ABSTRACT

THE CASKS FROM *VASA*.
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November 2012
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When the warship *Vasa* was raised in 1961, wooden casks were found in nearly every area of the ship. Unfortunately, this important find category was not subject to detailed recording and study until now. This thesis explains the use and distribution of casks aboard *Vasa*, and their place in seventeenth-century northern European cooperage. Recording of individual cask attributes formed the basis for these subsequent analyses. This shows there were at least 145 casks of five main types aboard when the ship sank in 1628. The majority of casks were made of oak timber; the remainder of pine. The most common type of cask could hold between 117 and 146 liters and featured square bungholes. These casks contained salt meat, and likely beer. The dimensions of these casks conform to multiples of the Swedish foot, suggesting they were produced locally or at least according to Swedish specifications. Distribution of the containers shows a clear stowage plan, with the majority of provision casks in the hold and casks of personal possessions on the gundecks above. A study of period art reveals that casks with square bungholes were common across seventeenth-century northwestern Europe, but have hitherto been underrepresented archaeologically. This iconographic evidence also supports the contention that many of the oak casks held beer. The casks from *Vasa* remain an important tool for understanding shipboard organization and the naval supply process during the seventeenth century.

THE CASKS FROM *VASA*.

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By

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(1555). “Finally, after drawing all these many facts from the North and bringing them out into the light, things which are clearly less common in other parts of the world … I have to admit that what I have adopted from my own researches is meager and bare, whereas the loans I have obtained from others’ treasuries are far richer” (Magnus 1555: 1184). Perhaps the richest intellectual treasury in this subfield belongs to Dr. Brad Loewen, whose pioneering work on the casks from Red Bay continues to set the standard for similar studies. Dr. Loewen kindly commented on my initial research plan, and offered valuable insights once I collected my data. Sarah Fawsitt sent me her excellent thesis on the casks from the Drogheda Boat, and Martijn Manders did likewise with his dissertation on the casks from the Scheurrak SO1 wreck. Aoife Daly brought several early examples of square bung casks to my attention, and has expressed her interest in a future dendroprovenance study. Ulrica Söderlind of Stockholm University provided me with a copy of her important study of diet and provisioning in the Swedish navy, and shared unpublished information that would be otherwise unavailable. Charles Bradley of Parks Canada allowed me to copy obscure sources, and Amy Borgens of the Texas Historical Commission generously sent me a copy of the preprint chapter on the casks from *La Belle*. Dr. Richard Unger of the University of British Columbia considered my theories on beer barrels, and offered his own expert opinions on the subject. Raymond Hejdström of the Gotlands Museum supplied photos of markings on the equestrian statue of St. George, in Visby. The traditional coopers at Williamsburg, Virginia, very patiently explained their craft during a visit in 2010. These included Master James Pettengell and Journeymen (and woman) M.S. Ramona Vogel, Jonathan Hallman, and Marshall Scheetz. The staff at the following libraries proved very helpful in locating difficult sources: ECU Joyner Library (ILL Department), the Nordiska Museet, Stockholm, the University of Waterloo Library, and the Wilfrid Laurier University Library.

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Chapter 1 – Introduction

The ubiquity of closed staved wooden containers, or casks, in the early modern world makes them analogous to cardboard boxes in our own era. Despite this apparently mundane role, the study of casks can reveal much about the economy and organization of past societies. During the 1961 excavation of the warship *Vasa*'s interior, archaeologists discovered a variety of casks in nearly every area of the ship. Some contained personal possessions of individual sailors, while others held provisions and stores. The quantity of casks and cask parts recovered means that these artifacts form a major find group, providing a collection of seventeenth-century coopered vessels with few parallels. Unfortunately, due to the prolonged demands of conserving and studying an essentially intact warship and its fittings, not all artifact categories received similar levels of analysis. The current study aims to remedy this situation by recording and studying *Vasa*'s casks in more detail than done to date, and attempting to answer the following questions.

Research Questions

What evidence do the casks from *Vasa* provide on cooperage in seventeenth-century northern Europe, organization and use of space aboard ship, and the naval supply process in the Baltic?

I. What are the attributes of the casks?

I. A. What information do tool marks and cask attributes provide about the process of production?

I. B. What are the dimensions and volumes of the casks?

I. C. Is there enough regularity in the collection to establish a typology of casks from *Vasa?*

II. How were casks used on *Vasa*?

II. A. How many casks were on *Vasa* when she sank, and what did they contain?

II. B. Is there a relationship between a cask's contents and construction characteristics?

II. C. How were the casks distributed, and what does this indicate about storage and use of space?

II. D. How well provisioned was the ship for sea?

III. What information do the *Vasa* casks offer on networks of exchange and the naval supply process in seventeenth-century northern Europe?

III. A. Are they typical of casks found on wrecks of a similar period or depicted in contemporary art?

III. B. Do cask volumes correspond to any particular system of metrology that would help determine their origins?

Answering these questions will produce a better understanding of a significant but underutilized collection at the Vasa Museum, and add to existing knowledge about the organization, outfitting, and provisioning of seventeenth-century European warships. The collection of casks at the Vasa Museum is large, but was poorly organized and documented. The collection's reordering and detailed recording has produced a cask typology that will serve as a comparative reference, and helps determine the extent to which Swedish administrative reforms and efforts at standardization were reflected in the 1628 naval supply system. An improved understanding of the distribution and use of casks on *Vasa* offers valuable insights into the shadowy worlds of shipboard organization and daily life. There is a tendency to extrapolate backwards from the existing corpus of knowledge on these subjects, which is largely based on sources from the eighteenth century onwards. *Vasa*'s casks offer an unparalleled opportunity to establish how naval personnel actually ordered their wooden world, on a voyage they all likely expected would last longer than a few hours. Interpreting the casks in a wider Baltic framework can suggest Sweden's level of integration into the northern European economy, and specifically if the kingdom could produce sufficient naval supplies within its borders or was forced to turn elsewhere to provision its warships.

Previous Studies

The field of historic cooperage is understudied, but expanding steadily through new contributions (Daly 2007; Smith 2009; Fawsitt 2010). Previous authors have generally either focused on the coopering trade itself, or the description and analysis of casks from archaeological contexts. The former category includes trade literature, which encompasses metrology and techniques of cask production (Diderot and Alembert 1772) and, in the twentieth century, shifts to mechanized cooperage (Hankerson 1951). Traditional artisans wrote histories of the trade (Gilding 1971; Kilby 1971), but these are generally biased towards nineteenth- and twentieth-century British practices. The nostalgia and idealism of these latter works means they do not necessarily reflect the reality of cooperage in previous centuries, and in different parts of Europe.

Archaeological studies of historic casks derive almost exclusively from maritime sites, as most vessels carried wooden casks. *Mary Rose* likely held between 120 and 150 casks when it sank in 1545; 33 were examined in detail (Rodrigues 2005: 409). Sarah Fawsitt recently studied sixteen casks from a late sixteenth-century wreck in Drogheda, Ireland (Fawsitt 2010: 23-29). Martijn Manders wrote his doctoral dissertation on the casks from the late sixteenth-century Scheurrak SO1 wreck (1996), which exhibit many similarities to the *Vasa* casks. During the excavation of the Basque whaleship *San Juan* (1565) in Red Bay, Labrador, archaeologists recovered almost 200 *barricas* originally intended to hold whale oil (Loewen 2007: 6)**.** Brad Loewen's (1999, 2007) work on these casks was significant because he used the attributes of the objects to deduce the production process and lifecycle of the casks, or *chaîne opératoire*. Similarly, his analysis of casks from the 1684 French ship *LaBelle* revealed early instances of mechanization and proto-industrial production of head pieces (Loewen 2014), which offers a different perspective to the idealistic individual artisan and guild-based interpretations of Kilby (1971: 16) and other modern historians. Casks from more recent archaeological contexts were recovered from the British supply ship *Betsey* of 1781 (Shackleford, Smith and Brown 1988) and the *William Salthouse* of 1841 (Staniforth 1987). Kimberly Smith from East Carolina University compiled and compared a large amount of data on historic casks from maritime contexts (2009), and her work provides a useful summary of the available literature. The current study builds upon these works and aims to add to the existing body of knowledge on historic cooperage.

