, highlighting that it cannot be assumed that theoretical considerations preceded practical solutions, or that formal

[340] This term may sound somewhat anachronistic, but considering that an attempt to separate technology and science is fraught with difficulties, and especially so when considering the 18th century, the word technoscience will be adopted to cover the intertwined area of technology and science.

knowledge developed by mathematicians and natural philosophers would produce a superior type of knowledge, compared to the skills of experienced shipwrights. A few examples are given as an illustration, restricted to issues that turned out to be important in the adaptation of the new design of the retourschip. It will be shown whether (and how) these insights made any inroads within the hybrid VOC-network. In the second section the shifting relation (and its underlying causes) between the VOC and the shipwrights' guild is discussed. The introduction of design drawings and the related change in building procedures had a profound effect on the way (master) shipwrights could perform their jobs. Political and social unrest in the Republic may – at least in part - have been related to these changes, although on a much smaller scale than was the case in England in the second half of the 18th century. The third section shows the re-opening of the black box of ship design by some local shipwrights. They did so by either using the outcome of small-scale experiments or by building an actual retourschip to an adapted design. To have their proposals accepted they succeeded in enlisting a sufficient number of sufficiently qualified allies within the VOC-network, or in introducing some allies from outside the network. In the last decade of the 18th century, the VOC operated in severe financial difficulties. In the final section of this chapter is described how some last-minute innovations were introduced by (or forced upon) VOC's shipping operations and how an equally last-minute adaptation of the standardized design was introduced. These changes never reached the phase of becoming standardized, because the VOC was dismantled just before the 18th century drew to a close.

4.1 Principles and practicalities of ship design

> *"After what has been said (…) I believe it will not be thought impossible to unite all these different qualities in one ship, so that all of them may be discerned in some degree of eminence, but when it happens otherwise, the fault must be owing to the builder, who has not applyed him to study the fundamental rules and principles of his art".*
>
> Henri Louis Duhamel de Monceau (inspector general of the French navy between 1739 and 1782) in "The Elements of Naval Architecture", as translated by Mungo Murray (1754), p. 48

4.1.1 Conflicting objectives

In 1752, Henri Louis Duhamel de Monceau, inspector general of the French navy, published a textbook called Elémens de l'Architecture Navale ou Traité practique de la Construction des Vaisseaux. In the words of James Pritchard "the Elémens is the first training manual for aspiring naval constructors ever produced".[341] It did not apply "scientific" knowledge to shipbuilding, but offered naval constructors practical tools, which they could use discriminately within their local practice. For instance, it replaced the intricacies of the recently developed infinitesimal calculus with numerical methods, making it possible to calculate more easily the displacement of a vessel, its stability or the resistance of its hull at the design stage. As a result, in French naval shipbuilding matters like displacement, metacentric height and resistance were calculated at the design stage and, after construction of a vessel, experiments were conducted to verify that the ship had indeed sufficient stability.[342] The book did not replace existing practical and theoretical knowledge of shipwrights with mathematical or geometrical principles. Duhamel wrote that "geometry in itself is not sufficient to solve (several) problems. A geometrician, not being a sailor, will produce nothing useful"[343]. Instead, he argued for rational inquiry (through observation and experiments) into the practice of shipbuilding by the shipwrights themselves.

[341] Pritchard (1987), p. 16
[342] The metacentric height is an important measure for establishing the inherent stability of a ship design; see Nowacki (2006), p. 11 and Ferreiro (2007), pp. 237-241
[343] Duhamel du Monceau (1754), according to the Dutch translation (1757), pp. 2-3

This implied that – ships being costly as they were - progress could only made by small, incremental steps and that experiments, relying on the existing skills and experiential knowledge of shipwrights were essential for this progress. Due to the huge costs of new vessels, experimenting on a real scale was hardly an option. One might therefore argue that the artefact itself put up some resistance against the development of a radical innovation.

Duhamel's textbook was translated into English and into Dutch[344]. Looking at the reactions by Dutch shipbuilders regarding the translation of Duhamel's treatise (as mentioned in section 2.3.2), it emerges that, on the one hand, shipwrights like the Van Zwijndregts were quite positive about his book, but on the other hand, they felt that Dutch shipbuilding had been undeservedly discredited. One could argue, as will be shown in section 4.3, that they in fact supported the gist of his argument, which was that practical knowledge of shipwrights was still an essential part of the process of shipbuilding and design. Theoretical considerations on resistance hardly entered the hybrid societies of shipwrights and certainly not those in the Republic. The results of practical experiments did, however, have impact on ship design and these experiments managed to enter the hybrid society of shipwrights and *retourschepen* as is shown by the experiments carried out by the Dutch master shipwright Pieter Van Zwijndregt. During the 1750s, he undertook towing experiments with models of ships, not so much to arrive at or to ascertain theoretical propositions about resistance as for the much more practical purpose of improving his (or others') designs. He mentioned these experiments and their outcome in a manuscript that he wrote in 1757 but which was never published. However, some of his results were incorporated in proposals to adapt the new design of the *retourschip*. His experiments were of a local character and were not intended to prove or disprove certain theoretical concepts. They incorporated several topics, such as resistance, the effect of the rudder, the effect of a rounded bottom and the relative strength of wood. As far as Van Zwijndregt's local experiments concerned the *retourschip*, they will be discussed in more detail in section 4.3.

When designing and building a ship, either a naval vessel or a merchantman, a master shipwright needed (and naval architects still need) to reconcile several objectives relating to the seaworthiness of the vessel in general: stability, carrying capacity (payload and/or armament), speed, manoeuvrability, strength and weatherliness. Sometimes these objectives may go hand in hand (e.g. a ship designed to carry a large payload or a large armament needs to be strongly built) but much more often objectives are at odds with each other (e.g. in order to be able to reach a large speed a ship needs to carry a large head of sail, however that may easily impede seaworthiness or counteract stability). More extensive examples of conflicting objectives have already been mentioned in section 2.1 (concerning the Dutch navy) and in section 3.1 concerning the VOC's *retourschip*). Although Duhamel was of the opinion that it ought to be possible to unite conflicting objectives "in some degree of eminence" in a single vessel, usually a compromise between these objectives had to be found, which often meant sacrificing one objective against another objective. It turned out that it was impossible to reconcile the carrying capacity and the sturdiness of the retourschepen with a great speed. In 1697, the VOC decided on a formalized compromise between conflicting objectives through the introduction of a system of standardization, which was described in a meticulous way (cf. section 1.5). It was based on an evolution of ship designs, gradually developed over the preceding decades by master shipwrights who were trying to square the requirements of the VOC with the requirements of nature. However, as has been shown in section 3.1, ongoing changes in the requirements by the VOC (such as an increasing volume of trade or shifting shallows) led to changes in the standardized design that caused a fatal instability concerning the requirements of nature in the adapted compromise. A solution was then sought in the introduction of a new design, inscribed in technical drawings (as described in section 3.2), and the design was materialized in a more rigorous way (as described in section 3.3). This new design was again based on the received

[344] The English translation (and adaptation) by Mungo Murray dates from 1754 and the Dutch translation - made on the instigation of Cornelis Schrijver (see section 2.3) - appeared in 1757.

wisdom and experiential knowledge of a master shipwright. Following Stephan Epstein, the term experiential knowledge of premodern craftsmen

> …includes implicit or tacit knowledge; non-propositional and non-linear knowledge, including imagery, which has both implicit and explicit components; and explicit, propositional knowledge, which is linear and verbal or mathematical. (…) Implicit knowledge relies on rule finding and abstraction, and is the basis for the acquisition of skills. Thus, the distinction between implicit and explicit knowledge is hazy, and they form part of a continuum; but the implicit component is consistently greater than the explicit.[345]

Apart from the increasing use of "images" in ship design and shipbuilding (i.e. technical design drawings) during the latter half of the 17th century (and even more so during the 18th century), the 17th and the 18th century also saw an increase in "linear and mathematical knowledge" regarding ships, ships' behaviour and ship design. This theoretization of ship design (the term "rationalization" is explicitly not used here, because that might give the impression that the experiential knowledge of shipwrights was non-rational) was in particular developed in France in the last decades of the 17th century and the early decades of the 18th century; in an effort to build a navy that could compete with the English and the Dutch navy. The idea was that ship design and shipbuilding not only needed to depend on the skills of shipwrights, on empirical methods and on experiential knowledge but that it could be possible to develop a more theoretical and mathematical foundation regarding the design of ships. An example of the thinking behind this approach is the quotation, given at the start of this section, which might at first sight be interpreted as giving priority to fundamental rules and principles, which might lead to a more predictable design process. However, on closer inspection one can notice that Duhamel still considered the process of ship design and shipbuilding an "art". Moreover, whether the design of ships would actually improve because of theoretical and mathematical considerations cannot have been clear at the time.

One should not mistakenly think that a theoretical/mathematical approach was anything new. In fact, Aristotle and Archimedes had already investigated some of these objectives and their ideas had found their way into the collective knowledge of the Venetian Arsenal[346]. During the turn of the 18th century, matters of displacement, payload, stability and resistance got the most attention. Theoretical considerations regarding displacement/payload and resistance will be discussed in some more detail below, because these aspects can be explicitly detected within the network surrounding the *retourschepen*. This does not mean that stability was not considered an important issue – on the contrary, it had been a major factor leading to the redesign of the *retourschepen* – but the only evidence to be found on the (proposed or actual) use of theoretical considerations regarding stability is to be found in the design and building of the small frigate Lynx. This vessel (carrying twelve to sixteen guns) was built on the orders of the Amsterdam admiralty by the amateur shipbuilder G.J. Palthe in 1784[347].

4.1.2 Displacement and payload

Aristotle had been concerned with the problem of buoyancy, which he explained in De Caelo (Of the Heavens) by pointing to the relative weight of materials submersed in water, compared to air and to the shape of the object: a small and sharp object would more easily part the water than a wide and shallow body did.[348] However, in his treatise On Floating Bodies Archimedes pointed out that the volume of the liquid displaced by a partly submerged body has the same weight as the whole body.[349] By the early 17th century, most natural philosophers and quite a

[345] Epstein (2006), p. 2; in this article "premodern" points to pre-1700.
[346] Ferreiro (2009)
[347] Hoving & Lemmers (2001), pp. 131-132
[348] Ferreiro (2009), p. 16
[349] Nowacki (2002), p. 13-14

few artisans had accepted Archimedes's concept that the displaced volume of water produces an upward force. But, when from the 1620s onwards, Jesuit colleges in France started teaching hydrography (which included ship design and construction), they still relied on Aristotle's insights. As a result, the Jesuit mathematics professor Fournier argued that it was *moralement impossible* to determine the displacement of a ship.[350] As there were no Jesuits to contend with in England, English shipwrights devised methods to calculate the displacement of ships, based on Archimedes's theory and using the technical drawings that had locally been introduced during the 17th century. This meant that the displacement of a ship could be known before it was being built. The method used by the English naval shipwright Anthony Deane survives in his manuscript Doctrine of Naval Architecture (1670).[351] Using drawings of the main frames, he approximated the form of each frame by a quarter circle, the radius of which was calculated based on several measurements in the drawing, or by dividing the hull into a series of rectangles and triangles. Of these two systems, the triangle system (an example of which is shown in fig. 4.1) was usually more accurate than methods using circles, provided a large number of triangles was used. Another system was based on the subdivision of the drawing into several trapezoids, a method originally devised in Italy[352]. A more refined method was Simpson's Rule, developed by the English mathematician Thomas Simpson in 1743. All these methods had in common that they avoided the use of Newton's and Leibniz's complicated infinitesimal calculus, and could therefore more easily be used by non-mathematicians.[353] There is no evidence that shipwrights in the Republic, either of Dutch or of English origin, used any of these methods to calculate displacement of their ships at the design stage, either before or after the introduction of technical drawings.

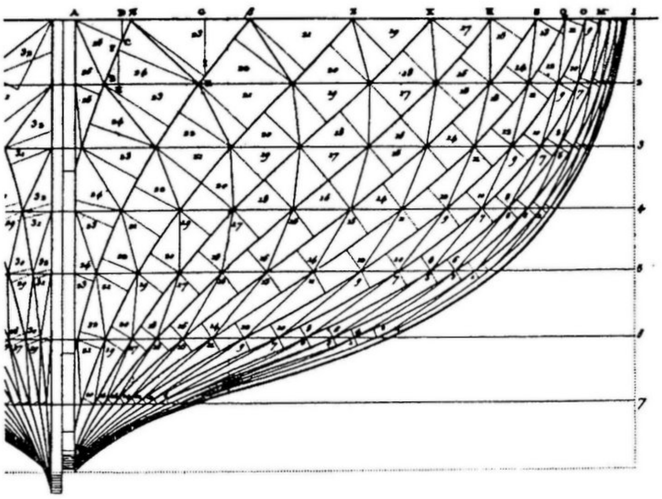


Fig. 4.1 Subdivision of main frame using a triangle method (in Duhamel du Monceau, 1752)

In 1608, the mathematician Simon Stevin had reformulated Archimedes's principle of buoyancy, adding to it the phenomenon of hydrostatic pressure on the submersed part of the hull. This led to attempts to find a method to calculate the cargo capacity of an existing ship, several of which were described by Witsen[354]. The first of these was the *volmaekte wijze* (perfect method) devised by the mathematician and patrician Johannes Hudde, who – just like Witsen – was a member of the town council of Amsterdam. His method was based on measuring waterlines on an empty ship's hull (as shown in fig. 4.2), making an educated guess of the waterlines when the ship was partly laden and fully laden. The difference in volume between an empty and a (partly or fully)

[350] Ferreiro (2009), p. 18-19
[351] In the re-edited version of his doctrine (Lavery, 1981) this method is described on pp. 71-73.
[352] Timmermann (1962), p. 19. See also http://en.wikipedia.org/wiki/Trapezium_rule
[353] Timmermann (1962), pp. 19-20. See also http://en.wikipedia.org/wiki/Simpson's_rule
[354] Timmermann (1962), pp. 15-16, Nowacki (2006), p. 10 and Witsen (1671/1690), Chapter 17

laden ship was calculated using several trapezoids to approximate the submersed volume. This volume (in cubic Amsterdam feet) was then converted into weight, by multiplying it with the weight (in pounds) of a cubic feet of IJ-water.[355] Dividing this number by 4000 gave the cargo capacity in *lasten.*[356]

Witsen also mentioned the usual Dutch way of determining the cargo capacity, in which overall length, overall width and a certain depth of the hold were multiplied, and divided by a number that was dependent of the type of ship. In addition, he wrote that a more practical method had been devised regarding traffic to Norway, which consisted of loading ships with cannons and cannonballs until the fully laden waterline was reached, then the cargo was taken out and the weight of it determined. After that, brandmarks were made near stem and stern and official letters of calibration given out for each ship. Discussing foreign ways of determining cargo capacity, Witsen first mentioned Fournier, who stipulated that a ship could take as much cargo as its own weight, followed by three more methods in which length, width and draught (using slightly different weighing factors) were multiplied and translated into weight and finally a method by which a ship – before being launched – was filled with water, the amount of water being measured and half the amount deemed to be the carrying capacity.

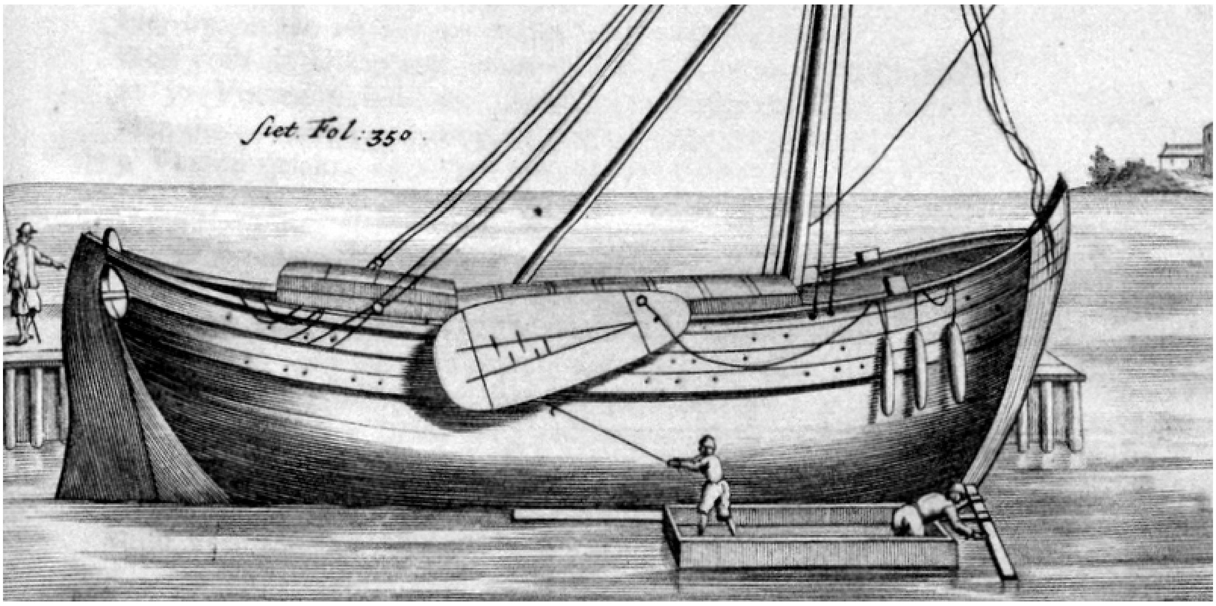
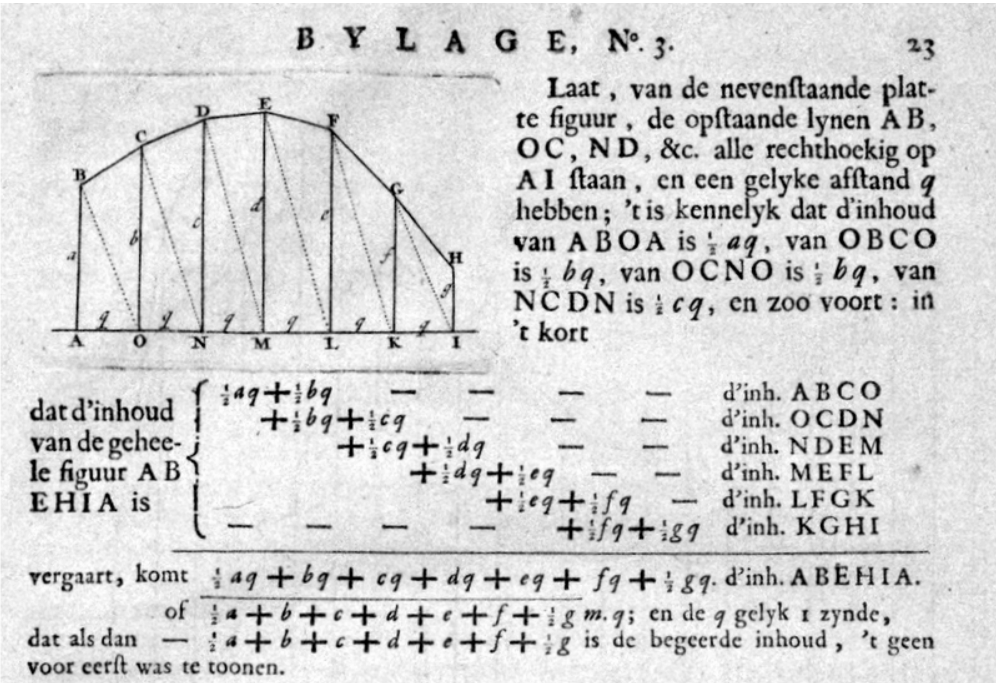


Fig. 4.2 Hudde's method of determining the cargo capacity of a ship as described by Witsen (1671). The illustration is in Van IJk (1697); photo from an original copy at the library of the University of Amsterdam (Bijzondere Collecties), taken by Johan de Jong on 7 July 2009

Problems with predicting the cargo capacity of *retourschepen* inspired VOC-councillor Hendrik Decquer to come up with a practical way to determine the amount of cargo *retourschepen* could safely take. Possibly inspired by Hudde's method, he wrote a book called Middelen om uit te vinden de ware ladinge der Scheepen na hare grootte, which was published between 1688 and 1690[357]. However, as Dutch shipbuilding did not use technical drawings of ships at the time, it was impossible to ascertain how large the displacement of a ship would be before it had actually been built. Instead, Decquer took measurements of existing ships, as he states in his *Bijlage Nº 3* (Appendix Nr 3). In order to infer results from these measurements, he used approximate numerical methods as shown in fig. 4.3. In addition, Decquer added drawings (*Bijlage Nº 9*) to show how cargo (either in barrels, parcels, crates or boxes) should be stowed in the most

[355] These measurements apparently took place in the brackish water of the IJ, North of Amsterdam.
[356] A *last* (as a weight unit) equals approximately 2000 kilograms.
[357] Translated: "Means to determine the real cargo of Ships related to their size" (see also section 1.5, note 88)

advantageous way. Decquer's handbook was used by the VOC's *equipagemeesters* to ascertain the amount of cargo existing ships could take and to standardize the system of loading ships.[358]



BYLAGE, N°. 3. 23

Laat, van de nevenſtaande platte figuur, de opſtaande lynen AB, OC, ND, &c. alle rechthoekig op AI ſtaan, en een gelyke afſtand q hebben; 't is kennelyk dat d'inhoud van ABOA is ½ aq, van OBCO is ½ bq, van OCNO is ½ bq, van NCDN is ½ cq, en zoo voort: in 't kort

dat d'inhoud van de geheele figuur ABEHIA is
½aq+½bq — — — — d'inh. ABCO
+½bq+½cq — — — d'inh. OCDN
+½cq+½dq — — d'inh. NDEM
+½dq+½eq — — d'inh. MEFL
+½eq+½fq — d'inh. LFGK
— — — — +½fq+½gq d'inh. KGHI

vergaart, komt ½aq+bq+cq+dq+eq+fq+½gq. d'inh. ABEHIA.
of ½a+b+c+d+e+f+½g m.q; en de q gelyk 1 zynde,
dat als dan — ½a+b+c+d+e+f+½g is de begeerde inhoud, 't geen voor eerſt was te toonen.

Fig. 4.3 Decquer's approximate numerical method; photo from the original at the library of the University of Amsterdam (Bijzondere Collecties), taken by Johan de Jong on 7 July 2009

There is, however, no evidence that (even after the introduction of technical drawings within the VOC) attempts were made to calculate the payload of the retourschepen during the design stadium. On the contrary, if one reads remarks made by Leendert van Zwijndregt, one gets the impression that the new VOC-charters were able to carry a smaller payload than the ships they replaced[359]. This suggests that no calculation had been carried out beforehand to ascertain the carrying capacity of these ships, but that one relied on experience with earlier designs

4.1.3 Resistance

Cods, mackerels, dolphins and ducks were some of the marine animals that shipwrights used to describe the form of hulls of their sailing ships until the 18th century. Common wisdom has it that the hulls were shaped with a "cod's head and a mackerel's tail", indicating that the broadest part of the hull was near the stem, tapering towards a more slender form near the stern. Although the quote seems to be rather apocryphal, in a drawing dating from 1570 the shipwright Matthew Baker overlaid the underwater part of the hull with a drawing of a cod and a century later, a French shipwright used a tuna to describe the form of the aft end of the hull.[360] It is definitely the case that William Sutherland (1711) commented on the "curiously formed, perfectly convex" shapes of mackerels and dolphins, and pointed to the "not unpleasant" way ducks swim and went on to suggest that "they may be of service to us in laying down such mathematical rules, as are used in forming them".[361] By that time, some natural philosophers (and others) had already been considering matters of resistance in fluids, both experimentally and theoretically. In 1671, Nicolaes Witsen made a tantalizing remark in Aeloude en

[358] It was apparently also used by the States-General to prescribe how to calculate the carrying capacity of ships of the West Indian Company, according to a note (dated 8 Aug 1730) inserted in the copy of Decquer's book at the library of the University of Amsterdam (Bijzondere Collecties).
[359] Leendert van Zwijndregt, as quoted in Hoving & Lemmers (2001), p. 82 and (verbatim) in Kist (1992), p. 74
[360] Ferreiro (2007), pp. 123-125
[361] Sutherland (1711), pp. 2-3

Hedendaegse Scheeps-Bouw en Bestier (Old and New Ship Building and Ship Management) when he wrote that "in the past by means of pulleys trials have been conducted concerning all sorts of hull shapes, to determine which hull would the best for fast sailing: the hull that – operated by these pulleys – went fastest through the water was thought to be the best sailing vessel."[362]

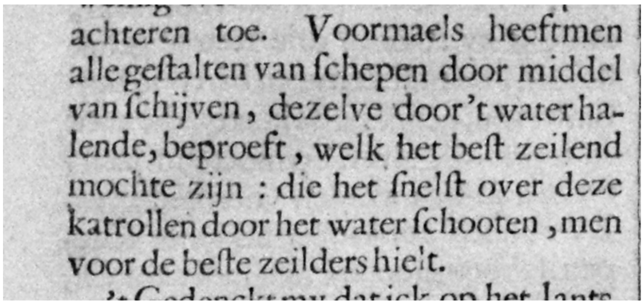

achteren toe. Voormaels heeftmen
allegeſtalten van ſchepen door middel
van ſchijven, dezelve door't water ha-
lende, beproeft, welk het beſt zeilend
mochte zijn : die het ſnelſt over deze
katrollen door het water ſchooten, men
voor de beſte zeilders hielt.

Fig. 4.4 Witsen (1671) referring to towing experiments, detail of page 274 (top). Photo of the original copy at the library of the University of Amsterdam (Bijzondere Collecties), taken by Johan de Jong on 27 August 2009

Small-scale experiments to determine the resistance caused by a fluid on hull shapes preceded any theoretical developments on this issue. In 1668/69, Huygens undertook experiments by towing simplified models of hull forms through a tank filled with water, using an apparatus with a falling weight.[363] These experiments led him to the conclusion that resistance was proportional to the square of the velocity. His results were published only after his death in 1698. At about the same time, in 1670, the English economist Samuel Fortrey undertook towing experiments with simplified hull shapes, arriving at the conclusion that hulls with a large length/width ratio travelled faster through the water.[364] Looking at the description given by Witsen, it is tempting to speculate that the experiments, performed by Huygens or Fortrey, were in some way communicated to him.

In 1683, a few years after these experiments, the French mathematician Gaston Pardies formulated – on theoretical grounds – that the resistance a body experienced in air or in a fluid was proportional to the square of its relative speed.[365] In 1684, Mariotte using a setup in which a stationary object was placed in a moving fluid, came to the same conclusions as Huygens, but he also discovered that resistance was proportional to the density of the fluid. His results were posthumously published in 1686. In 1685, experiments similar to those of Fortrey were undertaken by (amongst others) Anthony Deane who towed planks in the shapes of hulls of different ships. A model of a long, narrow galley was fastest and that of a Dutch ship slowest.[366]

Using a theoretical approach, Newton arrived at the same formula for resistance as Huygens and Mariotte, but as he finished his manuscript in early 1686, he cannot have been aware of the outcome of their experiments. Discussing resistance, Newton suggested that there might exist a *solid of least resistance*. As described by Sutherland, Newton demonstrated that this solid consisted of "the rotation of a crooked line about its axis, and is blunt and flatheaded".[367] Over the following years, the exact interpretation of this solid of least resistance became a holy grail in the early theory of shipbuilding. Whether there have actually any ships been built, using these solid of least resistance is unclear.

[362] Witsen (1671), p. 274
[363] Nowacki (2006), pp. 12-13 and Nowacki (2007), p. 11
[364] Meyer (1988, pp. 216-217 & 219) and Ferreiro (2007), p. 151
[365] Timmermann (1962), p. 17
[366] Ferreiro (2007), p. 151
[367] Sutherland (1711), p. 2. The rotated crooked line was an ellipsoid, with a flat nose attached to it. Newton is quoted by Ferreiro (2007), p. 130.

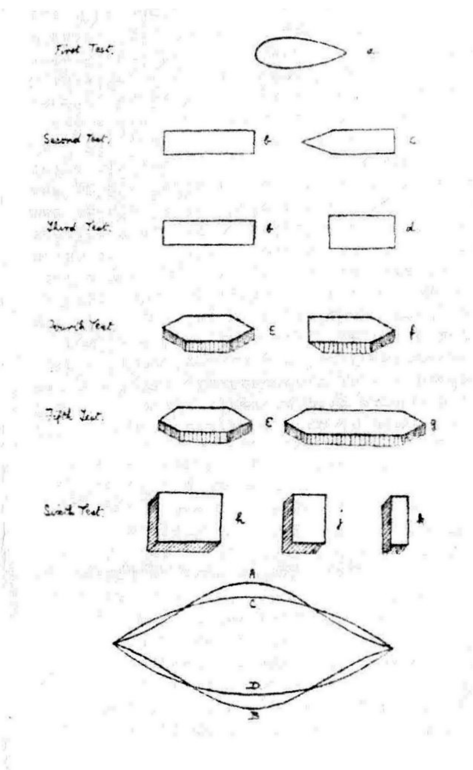


Fig. 4.5 Hull forms as used by Samuel Fortrey in his towing experiments, picture derived from Meyer (1988)

In 1737, the French shipwright and spy Blaise Ollivier (see section 3.4) wrote

> The English claim (…) that they have given to their new ships the shape of the solid of least resistance proposed by Mr Newton and it is on this in particular that they found their hopes that the new ships will be faster sailers than the old (….) Such a solid cannot on its own form the shape of the bow, or else the ship would roll excessively (….). It can therefore be employed only as part of the bow (….). The English Master Shipwrights (…) believe that they have overcome (the difficulties) by divers experiments they have carried out at the dock at Deptford, where they floated and drew through the water pieces of wood of different shapes.

Ollivier went on to say that he thought that the French had succeeded better in applying the solid of the least resistance to the bows. The English had moved the maximum breadth of their new ships more forward, claiming that this would improve sailing capacities. Ollivier is scathing about this, arguing that this improved effect will only be achieved by using a larger head of sail and accordingly more ballast, which would then probably result in no effect at all.[368] Interestingly, Ollivier mentioned towing experiments at Deptford, experiments that are not mentioned anywhere else. This search for and research into the solid of least resistance is an example of what Schaffer has called an intellectual project.[369] Apart from the point that improving the resistance of the hull might lead to a deterioration of other characteristics, as mentioned by Ollivier, it also called for increased control by the management of the yard to make sure that the new designs were meticulously materialized. Shipwrights could see this as an infringement on their independence.

Meanwhile, Newton's impact theory of a fluid (and its associated solid of least resistance) was slowly being replaced – within the internal development of the theory - by a field theory of fluid dynamics, first formulated by the Bernouillis between 1720 and 1740, and finalized by Euler (in

[368] Roberts (1992), pp. 183-184
[369] Schaffer (2007), p. 290. See also section 1.5

Latin) in the 1750s[370]. However, applying the field theory exactly to actual body shapes asked for numerical tools not yet available[371]. It was therefore through textbooks such as Duhamel's that new theoretical developments, translated into numerical approximations, became available to practising shipwrights. For instance, Duhamel proposed "a method to calculate the resistance of the water upon the fore part of the ship"[372]. It took almost twenty before Euler's theory became available in the form of a textbook, written in French[373]. Meanwhile, it was through experiments, such as carried out by Van Zwijndregt and others, that practical gains had to be reached. It is interesting to note that on the subject of resistance Van Zwijndregt wrote that he considered it "useful that a master shipwright investigates which form has the least resistance", adding that "the most capable (shipwright) would be the one who through experiments and experience had discovered which form was needed for that purpose". In addition, he mentioned that he did not want to express "that nobody was capable of designing a good sailing Ship, provided he was competent in foresaid sciences (i.e. laws of nature, hydrostatics or mechanics)". He points to experience handed down from earlier generation, which through small changes – some for the better, some for the worse –led to ships that almost answer to laws of nature. However, he says, its is "thoroughly true that a master having knowledge of the laws of nature and the principles of mechanics will lead the art of shipbuilding to perfection, as opposed to somebody who knows nothing of these ." [374] It seems therefore that he suggests that experiential and experimental knowledge would be enhanced by having more theoretical knowledge – more or less echoing the ideas of Duhamel.

Returning to the remarks by Duhamel that experimenting with full-size ships was hardly an option, we will see that – in addition to the small scale experiments carried out by Van Zwijndregt - this was exactly what happened a few times at the VOC-yard at Middelburg. As has been shown in section 3.1 and as will again be shown in section 4.3, at this yard local master shipwrights experimented with full-size ships, and they seemed to be able to strike luck when they did so. The only time the VOC-yard at Amsterdam tried its hand at a full-size experiment it failed spectacularly. In the case of the VOC, theoretical considerations regarding the design of ships did not enter the hybrid society of shipwrights and r*etourschepen*. Only practical calculations and the outcome of local experiments, either on a small scale or with full-size vessels, gained entry.

4.2 The changing role of guilds

The master shipwrights, employed by the VOC, became engaged in a shift from the classic guilds' approach to ship design and shipbuilding to the use of a more formalized way of ship design and of shipbuilding techniques associated with this approach. What happened at the yards of the VOC stood in contrast to the rather informal way in which standardization and innovation in Dutch shipbuilding seem to have been realized. Changes usually occurred through an exchange of knowledge within and between local shipyards, independent of whether developments in

[370] Nowacki (2007), p 6
[371] Nowacki (2006), pp. 21-22
[372] Duhamel du Monceau, according to the English translation by Mungo Murray (1754), p. 57
[373] Euler's "Théorie Complète de la Construction et de la Manoeuvre des Vaisseaux", published in 1773 (Nowacki (2007), p. 7
[374] Hoving & Lemmers (2001), p. 188. These quotations in Dutch are as follows *"nuttig dat een Scheepsbouwmeester ondersoekt wat figuur van de minste Reesistentie is"*, *"so een de Capabelste zou zijn, die door Proeven en Ondervindinge eerst hadt ontdekt wat voor een figuur dat tot dat eijnde (….) vereijste"*, *"of er niemant in staat was om een wel zeijlent Schip toe te stellen, of hij moet kundig zijn in de voorgenoemde Weetenschappen (i.e.Natuurwetten, Waterweegkunde, of Mechanica)"*, *"een seer grondige Waarheijdt, dat een Bouwmeester die de kennis der Natuurwetten en de gronden der Mechanica bezit, de Const der Scheepsbouw verder zal tot Volmaektheijdt brengen, dan een daar tegenoovergestelt die daar niets van weet."*

shipbuilding and design should be interpreted as incremental changes within a standardized design or whether adaptation to different purposes led to more fundamental innovative changes in design. This knowledge was of a practical nature, or – following Epstein – "experience-based".[375] It emerged from and was sustained by a local practice of shipbuilding, and was stimulated through shifting demands by individual customers. This meant that within a given design there was room for subtle changes and adaptation to use (e.g. the transport of wood as opposed to the transport of salt) or that more specialized ships could be developed (whaling ships as opposed to merchantmen). Both gradual evolution and innovative discontinuity were realized at local shipyards. From the Middle Ages until the end of the 18th century, the link between shipwrights at local shipyards was forged by shipwrights' guilds[376]. Shipbuilding, which provided the essential artefacts used in the expanding trade within and outside Europe, depended on the skills and knowledge of the artisans involved, skills and knowledge that needed to be transferred to the next generation. During the period between the Middle Ages and the "Industrial Revolution" (i.e. from 1300 until 1800), this transfer was organised and effectuated through guilds. Guilds played a major part in the production, development and transfer of technological knowledge and know-how. As technological knowledge at the time was largely based on experiment and not put down in writing, textbooks or drawings, it was transferred through a system of apprenticeship (controlled by the guild) from one person to another. Guilds seem to have Janus faces; some authors see them as blocking technological innovation, while others interpret them as instigators and spreaders of technological change. Looking at the situation in the Republic, one can detect a shift in the way knowledge was generated, appropriated and transferred. This process was reinforced through what happened at the Amsterdam admiralty, and more importantly, at the VOC-yards. In general it can be said that the designing and building of ships changed from being a collective (i.e. guild based) enterprise into a more privatized enterprise

Until the first decades of the 18th century, every ship was designed and built based on "common" or shared knowledge. Designs were not put down on paper, but existed in the minds of master shipwrights, fitted within the local tradition of shipbuilding and were materialized in the artefact. One could argue that the ultimate design of a ship took place during the building process. This local tradition was able to spread beyond its boundaries, as for instance the *fluit* spread from the town of Hoorn to yards all over the Republic.[377] This spatial spreading can be partly attributed to journeymen moving around from yard to yard, carrying with them the wisdom, received from older master shipwrights and partly to the fact that the artefacts themselves appeared in other ports. According to Unger (1978), Dutch shipwrights' guilds were not only concerned with their classical role of creating a social safety net for their members, the education of new artisans and the production of experience-based knowledge. They also rented out capital goods (such as cranes, jacks and bellows) that were too expensive to be owned by individual small shipbuilders.[378] Most importantly were guild meetings through which an exchange of ideas between shipwrights could take place, leading to knowledge sharing and technological innovation[379]. "Contrary to popular belief, these guilds never (at least not before 1600) regulated against new production methods", which led to the development of Dutch shipbuilding as a "fluid, adaptable and expanding industry".[380] Knowledge was spread over time through the system of apprenticeship, whereby the master invested his practical knowledge in apprentices, who in turn had to work at his shipyard for the duration of their term. Such a term usually lasted for quite a number of years (in England up to seven years) and after finishing their education, apprentices might be obliged to stay on for a number of years, in order for the master

[375] Epstein (2004), p. 382 & Epstein (2006), pp. 2-7
[376] In 1795, the new rulers of the so-called Batavian Republic formally abolished guilds.
[377] Cf. section 1.3.1
[378] Unger (1978), p. 74
[379] Epstein (2006), pp. 7-15
[380] Unger (1978), p. 80

to recoup his investment.[381] On a more general note, Epstein refutes the notion that "the Dutch Golden Age was (…) the result of strong technical innovation associated with (…) unusually weak craft guilds". On the contrary, "the majority of the guilds arose (…) during the boom years. Dutch craft guilds – including those associated with (…) shipbuilding – were at the forefront of technological innovation, both through inventions within their ranks and in their adoption of novelties from abroad"[382].

Because of these innovations, shipbuilding was an important enterprise in the Republic. The total number of seagoing vessels, built during the 17th century, may have been well over 40,000, implying a total workforce of about 10,000.[383] These numbers point to an early form of mass-production, which did not fit in with the way guilds operated. This may have been one of the reasons why this mass-production was confined to the area of the Zaan, to the northwest of Amsterdam. As there was no history of shipbuilding at the Zaan, shipwrights' guilds did not exist in that area and therefore it was able to support (for a while at least) a thriving shipbuilding industry, not regulated by guilds. The shipyards in this rural area could operate cheaper than the guild-controlled yards within the towns. They had the added advantage of a ready wood supply as the Zaan area had a large number of specialized wind powered sawmills. The effect was that yards, specializing in the building of new ships, more or less disappeared from towns like Hoorn, Enkhuizen, Rotterdam and, to a large extent, from Amsterdam as well. This left these towns concentrating on repair jobs, apart from the large VOC and admiralty yards. However, the mass production yards at the Zaan were lacking in innovation, quite possibly because of the absence of any technological exchange organized by and through the guilds.[384] Unlike the guild-regulated areas of shipbuilding elsewhere, the yards at the Zaan went through a classical boom-and-bust cycle, caused by a decline in replacement of ships, a decline in fisheries and whaling and a decline in the export of ships. Protective measures taken by Amsterdam and the silting up of parts of the river Zaan deepened the downward spiral. From a peak of about sixty-five shipyards in 1670, the number of yards went down to about twenty-six in 1730, leaving only two or three yards in 1792. Even accounting for an increase in the size of the remaining yards, this points to a decline that was not paralleled at neighbouring Amsterdam.[385] Deurloo has shown that, during the 18th century, shipbuilding in Amsterdam in general was a "very prosperous" affair, and that relatively speaking, it grew in importance compared to other enterprises.[386] To make his point, Deurloo quotes contemporary sources and sources from the late 18th and early 19th century[387]. Apart from the VOC-yard, most yards in Amsterdam specialized in repair jobs. This counteracted a trend in a decreasing demand for new ships, caused by a decline in local replacement of ships, a decline in fisheries and whaling and a decline in the export of ships.[388] To Deurloo's arguments can be added that it is hardly likely that the VOC would have employed more than 1100 workers during most of the 18th century (and especially in the latter half) had there not been enough work in building new ships and repairing existing ships. Apart from the Oostenburg yard, the number of private shipyards in Amsterdam during the second half of the 18th century remained at least stable, numbering between thirty and thirty-five, to which number should be added ten breakers' yards, five mast manufacturing plants and fifteen yards specializing in building small boats. These private yards employed on average about a hundred people each, which helps to put the impressive size of Oostenburg into perspective.

---

[381] Epstein (2006), pp. 2-7.
[382] Epstein (1998), pp. 700-701
[383] De Vries & Van der Woude (1995/2005), pp. 351-352
[384] De Vries & Van der Woude (1995/2005), pp. 352-353
[385] De Vries & Van der Woude (1995/2005), pp. 354-355
[386] Deurloo (1971), pp. 50-53
[387] Deurloo (1971), quotes from a survey amongst Amsterdam shipbuilders in 1808 and refers to 18th century entries in the "Archief van het Scheepstimmermans- en Mastenmakersgilde" and "Requesten betreffende het bedrijfsleven uit het Rechterlijk Archief van Amsterdam".
[388] Deurloo suggests that a decline in exports may have been caused by Dutch shipbuilding lagging behind theoretically.

Before the 18th century, shipbuilding was a typically open-ended enterprise: success could only be established after the artefact had been completed and was put out to sea. In order to get to grips with their designs, shipwrights tended to use rules of thumb, such as basing the dimensions of a new ship on the length it was supposed to have, or on the numbers of guns it was to carry. Practical knowledge, handed down through time or space, was crucial in this respect. During the 17th century, different systems developed whereby drawings were used to assist the (often tacit) experiential knowledge. These drawings grew in importance over time and covered an increasingly large part of the design: not only was the hull inscribed into drawings, but also details of the construction, of the rigging, and of the form of the sails.[389] Whether the development of drawings as such led to better designs and an improvement in the characteristics of ships is questionable, but drawings made it possible to separate the design process from the building process, to increase control of the building process and – important in the case of the VOC - to transfer the design to other yards. As mentioned in chapter 2, in the Republic the use of drawings did not occur until well into the 18th century. Before that, the only examples of written knowledge concerning shipbuilding are to be found in the rather encyclopaedic treatises by Witsen (1671) and Van IJk (1697).

Because of the development of drawings during the first half of the 18th century, designs and building methods became (in a way) more individualized. Instead of being based on the (mostly not documented) exchange of knowledge between guild members, designs could be attributed to specific designers, such as Slegt, Bentam or Van Zwijndregt. These shipwrights were not only explicitly responsible for the design, but they also controlled the building process, as is shown by the example of the Van Zwijndregt dynasty in Rotterdam.[390] The Van Zwijndregts developed a design process, based on technical drawings, a system which they kept secret from about 1725 until 1755. The building process they used was adapted to their design method, and could not kept secret, as the production of a large artefact consisting in a 150 ft.-ship was there to see for all. In a way, the VOC operated in rather similar way. Although until 1742 no design drawings were used, the way in which details of the design, building and equipment of the *retourschepen* were formalized[391] shows an increasing grip on the design and building process. Over time, ships tended to get larger and more complicated, which led to an increase in management activities compared to the actual building process, not only at the (Amsterdam) admiralty yard and the VOC-yards, but also at private yards.[392] In the case of the VOC, this became manifest in the resolutions from 1697, which specified in great detail how the retourschepen should be built. This meant that the leeway, available to the master shipwrights when materializing a ship was smaller than it had been before. The example of the VOC shows that the separation between design and building went even further, in that the designer of a ship was no longer responsible for the materializing of his design, but that responsibility fell to a different master shipwright. Large ships (such as *retourschepen*) could only be built on large yards, which also meant that the owners of such yards employed a large number of people to carry out the actual building, while the owner was responsible for design and management activities. Other guild members turned into employees instead of being small entrepreneurs themselves. At the same time, their employers played a prominent role in governing the shipwrights' guild[393]. For instance, in Amsterdam this guild was governed by five *overlieden* (governors), appointed by the burgomasters of Amsterdam, based on a recommendation made up by the guild. Almost without exception, these *overlieden* owned their own yard and it was not until 1749 that two guildsmen without a yard of their own (usually high-ranking shipwrights at the VOC yard and the admiralty

---

[389] Epstein (2006), pp. 17-19
[390] Cf. section 3.3
[391] Cf. section 1.5
[392] Unger (1978), p. 84
[393] It should be noted that the shipwrights' guild was also open to mast makers, and even more importantly, "ordinary" labourers at the shipyard – not being master shipwrights - could become members of the guild as well, which made the shipwrights' guild probably the largest in Amsterdam (Deurloo (1971), pp. 11-18).

yard) were eligible for these posts. Therefore, centralization can be seen to have occurred regarding both shipbuilding and the governing of the guild.

Looking at the situation within the VOC until the end of the 17th century, the master shipwrights, although bound by increasingly detailed guidelines (as described in section 1.5) were still able to exercise to some degree their own judgement when building and finalizing *retourschepen*. From the second half of the 18th century onwards, the VOC became the owner of a formalized, inscribed design that prescribed in detail the material manifestation of its *retourschepen*. Referring to what has been said about theoretical developments in the preceding section, the knowledge on which this design was based, was not of a formal nature, but was practically acquired and based on the experience of shipwrights and reports of users. The new, inscribed design in the form of an immutable mobile also implied that the ships ought to be built in a specified way[394] and it legitimized the grip that the management of the VOC was exercising over its staff. It might even be possible to read into this development an early example of proto-capitalism, whereby the owners of the means of production started tightening their control over the workers. They were able to do so because a crucial condition for the production of their ships, the design of the r*etourschepen,* existed no longer only in the minds of the shipwrights but was owned by and available to the *Heeren XVII*. The centralized approach within the VOC led to the fact that "with minimal costs and with great speed standardized ships were being built at its yards. Without any doubt, the yard (…) at Oostenburg was one of the most modern industrial complexes of its time" .[395] In addition, the VOC as an enterprise was "trying to get a grip on all aspects of its organization", although (as mentioned in section 3.2) committees consisting of shipwrights and skippers were sometimes asked for advice[396].

In general, Unger (2008) suggests that the emergence of a monopoly stimulates a program of research and development. In that respect, he mentions the Venetian Arsenal, the Lun-Chiang shipyard at Nanking, the conglomerate of shipyards resorting under the French minister of the Navy, the Portuguese Royal shipyards and the shipyards of the VOC.[397] However, in the case of the VOC the development remained confined to a technologically conservative design of East Indiamen and Unger refers to complaints about the Dutch admiralty yards and the VOC yards lagging behind technologically. He points to the fact that sometimes the way the English navy built its ships was an example of how to improve shipbuilding, but he also mentions that the English navy was mainly interested in precise classification and standardization, in order to arrive at a situation where parts and crews were easily interchangeable – a *modus operandi* which in this paper (cf. section 1.2) has also been attributed to the VOC.[398]

Because of the shift to formalized, drawn designs at the Amsterdam admiralty and at the VOC-yards, the shipwrights' guild in Amsterdam lost part of its impact on the technological and organizational aspects of shipbuilding in the course of the 18th century. It shifted its attention more towards the regulation of pay and the organization of funds providing for sickness, accident and retirement[399]. While originally guilds refrained from politics, the shipwrights' guild in Amsterdam in particular turned into an increasingly influential political force. During the late 17th and the 18th century, as its technological influence waned, the guild organizing the *bijltjes* (hatchets, the nickname for the Amsterdam shipwrights after their tools of the trade) increasingly emphasized social aspects. This regarded preferential treatment of guild members, the regulation of pay, and payouts in the case of sickness, accidents and old age.

394 Cf. section 2.3 and 3.3
395 Translated from Hoving & Lemmers (2001), p. 46
396 Translated from Hoving & Lemmers (2001), p. 45
397 Unger (2008), p. 27
398 Unger (2008), p. 27
399 Unger (1978), p. 97

From 1680 onwards, owners of shipyards (whether in the business of constructing new ships or specializing in repairing ships) had to employ guild members first, followed by townsfolk and only in the last instance could strangers be employed. Of course, in case of dismissal the inverse order had to be applied. In addition, from 1750 onwards it was decreed that only guild members were allowed to work in the repair of ships.[400] The number of ships to be repaired was very large as any ship, which had Amsterdam as homeport had to be repaired in Amsterdam; from 1750 onwards, it was added that any ship, loading or unloading in Amsterdam had to be repaired in Amsterdam as well.[401] This meant a very strong position for guild members and in practice, the effect was that – apart from the shipwrights working at the VOC-yard or at the admiralty – most guild members sought employment in repair jobs. This can be interpreted as a choice based on sound economic reasoning: there was a large demand for shipwrights at repair yards; the pay was higher than at the VOC or the admiralty, and in case of a downturn in the number of available jobs, one could always make use of the preferential treatment for guild members.

It is therefore not surprising that during this period the number of members of the shipwrights' guild in Amsterdam increased impressively, from 400 in 1688 via 800 in the 1730s to about 1100 in 1749 and possibly to about 1700 in 1788[402]. As the shipbuilding industry as a whole remained stable at best, the conclusion must be that the percentage of shipwrights who became a member of the guild increased. In 1717, however, there were already complaints that the increase in membership led to such an increase in old and sick members that their payouts could no longer be secured. Therefore, it was stipulated that, on entry, one should not be older than about thirty years of age, and in addition, the entrance fee rose sharply. The yearly contribution had already been rising steadily, but guild members refused to pay more unless the payouts were increased as well. This was reluctantly accepted by the guild, and invalids and those of old age were entitled to a payout of three guilders per week.[403] There was a problem, however, regarding guild members working at the VOC-yard and the admiralty yard. For instance, working at the VOC-yard meant that – even if one had not reached the status of master shipwright – one could nevertheless join the guild. Other working conditions at the VOC-yard were – compared to those at private yards – also relatively favourable. Although the basic wage for VOC-shipwrights (at 300 guilders annually) was slightly lower than on private yards, they had the advantage of a secure job, a good redundancy pay and a good pension, paid by the VOC[404]. Because of the supposedly dire situation of the guild funds, the o*verlieden* of the guild argued that any payouts by the guild should be additional, and they managed to elicit a court ruling to that effect by 1745.

During the second half of the 18th century, the *bijltjes* and the *klouwers* (the nickname for the local caulkers, after the tools they used in their profession) started wielding some political influence, sometimes assisted by the discriminate use of their tools. Their influence was not restricted to the local town of Amsterdam, but had indirectly an effect on the politics in the Republic as a whole[405]. The second half of the 18th century was a time of much political unrest in the Republic. In 1748, unrest that had been smouldering for some time came to a head through the *pachtersoproer* (revolt against taxfarmers), which was followed by the *Doelisten* -movement.[406] Grievances had been harvested for quite a few years about the nepotistic way local regents governed towns, provinces and the Republic as a whole. Popular feeling considered these regents as corrupt, incapable and very apt at lining their own pockets. An economic

[400] Deurloo (1971), pp. 17-18
[401] Deurloo (1971), pp. 18 and 35
[402] Deurloo (1971), pp. 12-13
[403] Deurloo (1971), p. 14
[404] Lucasssen (2004), p. 29
[405] Deurloo (1971), pp. 54-65
[406] *Doelen* were the galleries where the local civic guards practised. The word *doelisten* refers to people gathering at these *doelen*.

downturn in the years before, rising prices and failed politics during the War of the Austrian Succession, during which the southwestern part of Zeeland had been occupied by French troops, added to the unrest.[407] At first popular discontent was directed at taxfarmers and the way they took advantage of their office. By the end of June, it came to the large-scale looting of taxfarmers' houses in Amsterdam. A few days later the system of taxfarming was abolished by stadholder Willem IV, but that did not stop the quest for wider reforms.