Organization

This work is divided into nine chapters, the Introduction being the first chapter. Chapter Two aims to contextualize *Vasa* and the casks within by examining Sweden during the 1620s. Specifics of the ship's construction and form are provided, as well as the intended role of the vessel within the Swedish navy. The political situation, economy and society of the kingdom, and finally the city of Stockholm itself, are all discussed in turn, in an effort to furnish background information for the chapters which follow. Chapter Three explains how the cask collection arrived in its present state, and the methodology employed to gather the data for this study. The site formation processes at the wreck site influenced the condition of the casks, as did the eventual conservation measures used to stabilize and preserve the material. The excavation and recording techniques developed by the archaeological team between 1956 and 1961 are explained, as they form the basis for understanding find distribution throughout the ship. Collections management policies at the museum are important, since they too influenced the eventual form and organization of the cask collection. These factors illustrate the challenges faced by the author during the course of the study, and help explain the eventual methodology chosen to gather data. This recording process is explained in detail, to show both the strengths and limitations of the data, and as a possible aid to any future projects of a similar nature.

Chapter Four explains the specialized terms, techniques, and tools of cooperage, which are used liberally throughout but are likely unfamiliar to most readers. The origins and advantages of casks as containers are discussed. This is followed by a step-by-step explanation of how a cask is made, based on examples from *Vasa*. This is similar to Loewen's *chaîne opératoire* approach and allows for a detailed examination of the individual attributes of the *Vasa* casks. The cask attributes are also compared with those observed on other archaeological sites, and with modern descriptions of cooperage. Chapter Five continues the theme of the previous chapter, and covers those attributes not previously discussed. These include the bungs and bung holes, additional sample and vent holes, the hoops, and markings on the casks. Many of the *Vasa* oak casks have distinctive square bung holes, rarely seen in other archeological contexts. These same casks also feature numerous smaller holes drilled through the staves and head pieces, thought to be sample or vent holes. The hoops did not survive well, but the remaining fragments and excavation photos are interpreted to explain hoop placement and closure techniques. The numerous carved markings or *bomärker* observed on the casks are one of their more striking features. There are a total of 184 marks on 147 staves and head pieces. The diversity of these marks suggest they are individual owner's marks, rather than merchant or cooper's marks. The marks are divided stylistically into three categories, and each is illustrated with a line drawing.

Chapter Six divides the casks into a typology, based on construction characteristics, volume, and contents where possible. It is estimated there were at least 145 casks of all types on the *Vasa*. These casks are divided into five types: oak casks, lidded casks, pine casks, small casks, and shot kegs. Oak casks, not surprisingly, are those made of oak timber. They feature square bung holes, two or three-piece heads edge-joined with dowels, and generally have volumes between 117 and 146 liters. They contained a variety of material, including salted provisions, water and beer, and perhaps even gunpowder. Lidded casks are similar in size and construction to the oak casks, but often contained personal possessions. They formed an alternative to a sea chest, where crew members could store extra clothing, utensils, tools, and small items. The lidded casks were sealed with removable pine lids, often heavily marked. Pine casks are generally much smaller than oak casks, with volumes between 36 and 41 liters. Some of these casks contained fish. Others appeared to be deliberately charred on the interior, suggesting they might have held spirits. Small casks were made of both oak and pine, and were classified entirely based on size. They range from examples with volumes of around 18 liters down to the tiny "Micro Cask" of only 0.3 liters. Finally, the shot kegs formed a small distinct group of only six or seven examples, found forward in the hold. Together they contained around 9,000 lead shot for small arms or canister shot. Chapter Seven builds on the typology to explain the distribution of the estimated 145 casks throughout the four main decks of the ship. Not surprisingly, the largest number of casks was found in the hold, while the fewest were found on the orlop. The majority of personal casks came from the gundecks, which makes sense given this was the area where most men lived and worked. Clusters of casks throughout the ship indicate there was a definite plan for stowage, but also confirm that the ship was not fully provisioned and stored when she sailed. This distribution plan will prove useful for future studies of the use of space aboard *Vasa*, and for the construction of virtual and traditional models of the ship.

Chapter Eight attempts to move beyond the limited world of the ship, to understand the casks in a wider North European perspective. The vehicle for this effort is an iconographc study, using a selection of images primarily from Holland and Germany, from the fifteenth to the late seventeenth centuries. These images show other examples of casks with square bungs, similar to those from *Vasa*, as well as coopers at work, and casks in secondary contexts. Woodcuts, engravings, and etchings of casks with square bungs show this type of cask was common across northern Europe in the early modern period, but have been underrepresented in archaeological contexts. These casks are often strongly associated with wine, beer, and drinking, and with peasants. They suggest that some of the square bung casks from *Vasa* might have held beer, and offer a line of evidence otherwise unavailable from a strictly material culture viewpoint. Images of coopers range from thirteenth-century stained glass windows at Chartres, to Diderot's *Encyclopédie* of the late eighteenth century. These varied works exhibit a remarkable continuity, as coopers are shown in three characteristic poses of driving hoops, working with hoops, or standing near a flaming cresset. Depictions of coopers are also useful for assessing the types of tools available during the seventeenth century, which can be compared to the traces left on archaeological material. These images show the dress and workplace organization at cooperages, although they must be assessed critically and not always taken literally. Finally, a number of works exist showing casks reused in a variety of secondary contexts, which would remain otherwise unidentifiable archaeologically. Taken together, these artworks form a rich mine of evidence for interpreting the *Vasa* casks in a framework beyond that bounded by the wooden walls of the ship itself.

Although it has been a half century since *Vasa* was raised, the rich collection of artifacts still has much information to yield, not least from the abundance of casks. Study of these important containers will add to our understanding of cooperage, the organization and outfitting of seventeenth-century warships, and the economic organization and naval supply process in the seventeenth-century Baltic, an understudied field in comparison with the outpouring of scholarship on the Georgian Royal Navy. This information will benefit both the academic community and the hundreds of thousands of individuals who visit the Vasa Museum annually.

Chapter 2 – Sweden in the 1620s

This chapter aims to contextualize the casks from *Vasa* in the larger society in which they were used, Sweden in the 1620s. This will also allow the identification of some of the motivations and worldview of the individuals who stowed the casks below decks, checked the contents and quality of the provisions within, or carefully packed away their personal possessions. The casks were vital for provisioning and storage and a key component for the successful operation of the ship, and just as with the ship, cannot be understood in isolation. Sweden in the 1620s was a kingdom experiencing significant growth in almost every area of society, as part of its transformation from what many Europeans states regarded as only a peripheral kingdom into one of the guarantors of the Peace of Westphalia a scant twenty years later. The following sections explore *Vasa* and the Swedish navy in 1628, the political situation which led to the building and fitting out of the ship, the economy and society of the kingdom, and the city of Stockholm where *Vasa* was built and met her end.