Fig 4.6 Looting of the house of A.M. van Arssen during the taxfarmers revolt in Amsterdam (1748). Van Arssen was a wine merchant and also receiver of the tax on wine. Retrieved through http://nl.wikipedia.org/wiki/Bestand:Pachtersoproer.jpg

More specifically the way the *overlieden* of the guilds operated came in for a lot of criticism by the *Doelisten*. In the aftermath of the *pachtersoproer*, this movement tried to appoint representatives of citizens within the governing bodies of the civic guard and the guilds, because of its distrust of the current officers and *overlieden*. On 31 August 1748, an infamous parade of the *Bijltjes* took place, on the one hand meant as support for the orangist party and on the other hand to reclaim old prerogatives for guild members. Many guild members were employed at the yards of the VOC and of the admiralty, which meant they could be easily recruited. Moreover, they had a particular interest, as they wanted to have the court ruling of 1745 revoked[408]. A year later, a decree was announced, implying that apart from *overlieden*, each guild needed to have a group of *gecommitteerden* (representatives) to check the books. Apparently in early 1749, the shipwrights' guild already had six of these representatives. They argued for a higher wage for shipwrights working at the admiralty yard and the VOC-yard and staged a protest outside Cornelis Schrijver's house to that effect. By the end of 1749, the current *overlieden* of the shipwrights' guild were forced to resign and a new board of *overlieden* was appointed, including two members who were not owners of a shipyard, but instead (high-ranking) shipwrights at the

[407] See Wit, C.H.E. de (1974), and also http://nl.wikipedia.org/wiki/Pachtersoproer and http://nl.wikipedia.org/wiki/Doelisten

[408] Deurloo (1971), p. 60

yards of the admiralty and of the VOC[409]. In 1750, the court ruling of 1745 was revoked[410]. To be true, within ten years' time a new clique took up the position of *overlieden* again, but at least the independent financial control stayed in place.

The VOC was instrumental in creating an international labour market with an early emergence of a proletariat in the case of soldiers and sailors, but – as can be seen from this section – this did not apply to the workforce at its shipyards[411]. Even accounting for the highly organized division of labour at the yards, the high degree of organization through the guild and the political awareness of its members – to which one should add the continuing high demand for skilled shipwrights - made it possible for the *bijltjes* and *klouwers* to have some degree of control at their workplace. Members of the shipwrights' guild, whether boss or labourer, tended to act in a confident, self-assured way. They were in a rather strong position: they had a reasonably well paid job for most of the year and could count on financial support during sickness and old age[412]. Within the VOC-network, even with the separation in place between the design and the building of the *retourschip*, the artefact itself prevented the de-skilling of labour that would have led to a proletarization of shipwrights. Whereas Schaffer refers to industrial unrest at the London dockyards, brought about by attempts at standardization during the late 18th century[413], the social and political discontent in Amsterdam was directed at the (perceived) emergence of cliques and misappropriation of funds within the guilds, and at a more general political controversy within the government of the Republic (on the level of towns, provinces and at a federal level). One can hardly detect any dissatisfaction related to a change in terms of employment. Somewhat speculatively, one could argue that the increasingly high degree to which shipwrights were organized in their guilds and their political involvement counteracted to a certain degree the attempts by the VOC-management to get a larger grip on what happened on the shopfloor. When matters of design, standardization and technological development were taken away from shipwrights, one way in which they counteracted was by getting involved on a political level. This has been interpreted as "guilds becoming more restrictive"[414], but it may be that there was more at stake for guild members than just nostalgia for times past: it can also be read as a way to recoup at least part of their involvement in design and development. Another way in which at least some shipwrights were able to counteract was through re-opening the black box of the prescribed design and starting to adapt the design using their own insights. This re-designing and its effects will be described in the next section.

4.3 Artefacts, experiments, estuaries and three-deckers

In this section, we will see how local master shipwrights were able to re-open the black box of the standardized design, on a technological level by carrying out experiments. In the case of the Rotterdam yard, these experiments were done on a small scale, using models of hull-forms; in the case of the Middelburg and Amsterdam yard, the experiments took place with full-size ships. It seems that Middelburg (a yard that had already been experimenting in the 1730s) had more luck than Amsterdam. Apart from the outcome of the experiments, there was the matter of finding allies in sufficient numbers and of sufficient importance. The way Rotterdam and Middleburg were able to play with the system shows some interesting circuitous routes. First, the role played by Pieter van Zwijndregt, the master shipwright of the VOC in Rotterdam, will be described, next the attention shifts to Middelburg and Amsterdam.

---

[409] Deurloo (1971), pp. 58-59
[410] Deurloo (1971), p. 15
[411] As already mentioned in section 1.2. See also Lucassen (2004), p. 33
[412] Deurloo (1971), p. 33
[413] Schaffer (2007), pp. 296-297
[414] For instance Unger (1978), pp. 64-65

On 30 August 1745, only three years after the introduction of the new designs, the *Heeren XVII* decided "to continue with the new charters for the greater benefit and profit of the company, because of their sailing qualities, handling at sea and carrying capacity", although some matters still needed improvement. Some changes had already been introduced a year earlier, such as the fact that two galleys might be installed instead of one, that ventilation was improved, that only one longboat should be carried instead of two and that the armament was modernized. These changes to the new standard design were the first of many to come, partly based on information gathered from studying foreign vessels, partly responding to changes in local geography and – most importantly – based on experiments carried out by local VOC master shipwrights.

In February 1745, the English had captured three French East Indiamen in the East Indies. One of these, the modern *Dauphin*, had been built (in 1743) by the shipwright Gilles Cambry Jr after a trip to Holland during which he probably visited the VOC-yard at Amsterdam. This seems to show that the Republic still had some reputation as far as the practice of shipbuilding was concerned. The English sold the ships and their cargo to the VOC. The cargo was sold for a handsome profit and the ships were added to the fleet of the VOC[415]. The *equipagemeester* at the VOC repair yard at Onrust, opposite Batavia, made a thorough investigation of the ships, and as a result, he recommended introducing some changes in the design of the Dutch *retourschepen*. These changes (approved by the *Heeren XVII* in March 1746) included a slight redesign of the curvature of the upper part of the hull, different layout of cabins, the reintroduction of an awning against the sun, the moving of the galley back to below decks, and the introduction of one large, powerful capstan instead of the two smaller ones that had been usual.[416] A local innovation was the introduction of a mechanical ventilator, consisting of a pair of bellows, to refresh the air below decks, on which the *Heeren XVII* decided in November 1746.[417] Not only French ships were apparently considered useful artefacts to study. In 1747, director Walter Senserff of the VOC chamber Rotterdam bought a small East Indiaman, built by Wells and Stanton, a shipyard on the Thames. This was probably done with the purpose to examine in detail how the English East India Company had its ships built. The ship (with a capacity of only 250 tons) was named *Prinses van Oranje*.[418] Whether the examination of this ship made any impact is not clear. In 1748, however, formal suggestions for changes were put forward regarding the design of the 136 ft. and 150 ft.-retourschip. In 1763 and 1764 proposals to adapt the standardized design locally and nationally were put forward, the last proposals taking thirty years to be officially sanctioned.

4.3.1. Local experiments and local estuaries

> *"Ships that are mathematical Machines (...) are built with specific Purposes and Objectives in mind, but all explicitly directed to travelling through the Water in the easiest possible way in order to achieve Speed (...)".*
>
> Pieter Pauluszoon van Zwijndregt, master shipwright at the VOC-yard Rotterdam, in his manuscript De Groote Neederlandsche Scheeps Bouw Op een Proportionaale Reegel voor Gestelt (1757) [419]

---

[415] According to http://www.inghist.nl/Onderzoek/Projecten/DAS , the older two of these ships only made one trip from Batavia to the Republic and were not used again. The *Dauphin* (renamed *Hervatting*) apparently never left for the Republic, so this ship was probably only used in the East.

[416] Kist (1992), p. 67 and ARA VOC 7375

[417] Kist (1992), p. 68 and Kist (1995), p. 17

[418] Curiously, though, the trips made by this vessel were on behalf of the chamber Amsterdam. http://www.inghist.nl/Onderzoek/Projecten/DAS/voyages?clear=1&field_voynameship=PRINSES VAN ORANJE and Bruijn e.a. (1979-1987) Part 1, p. 47

[419] The quote is the very first sentence of the manuscript. In Dutch: *"De Scheepen die matimatische Machinens zijn (….) worden geboudt tot bijsondere Eijndens en Oogmerken, dog allen gericht met toeleg om op de gemakkelijkste wijs het Water aan te doen, om daardoor Snelheijdt te krijgen (….)"*. In translation the title of the manuscript reads "The Great Dutch Ship Building, Presented in a Proportional Way"

On 31 October 1748, Van Imhoff wrote a letter to the Heeren XVII, with proposals to change the design of the *retourschepen*. In the letter, he referred to an advice that was sent to him from the Republic and which was apparently accompanied by a ships' model.[420] Van Imhoff had the advice checked by some shipwrights who added a short treatise on the use of proportionality in ship design in which they referred to methods used in Rotterdam.[421] The main proposals were concerned with a widening at the stern of the 150 ft.-charter, with a lengthening of the 136 ft.-charter by 4 feet and with a fuller design of the stern of all charters, in order to improve sailing characteristics in rough seas. In the treatise, mention was made of experiments that had been carried out. It is not clear from the text who carried out these experiments, but in 1757 Leendert van Zwijndregt shed some light on the matter. In that year, this master shipwright at the yard of the Rotterdam admiralty published a book Verhandeling van den Hollandschen Scheepsbouw raakende aan de verschillende Charters der Oorlogsschepen , that appeared in the same series as the Dutch translation of Duhamel du Monceau[422]. He took issue with suggestions by Schrijver that Dutch shipbuilders lacked essential knowledge. He pointed out that Dutch ships needed to be of a sturdy construction because of the risk of grounding, that Dutch warships needed to have a shallow draught to be able to leave port whenever called to do so, and that a fuller fore- and aftership led to less problems when sailing in rough seas and that they prevented hogging. He argued that his brother Pieter was the instigator of the proposals made to the VOC, which is quite likely if one considers the type of experiments that he had carried out with models of hulls in the years before.

In 1757, Pieter van Zwijndregt (master shipwright at the VOC yard in Rotterdam from 1744-1764) wrote De Groote Neederlandsche Scheeps Bouw op een Proportionaale Regel voor Gestelt which was never published, and of which the first words of the introduction open this section.[423] He wrote that over the last few years he had tried to develop a proportional way of shipbuilding, in order to move beyond mere tradition. He had never intended to make his views public, but he felt obliged to do so, because of two compatriots publishing their views on shipbuilding and arguing that the science of Dutch shipbuilding was not inferior to that in other countries and that the theory of shipbuilding was well known in the Republic[424]. A second reason was to increase the knowledge of those who wanted to know more about shipbuilding and a third reason was that publication could improve the art of shipbuilding. He went on to say that even when using technical drawings, a ship designer still had the possibility to change any frames between the main frame and the end frames as he saw fit. He started his treatise with the description of towing experiments he had carried out, in order to investigate the water resistance of different hull shapes, the effects of hull shapes on steering characteristics and the effect of a curved bottom, compared to a flat bottom. These experiments must have been conducted before the writing of his manuscript, and the reference to experiments in the treatise from Batavia suggests that they may have been carried out sometime in 1747 at the latest. It seems quite likely that these experiments formed the basis of the proposals for change, especially those regarding to the 136 ft.-charter[425]. The results of the towing experiments contravened received wisdom in ship design, as is shown in fig. 4.8. It turned out that the classical configuration of the "cod's head and the mackerel's tail" (the so-called "solid of least resistance") was in fact the hull form that had the longest travel time through the water, and therefore had the largest resistance. Van

[420] ARA VOC 2708
[421] One of these was the shipwright Verleng who resided in the East at the time, probably at the VOC (repair) yard at Onrust near Batavia.
[422] As mentioned in section 2.4. See also Hoving & Lemmers (2001), p. 82
[423] As mentioned in Hoving & Lemmers (2001), pp. 98-109. The complete text is published in Hoving & Lemmers (2001), pp. 181-296
[424] Apparently he is referring to Leendert van Zwijndregt (mentioned before) and Willem Udemans (who will be mentioned later)
[425] Due to its moderate size, the VOC-yard at Rotterdam did not build *retourschepen* of the first (i.e. largest) charter, apart from a small series in the 1780s.

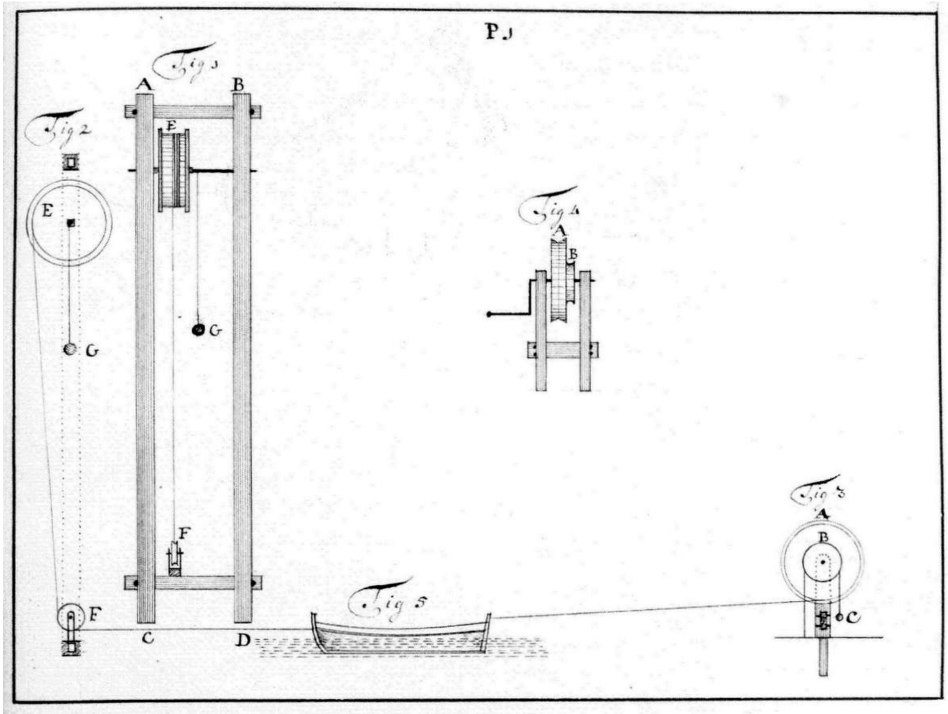


Fig. 4.7 Apparatus, used by Pieter van Zwijndregt for his towing experiments (Illustration from his manuscript as published in Hoving & Lemmers (2001), p. 184)

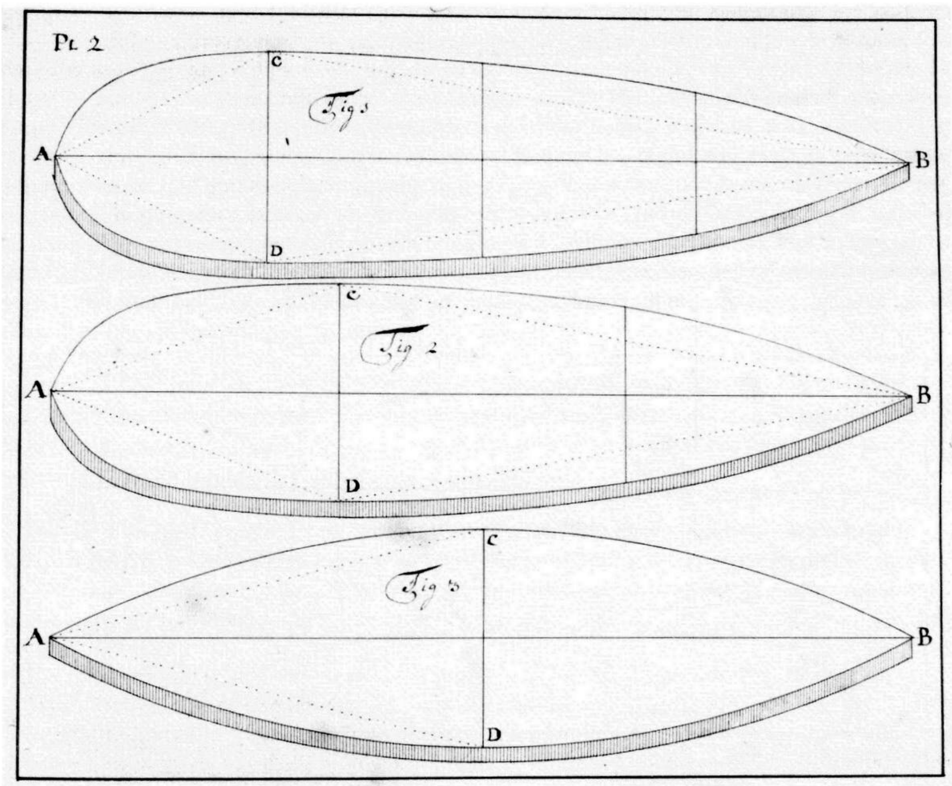


Fig. 4.8 Hull forms as used by Pieter van Zwijndregt in his experiments. The models were towed over a distance of 168 feet. Using point A as the stem, this led to relative travel times of 70, 63 and 56 time-units. Using B as stem produced times of (rasp.) 50, 53 and 56 time-units. (Illustration from his manuscript as published in Hoving & Lemmers (2001), p. 185)

Zwijndregt concluded that one should position the greatest width of the hull as far towards the stern as practically possible, but without compromising other characteristics.[426]

The second set of experiments was related to the effect of the rudder. Models that were increasingly narrow at the stern were towed and the amount of diversion from a straight course, compared to the distance travelled was measured. The results showed that a narrow underwater hull at the stern was the most advantageous as far as the effect of the rudder was concerned. Van Zwijndregt concluded however that a moderate narrowness (or sharpness) at the rear of the hull was the most useful. One gets the impression that he was trying to find a compromise between the outcome of his first sets of experiments (calling for a full stern) and his second set of experiments (calling for a narrow stern).[427] It is this compromise that can be detected in the proposals suggested to Van Imhoff: the stern was to be widened above the waterline, but should remain narrow under the waterline. A final set of experiments concerned the effect of a curved bottom, compared to a flat bottom. The outcome was that a curved bottom was superior as far a resistance was concerned to a flat bottom[428]. In addition, he wrote about the usefulness of experiments in physics[429] in general, about the outcome of experiments to determine the relative strength of wood, about the quality of wood, about different shapes and about the conservation of wood.

After the description of his experiments, he gave an overview of the requirements, needed to build a good ship. First, a hull should be formed in such a way that the water is trodden gently and that sufficient water reaches the rudder. Second, both stem and stern should be full enough to prevent the ship from pitching. Third, whatever the circumstances, a ship should be manageable, listen to the rudder, should not be too weatherly nor too leewardly, and should not drift too much. Fourth, a ship should be in proportion, meaning that hull, masts, rigging and sails are combined in such a way that the ship is balanced, either in light or in windy conditions. Finally, a heavily laden ship should be able to cope with rough sea conditions. The results of these experiments, combined with his considerations on what made a good vessel, might well have caused him to argue for a hull that was fuller formed at the stern, when he wrote his advice to Van Imhoff.

It is remarkable that a very vociferous opposition against the English shipwrights and their methods emanated from Rotterdam, both from shipwrights at the admiralty and the VOC-yards. If one looks closely at the design and building methods employed by the Van Zwijndregts, one gets the impression that there are quite some similarities between their system and the English approach. As was already shown in section 3.3, the transition from the existing system to the newly introduced system cannot have been too complicated. Therefore, it is rather inconceivable that the introduction of the principle of using design drawings or the introduction of a fully-fledged “frame first” building method as such was at the root of the conflict. The more so as there are no indications that the purchase of an English East Indiaman for experimental purposes met with any opposition from Pieter van Zwijndregt. Combined with the snide remarks made by Leendert van Zwijndregt against Van Imhoff and Bentam [430], one gets the impression that wounded pride (as mentioned in section 3.2, a proposal by the chamber Rotterdam for changing the VOC-charters in 1740 was rejected by the *Heeren XVII*) played at least some role in the Amsterdam- Rotterdam controversy.

---

[426] Van Zwijndregt as quoted in Hoving & Lemmers (2001), pp. 185-186
[427] Van Zwijndregt as quoted in Hoving & Lemmers (2001), p. 187
[428] Van Zwijndregt as quoted in Hoving & Lemmers (2001), pp 187-188
[429] He actually mentions “*Natuurwetten*, *Waterweegkunde of Mechanica*” (Laws of Nature, Hydrostatics or Mechanics) Hoving & Lemmers (2001), p. 188
[430] Quoted verbatim in Kist (1992), p. 74

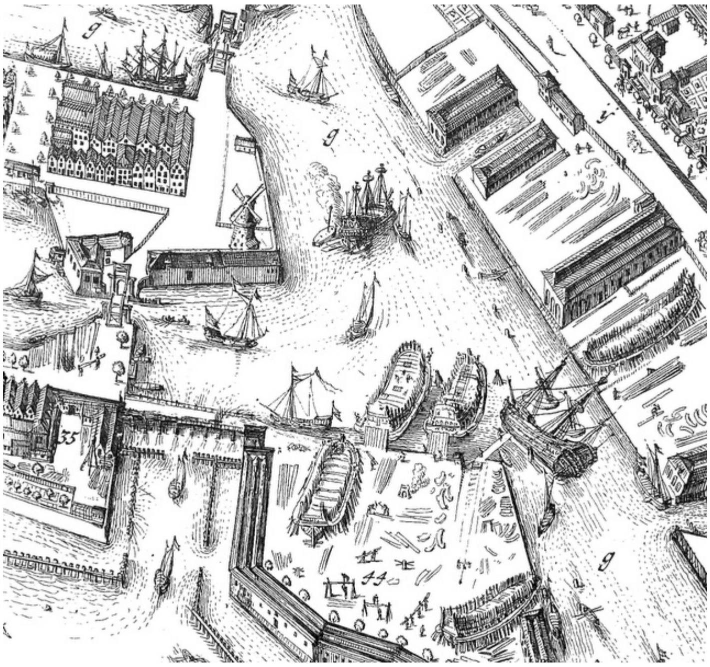


Fig. 4.9 Map of Rotterdam, showing the position of the two main shipyards. At the bottom of the picture is the admiralty yard (at nr. 44) and opposite to the right the VOC-yard. The masts of a careened naval vessel seem to be touching a VOC-ship under construction. Part of a map, drawn by Joannes de Vou (1694), derived from Grimm (1994), p. 21

Considering this, it is even more remarkable that Pieter Van Zwijndregt seems to have enlisted Van Imhoff as an ally within the hybrid society of the *retourschip* in an attempt to have his proposals accepted. On the other hand, the knowledge that Van Imhoff had exercised great influence on earlier decisions taken by the *Heeren XVII* and the possibility to bypass Amsterdam via Batavia, may have led Pieter van Zwijndregt to follow this circuitous procedure. In any case, it had the intended effect: on 22 September 1749, the Heeren XVII adopted most of the "Batavia"-proposals and in addition, on 28 November 1749, a new list was drawn up, containing adapted dimensions of masts, spars, sails and rigging.[431]

Whereas the local experiments of Pieter van Zwijndregt made their influence felt on a national level and assisted in introducing an adaptation in the design of retourschepen across the board, the local estuaries near Rotterdam played a more localized role. The difficulty of crossing the Zuyderzee from Amsterdam had been solved by the use of ships' camels, floating dry docks that lifted the retourschepen a few feet. However, it became increasingly difficult for ships to leave or reach Delfshaven and Rotterdam, because of the silting up of the local estuaries. The so-called direct route from Goeree via the river Maas was impossible to navigate for large vessels, and the circuitous route from Goeree via Dordrecht became also difficult to navigate because of expanding local shallows. On a regular basis, ships ran aground using this route. Because of the narrowness of the waterways (it was impossible for ships to pass each other at some places) the use of camels was no option. As a result, ships had to be partly loaded and unloaded at 's-Gravendeel, near Dordrecht.[432] The saying went that – on the way out – once one had reached Goeree one was already halfway the East Indies.[433] The VOC master shipwrights at Rotterdam and Delfshaven therefore had to incorporate their local estuaries and shallows in the hybrid network surrounding the *retourschip* to keep their ships afloat. In 1763, the chamber Rotterdam put forward a proposal to decrease the effective draught of the 140 ft.-charter by about 1½ feet,

[431] Kist (1992), p. 69, ARA VOC 7377 / 22.9.1749 and ARA VOC 7377 / 28.11.1749
[432] Van Kampen (1953), pp. 73-74
[433] Grimm (1994), p. 27

and to compensate for the loss of carrying capacity the design had to be widened at the bilges and the stem and stern were made wider (i.e. less sharp).

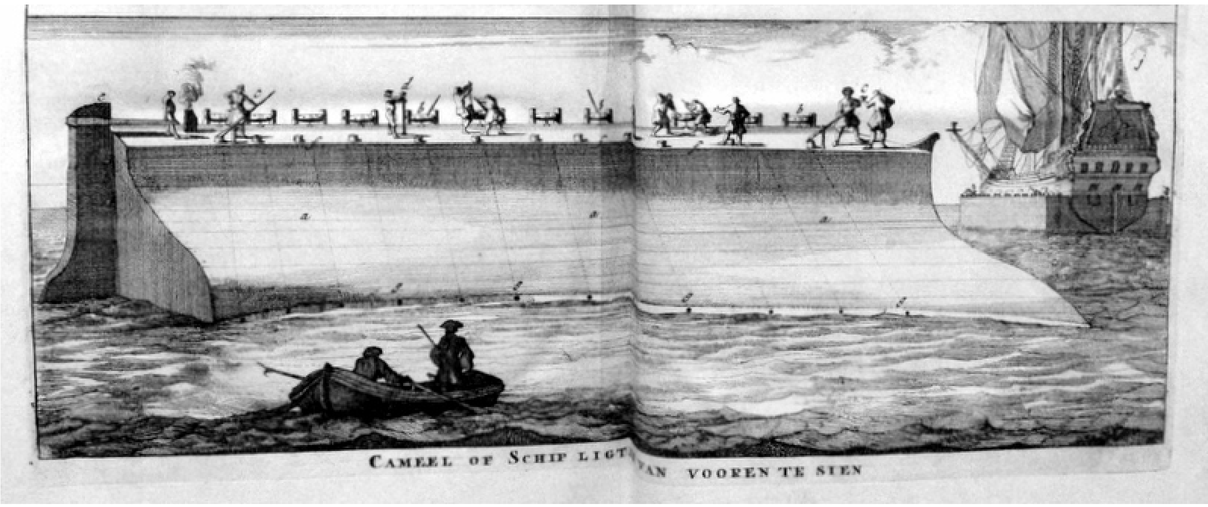


Fig. 4.10 Ships' camel, in the centre of the picture one half of the camel, in the background two camels lifting a retourschip. Illustration in Van IJk (1697), photo from an original copy at the library of the University of Amsterdam (Bijzondere Collecties), taken by Johan de Jong on 7 July 2009

The chambers Amsterdam, Zeeland, Enkhuizen and Hoorn opposed these changes, stating they would mean a return to the designs of 1714. However, the *Heeren XVII* gave permission to the each of the chambers Rotterdam and Delfshaven to build one ship of the adapted design as an experiment. Probably Rotterdam and Delfshaven kept building their ships according to the modified designs, although the designs, as adapted in 1749, remained in force and had still to be used by the other four chambers. In addition, drawings (especially those of timbers) were from 1763 onwards often added to the resolutions of the *Heeren XVII*[434].

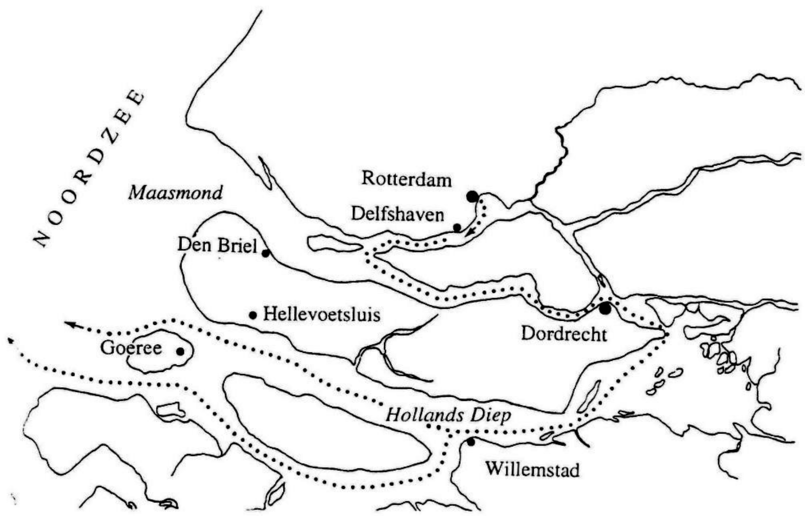


Fig. 4.11 The circuitous route between Delfshaven/ Rotterdam and the open sea. The dotted lines are the routes the *retourschepen* had to travel. Map derived from Grimm (1994), p. 27

Rather curiously, considering the problems caused by the local shallows, the VOC-yard at Rotterdam built five 150 ft.-retourschepen between 1785 and 1790. Although the dimensions of the yard in Rotterdam were sufficient to accommodate the building of these vessels, it must have

[434] Bruijn e.a.(1979-1987) Part 1, p. 47, referring to ARA VOC 58 / 11.10.1763 and 31.3.1764

been quite a problem to move these ships to open sea, because the 150-footers had a draught that was two feet larger than the standard 136/140-footer, and – as stated above – that draught was already considered too large for the local circumstances and had been reduced by 1½ feet. However, if one looks more closely at the use that was made of these ships, it turns out that they were predominantly used in the East Indies and only two made (once) a return voyage to the Republic[435]. Effectively, the shallows had to be beaten only once. Unlike the local experiments that had a nationwide effect on all charters of *retourschepen*, the local shallows needed only to be accommodated through local changes in one charter.

4.3.2 Three-deckers, geopolitics and health

> *"The difficulty of shipbuilding exists in the fact that conflicting requirements can be recognized within one ship; improving one aspect (…) often causes an even larger deterioration somewhere else"*
>
> Willem Udemans Jr. (assistant master shipwright and subsequently master shipwright at the VOC-yard Middelburg) in Korte Verhandeling van de Nederlandse Scheepsbouw[436]

The year 1757 was a fruitful year for publications by master shipwrights, written in response to Schrijver's Plan from 1755[437]. Willem Udemans Jr. - son of master shipwright Willem Udemans Sr. at the VOC-yard in Middelburg, and himself assistant master shipwright at the same yard - published a Korte Verhandeling van den Nederlandschen Scheepsbouw, for which the directors of the VOC chamber Zeeland awarded him a prize. He argued that the Dutch way of shipbuilding was *niet wiskonstig* (not mathematical) and could of necessity not be so. However, he proposed that quite a few shipbuilders were accomplished in *meetkonstige* (geometrical) drawing techniques. Willem Udemans and/or his father had developed a drawing method of their own, different from the one used by the Van Zwijndregts. In his treatise, he explained the local drawing techniques and discussed the form of the underwater part of the hull, dimensions of ships and the sturdiness of parts of the construction. Calculations and experiments are conspicuous by their absence. According to Udemans, the only reliable and sensible way of experimenting is by using a full-scale vessel. He wrote (as mentioned at the beginning of this section) that "the difficulty of shipbuilding exists in the fact that conflicting requirements can be recognized within one ship; improving one aspect (…) often causes an even larger deterioration somewhere else". He is therefore less optimistic than Duhamel du Monceau, who – according to the quotation given earlier - was of the opinion that conflicting requirements could be reconciled, if the ship designer was knowledgeable enough.

Apart from drawing techniques displaying a localized character, one gets the impression that the standardized design of the retourschip was being localized as well. The chambers Rotterdam and Delfshaven had already introduced a local adaptation of the 140 ft.-design. In 1764 father and son Udemans suggested changing both the 140 ft.- and the 150 ft.-vessels into fully fledged three-deckers. As such, the concept of a three-decker was nothing new. In the Republic, the navy had – rather unsuccessfully - experimented with three-deckers in the 1690s[438]. Foreign East

---

[435] Details concerning these ships, the Canton (built 1785), Teilingen (1786), Candia (1788), IJsselmonde (1789) and Nieuwland (1790) were retrieved through http://www.inghist.nl/Onderzoek/Projecten/DAS . The Canton made its second outward journey from Texel, and only the Teilingen left for a second time from Goeree.
[436] In Dutch: *De moejelykheid van den scheepsbouw bestaat daarin, dat men tegenstrydige vereischten in een schip gewaar wordt; waardoor men dikwerf een zaak verbeterende en deeze of gene gesteldheid aan een schip veranderende, aan een andere zyde nog groter gebrek maakt*. The quote appears in Hoving & Lemmers (2001), p. 83. Udemans's treatise (in translation: "A short treatise on Dutch shipbuilding") is partly available in Hoving & Lemmers (2001), pp. 111-127
[437] See section 2.3
[438] See section 2.1

India companies, such as the English and the Swedish also employed three-deckers.[439] The advantage of building a ship with a complete top deck instead of the usual forecastle and half deck, and a waist in between the two, was that it was less likely to take on lots of water when battling storms and heavy seas. Moreover, a three-decker could accommodate at least 100 people extra compared to the usual configuration, which promised – considering the high mortality rates as mentioned in section 1.4 – also to be quite an advantage. This meant that it was possible to send more soldiers to the East Indies, which was important if one considers that the French and the English were threatening the position of the VOC in the East. Therefore, geopolitical considerations can be seen to enter the hybrid VOC-network. Against the three-decker innovation, it was argued that there would be a lack of fresh air, and that the distance between officers and crew would disappear. Within the usual configuration, the half deck was the exclusive domain of officers and passengers, and the forecastle (and the area below the waist) was the area for the crew. A further disadvantage was the perceived lack of stability of the ships, which would be compromised because of the ships being higher, unless the draught was increased. The shipwrights of the other chambers therefore argued against the plan, but Zeeland got permission to finish one ship (the *Pallas*) as a three-decker[440]. Looking at details given by Bruijn e.a., it seems that the request was received by the *Heeren XVII* in their meeting of 4 April 1764, and that objections were raised in a meeting on 18 October 1764.[441] However, on 7 October 1764 the *Pallas* made a first attempt to sail from Rammekens (Zeeland). One gets the impression that the chamber Zeeland had gone ahead without waiting for an official approval, the more so as the year of building the Pallas is given as 1762[442]. Similar behaviour had been displayed between 1736 and 1740 when fast ships had been built without prior permission.[443]

On 26 July 1766, the *Pallas* succesfully completed its first return voyage, having sailed to China and back, and the chamber Zeeland got permission to build more three-deckers. Apparently, the chamber had anticipated this positive outcome because already in 1765 two more three-deckers had been built, a vessel of the 150 ft.-charter and a vessel of the 140 ft.-charter[444]. The Zeeland chamber and/or its shipwrights probably argued that it would not be too difficult to refit the ships back to the conventional waist if they were forced to do so. Until 1772, in total a number of nine more three-deckers were constructed at the yard at Middelburg, all but one belonging to the largest charter. In 1770, a proposal was put forward by Zeeland to lengthen the largest charter, and – as might be expected – a vessel of that size (the *Europa*) was already being built. It was able to carry 50 tons extra, but the other chambers argued that ships of this size were too large to be accommodated by the camels that were used to carry the retourschepen across the Zuyderzee. In addition, Zeeland asked for permission to build three-deckers on a regular basis, but the *Heeren XVII* suspended the building of three-deckers altogether[445]. This caused an endless argument over the pros and contras of three-deckers, which was only resolved in the last few years of the VOC's existence.

In the late 1770s, the master shipwright in Middelburg, Willem Udemans Jr., found an ally in a local surgeon, Ezechiel Lombard. In 1779/1780, the two of them wrote a treatise in which they answered prize questions, quite conveniently posed by the *Zeeuwsch Genootschap der Wetenschappen* (the Zeeland Fellowship of Sciences) about the usefulness of fully closed three-deckers. These questions related specifically to the building of *retourschepen*. In their answers, they argued that three-deckers were superior on technical and on medical grounds[446]. Shortly

---

[439] Bruijn e.a.(1979-1987) Part 1, p. 48
[440] Bruijn e.a.(1979-1987) Part 1, p. 48
[441] The first date is mentioned in Bruijn e.a (1979-1987) Part 1, p. 48 footnote 38; the second date in footnote 39.
[442] See http://www.inghist.nl/Onderzoek/Projecten/DAS/detailVoyage/94968
[443] See section 3.1.1
[444] See http://www.inghist.nl/Onderzoek/Projecten/DAS/detailVoyage/95048 and http://www.inghist.nl/Onderzoek/Projecten/DAS/detailVoyage/95074
[445] Bruijn e.a.(1979-1987) Part 1, pp. 48-49
[446] Hoving & Lemmers (2001), pp. 111-112 and Bruijn e.a.(1979-1987) Part 1, p. 49

after publication, the *Heeren XVII* decided to leave the choice to the master shipwrights: new *retourschepen* could be built either in the new three-decker layout or according to the conventional configuration with a waist.[447] This meant that the independence of the local shipwrights (at least temporarily) increased as they were allowed to build the ships as they saw fit. In 1784, the chamber Amsterdam embarked on a full-scale experiment of its own. It suggested building a larger charter of *retourschepen* [*160 ft x 42½ ft x 19½ ft*] together with special camels. Although the other yards objected by invoking the argument that they could not build these vessels because their yards were too small, Amsterdam got permission to build the new design. This ship (the *Admiraal de Suffren*) still had the classic deep waist. It perished on its first return voyage in the South China Sea, with a cargo to the value of more than 1.000.000 guilders[448]. In contrast, the three-deckers from Zeeland operated very successfully in the same area. The addition of medical considerations to the hybrid society (already expanded by geopolitical considerations which had grown in importance because of the fourth Anglo-Dutch war) and the failure of the Amsterdam innovation (with its huge financial loss) made the number of allies for the three-decker large enough for the *Heeren XVII* to concede that there was sufficient evidence that three-deckers were superior to the convential retourschepen. They decreed that from 28 December 1793 onwards, only three-deckers should be built[449]. Existing ships with a waist were to be refitted as three-deckers[450], which restored standardization. By that time, the process of adaptive (re)standardization had taken almost thirty years.

In their playing of the hybrid society, the Zeeland shipwrights managed to incorporate the directors of their local chamber, which can be inferred from the prize awarded to Willem Udemans Jr. and from the apparent willingness of the directors to propose changes that had already been materialized in an artefact. In addition, the fact that the *Zeeuwsch Genootschap der Wetenschappen* asked exactly the right questions can hardly have been coincidental. The most interesting addition to the hybrid society is however the artefact itself. By "doubling back on itself": i.e. changing before permission was granted and letting the mutated artefact prove materially that the immutable mobile could indeed be mutated with promising results, the artefact showed a versatility that went beyond the strict demands of the *Heeren XVII*. To put it differently, the artefact was not only appropriated by its builders, its users and its owners, but it actively assisted in the process of appropriation and adaptation.

In section 2.3, while discussing the spread of innovations, Inkster is quoted in mentioning a geographical perspective which led to the thesis that a "diffusing item (....) may be at once a stimulus to further innovations and itself subject to *adaptation* as it spreads from its physical point of origin".[451] The success of innovative technology imported from abroad is dependent on the ability of indigenous artisans to modify and reconstruct this technology; otherwise, the new technology will not spread beyond its original niche.[452] Whereas the master shipwrights of most admiralties refused to engage with innovative (and potentially standardized) designs, some shipwrights of the VOC were able to create some room to manoeuvre within (and outside) the standardized design. They did so through using practical (and innovative) insights and through effectively enlisting allies from within and from outside the current VOC-network. One gets the impression that the flexible and adaptable character of the 1742-design was essential in securing its standardized status and of the successful spread of the "English" methods within the

---

[447] It may be that the *Heeren XVII* were influenced by this publication, but as the minutes of their meetings do not refer to discussions and considerations, it is impossible to be sure.

[448] The ship was called *Admiraal De Suffren*, after the French admiral that prevented the English from taking the Cape of Good Hope during the fourth Anglo-Dutch war (De Jonge (1858-1862) Deel IV, p. 469). Also Bruijn e.a. (1979-1987) Part 1, pp. 49-50 and http://www.inghist.nl/Onderzoek/Projecten/DAS/detailVoyage/99038

[449] Bruijn e.a.(1979-1987) Part 1, pp. 49, quoting ARA VOC 144 / 28.12.1793

[450] http://www.vocsite.nl/schepen/scheepstypen.html under the heading "driedekker"

[451] Inkster (1991), p. 16, quoting Brown and Moore Diffusion Research in Geography: A Perspective . Italics appear in the original text.

[452] Inkster (1991), pp. 55-59

VOC. In their adaptation of the standardized design, the local master shipwrights in Rotterdam and Middelburg also showed convincingly that the practical knowledge of shipwrights was still an essential part of the process of shipbuilding and design. Although taking issue with the theoretical conceptions of Duhamel de Monceau in writing, in a practical way they supported his idea of the importance of practical knowledge.

4.4 The curtain comes down

The final decades of the 18th century were a period of great unrest in the Republic. This was related to the domestic situation, ranging from to the position of workers within their guilds to (localized) political upheaval in the Republic and related to severe problems in foreign policy. In 1780, the fourth Anglo-Dutch war broke out which lasted to 1784. This war led to a deterioration of the financial situation of the Republic and it triggered renewed unrest within the Republic, in turn leading to an invasion by Prussian troops. The dire situation in which the VOC found itself (in what turned out to be the dying days of the company) led to some (one might be tempted to say “desperate”) innovations, such as the introduction of new and specialized types of vessels, which meant that the importance of the “all-purpose” standardized *retourschip* diminished. In contrast to what had happened forty to fifty years earlier, this time innovation seems hardly to have been connected with any form of standardization. The standardized form of the *retourschip* itself was subject to adaptations, such as the earlier described conversion to the three-decker configuration and the introduction of coppering. In 1795, French troops invaded the Republic and shortly afterwards guilds were abolished, the VOC was taken over by the new government and was wound up a few years later. Innovation without standardization and the adaptation of existing standardization turned out not to be strong enough to stem the tide of financial disaster and to keep the VOC afloat. In the first subsection, the introduction of (last minute) innovations will be described. In the second subsection the ongoing adaptation of the retourschip will be discussed.

4.4.1 Innovation as a last resort

The fourth Anglo-Dutch war (1780-1784) had a devastating effect on the trade between the Republic and the East Indies. In 1780 only 25 retourschepen managed to get on their way to the East Indies (against a normal number of about 35), in 1781 not a single ship left the Republic, and in 1782 only 15 vessels made an outward journey. Several of these ships were hired foreign ships, or company ships that had been sold abroad and were now flying a foreign flag. The number of departing ships turned to normal again from 1783 onwards. Even worse was the situation concerning the homebound fleet. In the pre-war years of 1779 and 1780, twenty-one and twenty ships respectively arrived back in the Republic. In 1781, only six ships arrived back in Cadiz and these ships were consequently sold in France. In 1783, three ships managed to arrive in the Republic via Trondheim in Norway; in 1784, only three ships arrived back from the Cape and it was not until 1785 that the situation got back to normal with the arrival of 28 ships from the East Indies.[453]

In 1781, at the height of the war the *Heeren XVII* asked the Dutch government to send a naval flotilla to the East Indies to assist the VOC in defending its properties. As we have seen earlier, the need to carry extra troops to the East Indies also influenced the adaptation of the standardized design. After much delay four ships of the line, carrying between fifty and sixty guns and two frigates left for the East Indies, finally arriving there in March 1784, after the war had ended. Nevertheless, the flotilla proved useful in suppressing local uprisings, and after the

[453] Details retrieved through http://www.inghist.nl/Onderzoek/Projecten/DAS/search

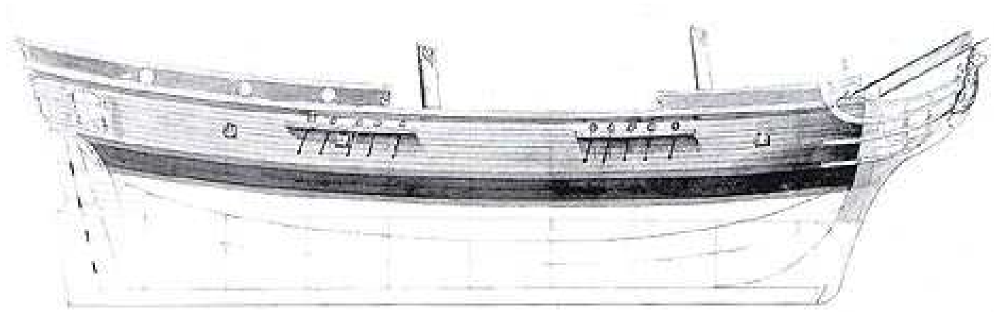


Fig. 4.12 Part of the technical drawing of a VOC *pakketboot*. Picture at the Nederlands Scheepvaartmuseum Amsterdam, retrieved through http://www.vaartips.nl/extra/pakketboot.htm

ships had returned to the Republic in 1786, the *Heeren XVII* made a request for a continued presence of warships in the East.[454] This was granted by the States-General on the condition that the VOC introduce a fast postal service to improve communications between the Republic and the Cape, between the Cape and Batavia and between the Cape and Ceylon. In 1788, the VOC started a building program that led to the construction of ten *pakketboten* (packet boats). These *pakketboten* were specifically designed for fast sailing, and the design was based on that of the naval brig *De Pijl* (The Arrow), but with a slightly heightened stern. The rigging consisted of two masts, with partly a fore-and-aft sailing plan. They measured 136 tons, had a length of between eighty and eighty-five feet, and manned by a crew of twenty-four[455].

Fig. 4.13 A brig or *barkentijn* (similar in design to the *pakketboot*), sailing close-hauled. Etching by G. Groenwegen, retrieved through http://geneaknowhow.net/in/schepen/groenewegen/barkentijn3.html

---

[454] De Jonge (1858-1862) Deel IV, pp. 684 et seq.

[455] Bruijn e.a.(1979-1987) Part 1, p. 50 and http://www.vocsite.nl/schepen/scheepstypen.html under the heading *pakketboot.* According to Bruijn e.a. the *pakketboot* carried one mast, but the technical drawing definitely suggests a two-mast configuration.

The schedule promised a departure on the first of March, June, September and December. The Cape was to be reached within three months' time, and from there it should take two months to reach Batavia. Although the schedule proved impossible to keep, a return trip (to and from Batavia) within twelve months was indeed possible[456]. Through the *pakketboten,* the need for speedy communications was added to the hybrid society surrounding the *retourschepen*, expanding the society to include a different type of ship altogether, which might be read as an indication of a change from the VOC as a predominantly commercial enterprise (belonging to the 17th and 18th century) to an emerging (19th century) colonial enterprise run by the state.

During the fourth Anglo-Dutch different types of vessels had been bought or hired from private owners – sometimes from abroad - and this apparently opened the eyes of the VOC to designs that promised to be more efficient and cheaper to build and to operate than its own *retourschip*. In 1784 and 1786, the chamber Zeeland purchased a *pink* (pink), the chamber Amsterdam built a *pink* in 1791 and hired one in 1794. The chamber Zeeland built two *pinks*, in 1791 and 1792, equipping these with a continuous upper deck, just like the three-deckers. Again, one gets the impression that the chamber Zeeland was ahead of events, just as it had been in the case of the three-deckers. The *pinks* were able to carry about 900 tons, placing them in the category of the 140 ft.-charter. Their actual size was [*142 ft x 37 ft x 17 ft*] and according to calculations made by Willem Udemans Jr. three of these ships could carry more cargo than two *retourschepen* of the 150 ft.-charter. Building costs were about half the usual cost, and the ships required a smaller crew[457]. There was no provision to take passengers, although at least some of these ships carried a number of soldiers (instead of cargo) on the outward trip[458]. One gets the impression that the emergence of *pinks* and *pakketboten*, instead of re-opening the black box of the standardized design, re-opened the hybrid network as a whole by suggesting that a different and simpler design might be a suitable substitution for at least some of the roles the *retourschip* had to play.

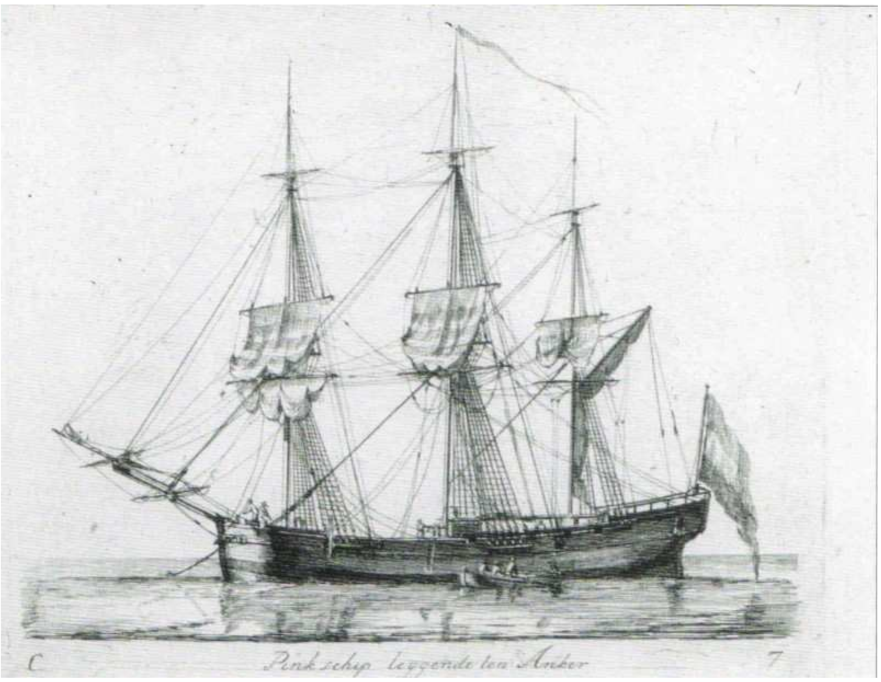


Fig. 4.14 A *pink* or *pinkschip* at anchor. The pink was a cheap, non-passenger carrying vessel, introduced with the VOC in the 1790s. Etching by G. Groenewegen, retrieved via http://geneaknowhow.net/in/schepen/groenewegen/pink2.html

---

456 Bruijn e.a.(1979-1987) Part 1, p. 50

457 Looking at (sometimes conflicting) figures given at http://www.inghist.nl/Onderzoek/Projecten/DAS/voyages it seems that a number of about 100 sailors operated a pink on the outward journey, and apparently, a number of 50 was sufficient for the homebound voyage. Larger numbers given include probably a number of soldiers.

458 Bruijn e.a.(1979-1987) Part 1, pp. 50-51

A combination of *pakketboten* (operating as vessels for fast communication), *pinks* for the (cheap) transport of soldiers on the outward voyage and cargo on the homebound voyage on return trips to Batavia, and three-deckers for the transport of passengers and for the hazardous (but profitable) return voyages to China (via Batavia) might have been the introduction of a shipping system based on specialized vessels, replacing the ubiquitous *retourschepen*.