***Vasa* and the Swedish Navy**

Gustav II Adolph ordered *Vasa* as part of a class of five large, three-decked warships built between 1624 and 1630. The other vessels in this series were *Äpplet*, *Kronan*, *Scepter*, and *Göta Ark* (Glete 2010: 403). Two Dutch entrepreneurs built the ship at the Stockholm dockyard under a contract system known as an *arrende*, where the crown paid the contractors a lump sum in exchange for finished products like warships. Henrik Hybertsson and his brother Arendt de Groot signed a contract with the crown in January, 1625. They laid *Vasa*'s 39 m long keel in 1626, and by the spring of 1628 the vessel was sufficiently complete to be towed from the Skeppsholmen dockyard to the Tre Kronor palace to take on guns. *Vasa* was supposed to carry a total of 72 guns, but 8 were not delivered by the time of sailing. The primary armament was 48 bronze pieces of a new standardized type, firing a 24-pound shot. This produced an impressive broadside weight of 588 pounds, making the ship one of the most heavily armed in Europe at the time and even comparing favourably with much later vessels such as USS *Constitution*. These guns were spread over two dedicated gundecks, while the orlop and hold below held stores and ballast. Brightly painted wooden carvings covered much of the ship, especially the stern, and proclaimed the power of the king while associating him with Biblical and Classical figures. Despite this imposing appearance and armament, all was not well. In the summer of 1628, Captain Söfring Hansson conducted a demonstration for Admiral Klas Fleming. As 30 sailors ran from one side of the vessel to the other, the ship heeled dangerously and exhibited serious stability problems. After continued pressure from the king, on campaign in Poland and unaware of this potentially serious problem, *Vasa* began her maiden voyage on the afternoon of August 10, 1628. The exact number of individuals on board is not known, but a manning list from the period indicates the normal complement for the ship was a captain, two lieutenants, a master, boatswain and their mates, and other specialists supervising a crew of 90 seamen and 20 gunners, for a total of 133 men. Wives, children and guests were aboard because of the festive occasion. An additional 300 soldiers would round out the ship's company once the vessel reached Älvsnabben, in the Stockholm archipelago. The crew set four sails and *Vasa* slowly made her way down Strömmen. After little more than a kilometer a gust of wind made the ship heel noticeably to port, before another gust pushed the ship even further over and water poured through the lower gunports. *Vasa* foundered about 100 m south of the small island of Beckholmen in 32 m of water. A disaster of this proportion ensured a formal inquest, where most parties involved were exonerated. Henrik Hybertsson had conveniently died in 1627, and his brother, Arendt de Groot, and successor, Hein Jacobsson, steadfastly maintained that they had built the ship the king ordered. Since the raising of the ship in 1961, a fixation has developed on *why* the vessel sank, with various schools of thought blaming either incompetent shipbuilders or an autocratic monarch pushing for an unsound and ultimately fatally flawed design. In an era before formal naval architecture and when warships routinely rode with their lowest tier of gunports close to the water, it should be remembered that *Vasa*'s design was not particularly unusual and perhaps she might have enjoyed a longer career if fully laden and under different command (Hocker 2006: 39-60). While *Vasa* is often now viewed as a sort of white elephant or monument to bad decision making, Fred Hocker has pointed out that this is a rather limited perspective since the other vessels in the class served successfully for a generation. Rather, *Vasa* should be seen as part of a larger pattern of military innovation, where prototypes sometimes fail dramatically (Hocker 2011: 145)

In 1628, the Swedish navy could already boast of a tradition stretching back more than a century. In fact, it was a force of armed merchantmen hired from Lübeck which proved instrumental in Gustav Eriksson's establishment of the Vasa dynasty in 1522. Purpose-built Swedish warships also achieved notable success during the Nordic Seven Years' War (1563-1570) (Glete 2000: 117-124). Karl IX built an impressive fleet at the turn of the seventeenth century, but mismanagement and reverses in the Kalmar War (1611-1613) almost halved the available naval tonnage from 26,000 to 14,000 tonnes by 1612 (Glete 2010: 392-393). It was in this context that the new Chancellor, Axel Oxenstierna, devised a long-term shipbuilding program in 1616. He envisioned a navy of 40 warships composed of eight large *royalskepp* with 200 men each, plus 20 medium-sized ships, a dozen pinnaces, and various transport craft (Glete 2010: 395). This ambitious plan produced significant results; by 1624, Gustav II Adolph possessed a navy of 23,000 tonnes composed mostly of modern, heavily armed warships built since 1620. *Vasa* formed part of a string of losses in the second half of the decade which eliminated much of this growth, however. Gales in 1625, a naval action off Danzig in 1627, and accidents resulted in the loss of 18 warships of almost 10,000 total tonnes between 1625 and 1628 (Glete 2010: 400-403).

Administratively, the navy in 1628 was in transition from the experiment with the contractual *arrende* system to a formal Admiralty Board (*Amiralitetskollegium*), established in 1634. Entrepreneurs like the Hybertssons produced ships, while others manufactured iron ordnance. The crown retained control of the production of bronze guns, while the Treasury took care of provisioning. Perhaps the *Vasa* debacle provided a catalyst for change, as the king decided to end the contract system in Stockholm in 1628. Admiral Klas Fleming took control of the Skeppsholmen yard and naval base and administered them from the Treasury (Glete 2010: 291-297). The navy recruited seamen largely through conscription, using methods similar to those of the army. Jan Glete has made the point that, while Sweden lacked a large population of merchant seafarers to form a nursery of seamen, as in many western European countries, much of the work on a sailing warship merely requires muscle power with some coordination (Glete 2010: 580-581). This concept is supported by *Vasa*'s rig, which was "optimized for a large crew of unskilled labor directed by a few experienced men" (Hocker 2011: 95). From 1623, the navy divided its personnel into four provincial companies to provide a permanent organisational framework. Peasants consented to provide a fixed number of recruits for the navy rather than face conscription themselves, while a company of long service seamen provided a professional nucleus. Between 1624 and 1628, there were approximately 2,300 to 2,400 men in the navy (Glete 2010: 598-599). This figure compared favourably with the naval manning plan for 1628, which called for 1,955 seamen and 2,700 soldiers for a total force of 4,655 men (Glete 2010:

587). The number of soldiers in the manning plan represents 58% of the total naval personnel, and suggests soldiers remained important for less skilled labour and gunnery, and that boarding still decided many engagements.

Strategically, *Vasa* could have been employed in several roles as part of a larger battle fleet. Large, heavily armed warships could operate defensively and protect Sweden's coasts from invasion. Offensively, the fleet could cruise against the old enemy in Danish waters or lurk around the centrally located island of Bornholm. Amphibious operations remained another main task of the navy (Glete 2010: 41-43). The navy's abilities in power projection became readily apparent in 1621, when it landed a force of 18,000 soldiers who captured the important city of Riga after a siege of six weeks (Frost 2000: 103). The navy could also blockade enemy ports to disrupt trade or collect tolls. The Swedish blockade of Danzig resulted in one of the few naval battles in the Baltic during the 1620s, and illustrates several features characteristic of period engagements. On November 18, 1627, the Polish Admiral Dickmann emerged with ten ships to engage the Swedish force of seven vessels under Vice-Admiral Stiernskold. The Swedes got the worst of it; *Tigern* surrendered and a crewman detonated *Solen*'s magazine after the Poles boarded her. The commanders on each side were killed. Ships at the Battle of Oliwa had only single gundecks, armed with an assortment of non-standardized guns. The commanders proved unable to coordinate their forces and only about six or seven of the 17 ships present actually took part in the fighting. Instead, ship-on-ship duels and boarding decided the outcome (Guthrie 2001: 263). Compared with the vessels involved in this action, *Vasa* represented the future with her two dedicated gundecks and powerful armament of standardized pieces.

The Political Situation in the 1620s

In 1628, *Vasa* formed one part of the state's military machine in an ongoing dynastic dispute with Poland, but other war clouds gathered on the horizon. Ever since his accession to the throne as a teenager in 1611, Gustav II Adolph had to contest his right as the legitimate ruler of Sweden against the claims of his cousin, Sigismund of Poland. Sigismund was elected king of Poland in 1587, but later inherited the crown of Sweden. His absentee rule and Catholic faith did not endear him to most Swedes, and helped Gustav Adolph's father, Duke Karl, depose him in 1599. Sigismund, however, never relinquished his claims as rightful ruler of Sweden (Ringmar 1996: 98-99). Simmering conflict erupted into open warfare in 1621, when Gustav Adolph invaded Livonia and captured Riga. This was followed by a truce which lasted four years. The king won notable victories over the Poles at Wallhof in 1626 and Dirschau in 1627, but the campaign of 1628 proved inconclusive and many soldiers began to desert in the autumn (Frost 2000: 104, 110). During these years, Swedish involvement in the wars in Germany became a distinct possibility, especially after the Treaty of Altmark in 1629 concluded the Polish war on terms favorable to Sweden. Christian IV of Denmark's disastrous foray into the German war ended with Wallenstein's imperial troops overrunning most of his kingdom, and threats of a Hapsburg naval base on the southern shore of the Baltic. In the summer of 1628, Sweden agreed to defend the northern German port city of Stralsund against Imperial forces (Palmer 2005: 102). The king divided the navy into three main squadrons: one to blockade Poland, a second to relieve Stralsund, and a third in reserve at Älvsnabben, to which *Vasa* was sailing (Hocker 2011: 65). Gustav Adolph (Figure 1), also used his powerful rhetorical skills to prepare for war. As the king presented the issues before the Council of the Realm and *riksdag*, the matter was not *if* the kingdom would go to war in Germany, but *when*. Since war was inevitable, the only matter

FIGURE 1. King Gustav II Adolph of Sweden (1594-1632), from a seventeenth century German engraving. *Vasa* was ordered as part of his effort to secure Baltic hegemony (Zijlma 1986: 191).

was to decide if it should be fought defensively, on Swedish soil, or offensively on foreign ground. Once the debate reached this stage, the councillors and estates were sure to endorse an overseas war as the only sensible option (Ringmar 1996: 125).