4.4.2 The final adaptation of the *retourschip*

As far as the *retourschip* was concerned, apart from the (long drawn out) conversion of these ships into three-deckers, another adaptation - the coppering of the bottom of hulls - was slowly introduced into the fleet of the VOC during the final years of its existence. Accretion (consisting in barnacles, mussels and other clams) on the hull of seagoing ships caused extra resistance, which meant a lower speed. Therefore, the hull had to be cleaned on a regular basis, which was a costly and time-consuming affair. Could accretion be considered a nuisance, shipworms created a problem that was far worse. These tiny creatures were able to eat their way through the hull of a ship within a relatively short time, ruining the hull in the process. Remedies had been the building of retourschepen with a double hull (with sometimes a layer of hair or tarred paper in between), so that after return in the Republic the outer hull could be replaced if affected. Furthermore, the Dutch had been experimenting with studding the hull with flat headed iron spikes[459] and the English had experimented with lead sheathing[460]. However, although successful in combating accretion and shipworm, lead sheathing caused severe corrosion of iron bolts. The first suggestion to use copper sheathing was made in 1708, but the first recorded evidence of a trial dates from 1761[461]. An English naval frigate destined for the West Indies was fitted out with copper sheaths; when after two years an inspection was carried out, some copper had been lost, but where it was still attached there was hardly any accretion and the vessel had been protected from shipworm. However, iron nails and fittings had been severely corroded. It was thought that covering bolts with lead or painting the copper plates from the inside might prevent corrosion. In due course coppering was implemented, spurred on by the impending (Anglo-Dutch) war; by 1781, the whole of the English navy had been coppered, as the advantages of higher speeds and less maintenance were considered to outweigh any disadvantages. However, a year later three vessels foundered on their way to England with a large loss of lives. Of the 65 vessels that were lost between 1775 and 1784, a large number must have fallen victim to the effects of corrosion.[462] Eventually the use of copper nails and fittings instead of iron proved to be a solution against the problem of corrosion. When the war ended in 1784, England started exporting its copper technology to several other navies, including those of France and the Republic. It seems that the Amsterdam admiralty had independently started experimenting with copper sheathing in 1777, followed by the Rotterdam admiralty in the early 1780s, Enkhuizen/Hoorn in 1783 and Zeeland in 1786. Problems with corrosion delayed a full-scale introduction and by 1795, several vessels in the Dutch navy had not yet been coppered[463].

In the 1780s, the (English) East India Company started coppering a number of its ships on the China tea trade, with positive results: ships could make faster crossings and could be used longer as there was less wear and tear on the hull. However, the grounding of a vessel might cause the copper sheathing to disintegrate[464]. The faster travels made by English East Indiamen did not escape the attention of officials of the VOC and they suggested that the only way to keep up with the English was to use coppered three-deckers. However, the cost seemed prohibitive, coppering

---

[459] This method had already been applied to the Batavia of 1628 and therefore dates back to the first decades of the 17th century. (Personal observation from parts of the wreck of the Batavia at the museums in Geraldton (WA) and Freemantle (WA) during June and July 2008).
[460] Harris (1966) p. 551 and http://www.bruzelius.info/Nautica/Shipbuilding/Lead_sheathing(1695).html
[461] The suggestion was made by “Charles Parry and others” Harris (1966), p. 552
[462] Harris (1966), pp. 553-555
[463] De Jonge (1858-1862) Deel V, pp. 7-9
[464] Harris (1966), pp. 563-565

being twice as expensive as applying iron nails. Opinions were divided between the VOC-chambers; Rotterdam and Delfshaven, together with Enkhuizen, took no interest, which in the case of Rotterdam and Delfshaven may be explained by the perceived risk of ships running frequently aground on the way to open sea and back. The first coppered retourschip was possibly the *Oosthuizen*, a ship of the 140 ft.-charter built (in 1791) and owned by the VOC-chamber Hoorn. Most of the *pakketboten* were copper sheathed, as speed was important for their post runs. The newly introduced *pinks* were also coppered. In 1792, the *Heeren XVII* advised coppering all new ships but this was not yet made compulsory. It was not before June 1794 that the decision was taken to copper all new ships.[465] Once again, the events surrounding coppering show that both human actors (the States-General asking for faster communication lines) ands non-human actants (such as barnacles, mussels and shipworms) explicitly resumed their role within the network, leading to innovative adaptations to existing and new designs.

In January 1795, French troops invaded the Republic, and the *Bataafse Republiek* (Batavian Republic) replaced the *ancient régime* of the Republic of the Seven United Provinces. On 1 March 1796, a *Committé tot de Zaken van de Oostindische Handel en Bezittingen* (Committee to the Affairs of the East Indian Trade and Possessions) took the place of the *Heeren XVII*, which meant in fact a nationalization of the VOC, which by that time was completely broke. Formal nationalization took place at the very end of 1799, meaning that the VOC did not exist anymore from the beginning of the 19th century onwards. On 14 April 1822, the huge storehouse at Oostenburg collapsed, suffering the same fate as its former owner, the VOC, some twenty years before[466].

It is rather surprising that during the last years of the VOC's existence, when the company was virtually on the brink of a (financial) collapse, the company embarked on a program of several innovations. One could suggest that these innovations had been partly forced upon the VOC, such as the introduction of *pakketboten*, partly came about through experiences with other types of vessels, such as the *pink*, and some were introduced in a response to actions by other East India Companies, such as the procedure of coppering hulls. Altogether, these innovations re-opened the black box of the existing *retourschip*. However, in doing so we might overlook that there are parallels with what happened in the early 1740s. At that time, the VOC was in severe trouble as well, and one gets the impression that an important reason why the VOC was able to survive as an (monopolized) company was the timely introduction of innovative and standardized ships. These ships made visible that changes were being made, suggesting that less visible problems such as an endemic financial mismanagement and corrupt employees lining their own pockets were being tackled as well. Relying on technological innovations to stem the adverse tide had led to the successful standardized *retourschip*.

During the fifty years of its existence, the black box of the standardized *retourschip* and its immutable, but mobile set of design drawings, had been re-opened and mutated repeatedly; in almost every case not instigated by the *Heeren XVII* but by independently minded shipwrights who introduced several new actors and actants within the hybrid society of the *retourschip*. This means that – from within a continually changing hybrid network - a regular program of innovative changes was applied to a standardized artefact, leading to its continuous re-standardization.

---

465 Bruijn e.a. (1979-1987) Part 1, p. 51-52
466 Gaastra (2001/2007), pp. 170-172

Summary

The artefact of the retourschip, standardized through the innovative immutable mobile of its drawn out design and through the innovation in building practices, was subject to a program of continuous change almost from its inception onwards. It has been shown in this chapter that several actors and actants participated in this program. Although developments in the theoretization of ship design (emanating from France) had little effect on shipbuilding practices in the Republic, nevertheless individual shipwrights from local VOC-yards, such as at Rotterdam and Middelburg, were able to introduce successful changes in the design and the materialization of the retourschip. These shipwrights were able to add and/or mobilize several actors, such as the governor-general of the East Indies, a scientific fellowship and even a surgeon, and several actants, such as storms in the South China Seas, shifting sands and expanding shallows within the hybrid society surrounding the retourschip. As actants, one may also count experiments carried out by one of these shipwrights. It is rather surprising that the most important yard of the VOC, Oostenburg at Amsterdam, only once introduced a (failed) innovation. This failure acted as an ally for proposals put forward by the VOC-chamber Zeeland.

Although the independence of shipwrights had decreased in the wake of the introduction of design drawings, local shipwrights regained at least part of their independence as is shown by what happened at the yards in Rotterdam and Middelburg. The role of the shipwrights' guild went also through a process of change. Guilds lost part of their impact on technological developments and put more emphasis on their role as provider of social security. This change had political implications as is most conspicuously shown in what happened in Amsterdam in the late 1740s.

Whereas the introduction of a system of design drawings did not spread from the Amsterdam admiralty to other admiralties (as was shown in chapter 2), the introduction and geographical spread of an almost identical immutable mobile at all yards of the VOC can be considered as a success. Part of an explanation has been sought in the ability and willingness of local master shipwrights to engage with this system, to adapt and appropriate it within their own local (sub) network, and to use it to materialize ideas of their own.

During the final years of the VOC, there were signs that a new debate about the retourschip might be about to start, which might have led to a fleet consisting of more specialized vessels. This change might be read as an early signal of emerging 19th century colonialism instead of 17th and 18th century commercialism. The collapse of the "ancient regime" and the disintegration of the VOC prevented any significant outcome as far as the VOC was concerned.

In the next chapter it will be shown how local shipwrights (cf. chapter 4) materialized the concepts of standardization (cf. chapter 1) and innovation (cf. chapter 2) into the artefact retourschip (cf. chapter 3).This implies a revisiting of the two concepts, coupled with a discussion of the hybrid society surrounding the retourschip and the flexible immutable mobile of the technical design drawings. It will also be shown that the retourschip itself - as already indicated in this chapter - played an active role in this process. Finally, the artefact retourschip will be interpreted as embodying an active connection between the VOC as a large commercial enterprise and the VOC as the largest single technological enterprise in the Dutch Republic of the 18th century, internationally unique through the introduction and implementation of technical design drawings in commercial shipbuilding.

5. The *retourschip* revisited

In dit hoofdstuk laat ik zien hoe de processen innovatie en standaardisatie materieel en procesmatig zichtbaar worden door en in het artefact retourschip van de VOC tussen 1742 en 1795. In par. 5.1 wordt beschreven hoe het retourschip een verbinding legt tussen de standaardisatie die beoogd werd door de VOC en de innovatie van de technische scheepsontwerptekening. Ook wordt daar de relatie belicht tussen het ontwerp en de bouwprocedures waardoor het ontwerp werd gematerialiseerd. Anderzijds (par. 5.2) kan dit artefact gelezen worden als de actieve uitkomst en tegelijk het centrum van een hybride netwerk waarin menselijke actoren en niet-menselijke actanten als één naadloos geheel samenwerkten, een geheel dat niet statisch was maar waarbij voortdurende wisselende bondgenootschappen werden aangegaan, en waarbij de tegendraadsheid van locale scheepsbouwers door het rekruteren van menselijke en niet-menselijke bondgenoten vertaald werd in officieel erkende innovatie en standaardisatie. Het artefact laat zo zien dat (om Latour te citeren) het sociogram onlosmakelijk verbonden is met het technogram.[467] In par. 5.3 wordt het begrip immutable mobile hernomen en wordt aan de hand van dat concept beschreven dat de introductie van de technische ontwerptekening van het retourschip de VOC kenmerkte als een "large technological enterprise". Deze "large technological enterprise" was uniek in de 18[de] eeuw omdat de VOC de technische ontwerptekening als eerste en als enige op grote schaal toepaste bij commerciële scheepsbouw, niet alleen in Nederland maar in Europa.

In this chapter, the *retourschip* takes centre stage. As a technological artefact, it shows the connection between innovation and standardization; as a hybrid quasi-object, it illustrates the ongoing construction of the hybrid network surrounding its design and building; the immutable mobile of its design helps to explain the transition of the VOC from being just a large commercial enterprise to a large technological enterprise as well.

Looking at the situation in the Dutch Republic well into the 18th century, ships were designed and built based on "common" or shared knowledge. Designs were not inscribed on paper, but existed in the minds and hands of master shipwrights and fitted within local traditions of shipbuilding, with the final design of a ship taking place during the building process. Local traditions were able to spread beyond their boundaries, as is shown by the spreading of the *fluit* from its origins in the town of Hoorn to yards all over the Republic.[468] Experiential knowledge, handed down through time and/or space, was crucial in the art of shipbuilding. Whether a design was successful could only be established after the artefact had been completed and was put out to sea. It was therefore essential for the development of ship design that practical experiences, gained by using a certain design, were incorporated into the next design. During the 17th century, in countries such as England and France technical drawings were increasingly used to codify the experiential knowledge of shipwrights. Over time, these drawings grew in importance and they tended to encompass an increasingly large part of the design: not only was the hull inscribed into drawings, but also details of the construction, of the rigging, and of the form of the sails[469]. Whether the development of drawings as such led to better designs and an improvement in the characteristics of ships remains an open question, but these drawings made it possible to separate the design process from the building process, to increase control of the building process and to transfer (both through space and time) the design to other localities where it could be materialized by other shipwrights than the original designer.

In the course of the 18th century, the phenomenon of using technical drawings in ship design was introduced in the Republic. As described in chapter 2, this occurred on the one hand through local master shipwrights devising their own localized systems of technical design drawings and on the other hand through the introduction of English shipwrights with their "English" designs

[467] Latour (1987), pp. 138-141
[468] Cf. section 1.3.1
[469] Epstein (2006), pp. 17-19

and “English” building methods at the yard of the Amsterdam admiralty.[470] Although a geographical spread to almost all other admiralties failed, the VOC employed the services of one of these English shipwrights to redress problems that had occurred in the design of its *retourschepen*[471]. Before the introduction of the innovation of technical drawings to assist in re-standardizing its ships, the VOC had already been engaged in increasingly formal processes of standardization and innovation, concerning the design of its *retourschip*[472]. The introduction of a new design and of new building procedures and the ensuing adaptation of this design within the VOC was highlighted in several stories in chapter 3 and 4. The different storylines emerging from these chapters, centred on the *retourschip* itself, will be joined together in an effort to formulate answers to the questions that form the basis of this thesis.

Reflecting on the way in which innovation and standardization within the VOC were related to one another, we may consider an artefactual relation, situated within the rationalized and standardized approach to ship design (materialized in standardized procedures, in experiments, in models and in the innovative immutable mobile of technical design drawings) and within the practicalities and practices of building ships according to these designs. This approach will be taken in section 5.1. On the other hand, in section 5.2 we will show that standardization and innovation were related on the level of networks, which incorporated VOC’s local master shipwrights and the increasingly regulated systems of production through which they had to build their ships; these systems were used by the *Heeren XVII* to standardize and control the building process, but they were also enlisted by the master shipwrights who used the networks to their advantage when adapting the design. In doing so, they used the inherent flexibility available within the immutable mobile. Finally, in section 5.3, we will revisit the concept of the immutable mobile of the *retourschip* design, and use it to explain the transition of the VOC from large commercial enterprise to the largest single technological enterprise in the Dutch Republic of the 18th century, internationally unique through the introduction and implementation of technical design drawings within commercial shipbuilding. This leads to a final interpretation of the character of the knowledge of the master shipwrights concerned.

5.1 Connecting standardization and innovation

The standardization of the *retourschepen* of the VOC was an interactive process that took more than a century before it reached its culmination in the 1740s. The standardization developed by and within the VOC, was built on developments in Dutch shipbuilding that can be traced back at least to the beginning of the 17th century. As mentioned earlier, the *fluit* was the “standard” Dutch merchantman of the 17th century. From its origins in the town of Hoorn, the *fluit* spread to yards all over the Republic.[473] This spatial spread can be partly attributed to the fact that the artefacts themselves appeared in other ports and partly to journeymen moving around from yard to yard, carrying with them the knowledge and skills received from older master shipwrights. Shipwrights’ guilds also offered opportunities for an exchange of ideas and skills between shipwrights, for the sharing of knowledge, for technological innovation, for codifying existing traditions and for a degree of standardization[474]. Despite differences in size and appropriations to the different purposes it was used for or the different areas it was used in, the very recognizable basic design of the *fluit* remained effectively the same, thereby displaying an early form of a rather informal standardization. As technical drawings were not used in the Republic at the time, we must assume that this standardization was agreed upon by means of an

[470] Cf. section 2.2
[471] Cf. chapter 3
[472] Cf. chapter 1
[473] Cf. section 1.3.1
[474] Epstein (2006), pp. 7-15, see also section 4.2

oral tradition and was founded “on sight”, with shipwrights materializing a three-dimensional object based on a mental image.

Meanwhile, the VOC had started on the road towards a more descriptive type of standardization regarding its *retourschepen*, which is shown by the fact that, as early as 1614, their main dimensions (i.e. length, width and *holte,* i.e. height of the lower hold or draught) were laid down in resolutions drawn up by the *Heeren XVII*, for each of the three classes (or charters) of *retourschepen.* [475] They did so in an increasingly detailed way, building on already existing designs, but these details were not put down into technical drawings. Such a (re)invention of ships, emerging from older types could be called a “conservative invention”[476]. These resolutions followed the current practice of ship design and shipbuilding instead of defining new practices. In the course of the 17th century, several dimensions were added to the description, descriptions were given of the materials that ought to be used and adaptations were made in response to changing circumstances. The descriptive standardization developed by the VOC might therefore be characterized as conservative and flexible at the same time.

This ongoing process reached it preliminary culmination in the standards that were negotiated in 1697 between VOC’s master shipwrights and the Heeren XVII[477]. On April 4 1697, the *Heeren XXVII* drew up a resolution through which they intended to settle the design and dimensions of the three charters of *retourschepen* once and for all. They did so after extensive consultations with the master shipwrights of their six shipyards. In addition to the three charters of 160 ft., 145 ft. and 130 ft. in length respectively, it was permitted to build ships of the 130 ft. charter in the shape of a *hekboot* or a *fluit* and a smaller ship could be built for service within Asia[478]. To this negotiated, descriptive standardization was added an extensive list of dimensions of masts, yards, sails and anchors, their position, and the materials they were to be made of. This gives the impression that – at least on the large shipyard at Oostenburg with its early system of division of labour in specialized workshops – these parts could be prefabricated as standard parts.[479]

This suggests that by the end of the 17th century the VOC had turned the art of commercial shipbuilding (partly) into an assemblage of prefabricated, exchangeable parts. The hulls of the *retourschepen* were still individually crafted, but in a standardized way as well. This is borne out by the fact that as far as the form and the dimensions of the hull were concerned, a procedure was put in place to check at nine equidistant frames on five points each the prescribed width and draught[480]. Combined with this, there was a strict control – using moulds - on compliance with these rules, for which the responsibility was moved to the master shipwrights, whereas earlier the directors of the local VOC-chambers had been responsible. The existence of three different classes (or charters) of these ships, coupled with the fact that these ships were built on six different yards, added to the complexity of the building process and resulted in an increase in management activities to control the way these ships were built. By the end of the 17th century, the VOC had established a regime for efficient and fast production of its retourschepen, manufacturing large numbers of a reliable and predictable standard design. The development took place within the context of dynamic developments in its activities, and therefore this process of standardization cannot be seen as anything static or as leading to a pre-defined result. It is intricately linked to and co-constructed with the way the VOC developed as a whole.

---

[475] Cf. section 1.5
[476] See footnote 97
[477] Van Dam (1702/1927), pp. 455- 480, pp. 493-496 and pp. 501-504
[478] Cf. section 1.3 and 1.5
[479] Cf. section 1.2
[480] Cf. section 1.5

On standards and standardization we followed the rather pragmatic (and materialist) perspective formulated by O'Connell[481], implying that science and technology are not just a matter of ideas, but that these ideas have to be materialized at a certain place at a given time, be it in the form of texts (e.g. a list of specifications[482]), artefacts (e.g. a ship's model or a mould[483]) or procedures (e.g. such as those dating from 1614 or 1697, as described by Van Dam). Materialized ideas or conceptualized objects are able to circulate through different communities, eventually leading to universal acknowledgement by all concerned. For this communication to be intelligible across different localities, an amount of standardization is needed, because not only should these localities speak the same technological language, but also numbers used in this language should carry the same meaning for everyone. This means that there needs to be an agreement on standards; in the case of VOC's shipbuilding, the Amsterdam foot was adopted as the standard unit of length on all six yards, even outside of Amsterdam. However, such an agreement on basic standards cannot be imposed, but needs to be done through a form of circulation as well. This suggests a two-tier system, a circulation producing an agreement on standards and a circulation of materialized ideas leading to a universally acknowledged and accepted standardized technology. These circulations are not independent of each other, as it seems hardly possible to have a discussion on standards without already taking into account the underlying technological content. Once a form of standardization is in place, it has to be locally implemented which means that there is some scope for local variation, depending on how strict the definition of the standard has been constructed. For instance, the dimensions of the *retourschepen*, as standardized in 1614, granted local shipwrights more room for variation than the standards of 1697.

To be able to build its *retourschepen* the VOC accumulated large amounts of different materials, coming from all over Europe, some as far as Russia. Hundreds of supply lines came together at Oostenburg, the largest yard of the VOC, where the accumulated raw materials and goods were turned into complete merchantmen[484]. The same applied – although probably to some lesser extent – to the smaller yards. The yards of the VOC can be thought of as semi-independent centres of a complicated international logistical and technological network, or as centres of accumulation. Not only materials and goods were accumulated at the yards, but we might say that standard designs and procedures were accumulated as well. On the one hand, the similar accumulation processes at each yard joined the local master shipwrights together into a single designing and building network, but on the other hand, there remained a degree of independence, because the final design of every *retourschip*, although extensively described, still had to be worked out at every yard. Whether each ship was built according to the standardized specifications was a matter that could only be established after the artefact had been completed.

Storms in the early decades of the 18th century exposed fatal weaknesses in the standard designs that had continually been adapted since 1697. In combination with concerns raised about the running of the enterprise VOC as a whole, several efforts were undertaken to redress the situation within the VOC in general and its shipbuilding and shipping operations in particular[485]. A solution regarding the ship design was finally sought in a series of three newly designed charters, each design materialized into a set of three technical drawings made by the English shipwright Bentam, who was master shipwright at the Amsterdam admiralty. Quite remarkably, once the design of the *retourschepen* had been renegotiated the VOC was granted time to carry on with its operations and was allowed to take its time in redressing other outstanding issues. The introduction of the new technical design drawings apparently displayed considerable

481 Cf. section 1.5
482 Van Dam (1701/1927), Cap. 17. See also section 1.5, section 3.2 and section 4.3
483 Kist (1985) and Lemmers (1996). See also section 3.2
484 Cf. section 1.2
485 Cf. section 3.1

political power.[486] The introduction of the innovation of technical design drawings for the three different charters of *retourschepen* linked the master shipwrights of the six VOC-yards together in a single constructive network, even more than had been the case beforehand.[487] Instead of each of them being allowed to use his own discretion in the final stages of the design and to use local building techniques, they had all to follow a single prescribed and inscribed design and the appropriate building techniques.

These sets of technical design drawings were interpreted as immutable and combinable mobiles.[488] Such a mobile is indeed immutable in that it can travel through time and space without losing its content, as is convincingly shown by surviving technical design drawings from the 18th century. The drawings allowed the design of a *retourschip* to be moved through time and through space, while remaining exactly as it was; it could be spatially moved from Amsterdam to Middelburg, Rotterdam, Delft, Enkhuizen or Hoorn and it could be moved time wise from 1742 to 1795. This meant that another layer of accumulation and of calculation was added to already existing layers. Several aspects needed for this specific design had to be accumulated by the designer, such as existing experiential and theoretical knowledge, knowledge about nature in the areas the ships had to operate in, commercial considerations, knowledge about the mutable purposes of the ship to be designed, financial constraints and requirements put forward by the VOC[489]. The "English" system for the construction of architectural technical (or measured) drawings, with its layer of calculation used to work out the frames of the designs, formed the basis through which the designs could be put onto paper. At the same time, the mobile displays an inherently flexible character, in that it is open to considered and informed proposals for adaptation, built on negotiations in the network surrounding the *retourschip*.[490] The fact that the design was inscribed made it possible to change details, interacting with changing requirements or experiences of users, leading to a renewed immutable mobile, which in due course again showed that it was open to flexibility, as has been shown in section 4.3. As far as the adjective "combinable" is concerned, apart from the combination of several separate immutable mobiles (three different charters making up the retourschip family within the VOC), combinability is an essential part of the design itself. The three two-dimensional drawings that make up each design need to be combined during the drawing process in order to see to it that the drawings do connect properly with each other. All three drawings are needed to build the three-dimensional artefact.

Through the implementation of technical design drawings, the VOC increased its grip on the materialization of the design, which led to an increase in standardization, but also led to a decrease in the independence of the local shipwrights engaged in the actual building of the retourschepen on the different yards. They became subordinate to drawings and had hardly any scope for adapting the design during the building process, the more so as the existing control procedures remained in place. The role of the VOC master shipwrights seemed reduced to controlling subordinate shipwrights who were reproducing designs made by somebody else than the master shipwright himself. Standardization – already changed from an oral to a descriptive form – changed character again and became prescriptive; inscription of the design into drawings led to the fact that standardization no longer followed practice but prescribed practice.

The use of standardized parts, the use of moulds in inspecting ships and (following the introduction of the new design, worked out in drawings) the use of prescribed frames when building the ships, all point to what Ken Alder characterized as "an attempt to settle ongoing

---

[486] Cf. section 3.2
[487] Cf. section 3.3
[488] As coined by Bruno Latour (1987), p. 227. See also section 2.2.3
[489] Cf. section 3.2. For the mutable purposes of the *retourschepen*, see section 1.4
[490] Cf. section 2.2.

disagreements by making judgments about workmanship as impersonal as possible – shifting conflict even further away from individuals and lodging it at the most general level at which production was organized."[491] Within the shipbuilding activities of the VOC, the responsibility for complying with the standardized designs shifted from the directors to the master shipwrights in the late 1600s by which time moulds were used to ascertain the correct dimensions.[492] The next shift took place from the 1740s onwards, when the responsibility moved from the master shipwrights to the impersonal prescribed frames.[493] Instead of testing compliance with the rules after the artefact had been completed, the new regime of standardization made it possible to build compliance with the rules into the artefact at the very early stages of its construction. The set of design drawings bridged – in a (quasi-)impersonal and (quasi-)objective way - the gap between design and materialization of the *retourschip*. The prefix "quasi-" is used because it has been shown that individual master shipwrights were still able to renegotiate the design by extending the hybrid network to suit their purposes, meaning that the rationality of the design remained subject to adaptation by local practices.

The innovation brought about by the introduction of technical drawings meant that the shape of a ship was determined before the building process got under way, and therefore the processes of design and of building could be separated. Ships got their definitive form during the design process instead of during the actual building; the design process changed from being partly a material process at the yard to a process worked out on paper at a drawing board in an office.[494] In the words of Epstein, drawings were "a strategic element in the cultural and functional separation between designers and builders."[495] Whether those who first used technical drawings in England, France or the Republic intended such a separation seems open to question. People connected with early drawings, such as Matthew Baker, Anthony Deane, Blaise Ollivier, Thomas Davis or Charles Bentam, were not only designers but also acting master shipwrights. In any case, the building process became subordinate to the design process, as is shown by the change in building methods both at the Amsterdam admiralty and at the yards of the VOC. In order to faithfully follow the design, the existing methods of building "shell first" had to be abandoned in favour of a "frame first" method; within this method the frames, meticulously copied from the drawings in turn dictated the form of the hull.[496]

In addition, the innovation of technical drawings offered two (rather contradictory) possibilities. First, it offered the possibility of building ships that were – to a large degree – similar sisterships. The design remained immutable when moved (repeatedly) to the lofts where the frames were produced based on the existing inscribed design; the frames in turn dictated the form of the hull. Another layer of innovation was that directors at the VOC and councillors at the Amsterdam admiralty could get an accurate impression of how a design would look even before the artefact itself was built, supposing that they could interpret and visualize the set of drawings. To assist them, the master shipwright producing halfmodels or even complete models of the new design, adding a three-dimensional layer to immutable mobile of technical design. Such complete models were also used to show construction details to the (master) shipwrights who had to materialize the design. The first halfmodels that were produced in the Republic can be traced back to the time that technical drawings were introduced. One of the surviving halfmodels can with certainty be attributed to Charles Bentam because his signature appears at the bottom[497]; a full model of a 150 ft. retourschip by his hand also survives.[498]

[491] Alder (1997), p. 282
[492] Cf. section 1.5
[493] Cf. section 3.3
[494] As was the case with naval shipbuilding in England (see Schaffer (2007))
[495] Epstein (2006), p. 20
[496] Cf. section 2.3.1 and 3.3
[497] Lemmers (1996), pp. 33-37
[498] See also fig. 3.4

Fig. 5.1 Halfmodel of a naval frigate (left) and full model of a 150 ft. VOC *retourschip* (right), both currently in the collection of the Amsterdam Historisch Museum. These models were made by the English master shipwright Charles Bentam. Photo taken by Johan de Jong on 11 Feb 2010

The result of this – within the VOC - was the production of a large series of very similar ships.[499] At the Amsterdam admiralty, this advantage of technical drawings was hardly exploited, through a combination of (on the one hand) the fact that small numbers of several different types of ships had to be built and (on the other hand) the fact that other admiralties refused to align themselves with this innovation. A joining of forces might have led to admiralty yards specializing in the building of (standardized) specific types of ships[500], but in the political climate of the day, this proved impossible.[501] Second, in a break with former practices, changes within a design had no longer to rely on adaptation on sight; instead, by using the flexibility built into the drawings, one could modify those parts of the design that turned out to be unsatisfactory in practice while maintaining other details. An existing design could be adapted (e.g. to variations in uses and circumstances) while at the same time explicitly retaining those characteristics that had proven to be satisfactory, thus saving the time and expense of having to go through a completely new design process, and at the same time linking the adapted design to the existing level of standardization.[502]

The innovation of using technical drawings at the Amsterdam admiralty was interpreted as radical and system changing, because it created an intended break with previous procedures and practices, affecting not only the design process but also building practices.[503] Although the innovation was definitely successful in changing the way ships were being built, adding to a more predictable outcome of the production process, it remains questionable whether the (intended) standardization of design building was realized. As was argued in section 2.4, the failed geographical spread of the innovation meant that the immutable mobile of ship design was not allowed to travel beyond the boundaries of the Amsterdam admiralty. When the same innovation was introduced within the VOC, the outcome was partly similar to what had happened earlier at the Amsterdam admiralty and was partly different. It was similar in the radical effects it had on practices employed in ship design and shipbuilding, but it differed in the effectiveness of its results and in the degree of its acceptance. The new design was used to build dozens of ships over several decades to exactly the same specifications– apart from adaptations made to the design, of which more will be said in the next sections – without the disagreements that had been visible at the Amsterdam admiralty and beyond, reasons for which will be explored in the next section.

The new system of design drawings and building methods produced pre-drawn, prescribed and prefabricated mainframes. The system of using prescribed and prefabricated artefacts such as masts, yards, sails, ropes, guns etc. was therefore extended with the prescription and the

[499] Cf. section 3.3
[500] See section 2.1 on the need for specialized types of ships within the Dutch navy.
[501] Cf. section 2.3.2
[502] A documented example of such an adaptation in the case of the VOC was given in section 4.3
[503] Cf. section 2.4

prefabrication of mainframes. From the mid-18th century onwards, the innovation of technical design drawings, in combination with the appropriate building techniques, made the definitive standardization possible that had been on the cards since the early 17th century. The *retourschip* showed that standardization was dependent on innovation, both concerning the design phase and the building procedures and techniques. In reverse, the fact that this innovation succeeded within the VOC - whereas it had a chequered history within the admiralties where it had been introduced earlier[504] - shows that the availability of an existing (explicit or even implicit) system of standardization can be considered a *conditio sine qua non* for an innovation to succeed. We might therefore say that the artefact *retourschip* connected innovation and standardization, and that it gave a foreshadowing of standardization processes and the use of interchangeable parts that was about to begin elsewhere in Europe in the course of the 18th century.[505]

In addition, the innovation related to the re-invention of the *retourschip* was essential in stabilizing and consolidating the VOC as a whole; the VOC was re-standardized through the fact that a radical innovation in ship design and shipbuilding could be turned into a system-stabilizing innovation. In that sense, the new design of the *retourschip* was crucial to the survival of the VOC in the 1740s[506]. However, we should note that the *retourschip* did not operate on its own but was the focus of a continually shifting hybrid network. In the next section, we will concentrate on this network, and the interaction between *retourschepen* and local master shipwrights of the VOC within this network, and on how they exploited the flexibility of the design to adapt it to demands put forward by different human actors and non-human actants.

5.2 Navigating a hybrid network

The relation between the developments in designing and building *retourschepen* and the ongoing process of VOC-building was one of co-construction[507], a co-construction that continued throughout the introduction and implementation of the new design and beyond. This means that the *retourschip* was more than just a complicated material artefact, used to further the interests of the VOC, but that it was actively involved in the networks that made up the VOC. Seen in this way, the *retourschip* could be termed a hybrid quasi-object[508], meaning that it wended its way not only between the Republic and the Dutch East Indies but also connected the two poles of "nature" and "society" within a hybrid network consisting of both human actors and non-human actants.

While discussing the standardization involved in design and production we noted that the social construction of standards appears on two levels[509]. The first level of social construction is linked to interactions between different groups of humans concerning non-human entities, or - in other words – is concerned with the way humans translate definitions into practical measures. In the case of the VOC, examples of this level of construction were the agreement on the unit of length to be used or on the way the hull of a *retourschip* should be inspected. The second level of social construction is concerned with the construction of a hybrid society of material collectives, on the one hand consisting of persons (and/or institutions consisting of humans) and on the other hand of material objects representing technological entities. Master shipwrights, skippers and directors were among the human actors belonging to this hybrid network, and among the material objects we could count wood and other natural materials for building the ships, tools,

---

[504] Cf. chapter 2
[505] Alder (1997)
[506] Cf. section 3.2
[507] Cf. section 1.5
[508] As introduced by Latour (1993), pp. 51-55
[509] Cf. section 1.5

pre-fabricated parts, the *retourschepen* themselves, and texts and procedures. We should, however, not overlook the existence and importance of other non-human actants, such as estuaries and climatological and geographical conditions. The innovation of using technical design drawings added an immutable mobile to the network. The position of the artefact *retourschip* within the hybrid network was reinforced by the fact that its design became an artefactual part of the network as well. The *retourschip* and the drawings of its design linked the different parts of the network together, engaging the heterogeneous actors and actants in negotiations.

Fig. 5.2 Retourvloot of the VOC, navigating the seas (anonymous drawing from 1720), retrieved through http://www.scheepvaartmuseum.nl/actueel/nieuws/studium-generale-studenten-onderzoeken-objecten-collectie-

On the question which humans (or groups of humans) were actually translating definitions into practical measures as far as the design and building of ships by the VOC was concerned, we looked two ways, towards the VOC master shipwrights (organized through their guilds) and towards the management of the VOC shipyards. During the late 17th and the 18th century, one can notice a shift away from guilds as a corporation of independent owners of (small) shipyards towards a situation in which guild members became employees who entered into a contract with a large shipbuilding company, such as the VOC or an admiralty.[510] Consequently, the guilds had less impact on technological and organizational aspects of shipbuilding, and they shifted the focus of their attention towards the regulation of pay and the organization of funds providing for sickness, accident and retirement[511]. The shift towards concentration and centralization was very outspoken in the case of the shipbuilding activities of the large commercial enterprise of

[510] Cf. section 4.2
[511] Unger (1978), p. 97

the VOC, as became apparent by the building of increasingly standardized ships at its own shipyards. Apart from moving towards becoming a large technological enterprise (more about which will be written in the next section), this led to an increased emphasis on administrative and political rules, and the responsibility for technological developments shifted (or at least appeared to do so) away from the shipwrights on the shop floor to the master shipwrights or even to the *Heeren XVII.* The centralization at the VOC therefore implied that the first level of social construction took place between the master shipwrights of its six shipyards and the *Heeren XVII* instead of within the guilds. The guilds, which originally must have played a part in the hybrid network all but disappeared as far as the retourschip was concerned and their role was taken over by the master shipwrights and the *Heeren XVII.*

About fifteen years before these events took place within the VOC, similar things had been happening at the Amsterdam admiralty. As soon as English shipwrights had been employed, the Amsterdam admiralty ordered that drawings should be kept of each ship that was built, with the intention of being able to reproduce this design exactly. This points to a similar shift towards centralization as was the case within the VOC. There were, however, some important differences. First, there seems to have to been some considerable opposition on the shopfloor against the introduction of English shipwrights and their methods, as was borne out by the (presumed) attempts to sabotage some of the ships that were built at the time.[512] This suggests that ordinary shipwrights were trying to force their entry into the design/constructive network at the admiralty, an entry that apparently had been denied to them. Next, the obligation to keep records of the drawings seems to have been cancelled in the 1750s, which might point to the fact that the councillors of the admiralty no longer constituted an important part of the design/constructive network at the admiralty, leaving the master shipwright in control.[513] Third, it proved impossible to introduce the "English" technical drawings at other admiralties and therefore the Amsterdam network remained a local network, caused by the fact that the number of allies (be it either other admiralty boards or other master shipwrights) could not be expanded.

The fact that it was possible for the central and local VOC networks to accommodate the new regime of designing and building ships may have been helped by the fact that the search for allies started before the implementation of these new procedures took place. Van Imhoff was not only successful in enlisting allies from outside the existing network but he also enlisted allies from inside the network, by discussing the new designs with a group of master shipwrights and skippers .[514] It is interesting to note that a rather similar procedure, enlisting master shipwrights, had been followed during the standardization process of 1697, and also during the early attempts for "redress" in 1740-1741. The movement of drawings and models as such was not sufficient to transfer the skills and knowledge of the English shipwright Charles Bentam successfully from its place of origin (the mind and hands of Bentam, residing at the Amsterdam admiralty) to a new locality (the mind and hands of the master shipwrights working at the yards of the VOC). Also needed was "the essential component (of) the social organization of trust".[515] A form of trust was organized by Van Imhoff, fitting into a tradition that apparently existed within the VOC. This component of trust may have been missing when a similar transfer was at stake at the admiralties. "The basis of knowledge is not empirical verification as the orthodox view would have it, but trust".[516] Objectively spoken, the introduction of technical drawings may have been an innovation, but an insufficient number of allies leading to a lack of trust meant that the innovation remained a local affair at the admiralty. In contrast, the expansion of the network

[512] Cf. section 2.3.1
[513] Cf. section 2.3.1
[514] Cf. section 3.2
[515] Turnbull (1997), p. 553
[516] Steve Shapin, as quoted in Turnbull (1997)

centred on the *retourschip* with trusted allies made the innovation possible across all yards of the VOC.

Despite the increasingly centralized organization of the shipbuilding of the VOC, a degree of localized independence still existed, as became apparent in the way local master shipwrights started tinkering with the official design of the *retourschip* and used it to regain some initiative[517]. The master shipwright at the Rotterdam yard succeeded in adapting the 1742-design for the whole of the VOC by adding experiments to the network and by enlisting the governor-general of the Dutch East Indies. The unavoidable enlisting of the expanding shallows between Rotterdam/Delfshaven and Goeree called for a more localized adaptation.[518] When introducing a three-decker conversion of the *retourschip*, the master shipwright at the Middelburg yard expanded the network with the directors of his local chamber, with a local learned society, with a ships' surgeon, with geopolitical considerations and with an experimental version of the *retourschip* that had already been built before the Heeren XVII granted permission. In addition, the failure of an experimental enlarged version of the *retourschip*, originating from Amsterdam might have constituted an important negative addition to the network[519]. The *retourschip* therefore played a crucial role within the network, partly opening the way for its own adaptation. In their adaptation of the standardized design, local master shipwrights showed that the practical and experiential knowledge of shipwrights was still an essential part in the ongoing development of the design, irrespectively whether it led to failure or to success.

In the closing years of the 18th century, the hybrid network was expanded even further with copper when it was realized that copper sheaths could be used to neutralize the destructive activities of barnacles, mussels and shipworms that had been part of the network from the beginning, causing accretion and structural damage. Once again, a local master shipwright (in this case at the VOC-yard Hoorn) adapted the standard design of the *retourschip* by adopting this innovation for the first time. He was probably spurred on to do so by the experiences that had been gathered through the coppered *pakketboten*; these *pakketboten* themselves pointing to a further extension of the hybrid network by human actors such as the States-General asking for faster communication lines[520]. By that time, the hybrid network surrounding the *retourschip* might have been on the brink of breaking up into separate networks, each geared to a specific type of more specialized ships[521].

In a discussion on the geographical spread of innovations, we mentioned that a "diffusing item (….) may be at once a stimulus to further innovations and itself subject to adaptation as it spreads from its physical point of origin".[522] As we have seen earlier, local master shipwrights of the VOC (from the yards at Rotterdam, Middelburg and - to a somewhat lesser degree - at Amsterdam and Hoorn) created room to manoeuvre within (and outside) the standardized design. Through using their own practical and innovative insights and knowledge and through effectively enlisting allies within and outside the existing hybrid network they succeeded in enlarging this network sufficiently to have their views accepted throughout the network. In other words, a cultural appropriation of the new technology ensured that the technology became embedded in different localities, thus providing an essential precondition for the continued success of the innovation. These adaptations were documented by means of adapted technical drawings. The *retourschip* (standardized and flexible at the same time) acted as a *trait d'union*, connecting localities to the central hybrid network by means of the immutable mobile of its

[517] Cf. section 4.3
[518] Cf. section 4.3.1
[519] Cf. section 4.3.2
[520] Cf. section 4.4
[521] Cf. section 4.4
[522] Cf. section 2.3 and 4.3

design, travelling inwards from localities to the centre and outwards again. We could probably say that – in response to the innovation - master shipwrights of the VOC engaged in a form of "subversive rationalization, interactively using the recently introduced new technology to partly undermine the existing social hierarchy and forcing it to meet needs that it had ignored."[523] They used situated, localized knowledge to come up with creative appropriations of the new standard design, and in doing so challenged this design. We might term these challenges "anti-programs", which is not to suggest that the purpose of the shipwrights was to destabilize the existing network, but rather that they were intent on a re-structuring of the network, re-creating power for themselves. To that end, they used their capacity to follow the artefact *retourschip* and the immutable mobile of its design, and to engage with new actors and actants in its network. In the next section, we will look towards the role of the immutable mobile in this expanded and strengthened network as significant for the development of the VOC into an early form of a large technological enterprise.

5.3 Mobilizing a large technological system

The *retourschip*, its design and the surrounding network were instrumental in the transition of the VOC from being a large commercial enterprise to an early example of a large technological enterprise. This transition will be explained by connecting the technological development of the VOC with the immutable and mobile character of its new system of technical designs for the *retourschip.*

The building program that the VOC embarked upon after the introduction of the new designs was responsible for the production of large numbers of ships, originating from six different shipyards (signalling a spatial movement of the design) and stretching over several decades (signalling a movement through time)[524]. The fact that so many *retourschepen* were built by the VOC using standardized, inscribed designs and using standardized building techniques, shows that the innovation of technical design drawings offered promising and viable possibilities concerning the building of standard ships on a (pre)industrial scale. We could argue that it facilitated an early form of serial production, whereby almost identical ships were constructed, while - to a certain extent – pre-fabricated parts were used, such as masts, yards, anchors, sails and, most importantly, main frames. No longer were these frames constructed inside the hull as it stood, but they were prepared beforehand, following the instructions contained in the set of technical drawings. This resulted in the hull being constructed outside these frames.

In section 2.2.3, the set of technical design drawings was characterized as an immutable (and at the same time rather flexible) mobile. In general, an immutable mobile contains descriptions of relevant skills, knowledge and procedures, either in the form of words, maps, templates, diagrams or drawings. In the case of a ship design, we are looking at the accumulation of shipwrights' skills, existing practical/experiential and theoretical/formal knowledge, skills, knowledge about nature in the areas the ships had to operate in, considerations of strategy and tactics (either naval or commercial), knowledge about the purpose of the ship to be designed, and financial constraints. Through combination, calculation and manipulation these aspects were integrated into the design for a specific vessel (such as a 150 ft. *retourschip*), consisting of a set of three interrelated design drawings, inscribed onto paper, thus producing a specific immutable mobile. This took place against the background of the accumulation of the materials needed to build such a ship at a specific shipyard or group of shipyards.

---

[523] Feenberg (1998), p. 2. The quote is slightly adapted to fit in with the situation at the VOC. The original quote reads "Subversive rationalization: new technology can also be used to undermine the existing social hierarchy or to force it to meet needs it has ignored."
[524] Cf. section 3.3

The immutable mobile was an essential step in transforming ideas into artefacts. It was could transport these ideas to various localities over time. The mobile character of the drawings made it possible to transfer them spatially to the different yards and to the space in the lofts where the frames were produced; the immutable character of the drawings saw to it that the design remained consistent, independent of place and time. This consistency was not only related to the building of a specific vessel but to the whole timeframe during which the immutable mobile was used, a timeframe that stretched from 1742 to 1795. The technology remained fundamentally unchanged for more than half a century, concerning both its basic design and its accompanying mode of production.[525] Therefore, we move beyond the stage of innovation and we are looking at technology-in-use. To this technology-in-use, small, incremental changes were being made, as was shown in section 4.3.[526] These changes were captured in a general (sometimes even local) adaptation of the immutable mobile, made possible by its inherent flexibility. Once the design has been described as an immutable mobile, it is possible to change details in a controlled way, producing an adapted immutable mobile, which in due course may again show its openness to flexibility.

In addition (as was already argued in section 5.1), the responsibility for controlling whether the master shipwrights followed the prescribed designs was to a large degree delegated to the same immutable mobile that contained the inscription of the design. The obligation to use prescribed frames when building the ships made it almost impossible to deviate from the design, unless when shipwrights explicitly started experimenting, as mentioned earlier. Responsibility for complying with the design moved from the shipwrights to the impersonal frames prescribed by the immutable mobile; this can be seen as the most fundamental artefactual level through which the VOC organized its production. It makes therefore sense to investigate the lasting impact the new technology of ship design and shipbuilding had on the character of the VOC.

In the preceding paragraph, we have used the word "technology" in relation to some activities of the VOC. However, we need to answer the question whether the use of that word is appropriate, considering that it was introduced in the early 19th century; its meaning at the time given as "a description of the arts, especially those which are mechanical".[527] Exploring the question "What is technology?" Thomas Misa has suggested four possible answers.[528] The first of these is the interpretation of technology as a type of knowledge, the second answer consists in giving empirical examples, the third answer actually tries to come up with a definition (such as "a systematic, purposeful manipulation of the material world"[529]) and the final answer concentrates on the relationship between the material world and the human world. It seems that each of these answers has some bearing on the skills and knowledge employed by the VOC and its master shipwrights in designing and constructing the *retourschepen*. Looking at the first interpretation: skills and art, as well as experiential and formal knowledge were involved in the making of ships, as was described in section 4.1 and 4.2. Second, we could consider the construction of the largest manmade machine-like structures of the era as a typical example of technology. An example that was recognized at the time in the writings of Pieter van Zwijndregt: "Ships that are mathematical Machines (...) are built with specific Purposes and Objectives in mind, but all explicitly directed to travelling through the Water in the easiest possible way in order to achieve Speed (...)", whereby he actually defines ships as machines.[530] This example takes us to the third interpretation, that of the manipulation of the material world, which can be explicitly recognized in the "purposes and objectives" Van Zwijndregt mentioned. Finally, in the

[525] Cf. section 3.3
[526] Edgerton (1999), pp. 123-126
[527] George Crabb, *Universal Technological Dictionary, or Familiar Explanation of the Terms Used in All Arts and Sciences, Containing Definitions Drawn From the Original Writers*, (London, 1823), s.v. "technology."
[528] Misa (1992), pp. 4-7
[529] Alex Roland as quoted in Misa (1992), p. 6
[530] Cf. section 4.3.1

preceding section we explored technology as a relation between the material world and the human world when we discussed the hybrid network, centred on the *retourschip*. We may therefore conclude that the designing and building of *retourschepen* by the VOC was indeed of a technological nature, even though the word as such had not yet been introduced.

Through the *retourschip*, its design, the way it was built and the use that was made of it, the VOC seems to fit into the description given by Hughes of a large technological system. [531] We will explore this similarity in more detail, and therefore Hughes's description is repeated here:

> These systems contain messy, complex, problem-solving components. They are both socially constructed and society shaping. Among the components in technological systems are physical artefacts (…). Technological systems also include organizations, such as manufacturing firms (…) and investment banks and they incorporate components usually labelled scientific such as books, articles (…) and research programs. Legislative artefacts (…) can also be part of technological systems. Because they are socially constructed and adapted, in order to function in these systems, natural resources (…) also qualify as system artefacts.[532]

In sections 3.1 and 3.2, we discussed the "messy, complex, problem-solving components" surrounding the design and re-design of the retourschepen, leading to the introduction of the new design. We encountered the "socially constructed and society shaping" aspects throughout chapter 3 and again in section 5.2. The "manufacturing firms" - consisting of VOC's own shipyards - constructed the "physical artefacts" of the *retourschepen*, based on the immutable mobile of their design. Through its mobility and its immutability, the design connected the yards of the VOC that were originally six rather separate enterprises. As we have seen in section 3.3., this concerned both design and building procedures and techniques. The ships had to be paid for by the proceeds, generated through VOC's commercial operations. After their construction, the *retourschepen* in turn helped to generate these proceeds by acting as mutable mobiles. On their outward journey, they carried precious metals (for VOC's complex system of financial transactions between the Republic and the East Indies), soldiers (for the re-enforcement of VOC's position in the East Indies) and sailors (for the operation of the local fleets in the East Indies). On their return, they carried spices and other valuable commodities to be sold in the Republic and beyond.[533] The VOC (acting as a state within the state) was governed by its own set of rules and legislations (i.e. their legislative artefacts). The VOC was utterly dependent on natural resources for its continued existence. Whether these resources took the form of materials for the building and equipment of its ships (such as wood, iron, hemp, tar, resin and sulphur) or the form of merchandise (such as spices, tea, coffee and commodities), they mostly had to be purchased, collected or harvested abroad. Materials for shipbuilding were purchased from all over Europe and accumulated at the shipyards of the VOC. Merchandise from the East Indies, which might come from as far away as Japan, had to be shipped for accumulation to Batavia, next it had to be accumulated in the hold of *retourschepen* and subsequently it was accumulated at the large storehouses of the VOC in the Republic.

When (in section 3.1.2) the first mention was made of the VOC as large technological system, it was said that the inclusion of scientific components might be considered questionable, but – on a rather practical level - it was argued that the label "scientific" as used by Hughes in the post-19th century interpretation did not exist in that sense during the 17th and 18th century. Looking into this aspect more closely, we need to explore what Hughes means with this label and to see how the concept of science might be positioned within VOC's 18th century shipbuilding. Hughes makes some explicit references to the matter of science when he introduces the concept of technological style. [534] He writes that the concept of style fits in with the notion that technology

[531] Cf. section 3.1.2 and 3.3
[532] Hughes (1987), p. 51
[533] Cf. section 1.4
[534] Hughes (1987), p. 68

is socially constructed, and that it makes clear that there is no single best way to design a ship, to build a ship or to help a large enterprise survive in changing circumstances. "Technology should be appropriate for time and place."[535] He goes on to say that this "counters the false notion that technology is simply applied science and economics."[536] This means that his mention of scientific components in the context of a large technological system cannot be taken to refer to formal knowledge, separated from or preceding technological application. When the 18th century shipwright Pieter van Zwijndregt (VOC master shipwright at Rotterdam) described his experiments, he wrote that it was clear to him that there would be many people who would not think much of his experiments, because these experiments had been carried out with small-scale objects, especially such people who had no grasp of the laws of nature, hydrostatics, or mechanics. [537] When writing on the subject of ships that do sail well, he pointed out that he did not want to suggest that nobody was capable of building a good ship unless he was proficient in these sciences. He added that many experiments and changes had succeeded in the fact that these (ships) corresponded in some way to the laws of nature.[538] Van Zwijndregt points to the interconnectedness between formal knowledge and the practicalities of ship design and shipbuilding, but he does not grant formal knowledge a status as preceding technological applications. The approaches of Hughes and Van Zwijndregt, although separated by more that two centuries, fit together remarkably well. The label "scientific" as used by Hughes – pointing to a non-hierarchical combination of formal and practical knowledge and skills – is rather similar to the way in which one of the most important master shipwrights of the VOC integrated formal and practical knowledge and skills. We may therefore interpret the immutable mobile of VOC's technical design drawings as a "scientific component", seeing that it accumulates and codifies skills, formal and practical knowledge, experience and requirements into a specific design.