Gustav Adolph and an army of 12,000 men landed on the north German coast in June 1630, providing another example of the impressive amphibious capabilities of the Swedish navy but perplexing generations of historians, who sought to explain the country's involvement in the Thirty Years' War. Some reference should be made to this historiographical debate. Traditionally, historians explained Swedish expansion as either a quest for security against encircling enemies, or as an effort to secure increased revenues from Baltic trade (Lockhart 2004: 13-14). Erik Ringmar (1996) suggests the march to war was predicated instead on the king's desire to assert himself and his nation as great actors on the world stage, which is perhaps not as farfetched as it might sound. Jan Glete has identified a profound Anglo- or continental Eurocentric bias in most of these explanations, which reduce Sweden to a "backward" nation on the "periphery" of Europe. Against the idea of either political or economic encirclement, he argues that Sweden's neighbours did not resent the country as long as it remained within its pre-1561 borders, and that Danish control of the Sound actually proved beneficial for all parties involved. In Glete's view, the extent to which Swedish society could be mobilized for war in the seventeenth century is evidence of a modern, highly efficient state, certainly not backward, while Sweden can only be considered peripheral from a continental perspective (Glete 2010: 28-36). He turns accepted historiography on its head when he claims "it is more realistic to describe Sweden's neighbours as unfortunate victims of *their* geostrategic position" (Glete 2010: 37). In Glete's paradigm of state formation, Sweden was successful not because it had the most resources, but because it used those resources most effectively.

Economy and Society

The Swedish economy in the 1620s remained largely based on primary resource production and subsistence agriculture, as it had for centuries, but foreign trade and investment were growing rapidly under royal patronage. The country possessed enormous reserves of copper, iron, and timber, and as Jan Glete observes "more than any other early European state, Sweden was independent of the foreign supply of arms and naval stores" (Glete 2002: 180). The Copper Mountain or *Stora Kopparberget* at Falun produced the majority of Europe's copper. From 1619, the king attempted to control copper exports through the creation of a monopoly company, until the demand for copper in Amsterdam collapsed in 1625. Foreign entrepreneurs were crucial in expanding and modernizing iron production; and in 1629, the Dutchman Louis de Geer informed the king that the country was now self-sufficient in arms production. Dutch and Prussian merchants encouraged Finnish peasants to produce pitch and tar, vital naval stores, and were exporting over 80,000 barrels annually by 1637 (Kirby 1990: 148-149). This economic growth was impressive since the overall level of trade in the Baltic declined during the 1620s and 1630s (Israel 1990: 121). The level of grain carried through the Sound fell from 100,000 lasts annually in the years 1618-1621 to only 30,000 lasts by 1625. The Swedish armed forces aggravated this situation through a blockade of Danzig from 1626 to 1629, and the destruction of agricultural land in northern Poland (van Tielhof 2002: 47-48).

Despite an impressive arms industry, the economy of early modern Sweden was characterized by the export of primary goods and the import of manufactured goods and primary goods which could not be produced locally. This trade is summarized in *Civitates Orbis Terrarum*, which appeared in six volumes between 1572 and 1618.

> The chief imports of these seaside towns are: German and English cloth, salt, hops, wine, beer, wheat, fruit, fine linen, velvet and silk, many kinds of gold and silver ornaments and all sorts of furniture. On the other hand, the following goods are exported from the various districts of Sweden via Stockholm to Germany and elsewhere: iron, ore, steel, casks, many kinds of fish, martin and sable skins and others of smaller value, also tallow, butter, cheese, horses and so on (Braun and Hogenberg 1955: 125).

A study of customs records for the Stockholm-Danzig trade in the year 1643 reveals that this pattern of trade remained fairly consistent a generation later. Iron constituted 85% of Stockholm's exports to Danzig, while in turn manufactured goods such as textiles, clothing and glassware formed 32% of the imports (Bogucka 1980: 113-114). A fifth of the 166 ships recorded as entering Stockholm harbour that year hailed from Danzig, while almost a third originated from north German ports like Stralsund and Lübeck, illustrating the importance of inter-Baltic exchange, as well as Sweden's relatively limited participation in international trade. The majority of the 175 outbound vessels were still bound for Dutch ports, and serve as evidence for the well-established economic links between the United Provinces and Sweden (Bogucka 1980: 110). Maritime trade with Stockholm was regulated by ice conditions (Leijonhufvud et al. 2010: 110), which halted sailing for several months altogether each year. Official correspondence from 1502 to 1637 noted the *första öppna vatten* or "first open water" each spring, which allowed sailing to resume (Leijonhufvud et al. 2010: 121). These conditions meant that the Baltic sailing season generally ran from March to October (van Tielhof 2002: 211), although the navy began sailing later into the fall and eventually developed year-round capabilities (Fred Hocker 2012, pers. comm.).

Although total Dutch trade with the Baltic declined in the period from 1621 to 1640, this was offset by their increased control over the supply of luxury goods and cloth to the region (Israel 1990: 143). Trade with Russia grew after the Treaty of Stolbova in 1617, which secured more territory around the Gulf of Finland for Sweden and effectively cut Russia off from direct access to the Baltic. The first recorded merchant from Novgorod arrived in Stockholm in 1622, harbinger of a successful trade which saw Swedish copper and iron exchanged for Russian furs, flax, hemp, textiles and leather (Šaskolskij 1986: 44-47). The importance of dairy products and preserved fish in the economy is recorded by the inveterate compiler Olaus Magnus, in his *Description of the Northern Peoples* of 1555. "As you pass through the individual provinces of the northern region…you can find everywhere a huge quantity of butter," purchased by "merchants from overseas [who] take many thousands of great casks" (Magnus 1555: 661-662). Magnus praises the cheeses from the Västgötar and Östgötar regions (1555: 662-663), before discussing the merits of salt fish in his third volume. He notes that "immense numbers of wholesome fish are given the stamp of approval by the authorities and, to gain a good profit, are exported to distant lands in barrels designed for the purpose" (Magnus 1555: 1060).

The crown's mercantilist effort to control trade manifested itself in the creation of the staple system. Decrees of 1614, 1617, and 1636 divided towns into "staple" and "hinterland" communities, with the former generally located on the coast and the latter inland. Staple towns could participate in foreign trade, while the hinterland or *uppstäder* towns were limited to local trade and supplying the larger staple towns. These *stapelstäder* further dominated the hinterland towns through their comparative advantage in capital. Staple town merchants could extend generous credit directly to peasant producers and eliminate the role played by small town burghers (Lilja 2002: 65-66). Crime statistics from the sixteenth century provide evidence of the crown's increasing efforts at economic regulation. Laws set standards for merchandise, weights and measures, as well as customs duties and the movements and dealings of local and foreign merchants. Punishment for infringement of these regulations peaked in the 1570s, when commercial offences accounted for 40 percent of all fines imposed in Stockholm (Lindström 1988: 117-118). Arriving and departing vessels were taxed both by the Crown and the city. The Crown collected the Great Sea Toll from 1533 onwards after curbing the powers of the Hanseatic League, while the city levied a fee known as the *Tolag* to pay for municipal works (Leijonhufvud et al. 2010: 116).