This means that the immutable mobile of design is the missing link in interpreting the VOC as a large technological enterprise.[539] It suggests that this concept can already be validly recognized in the mid-18th century, and thus enables us to get a grip on the technological activities of the VOC. Following Hughes, the crux of a technological system is its problem-solving capacity, "usually concerned with the re-ordering of the material world to make it more productive of goods and services."[540] Through the accumulation of skills, knowledge and experience, brought into the enterprise by the immutable mobile, the VOC could keep developing artefacts that assisted it in making materials, goods and commodities available for its commercial operations. At the same time, part of the proceeds generated by these materials was used to keep the "technological system" developing. It is tempting to see in the activities of the VOC a foreshadowing of "an ordering of the world to make it available as a "standing reserve" poised for problem solving and, therefore, as the means to an end."[541]

Writing about the lifecycle of technological systems, Hughes argues that they acquire momentum, even after prolonged growth and consolidation. It may appear that the system becomes autonomous, but that is not the case. "Inventors, engineers, scientists, managers,

---

[535] Hughes (1987), p. 68

[536] Hughes (1987), p. 69

[537] Pieter van Zwijndregt, quoted verbatim in Hoving & Lemmers (2001), p. 188. In Dutch it says "*Mij is wel bewust dat veelen deze voorgestelde proeven zullen gering in haar Denkbeelt voorkoomen, omdat deselve met cleijne Lighaamen genoomen zijn, vooral die, die van geen Natuurwetten, Waterweegkunde, of Mechanica eenige Bevatting hebben (…)*". For more on Van Zwijndregt, see section 4.3

[538] Pieter van Zwijndregt, quoted verbatim in Hoving & Lemmers (2001), p. 188. In Dutch it says "*Ik wil hier niedt bij uijtdrukken als, of er niemant in staat was om een wel zeijlend Schip toe te stellen, of hij moet kundig zijn in de voornoemde Weetenschappen. (….) Egter door de meenigvuldige Soekingen en veranderingen, het bijna so over is gebragt, dat deselven eenigsins met de Natuurwetten overeenkoomen.*"

[539] The word "enterprise" seems a reasonable choice to avoid the somewhat anachronistic term "system", without compromising its content.

[540] Hughes (1987), p. 53

[541] Hughes (1987), pp. 53-54, quoting Heidegger in "The Question Concerning Technology"(1977), p. 19

owners, investors, financiers, civil servants, and politicians often have vested interests in the growth and durability of a system. (…)"[542] It seems not too difficult to replace these categories with master shipwrights, shipwrights, Heeren XVII, directors of local chambers, investors and members of the provincial States and of the States-General. Hughes adds that "Actor networks (…) add to system momentum", networks that were effective within the VOC as well.[543] Interesting are his remarks about the durability of artefacts and knowledge in a system. "Durable physical artefacts project into the future the socially constructed characteristics acquired in the past when they were designed. This is analogous to the persistence of acquired characteristics in a changing environment."[544] This suggests that the rather conservative approach to shipbuilding that can be recognized within the VOC, building basically the same design for over fifty years, is probably nothing out of the ordinary as far as technological systems are concerned. This is in line with a point made by David Edgerton; he argues that "for many decades now the term "technology" has been closely linked with *invention* (the creation of a new idea) and *innovation* (the first use of a new idea)."[545] He suggests that we should shift our attention from the new to the old, and start thinking about technology-in-use, which would lead us to discover that "old" technology has a surprisingly large longevity. Although Edgerton concentrates on the 20th century, the case of the VOC also shows a reliance on tried-and-tested technology, rather reluctantly (and out of necessity) moving towards newer technologies.

The immutable mobile, having shown its mobility by spreading its codified contents (by means of drawings, diagrams and templates), across all production spaces of the VOC, showed its flexibility through the adaptation of the design to changes emerging in the network. Probably as important as its mobility was the effect its immutability (by means of the same drawings, diagrams and templates) had on the stability and standardization of the design and technology used by the VOC in producing its *retourschepen*.

On the one hand, the introduction of technical drawings (which made the master shipwrights subordinate to the design) and of its associated building techniques (which made the shipwrights subordinate to both the master shipwright and to the design) can be seen as a radical innovation within the VOC or Dutch commercial shipbuilding in general. Considering that David McGee writes that the use of "architectural designs" was restricted to naval shipbuilding until the mid-nineteenth century[546], or that "plans were used almost solely for the construction of warships", we might even interpret it as a radical innovation within European commercial shipbuilding[547]. He argues that drawings were used in naval shipbuilding because "they promised to save money in construction"[548]. This reasoning can be applied to the building of commercial vessels as well, provided that the number of vessels that is being build is large enough to offset the costs of the elaborate construction of the drawings. Because of the intricate relationship between the three different plans that made up the design, it had to be negotiated over and over again, as every change in one of the drawings had to be translated into changes in the other drawings as well. This re-iterative process could take months.[549]

On the other hand, the VOC as owner and builder of (almost all of) its ships – in contrast to the English East India Company that rented its ships from private ship-owners - can be thought to have had an interest in keeping the cost of building ships down. This could be realized by a process of standardized production of standard ships, a process that had (and was indeed) to

[542] Hughes (1987), p. 77
[543] Cf. section 3,2, 3.3, 4.3 and 5.2
[544] Hughes (1987), p. 77
[545] Edgerton (2006/2008), p. ix. Italics appear in the original text. Edgerton raised similar point sin Edgerton (1999).
[546] McGee (1999), p. 222
[547] McGee (2003), p. 35
[548] McGee (1999), p. 226
[549] McGee (1999), p. 227, also McGee (2003), p. 38

run for several decades, signalling a shift from innovation and invention to technology-in-use. We might therefore suggest that the fact that the innovation of using technical drawings within commercial shipbuilding succeeded at the VOC was - at least partly - linked to the factory-like production of large numbers of similar vessels. This made it worthwhile to invest in the time-consuming procedures of drawing measured plans. Added to this was the possibility, opened up by the immutable mobile, of a more strict control of the building process. It therefore makes sense to consider the *retourschip* not only illustrative for the VOC as large technological enterprise but also illustrative for the VOC as a (proto)capitalistic and (pre)industrial enterprise.

It has been shown in this thesis that technoscientific developments in the Republic of the United Provinces were not confined to the 17th century (usually characterized as the "Golden Age" of the Republic) or the 19th century (when the Kingdom of the Netherlands turned into a colonial power of international importance). The 18th century can be characterized as an important chapter in the development of the process of technological design and of the organization of production. The word technoscientific [550] is used in an attempt to avoid ontologically separating the words "scientific" and "technological". Earlier on, we rejected an interpretation of science as "formal knowledge" positioned against technology as "practical knowledge" (or as a "set of practices"), or an interpretation whereby technology is seen as "applied science". McGee argues that technical drawings were a pre-condition for the use of mathematical physical theory ("drawings first, then science")[551]. This illustrates that the route from "science" towards "technology" is not inevitable, and the remainder of McGee's essays makes it clear that any progress offered by "science" towards the "technology" of shipbuilding relied on an interaction between the two. We should realize that science and technology are intertwined concepts and that they are co-constructed in extensive and ever-changing hybrid networks of the type described earlier. Attempts to separate formal (i.e. scientific) knowledge from practical, experiential (i.e. technological) knowledge are likely to cause confusion instead of clarification[552]. This can be noticed when Karel Davids comments on the experiments carried out by Pieter van Zwijndregt.[553] In discussing the decline of Dutch technological leadership, Davids follows Joel Mokyr in making a distinction between Ω- (i.e. propositional or formal) and λ- (i.e. prescriptive or applied) knowledge, whereby the Ω- knowledge displays primacy over the λ-knowledge.[554] When mentioning experiments carried out by Pieter van Zwijndregt, he states that Van Zwijndregt made the connection between the two sets of knowledge. His "experiments (…) were based on a sound grasp of hydrostatics"[555]; in addition Davids says that Van Zwijndregt knew Duhamel du Monceau's book, published in 1752. However, theoretical knowledge derived from Duhamel's book cannot have contributed to Van Zwijndregt's experiments, as they must have been carried out before 1747, the year when he proposed changes to the *retourschepen* based on his experiments.[556] Moreover, when describing his own experiments, Van Zwijndregt writes that "(…) research can present us with lessons that are worth following, to be considered in shipbuilding (…)"[557] . This implies that the experiments were – in contrast to Davids's suggestion - the basis of his grasp of hydrostatics. This illustrates that dividing knowledge into two types, one of which is deemed to have primacy over the other and leading to the other, is an artificial distinction that does not accurately describe the process of gaining knowledge and that

[550] The term "technoscience" was used by Bruno Latour in Science in Action (1987), p. 29. However, it seems that in hindsight Latour has distanced himself from the term (Science, Technology & Human Values Vol. 35 No. 1 (Jan 2010) p. 142.
[551] McGee (1999), p. 230, also McGee (2003), p. 40
[552] See Roberts & Schaffer (2007) in their preface to The Mindful Hand.
[553] Davids (2008), pp. 505-506. For a description of Van Zwijndregt's experiments, see section 4.3.1
[554] Davids (2008), p. 500
[555] Davids (2008), p. 505
[556] Cf. section 4.3.1
[557] Pieter van Zwijndregt, quoted verbatim in Hoving & Lemmers (2001), p. 184. In Dutch it says " (…) *Egter kan het ondersoek, ons eenige navolgbaare Leeringen aan de hand geeven, die men in de Scheepsbouw in agt kan neemen* (…)

might even suggest a sequence of events that is not borne out by what actually happens. Moreover, the suggestion that the two sets of knowledge then have to be connected suggests that these sets are initially not connected, whereas the way through which Van Zwijndregt produced his knowledge shows that "formal" and "experiential" knowledge were intricately interwoven, right from the start.

In the second half of the 18th century, Dutch commercial shipbuilding – as carried out by the VOC - was internationally unique in its use of technical design drawings, and in connecting innovative ways of designing ships with standardized building methods and large-scale production. Although originally the immutable mobile of design drawings was introduced as an "English" invention by English master shipwrights, Dutch master shipwrights – having concurrently developed systems of measured plans of their own – adopted, adapted and appropriated the system handed down to them. Therefore, developments in large-scale commercial shipbuilding by the VOC – during the 18th century - can be attributed not so much to "scientific" knowledge, but to technoscientific knowledge and skills developed by master shipwrights in a practical and experiential way. They used their practical intelligence to design, construct and adapt standardized *retourschepen*, using the innovation of technical design drawings. They did so as part of a continually developing hybrid network centred on the retourschip, which seamlessly combined ship design, shipbuilding, shipwrights, economic considerations, organization, natural phenomena, directors, (geo)political considerations, the governments of the provinces and the federal government of the Dutch Republic and the accumulation of materials and ideas.

Summary

The central question of this thesis was the interpretation of the complicated relation between innovation and standardization. In particular, I explored and investigated whether the innovation in 18th century Dutch shipbuilding technology can be mainly attributed to the introduction of rational, standardized design- and building methods or rather to artisans (such as shipwrights) using their practical intelligence.

The first sub-question was formulated as: "How was the standardization and innovation of the constructed artefact retourschip actually given shape?" In the first section, we showed how a long process of standardization found its culmination through the introduction of the innovation of using technical design drawings. These drawings, interpreted as an immutable mobile, connected the shipyards of the VOC in a single constructive network, concerning both the design phase and the building procedures and techniques. The artefact retourschip connected innovation and standardization, and it gave a foreshadowing of standardization processes and the use of interchangeable parts that was about to begin in Europe in the course of the 18th century.

The second sub-question read: "Which relation existed between the standardization of working procedures at the shipyards concerned and the way in which these yards were structured?" An answer was found in the concept of hybrid networks, centred on the retourschip acts as a focal point. The position of the artefact retourschip within the hybrid network was reinforced by the fact that its design became an artefactual part of this network as well, emphasizing its central position. Shipwrights, captains and directors were among the human actors belonging to this hybrid (design- and constructive-) network, and among the non-human actants, we could count entities such as estuaries, climatological and geographical conditions. A shift towards concentration and centralization in the organization of VOC's shipbuilding activities became apparent by the building of increasingly standardized ships at its own shipyards. The responsibility for technological developments shifted (or at least appeared to do so) away from the shipwrights on the shop floor to the master shipwrights or even to the Heeren XVII. The responsibility for complying with the design moved from the master shipwrights to impersonal prescribed frames. Instead of testing compliance

with the rules after the artefact had been completed, the new regime of standardization made it possible to build compliance with the rules into the artefact, at the very early stages of its construction.

The third sub-question was: "Clarification about the way local (master) shipwrights used their practical intelligence, on the one hand constructing the prescribed innovative and standardized vessels and on the other hand shaping anti-programs while they adapted existing, prescribed designs to demands put forward by different human actors and non-human actants". An answer has been proposed by arguing that developments in large-scale commercial shipbuilding by the VOC can be attributed not so much to "scientific" knowledge, but to technoscientific knowledge developed by master shipwrights in a practical and experiential way. They used their practical intelligence to design, construct and adapt standardized retourschepen, using the innovation of technical design drawings. They did so as part of the continually developing hybrid network centred on the retourschip, which seamlessly combined the immutable mobile of ship design, shipbuilding, shipwrights, economic considerations, organization, natural phenomena, directors, (geo)political considerations, the governments of the provinces and the federal government of the Dutch Republic and the accumulation of materials and ideas. The master shipwrights used situated, localized knowledge to come up with creative appropriations of the new standard design, and in doing so challenged this design. These challenges might be termed "anti-programs", which is not to suggest that the purpose of the shipwrights was to destabilize the existing network, but rather that they were intent on a re-structuring of the network, reclaiming power for themselves.

Finally, it was argued that the VOC was internationally unique in its use of technical design drawings in commercial shipbuilding, and in connecting innovative ways of designing ships with standardized building methods and large-scale production. The company and its master shipwrights played an important role in the development of the process of technological design and of the organization of production.

Over the horizon

In deze epiloog wil ik wijzen op enkele onderwerpen die binnen het bestek van deze afstudeerscriptie niet of niet uitgebreid aan de orde konden komen, maar waarvan ik denk dat ze de moeite waard zijn om nader te onderzoeken.

De eerste opmerking gaat over de meester-scheepstimmerman Gerbrand Slegt. Slegt was de ontwerper van het enige fregat dat qua eigenschappen opgewassen was tegen de Barbarijse zeerovers, maakte als een van de eerste Nederlandse scheepsontwerpers gebruik van tekeningen, werd benoemd als meester-scheepstimmerman bij de Amsterdamse admiraliteit en nam na enkele jaren ontslag na beschuldigd te zijn van incompetentie en oneerlijkheid. Sommige van zijn tekeningen bevinden zich tamelijk verscholen in de "Moll"-collectie in de bibliotheek van de Universiteit Utrecht. Wellicht is het mogelijk om een essay te wijden aan deze meester-scheepstimmerman die tot nu toe slechts in de marge van voetnoten vermeld wordt.

De volgende opmerking gaat over de aard van de kennis van de Nederlandse scheepstimmerlieden in de 17de en 18de eeuw. Zoals eerder (onder andere in hoofdstuk 5) beschreven is, was deze kennis gebaseerd op praktische ervaringen, deels overgedragen vanuit het gilde, deels verworven door uitwisseling tussen werven en deels zelf verworven. Tot aan de introductie (in het midden van de 18de eeuw) van de "immutable mobile" van de technische scheepstekening, van handboeken en van polemische geschriften stond deze kennis niet op schrift, en daarom had ze het karakter van "tacit knowledge". Het zou de moeite waard kunnen zijn om dieper in te gaan op het fenomeen "tacit knowledge" in relatie tot de scheepsbouwkundige kennis in Nederland in de late 17de en vroege 18de eeuw.

De derde en laatste opmerking betreft aspecten van het transplanteren van "Westerse" technologie naar het "Oosten". De VOC heeft in het begin van de 18de eeuw een tijdlang scheepsnieuwbouw op "Westerse" wijze beoefend op Java, maar heeft zich vanaf 1714, op uitdrukkelijke opdracht van de Heeren XVII beperkt tot reparatie. Alleen kleine schepen voor locaal en inter-archipel gebruik werden nog lokaal gebouwd. De VOC exporteerde tijdelijk "Westerse" vernieuwingen maar maakte tegelijk gebruik van lokale kennis en vaardigheden. Vervolgens ziet men die vernieuwingen in de loop van de tijd weer worden vervangen door gebruikelijke lokale oplossingen. In tegenstelling tot de Engelsen en Portugezen die hun scheepsbouwkunde en – kennis overplantten naar hun koloniën lijkt dit vanuit Nederland nauwelijks gebeurd te zijn. Ook hier lijkt een verder onderzoek op zijn plaats.

While I was researching and writing this thesis, some subjects emerged that promised to be interesting but that had to be left aside because of the limited amount of time (and space) available. I mention three of these subjects which might be worthy of further exploration. They concern a possible biographical essay about a master shipwright, a techno-philosophical inquiry into "tacit knowledge" and a techno-political enquiry into the introduction (or lack of it) of Dutch expertise and knowledge regarding shipbuilding into the colonized East Indies.

A. Gerbrand Slegt

Gerbrand Slegt was the designer of the frigate *Wageningen*, the only naval vessel that could at least cope with the ships of the privateers of the Barbary coast. As mentioned in section 2.1.3, he was the winner of the competition to design and build a fast sailing frigate. He was still a private shipwright then, but after winning the prize was appointed as master shipwright at the Amsterdam admiralty in 1723, as successor to Jan van Rheenen who had died in 1722.[558] Drawings of the frigate *Wageningen* still exist, as was shown in fig. 2.3. It is not quite clear whether these drawings are actual design drawings or whether they were made by copying the

[558] Bruijn (1970) pp. 9-11 (footnote 12) and 27-28; Hoving & Lemmers (2001), p. 16

lines from a three-dimensional model. It is a matter of debate whether these drawings can be classified as proper "technical" drawings, but even so the existence of these drawings points to the fact that Gerbrand Slegt was experimenting with technical drawings, an impression that is reinforced by surviving drawings of the *Damiaten* and the *Pallas*, ships that he also designed and built.[559] Because of accusations of incompetence and dishonesty, Gerbrand Slegt was forced to resign in March 1726. Whether he was incompetent, remains an open question, the more so if one considers that he designed the successful frigate *Wageningen* and that he developed an early system of technical drawings for ship designs. It may be that the accusation of dishonesty was the real reason: he owned a private shipyard while he was employed by the admiralty[560]. It might be interesting to see whether it is possible to write an essay about this shipwright, who until now only seems to appear in the margins and footnotes of other books and essays. The suggestion that councillor Torck van Roosendaal paid for the frigate *Wageningen* out of his own pocket might be investigated as well.[561]

B. Tacit knowledge

The knowledge of the master shipwrights of the VOC (and of Dutch shipwrights of the 17th and 18th century in general) has – at several points - been described as practical and experiential of character. In addition, this knowledge was of a "tacit" nature, at least until the introduction of technical design drawings[562], the publication of manuals (as written by Duhamel du Monceau) and the rather polemic publications about the state of Dutch shipbuilding, written in response to accusations made by Cornelis Schrijver in his pamphlet from 1755.[563] Transfer of this traditional, tacit knowledge was organized through the shipwrights' guild.[564] On the one hand, this transfer was regulated by the way the guild operated, but on the other hand, standardization based on this knowledge came probably about in an informal way. The standardized Dutch merchantman of the 17th century, materialized in the *fluit*,[565] emerged through an exchange of (tacit) knowledge between local shipyards, developed and sustained by the practices and practicalities of shipbuilding and stimulated by an increase of traffic by sea.[566] This – rather informal - standardization left ample room for subtle, local variations on the basic theme, allowing space for adaptations to changed circumstances.

Whereas the experiential and practical character of the shipwrights' knowledge was discussed in this paper[567], it might be interesting to consider also the tacit character of this knowledge. This might – in part - be done by exploring literature such as

> Collins, H.M. "What is tacit knowledge?" in *Schatzki, Knorr-Cetina & von Savigny (eds.) "The Practice Turn in Contemporary Theory"* Routledge London/New York 2001
> Collins, H.M. "Bicycling on the Moon: Collective Tacit Knowledge and Somatic-limit Tacit Knowledge" in *Organization Studies* 2007, Vol. 28(02) pp. 257-262

---

[559] These drawings are also in the Moll collection at the library of the University of Utrecht. See also Hoving & Lemmers (2001), pp. 32-33.
[560] Bruijn (1970), p. 11 footnote 12. However, in contrast to what Bruijn suggests, it seems rather unlikely that Slegt operated a private yard on the premises of the admiralty yard, the more so as he had operated his own yard already before he was appointed. It is therefore more likely that he still operated his private yard at Wittenburg, between the VOC-yard at Oostenburg and the admiralty yard at Kattenburg.
[561] As mentioned at http://nl.wikipedia.org/wiki/Lubbert_Adolph_Torck .
[562] Cf. section 2.2 and section 3.2
[563] Cf. section 2.3.2, section 4.1 and section 4.3
[564] Cf. section 4.2
[565] Cf. section 1.3.1
[566] Unger (1978)
[567] Cf. section 4.2 and section 5.3

Klein, Ursula "Technoscience avant la lettre" in *Perspectives on Science* 2005, Vol. 13, No. 2 pp. 226-266

Roberts, Lissa & Schaffer, Simon "Preface" in *Roberts, Schaffer & Dear (eds.) "The Mindful Hand: Inquiry and Invention from the late Renaissance to early Industrialisation"* Amsterdam 2007 ISBN 978-90-6984-483-1

Turnbull, David "Reframing Science and Other Local Knowledge Traditions" in *Futures* 1997 Vol. 29 (6) pp. 551-562

C. Transfer of technology

During the late 17th and early 18th century, the VOC was – for a while - engaged in shipbuilding in the East Indies[568]. This was confined to rather small ships, some of "Western" design and some of local design, with a maximum overall length of about 75 ft. In 1714, the Heeren XVII decreed that no vessels, exceeding 60 ft. in length, should be built in the East Indies. At that time three *brigantijnen* (brigantines) were on the stocks, two at the yard in Rembang (east of Batavia) and one at the VOC establishment at Onrust, opposite Batavia. After 1714, local Javanese and Chinese shipbuilders near Rembang were still building smaller ships for the VOC, of the types *chialoup* (or *sloep*), *pantchiallang* and *gonting*. The *pantchiallang* was a traditional merchantman, originating from the western part of the Indian archipelago; they were built for the VOC to be used as small transport vessels within the archipelago, in addition to relatively small ships built in the Republic specifically for the same purpose[569] and in addition to the larger retourschepen that were (in between journeys) also employed in local traffic. Towards the end of the 18th century, only *pantchiallangs* were built locally for the VOC. These *pantchiallangs* were slightly larger than those built for local merchants, and they tended to become even larger; whereas the length of these ships measured between 55 and 60 ft. at the beginning of the 18th century, towards the end of the century this had increased to 60-75 ft.

It is therefore questionable whether the VOC was engaged in transferring "Western" shipbuilding technology to the "East", the more so as VOC's own shipyard at Onrust (near Batavia) was only carried out repairs and maintenance of the ships of the VOC.
However, I came across an intriguing remark

"In another case, opperhoofd Hemmij offered to provide a drawing of a ship rather than supervise the construction of a model as requested. Interestingly, he was then asked whether Batavia was interested in actually building such a ship for the shogun, which he immediately linked to a counter-request that the Japanese raise their copper quota"[570].

It is not clear whether the drawing was a technical design drawing or an artistic drawing and whether the ship was actually built.

It seems that, on a temporary basis, "Western" shipbuilding technology was used in the East Indies related to the building of ships of European design. On a slightly more permanent basis, "Western" technology was implemented in the building of local designs, but in due course local shipbuilders returned to their local technology, even for ships that were to be used by Westerners. This can be illustrated by the fact that the European way of attaching the rudder to

[568] http://www.vocsite.nl/schepen/scheepstypen.html
[569] Cf. section 1.3
[570] Lissa Roberts in a draft paper "Canton and Nagasaki as centers of accumulation and mediation", presented at the "Canton and Nagasaki Compared" Conference at Nagasaki, 30.11.2009-3.12.2009. Hemmij was *opperhoofd* at the VOC factory at Dejima (near Nagasaki) between 1792 and 1798.

the centre of the stern, although initially used by local shipbuilders producing ships for the VOC, was discarded in favour of the local technology of attaching the rudder to the side of the ship, as is shown in fig. 6.1.