The imposition of taxes and tolls on foreign territories yielded another lucrative source of income. The king and his administration embraced the pragmatic attitude of *bellum se ipsum alet* or "war must pay for itself," and so the territories in Prussia provided 700,000 *riksdaler* during the winter of 1627-1628. From 1626, a naval squadron collected tolls from ships entering Danzig. In the following two years, the toll system expanded to cover other ports under Swedish control such as Stralsund and Memel, yielding a total of 584,000 *riksdalers* in 1629 (Roberts 1973:122-123). These are not insignificant sums if one considers that the annual income of the country that year is estimated at 9.2 million *daler*, and expenditures as 11.3 million *dalers* (Åström 1986:137). Hocker, however, has pointed out that caution is needed when interpreting Swedish financial figures from the 1620s. For domestic transactions Swedes traditionally used a silver currency based on the unit of the *daler*, composed of 4 marks or 32 *öre*. Another silver coin known as the *riksdaler* was reserved for transactions with foreign states or merchants. In 1624, Gustav Adolph introduced copper coinage which quickly declined in value relative to silver, so that within five years a copper mark was worth only 43% of a silver mark. The existence of the two parallel currencies has sometimes confused modern historians. The nearly 4,000 coins from *Vasa*, however, are almost exclusively copper and demonstrate the importance of these low denomination coins in people's daily lives. Some idea of the relative prices in Sweden in 1628 can be derived from the following figures. While the contracted price for *Vasa*, without rigging, was 40,000 *dalers*, her captain received an annual salary of 450 *dalers* and a common seaman received 48 *dalers* a year. A litre of beer cost about 1.5 *öre* while a pair of boots would set the purchaser back 6 *öre* (Hocker 2006: 16-17). The ship was over budget, and the final cost to build *Vasa*'s hull was 53,300 *dalers*. It is possible this cost overrun was due to inflation caused by the collapse of the newly introduced copper currency (Hocker 2011: 44).

In 1628, the kingdom itself did not entirely correspond to the modern territory of Sweden. Finland remained part of the realm, and was an important source of natural resources and conscripts. The 1617 Treaty of Stolbova ceded the regions of Karelia and Ingria to Sweden, and eliminated direct Russian access to the Baltic. The Polish campaigns of the 1620s added most of the modern states of Estonia and Latvia to Swedish territory. Denmark-Norway, however, still controlled large portions of modern Sweden, including the southern provinces of Scania and Blekinge, Bohuslän and Halland in the west, Jämtland in the north, as well as the important Baltic island of Gotland (Frost 2000: 370-371). The population of Sweden and its territories in the 1620s remained small by European standards – perhaps 1.25 million in total, although this number would effectively double by 1660 with the addition of further territories (Glete 2002: 179). The vast majority of these 1.25 million people lived in rural areas. In the early seventeenth century, perhaps no more than 4% of the population lived in an urban setting. Most towns had less than 500 residents, although the decade of the 1620s saw many new towns founded and impressive growth in Stockholm as it truly became a capital city (Lilja 1994: 240-241). The total number of towns grew from about 70 to over 100 in this period and the urban population as a whole increased from 50,000 to 120,000 (Lilja 2002: 55). Household size varied by region, but averaged between 4.7 and 6.7 people per household prior to the third quarter of the eighteenth century (Palm 1999: 87).

Agriculture was important, but Danish control of the southern provinces meant that it was mostly confined to the Mälaren basin (Glete 2002: 178). Peasants grew barley, rye, wheat, and oats, depending on the nature of the soil and the length of the growing season. Coarse bread formed the major component of the diet for most people, and Vilhelm Moberg claims that "not until some way into the 20th century did white bread become the Swedish people's daily bread" (Moberg 1973: 37). Food insecurity and famine were not uncommon occurrences. A particularly severe famine struck Sweden between 1596 and 1598 and the peasants resorted to eating bread made from tree bark (Moberg 1973: 43). A cool climate limited the already short growing season. The coldest decade of the last five hundred years in the Stockholm region was 1567-

1576, while the decades of 1614-1623, 1624-1633, and 1592-1601 are ranked as the second, fourth, and fifth coldest decades on record in the area (Leijonhufvud et al. 2010: 131).

Despite a harsh climate and frequent warfare, the peasants proved remarkably resilient to hardship and the overall cohesiveness of Swedish society was one of its major strengths. Society was formally organized into four estates: nobles, clergy, burghers, and peasants. Each estate was represented at the Parliament (*Riksdag*) which met regularly, and also served as an effective political theatre where Gustav Adolph could employ his rhetorical talents to rule through persuasion. The Lutheran Reformation became firmly established in Sweden during the sixteenth century and was an invaluable tool of the state. Priests kept detailed parish records necessary for effective conscription and transmitted royal propaganda to their parishioners (Lockhart 2004: 31-32). Swedish society was increasingly militarized during the 1620s, as the crown demanded more men and matériel to maintain the ongoing conflict in Poland and the anticipated intervention in Germany. In 1628, a total of 10,351 soldiers were conscripted in Sweden and Finland, the third highest annual total between 1626 and 1659 (Åström 1986: 145). The king reorganized the system of conscription beginning in 1620, to make it more efficient. All peasants older than fifteen were grouped into *rota* of ten men, or twenty if they lived on noble lands, and registered for possible service. Draft boards composed of the local baliff, priest, and six reputable citizens then selected conscripts from the *rota* as required (Lockhart 2004: 33). Few men drafted into the army returned, which led Geoffrey Parker to conclude “enlistment was thus virtually a sentence of death and its demographic impact was profound” (2007: 173). Records from the village of Bygdeå in northern Sweden show that 215 of the 230 men conscripted between 1621 and 1639 never returned home, while the number of adult males in the community declined from 468 in 1621 to only 288 in 1639 (Parker 1988: 53). Bygdeå is an extreme example of the effects of conscription, and the death toll in naval service was less severe. Despite the widespread use of mercenaries in the armed forces, there always remained a core of about 40,000 Swedish troops which represented approximately 3.5% of the entire population (Glete 2002: 205). People in Sweden in 1628 were familiar with war, military service, and the hardships brought about by conscription.

The City – Stockholm in the 1620s

The city in which *Vasa* was built, launched and met her end was still largely medieval in appearance, but changing quickly. A settlement existed on the islands and shores of Saltsjön Bay and Lake Mälaren from at least 1252 onwards, which by the end of the sixteenth century contained between 8,000 and 9,000 people. In 1582, there were 429 stone and 164 timber or half-timbered buildings in Stockholm. In the early seventeenth century, the city began to expand beyond this medieval core of tightly packed houses on Stadsholmen, encircled by a defensive wall. The new suburbs of Norrmalm and Södermalm sprang up, built almost entirely of wood. Many workers in the navy yard lived in Norrmalm, which administratively remained a separate town until 1635 (Lindström 1988: 68). Two views of the city (Figure 2, below), appeared in *Civitates Orbis Terrarum* between 1572 and 1618. The upper view, from the north, shows a skyline dominated by the Tre Kronor palace. Most houses are still clustered around the palace, although newer timber houses in Norrmalm are visible in the foreground. The semi-circle of timber pilings visible in the harbor might be a defensive blockade, linked with booms that could be raised or lowered. Between 1603 and 1620 a fee known as the *pålpenning* or "pole penny" was levied to pass through this blockade (Leijonhufvud et al. 2010: 119). These pilings might also have been used as dolphins to allow ships to warp away from the waterfront (Hocker 2011: 121). The lower view shows the city from the south, and there appears to be little development in

Södermalm besides some mills to the west. In 1628, the city was recovering from the fire which had gutted much of the Old Town (Gamla Stan) three years previously. The destruction permitted the laying out of more regular streets and an extensive program of rebuilding. Almost one house in two was rebuilt or remodelled during the seventeenth century (Råberg et al . 1980: 291-293).

FIGURE 2. Two views of Stockholm in *Civitates Orbis Terrarum*, (ca.1572-1618) show that the city remained largely confined to the islands of Stadholmen and Riddarholmen in the early seventeenth century (Braun and Hogenberg 1955: 126-127).

The city expanded commensurately with Sweden's role on the world stage but remained quite small by European standards. When Swedish forces captured Riga in 1621, the city's population of 30,000 was likely three times that of Stockholm (Frost 2000: 103), but Crown efforts at centralization and mercantilist reform encouraged growth in the capital. Prior to the reign of Gustav Adolph, the court remained highly mobile. It could be argued Stockholm did not even become a capital until after 1611, when it became the centre of administrative, military and naval activity. There were likely as many crown servants as burghers, who made up 40% to 45% of the city's residents. Stockholm also benefitted enormously from the staple system instituted by Oxenstierna in 1614, which channelled most of the country's foreign trade through the city (Sandberg 1992: 297-300). Despite impressive growth, Stockholm remained underwhelming to most foreign visitors in this period. The Council was acutely aware of this fact and even discussed how to minimize the number of foreign guests at the king's funeral in 1634. Their fears proved well-founded after a French representative dismissed the city as "tied to a few naked rocks" (Sandberg 1992: 313). Most of the grand architecture visitors see today dates from the second half of the seventeenth century and later. *Vasa* and her crew sailed from a much humbler town.

Overall, growth and transformation characterized almost every aspect of Sweden during the 1620s. *Vasa* represented the trend towards modernization in a navy expanding in terms of both overall tonnage and personnel. The navy was experienced and capable of both amphibious operations and blockade. Protracted conflict with neighboring states meant that peace was the exception rather than the rule in most people's lives. The prospect of war in Germany meant increased demands on an already heavily militarized society, where people were familiar with service and conscription. The charisma of the king built on a homogenous society to ensure that most were willing to serve and make sacrifices. An economy traditionally based on primary resource production and export became more diversified as foreign entrepreneurs brought new skills and knowledge. Most common people, however, were still used to a simple material culture revolving around wood, and an unsophisticated diet. *Vasa* and the casks stowed within offer a snapshot of an ambitious society poised on the brink of greatness.

Chapter 3 – Site Formation, Collections Management, and Methodology

In order to fully appreciate the strengths and limitations of this study, as well as the conclusions drawn, it is necessary to understand how the cask collection arrived in its present form. Taphonomic processes on the wreck site influenced the condition, number, and location of casks in the archaeological record. The excavation and recording strategies employed by divers and archaeologists in the period 1956-1967 form the basis for interpreting the casks and their distribution. Conservators succeeded in stabilizing and preserving the casks, although the techniques used created challenges for future interpretation and recording, as did the efforts of collections managers in the 1980s. In turn, the methodology developed during the course of this study was based on the nature and condition of the collection, the existing museum system for organizing artifacts, and the work of other students of historic cooperage.

Site Formation

Vasa remained underwater for 333 years after sinking in 1628. During this time, a variety of human and natural agents influenced the condition of the wreck and artifacts within. It seems likely that most of the casks stowed in 1628 remained on the wreck. Some might have floated away during sinking and shortly thereafter, but these would only be some of those on the weather or gun decks. While we will never know with absolute certainty the exact number of casks on board, we can be sure that the vast majority remain as the wreck represents much of the archaeologist's ideal of a "closed context." The structure of the ship hindered the movement of objects from their original locations, although hatches allowed some mixing between decks. Some modern material found its way onto the site, hardly surprising given the location of the wreck in a major shipping channel (Cederlund 2006: 328). *Vasa* lay in Stockholms Ström, which carries the sediment laden waters of Lake Mälaren towards the Baltic. The weight of the wreck pushed it through the soft sediment on the bottom of Strömmen to the firmer grey glacial clay beneath. Silt and mud settled out of the water column so that eventually all decks were covered with at least a meter of sediment. Clay and silt formed the bottom component of this layer while more fluid mud remained above. These layers of sediment helped preserve the site by creating a largely anaerobic environment, and inhibited the movement of artifacts (Hocker and Wendel 2006: 150). While the cold, murky waters of Strömmen preserved wood and organic material, almost no ferrous metal survived. The constant flow of water "acts like a low-speed sandblasting machine" and eroded the surfaces of wooden objects exposed to the water column (Hocker and Wendel 2006: 148-149). This is readily apparent on many of the cask parts found outside the ship or on the upper gundeck, where they were not covered by a protective blanket of mud. Erosion makes it more difficult to determine original dimensions and features, and is pronounced on this head piece currently on display.

FIGURE 3. Pine head piece with incised gaming board, showing pronounced effects of erosion. (Photo by author, 2010.)

Humans certainly played a role in the formation of the site. Salvage efforts in the year following the sinking resulted in many anchors stuck fast in the side of the wreck, while salvors in the 1660s removed most of the weather deck planking to get at the valuable bronze guns. From the mid-nineteenth century, a significant amount of blasting rubble was dumped on the site during the construction of drydocks on nearby Beckholmen (Hocker and Wendel 2006: 151). Using Muckelroy's paradigm of site formation (1978: 159-176), we see that his "extracting filters" have little influence here, as little material was lost through either the wrecking event or disintegration, besides the guns removed by salvors in the 1660s. His "Scrambling Device A – the process of wrecking" is somewhat relevant in understanding the artifact distribution, as some of the material on board might have shifted to port during the sinking. The second Scrambling Device of "sea-bed movement" has little application to the distribution of artifacts, which remained relatively static after deposition, but could encompass the hydrological effects of water erosion on the artifacts. Employing another paradigm, we could refer to the natural taphonomic factors at work at the *Vasa* site as N-transforms, and the effects of salvors as C-transforms (Schiffer 1976: 14-15). Regardless of the terminology we employ regarding site formation, the level of preservation on *Vasa* is truly remarkable and it is estimated that the vessel retains 98 percent of its original timber (Hocker 2011: 197).

Excavation and Recording Techniques

The excavation of *Vasa* can be divided into two phases: work underwater primarily devoted to raising the ship, from August 1956 until April 1961, followed by complete excavation of the interior from April to September, 1961. The location of the wreck was never entirely forgotten, and, in 1956, Anders Franzén and Per Edvin Fälting relocated *Vasa* using a primitive grapnel and coring device (Cederlund 2006: 176-177). Initial dives confirmed the size and impressive preservation of the wreck; and, by the end of the year, the Navy, National Maritime Museum (SSHM), and Neptunbolaget salvage company discussed the possibility of raising the entire ship (Cederlund 2006: 184). Neptunbolaget decided that the most effective method was to use lifting pontoons on the surface, attached to either end of cables passed beneath the wreck. Between 1957 and 1959, Navy divers in hardhat dress dug six tunnels underneath the wreck for the lifting slings; and in a series of 18 lifts beginning in August 1959, Neptunbolaget moved *Vasa* into shallower water (Franzén 1960: 15-17). Divers continued to lighten the ship by removing overburden on the upper decks and made the hull as watertight as possible (Cederlund 2006: 276), so that it could be successfully raised on April 24, 1961 (Cederlund 2006: 290). Altogether, the divers recovered approximately 4,000 objects (Cederlund 2006: 444), including several small casks and many cask parts. The cask parts recovered by the divers are readily identifiable because of their light colour, rather than the dark, almost black colour of all other wood in the collection, and suggest a slightly different conservation treatment than that adopted later. While some of these casks are likely associated with the ship, the provenience of others should be suspect. Head 23534, for example, is recorded as coming from outside the ship on the port side. This head is unique in the collection for having a reinforcing *barre* which slides horizontally across the other head pieces to hold them in place. The uniqueness of this head raises the question as to whether it is contemporary with the casks inside the ship or intrusive material, a concern which applies to much of the material recovered from outside the wreck by divers.

The first rudimentary system for plotting and registering finds was created during this period. Divers numbered the deck beams from the stem aft (Cederlund 2006: 277), and recorded

FIGURE 4. Head 23534 is unique in the collection for the reinforcing barre which extends across the head pieces. Its find location outside the ship, however, raises the question as to whether it is contemporary with the other artifacts or intrusive, a concern which applies to much of the cask material recovered outside the wreck. (Photo by author, 2011.)

the position of finds by deck, and in relation to the nearest deck beam and location either to port or starboard of the centerline of ship. From 1957, finds were registered sequentially, numbered with embossed copper strips and later waterproof cardboard tags (Cederlund 2006: 250). Many of the staves and head pieces raised by the divers still bear these original tags, which have not survived well. The copper strips are corroded and difficult to read, and several of the cardboard tags are sufficiently faded to be illegible. Despite the divers' lack of archaeological training and the difficult conditions in which they worked, one must agree with Cederlund's (2006: 290) assessment that they "not only accomplished a unique feat of salvage, but had also carried out archaeological work of a commendably high standard."