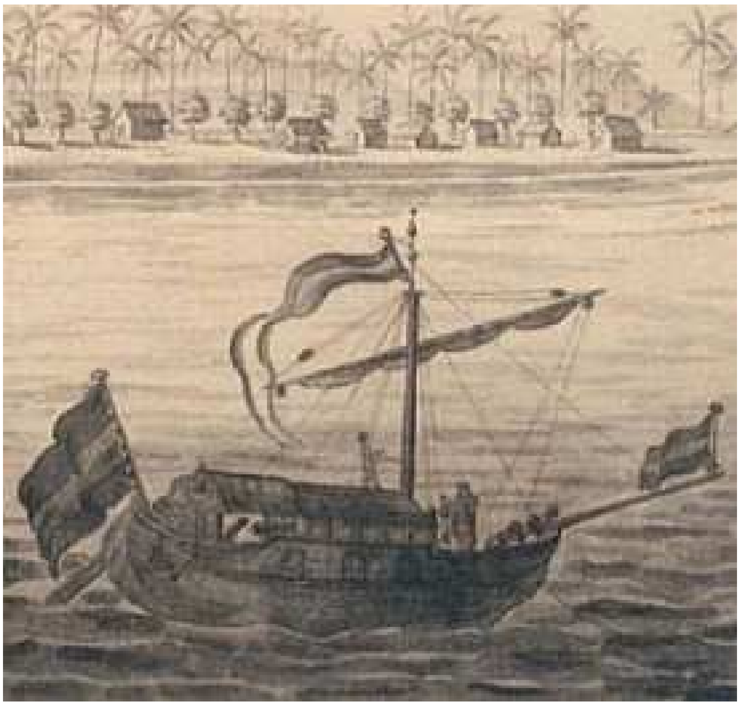


Fig. 6.1 Detail of the painting "View of the fort at Rembang" by Johannes Rach (1770), showing a *pantchiallang*; note the local construction of the rudder. Picture derived through http://www.vocsite.nl/schepen/scheepstypen.html

What happened (or not) seems to be in contrast to what other (pre)colonial powers practised. The British built (large) ships in India and so did the Portuguese in Brazil, and in doing so they exported their shipbuilding technology "lock, stock and barrel"[571] to their colonies. It might be interesting to do research into how, why and to which degree the VOC (and later the Dutch colonial shipping company KPM[572]) transferred its shipbuilding technology on any significant scale to the East Indies. When writing about the role of technology and nationalism in the Dutch East Indies during the 20th century, Rudolf Mrazek (in "Engineers of Happy Land", Princeton 2002 / ISBN 0-691-09162-5) mentions various technological subjects, but shipbuilding is conspicuous by its absence.

[571] Unger (1978)
[572] De Jong (Nov. 2007)

Acknowledgements

In general, studying WWTS has been a marvellous adventure and a journey of discovery for me, thanks to its academical content, the skills and critical sense it taught me, its inspiring staff and the fun I had with my fellow students.

Specifically related to the writing of this thesis, I would like to thank the staff at several libraries and archives for their assistance and support in providing me with literature, both old and new. First of all, the staff at the library of the University of Twente, to whom a must have become a familiar figure, enquiring after material from the *Boot Collectie*. The library at the University of Leiden provided access to a (general historical) thesis about the changes in the charter of the VOC 1740-1742. I visited the library at the University of Amsterdam (*Bijzondere Collecties*) two times to indulge myself in original editions of Witsen, Van IJk, Duhamel du Monceau and Decquer; the staff allowed me kindly to take pictures. Staff at the library at the University of Utrecht went out of their way to open up the *Moll Collectie* for me. This collection contains some original technical drawings by Gerbrand Slegt, Thomas Davis and Charles Bentam. Staff at the *Koninklijke Bibliotheek* at The Hague provided access to a re-edition of Blaise Ollivier's comments on the English and Dutch navies. The library at the *Nederlands Scheepvaartmuseum* Amsterdam was unfortunately closed because of the reconstruction of the museum, but staff was able to send me a few essential copies of technical drawings by Charles Bentam. I spent several days at the National Archives (*Nationaal Archief)* studying and photographing original documents of the VOC, a truly inspiring experience.

Being on the replica of the *retourschip Amsterdam*, moored in Amsterdam, and visiting the Batavia Shipyard at Lelystad gave me a feel for the "real" artefacts and the methods of shipbuilding employed.

A special word of thanks should go to my supervising committee,
to Peter-Paul Verbeek for showing to me that philosophy is nothing to be afraid of, but can be great fun;
to Fokko-Jan Dijksterhuis for giving me the first introduction to the history of science and technology and for keeping me on my toes on several occasions since;
and – most importantly - to Lissa Roberts for her inspiration, critical feedback, patience and for putting up with my English. It is a great feeling to realize how much trust she placed in me.

Finally, I would not have been able to reach the end of this line without the unfailing support and love of Lidy, who – over these past six-and-a-half years - kept asking me whether I still liked what I was doing. Whenever I said "Yes" she ushered me upstairs to get it over and done with. She did not even object to me taking the computer along on our holidays to do some work. The most amazing thing she did was accompanying me on the flight out to the Abrolhos Islands off Western Australia; although she had not exactly developed a liking to small planes after our experience in New Zealand.

Literature

Material from the National Archives (ARA)

VOC Archives (1.04.02)

37 (9.3.1714 / 24.?.1714)
118 (25.2.1727 / 4.4.1727)
123 (8.3.17412 / 12.6.1741 / 15.6.1741 / 28.11.1741 / 14.3.1742 / 26-28.2.1742 / 14.3.1742 / 28.8.1742)
4744 (24.8.1740)
4944 (30.5.1727)
7237 (23.7.1740 / 28.8.1740 / 3.1741 /12.6.1741 / 16.6.1741 / 28.9.1741 / 11.12.1741)
7418 (12.6.1741 / 6.10.1741 / 28.11.1741 / 11.12.1741 / 14.3.1742)
11153 (13.4.1741)

Fagel Archives (1.10.29)

1099 / Bentam (1752)
1099 / Schrijver (1753)

Primary sources

Dam, Pieter van "Beschrijvinge van de Oostindische Compagnie" (1701), edited by Dr. F.W. Stapel, 's-Gravenhage 1927 (17de Capittel). Retrieved through http://www.inghist.nl/retroboeken/vandam

Decquer, Hendrik "Middelen om uit te vinden de ware ladinge der Scheepen na hare grootte", Amsterdam (?), 1688/1690. Very few copies of this book survive, the copy at the library of the University of Amsterdam (Bijzondere Collecties, OTM: OF 63-315) was photographed by Johan de Jong on 7 July 2009

Duhamel du Monceau, H.L. (translated & carefully abridged by Murray, Mungo) "The Elements of Naval Architecture or, a Practical Treatise on Ship-building" London, 1754

Duhamel du Monceau, H.L. "Grondbeginselen van den Scheepsbouw of Werkdadige Verhandeling der Scheepstimmerkunst, vertaald door een liefhebber der vrije kunsten onder opzigt van twee beroemde scheepsbouwers, P. de Hondt en H. Scheurleer" Den Haag 1757/1793
Retrieved through http://books.google.com/books?id=bvAOAAAAYAAJ&pg=RA2-PT1&lpg=RA2-PT1&dq=duhamel+monceau+grondbeginselen&source=bl&ots=xtLCJ-q_7u&sig=FOYRwcGyHr0qal6xEEuNs8VGMAM&hl=en&ei=f2EuSumQOIPV-AaM8dyFCg&sa=X&oi=book_result&ct=result&resnum=1#PPP5,M1

Lavery, Brian (ed.) "Deane's Doctrine of Naval Architecture, 1670" Conway Maritime Press Greenwich/London 1981 ISBN 0 85177 180 7

Roberts, David H. "18th Century Shipbuilding: Remarks on the Navies of the English and the Dutch from Observations made at their Dockyards in 1737 (by Blaise Ollivier)" Rotherfield 1992 ISBN 0948864117

Sutherland, William "The Shipbuilders Assistant" London 1711
Retrieved through http://echo.mpiwg-berlin.mpg.de/ECHOdocuView/ECHOzogiLib?mode=imagepath&url=/mpiwg/online/permanent/library/AE4UUGBR/pageimg

Witsen, Nicolaas "Aeloude en Hedendaegse Scheepsbouw en Bestier" Amsterdam 1671
Partly retrieved through http://www.bruzelius.info/Nautica/Shipbuilding/Shipbuilding.html
Parts of an original copy at the library of the University of Amsterdam (Bijzondere Collecties, OTM: OF 93-5) were photographed by Johan de Jong on 7 July 2009

Witsen, Nicolaas “Architectura navalis et regimen nauticum Ofte Aaloude en hedendaagsche scheeps-bouw en bestier” [2 parts] Amsterdam 1970 (photomechanical reprint of the original edition by Pieter & Joan Blaeu, Amsterdam 1690)
Retrieved through http://www.dbnl.org/tekst/wits008arch01_01/index.htm

Yk, Cornelis van “De Nederlandsche scheeps-bouw-konst open gestelt” Amsterdam 1697
Partly retrieved through http://www.bruzelius.info/Nautica/Shipbuilding/Yk(1697)/toc.html
Parts of an original copy at the library of the University of Amsterdam (Bijzondere Collecties, OTM: OTM: KF 61-1810) were photographed by Johan de Jong on 7 July 2009

Zwijndregt Pauluszoon, Pieter van “De Groote Neederlandsche Scheeps Bouw Op een Proportionaale Reegel voor Gestelt” (manuscript 1757), published in Hoving, A.J. & Lemmers, A.A. (2001)

Secundary sources

Boxer, C.R. “The Dutch Seaborne Empire, 1600-1800” London 1965

Bruggen, B.E. van “Aspecten van de bouw van oorlogsschepen in de Republiek tijdens de achttiende eeuw” in Mededelingen van de Nederlandse Vereniging voor Zeegeschiedenis (1974) issue 28, pp. 29-42 & issue 29, pp. 5-21

Bruggen, B.E. van “Schepen, ontwerp en bouw” in *Asaert G. e.a. “Maritieme Geschiedenis der Nederlanden”*, dl. 3 pp. 14-58 Bussum 1976-1978

Bruijn, J.R. “De Admiraliteit van Amsterdam in rustige jaren 1713-1751” Amsterdam/Haarlem 1970

Bruijn, J.R. “Engelse Scheepsbouwers op de Amsterdamse admiraliteitswerf in de achttiende eeuw – enkele aspecten” in *Mededelingen van de Nederlandse Vereniging voor Zeegeschiedenis* (1972) issue 25, pp. 18-24

Bruijn, J.R., Gaastra F.S. & Schöffer I. “Dutch Asiatic Shipping in the 17th and 18th Centuries” (Part I) Den Haag 1979-1987.

Bruijn, J.R., Gaastra F.S. & Schöffer I. “Dutch Asiatic Shipping in the 17th and 18th Centuries” (Part II and III) Den Haag 1979-1987. Transformed into database, retrieved through http://www.inghist.nl/Onderzoek/Projecten/DAS

Bruijn, J.R. “William III and His Two Navies” in *Notes and Records of the Royal Society of London* Vol. 43, No. 2 Science and Civilization under William and Mary, (July 1989), pp. 117-132

Bruijn, J.R. “The Dutch Navy of the Seventeenth and Eighteenth Centuries” University of South Carolina Press, Columbia 1993

Brunt, I.M. "De veranderingen in het charter van de VOCschepen 1740-1742" Doctoraalscriptie Geschiedenis Universiteit Leiden 1997 (nr. 494)

Dash, Mike “Batavia’s Graveyard” London 2003 ISBN 0-7538-1684-9

Deurloo A.J. “Bijltjes en Klouwers: een bijdrage tot de geschiedenis der Amsterdamse scheepsbouw, in het bijzonder in de tweede helft der achttiende eeuw” in *Economisch en Sociaal Jaarboek*, Vol. 34 (1971) pp. 4-71

Ferreiro, Larry D. “The Aristotelian Heritage in Early Naval Architecture, from the Venetian Arsenal to the French navy, 1500-1700” Preprint 371, Max-Planck-Institut für Wissenschaftgeschichte, Berlin, 2009

Ferreiro, Larry D. “Ships and science” MIT Press, Cambridge Mass./ London, 2007 ISBN 0-262-06259-3

Gaastra, Femme S. “De Geschiedenis van de VOC” Zutphen 2001/2007 ISBN 978.90.5730.184.1

Gawronski, Jerzy "The Hogendijk Shipyard in Zaandam and the VOC Shipyard Oostenburg in Amsterdam" in *Beltrame, Carlo (ed) "Boats, Ships and Shipyards" Proceedings of the Ninth International Symposium on Boat and Ship Archeology (Venice 2000)* Oxford, 2003 pp. 132-143

Gawronski, Jerzy "De Equipagie van de Hollandia en de Amsterdam. VOC-bedrijvigheid in 18de eeuws Amsterdam" Amsterdam 1996

Grimm, Peter (ed.) "Heeren in Zaken – De Kamer Rotterdam van de Verenigde Oostindische Compagnie" Historisch Museum Rotterdam/Walburg Pers Zutphen 1994 ISBN 90-6011-903-7

Harris, J.R. "Copper and Shipping in the Eighteenth Century" in *The Economic History Review, New Series*, Vol. 19, No. 3 (1966), pp. 550-568

Hoving, A.J. & Lemmers, A.A. "In tekening gebracht, de achttiende-eeuwse scheepsbouwers en hun ontwerpmethoden" Amsterdam/'s-Gravenhage 2001 ISBN 90-6707-541-8

Hoving, Ab & Parthesius, Robert "Twee 17de-eeuwse bouwmethoden" in *Batavia Cahier* 3 (1991) Lelystad ISBN 90 73857 03 1

Ingelman-Sundberg, C. "The V.O.C. Ship 'Zeewijk' 1727 report on the 1976 survey of the Site". 'Australian Archaeology', no.5 (1976), 18-33. Retrieved through http://dspace.flinders.edu.au/dspace/bitstream/2328/342/1/1976005018033_FINAL.pdf

Jonge, J.C. de "Geschiedenis van het Nederlandsche Zeewezen" Part I-V (Second, enlarged edition) Haarlem 1858-1862. Retrieved through
I http://books.google.nl/books?id=bMEsAAAAYAAJ&printsec=frontcover&dq=editions:OCLC11433776#PPP1,M1
II http://books.google.nl/books?id=ecIsAAAAYAAJ&printsec=frontcover&dq=editions:OCLC11433776
III http://books.google.nl/books?id=4cAsAAAAYAAJ&printsec=frontcover&dq=editions:OCLC11433776
IV http://books.google.nl/books?id=WvFMAAAAMAAJ&printsec=frontcover&dq=editions:OCLC11433776
V http://books.google.nl/books?id=G_BMAAAAMAAJ&printsec=frontcover&dq=editions:OCLC11433776

Kampen, S.C. van "De Rotterdamse particuliere scheepsbouw in de tijd van de Republiek" Assen, 1953

Ketting, Herman "Fluitschepen voor de VOC" Aprilis, Zaltbommel 2006 ISBN 90 5994 141 1

Kist, Bas "Methodice en op egualen voet: Ontwerp en invoering van een nieuw retourschip van 150 voet door de VOC 1740-1750" in *Tijdschrift voor Industriële Archeologie* 1985 pp. 9-18

Kist, Bas "A short discussion of the political and technical aspects of reform in the Dutch East India Company with regard to shipbuilding" in *Gawronski, Kist, Stokvis-van Boetzelaer & Roth "Hollandia Compendium"* Amsterdam 1992 ISBN 0-444-89415-2

Krom, Dr. N.J. "Gouverneur Generaal Gustaaf Willem van Imhoff" P.N. van Kampen & Zoon N.V. Amsterdam 1941

Lemmers, Alan "Techniek op schaal, modellen en technologiebeleid van de Marine 1725-1885" Amsterdam 1996 ISBN 90-6707-423-3

Leys, Simon "The wreck of the Batavia" London 2007 ISBN 978-1-84354-581-1

Lucassen, Jan "A Multinational and its Labor Force: The Dutch East India Company, 1595-1795 in *International Labor and Working Class History* No.66, Fall 2004, pp. 12-39

McGee, David "From craftsmanship to draftsmanship: naval architecture and the three traditions of early modern design" in Technology and Culture Vol. 40 (1999), pp. 210-236

McGee, David "Ships, Science and the Three Traditions of Early Modern Design" in *Lefèvre, Renn & Schoeplin (eds) "The Power of Images in Early Modern Science"* Birkhäuser Verlag, Basel/Boston/Berlin 2003

Meyer, Michael “Zu einigen Fragen von Schiffbau, Schiffart und Schiffstheorie” in *“Beiträge zur Wissenschaftsgeschichte, Naturwissenschaftliche Revolution im 17. Jahrhundert”* (pp. 213-220) Berlin 1988

Nowacki, Horst “Archimedes and Ship Stability” Preprint 198, Max-Planck-Institut für Wissenschaftgeschichte, Berlin, 2001

Nowacki, Horst “Developments in Fluid Mechanics Theory and Ship Design before Trafalgar” Preprint 308, Max-Planck-Institut für Wissenschaftgeschichte, Berlin, 2006

Nowacki, Horst “Leonhard Euler and the Theory of Ships” Preprint 326, Max-Planck-Institut für Wissenschaftgeschichte, Berlin, 2007

Nowacki, Horst & Valleriani, Matteo “Shipbuilding Practice and Ship Design Methods from the Renaissance to the 18th Century” A Workshop Report Preprint 245 Max-Planck-Institut für Wissenschaftgeschichte, Berlin, 2003

Pritchard, James “From Shipwright to Naval Constructor: The Professionalization of 18th Century French Naval Shipbuilders” in *Technology and Culture* 1987 Vol. 28 (1) pp. 1-25

Ridder, B. de “De Saturdagse Krans” in *Ons Amsterdam* Vol. 18 (1966) pp. 378-380

Roach, Alistair “Model Boats in the Context of Maritime History and Archaeology” in *The International Journal of Nautical Archaeology* (2008) Vol. 37.2, pp. 313-334

Steur, J.J. “Herstel of ondergang: de voorstellen tot redres van de Verenigde Oost-Indische Compagnie 1740-1795” HES Uitgevers, Utrecht 1984 ISBN 90-6194-214-4

Timmermann, Gerhard “Das Eindringen der Naturwissenschaft in das Schiffbauhandwerk” in *Deutsches Museum, Abhandlungen und Berichte*, 30.Jahrgang 1962 - Heft 3 München/Düsseldorf 1962

Unger, Richard W. “Dutch Shipbuilding before 1800” Assen/Amsterdam 1978

Unger, Richard W. “Warships*,* cargo ships and Adam Smith*:* trade and government in the eighteenth century” in *Mariner's Mirror*, 92:1 (2006), pp. 41-59

Unger, Richard W. “The technology and teaching of Shipbuilding 1300-1800” Draft paper for the S.R. Epstein Memorial Conference “Technology and Human Capital Formation in the East and the West”, London School of Economics, 19-21 June 2008

Voorbeijtel Cannenburg, W. “Het “karrepad” onzer Oost-Indiëvaarders” in *Tijdschrift van het Aardrijkskundig Genootschap* (1953), Vol. 70, pp. 467-471

Wit, C.H.E. de “De Nederlandse revolutie van de achttiende eeuw 1780-1787” (1974). Retrieved through http://www.dbnl.org/tekst/wit_079nede01_01/wit_079nede01_01_0011.htm

Methodological/historiographical sources

Alder, Ken “Innovation and Amnesia: engineering rationality and the fate of the interchangeable parts manufacturing in France” in *Technology and Culture* 1997 Vol. 38 (2) pp. 273-311

Croissant, Jennifer L. “Theory, Narrative and Discipline at the Intersections of Science and Technology Studies and History” in *Bulletin of Science Technology Society* 2003; 23; pp. 465-472 Retrieved through http://bst.sagepub.com/cgi/content/abstract/23/6/465

Davids, Karel “Guilds, guildsmen and technological innovation in early modern Europe: the case of the Dutch Republic” www.lowcountries.nl/2003/workingpapers

Davids, Karel "Public Knowledge and Common Secrets, Secrecy and its Limits in the Early-Modern Netherlands" *in Early Science and Medicine* Vol.10 (2005) No.3 pp. 411-427

Davids, Karel "The Rise and Decline of Dutch Technological Leadership" (2 vol.) Leiden/Boston 2008 ISBN 978 90 04 16865 7

Edgerton, David "From Innovation to Use: Ten Eclectic Theses on the Historiography of Technology" in *History and Technology* 1999, Vol. 16, pp. 111-136

Edgerton, David "The Shock of the Old: Technology and Global History since 1900" Profile Books London (2006/2008) ISBN 978 1 86197 306 1

Epstein S.R "Craft Guilds, Apprenticeship, and Technological Change in Preindustrial Europe" in *The Journal of Economic History* Vol. 58 No.3 (Sep. 1998) pp. 684-713

Epstein S.R. "Property Rights to Technical Knowledge in Premodern Europe" in *The American Economic Review*, Vol. 94 No.2 (May 2004) pp. 382-387

Epstein, S.R. "Transferring Technical Knowledge and Innovating in Europe, c.1200-1800" Paper presented at the Economic History Seminar, Department of Economics, Tokyo, 18 December 2006

Feenberg, Andrew "Escaping the Iron Cage, or, Subversive Rationalization and Democratic Theory" in *Schomberg, R. (ed) "Democratising Technology: Ethics, Risk and Public Debate"* Tilburg 1998

Fleischer, Alette "The Beemster Polder: conservative invention and Holland's great pleasure garden" in *Roberts, Schaffer & Dear (eds.) "The Mindful Hand: Inquiry and Invention from the late Renaissance to early Industrialisation"* Amsterdam 2007 ISBN 978-90-6984-483-1

Gorman, Michael John "The elusive origins of the immutable mobile", 2001. Retrieved through http://www.stanford.edu/group/STS/immutablemobile.htm

Hård, Mikael & Jamison, Andrew "Hubris and Hybrids, a Cultural History of Technology and Science" Routledge London/New York, 2005, ISBN 0-415-94938-6

Hughes, Thomas P. "The Seamless Web: Technology, Science, Etcetera, Etcetera" in *Social Studies of Science*, Vol. 16, No. 2 (May, 1986), pp. 281-292

Hughes, Thomas P. "The Evolution of Large Technological Systems" in *Bijker, Wiebe E., Hughes, Thomas P. & Pinch, Trevor J. "The Social Construction of Technological Systems"* MIT Press, Cambridge Mass., 1987 ISBN 0-262-02262-1

Inkster, Ian "Science and Technology in History: An Approach to Industrial Development" MacMillan, Basingstoke and London, 1991 ISBN 0-333-42858-7

Jamison, Andrew & Hård, Mikael "The Story-lines of Technological Change: Innovation, Construction and Appropriation" in *Technology Analysis and Strategic Management*, nr 1, 2003.

Jong, Johan de "Triple Expansion: on the link between modern 19th century steamships and expanding imperialism in the Dutch East Indies, forged by a colonial shipping system" , written as final essay for "Society, Technology & Modern Society", Nov. 2007

Jong, Johan de "De ontdekking van Bruno's Artefacten", written for "Capita Selecta WWTS", Dec. 2007

Laet, M. de & Mol, A. "The Zimbabwe Bush Pump: Mechanics of a Fluid Technology" in *Social Studies of Science* Vol. 30 No. 2 (Apr.,2000), pp. 225-263.

Latour, Bruno "Science in Action" Harvard University Press, Cambridge Mass., 1987 ISBN 0-674-79291-2

Latour, Bruno "We have never been Modern", Harvard University Press, Cambridge Mass., 1993 (esp. chapter 1 and 4) ISBN 0-674-94839-4

Law, John "Technology and Heterogeneous Engineering: The Case of Portuguese Expansion" in *Bijker, Wiebe E., Hughes, Thomas P. & Pinch, Trevor J. "The Social Construction of Technological Systems"* MIT Press, Cambridge Mass., 1987 ISBN 0-262-02262-1

Law, John "Theory and Narrative in the History of Technology: Response" in *Technology and Culture* 1991 Vol. 32 (2) pp. 377-384

Law, John "Notes on the Theory of the Actor-Network: Ordering, Strategy, and Heterogeneity" in *Systems Practice* 1992, Vol. 5, No. 4

Lubar, Stephen "Representation and Power" in *Technology and Culture* 1995 Vol.36, pp. S54-S81

Misa, Thomas J. "Theories of Technological Change: Parameters and Purposes" in *Science, Technology and Human Values*, Vol. 17, No. 1 (Winter 1992), pp. 3-12

Misa, Thomas J. "From Leonardo to the Internet: Technology & Culture from the Renaissance to the Present" John Hopkins University Press, Baltimore and London, 2004 ISBN 0-8018-7809-8

O'Connell, Joseph "Metrology: The Creation of Universality by the Circulation of Particulars" in *Social Studies of Science*, Vol. 23, No. 1 (Feb, 1993) pp. 129-173

Pinch, Trevor J. & Bijker, Wiebe E. "The Social Construction of Facts and Artifacts: Or How the Sociology of Science and the Sociology of Technology Might Benefit Each Other" in *Bijker, Wiebe E., Hughes, Thomas P. & Pinch, Trevor J. "The Social Construction of Technological Systems"* MIT Press, Cambridge Mass., 1987 ISBN 0-262-02262-1

Pye, David "The Nature and Art of Workmanship" Cambridge University Press Cambridge 1968

Raj, Kapil "Circulation and the Emergence of Modern mapping: Great Britain and Early Colonial India, 1764-1820" in *Markovits, Pouchepadass & Subrahmanyam (eds) "Society and Circulation: Mobile People and Itinerant Cultures in South Asia 1750-1950"*, Permanent Black, New Delhi, 2002 pp. 23-54

Roberts, Lissa & Schaffer, Simon "Preface" in *Roberts, Schaffer & Dear (eds.) "The Mindful Hand: Inquiry and Invention from the late Renaissance to early Industrialisation"* Amsterdam 2007 ISBN 978-90-6984-483-1

Schaffer, Simon "Fish and Ships: Models in the Age of Reason" in *Chadarevian, Soraya de & Hopwood, Nick "Models: The Third Dimension of Science"* Stanford University Press, Stanford 2004
ISBN 0804739722

Schaffer, Simon "The charter'd Thames: naval architecture and experimental spaces in Georgian Britain" in *Roberts, Schaffer & Dear (eds.) "The Mindful Hand: Inquiry and Invention from the late Renaissance to early Industrialisation"* Amsterdam 2007 ISBN 978-90-6984-483-1

Scranton, Philip "Labor and Technology" in *Technology and Culture* 1988 Vol.29 (4) pp. 719-721

Scranton, Philip "None-too-porous Boundaries: Labor History and the History of Technology" in *Technology and Culture* 1988 Vol.29 (4) pp. 722-743

Turnbull, David "Reframing Science and other Local Knwoledge Traditions" in *Futures* 1997 Vol. 29 (6) pp. 551-562

Vries, Jan de & Woude, Ad van der "Nederland 1500-1815: De eerste ronde van moderne economische groei" Amsterdam 1995/2005 ISBN 90-5018-648-3