From April 25 until the end of September 1961, Per Lundström led a team of eleven archaeologists to completely excavate the interior of *Vasa*. The task was daunting, as they were dealing with an "essentially intact, four-story structure full of its original contents" (Figure 5) (Cederlund 2006: 298). It should also be remembered that the fields of both historical and maritime archaeology were in their infancy in 1961, so there was little precedent to rely upon both in terms of training and methodology. Excavation proceeded deck by deck. First, the upper and then the lower gundecks were cleared, followed by the hold, and finally the orlop, which was the least disturbed of the four decks. Thick layers of sediment coated all the decks, but were divided into two distinct strata. A layer of firmer mud and clay directly above the deck surfaces contained the vast majority of artifacts, while a layer of liquid mud above remained fairly sterile. The loose consistency of the sediment matrix within the ship allowed the use of spray hoses and screens as the chief excavation tools. Two or sometimes three teams often worked simultaneously on different areas of the same deck, and generally one deck was completely cleared before moving onto the next. Finds were registered in specially prepared notebooks, with a separate page for each find number, and space for a quick sketch and some basic dimensions. Scale drawings and photographs supplemented this record (Cederlund 2006: 299-300). The two gundecks were the most disturbed by the salvage efforts in the 1660s and from 1957-1961. There was also some movement of material between decks via the hatchways. The level of disturbance influenced the recording strategy, with more scale drawings made of the storage decks where finds were more likely to remain completely in situ (Cederlund 2006: 409). Cask parts found as individual elements were recorded as such, but the excavators attempted to keep whole casks or nearly whole casks intact and ensure that individual components retained their original association as part of the same container. Differential preservation meant that wooden hoops and their bindings

FIGURE 5. *Vasa* in drydock on Beckholmen, May 5 or 6, 1961. The steel cylinders are submersible lifting pontoons. The archaeological team is visible working in the Great Cabin area. The team was faced with the challenging prospect of excavating an “essentially intact, four-story structure” under tight time constraints. (Courtesy of the Vasa Museum, Stockholm.)

often decayed faster than the oak or pine staves, leaving a circle of splayed out staves clearly part of a single container. Where possible, especially on the less disturbed lower decks, casks found intact were block lifted (Figure 6) as complete units for later analysis. Unfortunately, Cederlund notes that "detailed reports on the investigations of these closed finds were not written or have not survived" (Cederlund 2006: 404).

FIGURE 6. Intact casks were block lifted, where possible, for later analysis. This image also gives of an idea of the challenging conditions which faced the excavators. A young Hans Soop is visible on the right. (Courtesy of the Vasa Museum, Stockholm.)

The archaeologists recorded a total of 14,034 find numbers during the excavation. Artifacts were numbered sequentially from the series begun by the divers, but were labelled using circular stainless steel discs with stamped numbers rather than the earlier copper or cardboard tags. These *fyndbricka* (Figure 7), measure 30 mm in diameter by 1 mm thick. Most objects have a unique find number (abbreviated as FNR in place of *fyndnummer*), although some groups of objects were lumped together under a single number. Most objects were numbered in the order in which they were found, although there were often several groups of archaeologists working simultaneously, each with a set of fifty numbered *fyndbricka* (Cederlund 2006: 302). On occasion, this creates the slightly confusing situation where a group of objects with sequential numbers come from noticeably different locations, and means that sequential numbers alone cannot be used as a tool for establishing connections between objects.

FIGURE 7. Example of a stainless steel *fyndbricka* or FNR disc used to number artifacts, replacing earlier copper or cardboard tags. Unfortunately, many of the casks and cask parts have lost their *fyndbricka* over the years. (Photo by author, 2011.)

The excavators continued to use the earlier system for recording the provenience of finds, using the internal structure of the ship as reference points. The decks themselves created a system of vertical control, while the numbered deck beams, from 1 to 27, created reference points within a deck. The “rooms” created between two deck beams were then divided into port (BB for *babord*), midships (MS for *midskepps*), and starboard (SB for *styrboard*) sections to further refine the recording process. The decks are abbreviated as the ÖB (upper gundeck, *övre batteridäck*), UB (lower gundeck, *undre batteridäck*), TD (orlop, *trossdäck*), and HS (hold, *hålskeppet*) (Cederlund 2006: 304). This system continues in use as the chief means of recording the provenience of objects. Here is a sample entry for a single stave:

19114 TD BB 7-8

This indicates that the stave was assigned find number 19114, and was found on the orlop or *trossdäck*, between deck beams 7 and 8, and on the port (BB) side of the ship. The archaeological team successfully completed the enormous task of excavating the interior of the vessel and recording the contexts within, but now the challenge of conserving all this material lay ahead.

Conservation

Material recovered during the salvage operation and excavation was stored in temporary tanks on Beckholmen, near where *Vasa* sank, as plans for conserving and restoring the ship crystallized. In 1963, Per Lundström estimated there remained approximately 21,000 loose objects to conserve – 4,000 from the underwater salvage work, 16,000 from the interior, and another 1,000 objects retrieved in a further season of diving in 1963 (Cederlund 2006: 444). The majority of these objects were wooden. This posed another obstacle, as so much wet archaeological wood had never been conserved before. When wood is submerged for long periods of time, water replaces the cellulose in the cells, creating an object that, while maintaining its external appearance, is actually very fragile (Cronyn 1990: 250-255). Oak is very resistant to decay underwater, but this is also a factor of the size of the timber. The structural timbers of the ship remained sound because of their low surface area to volume ratio, and because the exterior sapwood had been stripped away (Hocker and Wendel 2006: 147). Barrel staves, even when made of oak, would often be more waterlogged than larger timbers because of their high surface area to volume ratio. Cask components in the collection are rarely more than 20 mm thick and additionally, many are of pine which deteriorates more rapidly than oak. The conservation regime decided upon was to stabilize the wood by replacing the water in the cells with the synthetic polymer polyethylene glycol, or PEG. When the wood is placed in a heated PEG solution, the water gradually evaporates and the wax fills and strengthens the cell cavities. At the time this, was still a very new technique, the process having only been patented by two Swedes in 1960 (Grattan 1988: 240).

The immersion treatment of the loose wooden objects from the ship began in 1962, in two large tanks where oak and pine material were mixed together (Håfors 2010: 492). A total of twenty batches of loose wooden objects received the PEG immersion treatment between 1962 and 1977 (Håfors 2010: 312). Eventually, the procedure was refined so that the objects were sprayed with a different molecular weight of PEG after being removed from solution (Håfors 2010: 452). The conservation program succeeded in stabilizing and preserving the artifacts, although there were some drawbacks to the PEG immersion treatment. The conserved objects have a dark, almost black colour and waxy finish. This obscures details like tool marks, wood grain, and other marks carved onto the casks. Figure 8 shows a stave with a particularly thick coat of PEG. It is possible to remove excess PEG with warm water and a soft cloth, but this is a time consuming process. Figure 9 shows head pieces 17267 and 17268 with patches of surface PEG cleared away to expose the natural wood surface beneath. While PEG immersion remains a standard conservation treatment today, it has been refined during the intervening half century.

Conservators processing the casks from the 1565 wreck of the Basque whaler *San Juan* used PEG immersion followed by freeze drying, rehumidification, and surface cleaning (Loewen 2007: 6). The result is material that retains a more natural looking wood surface, and is easier to study as a result. Still, one must remain impressed by the skill of the Vasa Museum conservators in the 1960s, using relatively untried technology to great effect.

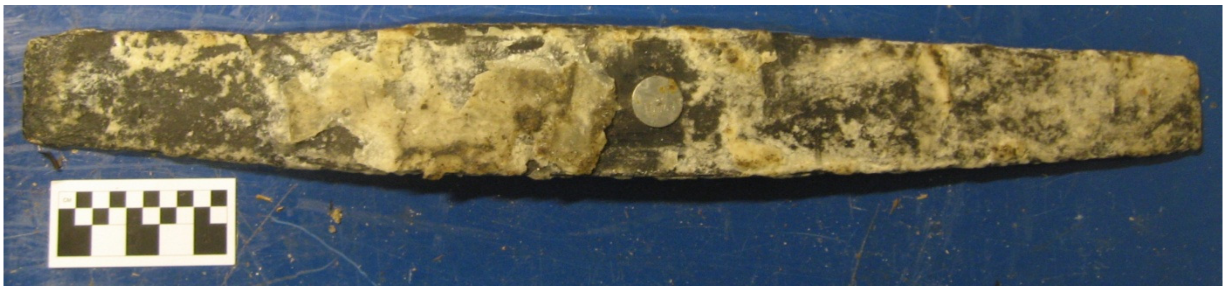


FIGURE 8. The PEG immersion treatment used to conserve the casks posed problems for study on occasion, as this stave with a particularly thick coat of PEG demonstrates. (Photo by author, 2010.)

FIGURE 9. This image shows the contrast between dark, waxy surface found on the majority of the casks, and the natural wood surface underneath. Surface PEG made it difficult to detect tool and other marks on occasion. (Photo by author, 2010.)

Collections Management

The process of managing the large collection of artifacts from *Vasa* began as early as 1957 with the recovery of the first objects, and only accelerated after the excavation of the interior in 1961. The ship itself was enclosed in a purpose-built structure while undergoing years of PEG spraying, while loose finds were kept on Beckholmen and on a nearby barge (Cederlund 2006: 431-432). The finds were catalogued in more detail, photographed, and a comprehensive find register on index cards created (Cederlund 2006: 443). Analyses of specific find categories were done on a more or less ad hoc basis. The block lifted casks and their contents were studied, and some published as part of the *Wasa* Studies series (Kaijser et al. 1982). As a group, however, the casks were not subject to detailed study and publication.

In 1990, the current Vasa Museum opened. It is perhaps the most visited maritime museum in the world and attracts over a million visitors annually (Hocker 2011: 197). While most museums can only dream of these kinds of attendance figures, the building has several drawbacks admirably summed up by Irene Lindblom, Collections Manager at the museum.

> As an exhibition hall the building is very inspiring and useful. Unfortunately, additional space, for storage facilities and conservation laboratories, are too small or non-existent. The museum was built with exhibitions in mind, not collection management (2003: 192).

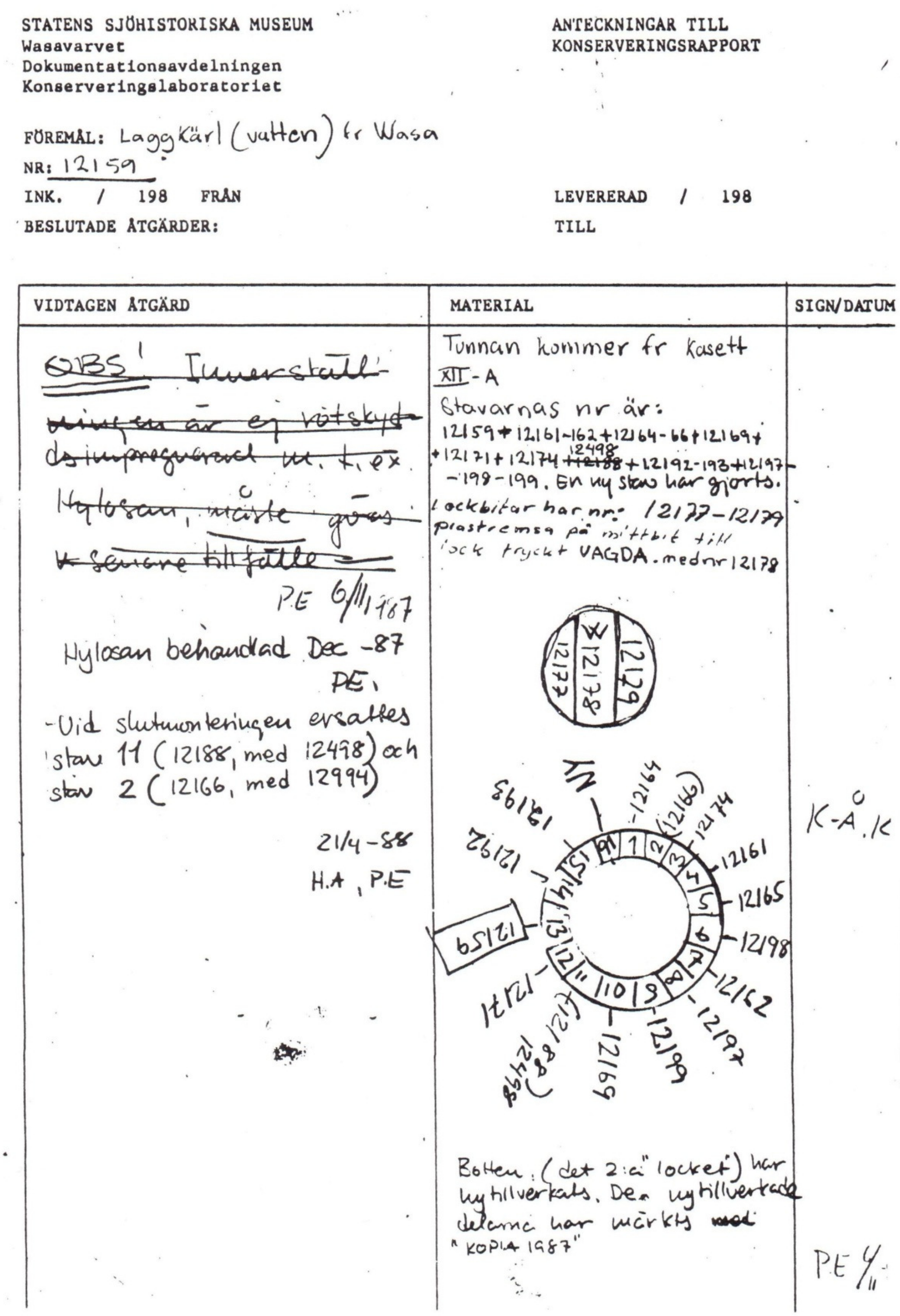
The artifacts not displayed in the exhibition areas are stored in a series of six rooms on the lowest level of the museum, known as the magazine. Climate control and security are excellent, but space is limited to only 330 square meters (Lindblom 2003: 192). When preliminary research for this thesis began in July, 2009, the majority of the cask collection was housed in Room 141 of the storage magazine. This consisted of approximately 1,500 loose staves and stave fragments, 600 head pieces and fragments, 800 hoop fragments, and 30 reassembled, whole casks. An additional seven shot kegs and various loose staves, head pieces, and hoop fragments were stored in Room 146. In the exhibit areas, an additional 29 casks were on display. Of these, 22 were suspended by chains from the ceiling and very difficult to access. The staves and heads in Room 141 were stacked vertically on narrow wooden racks (Figure 10), with wooden spacers between each object to ensure air circulation. The racks of staves, particularly, were very unstable and difficult to handle, and were bound with string to keep the objects together. Racks of staves and head pieces stood on two tiers of wooden pallets, and could only be accessed with a pallet lifter or forklift. There seemed little to no order in how objects were stored, beyond separating staves and head pieces.

FIGURE 10. When this study began in August 2009 hundreds of loose staves were stored on narrow wooden racks in Room 141, bound with string. There seemed little order to the storage system and objects were difficult to access. (Photo by author, 2010.)

As of 2009, museum personnel had reassembled a total of 66 casks of various sizes. The larger examples were built up using plywood frames (Figure 11) composed of three identical discs linked by vertical risers, while wooden wedges glued to the middle disc increased its diameter and compensated for the curved shape of the staves. The staves of these reassembled casks were held in place either with steel worm clamps overtop rubber gaskets, or with reproduction wooden hoops. The wooden hoops were often fastened to the cask with finishing nails, and head pieces were frequently either glued or screwed to the plywood frames beneath. Reproduction wooden staves and head pieces, painted black, filled gaps where original components were absent.

FIGURE 11. A total of 66 casks were reassembled by museum personnel in the years following the excavation. Larger oak casks (right) were built around plywood frames (left). (Photo by author, 2011.)

In October 2010, when this study began in earnest, the author received a file of handwritten notes about the museum's casks from 1988 (hereafter referred to as the "1988 file") (Figure 12). The diagrams and find numbers seemed to relate to casks, but the purpose of these notes remained unclear. After two weeks of recording rebuilt casks, the information in the 1988 file began to correspond with actual objects. The file recorded how approximately thirty-five casks were reassembled between 1986 and 1988 by museum personnel. Checking the find numbers for the individual components of the rebuilt casks soon revealed a deeply disturbing trend. The staves and head pieces of these rebuilt casks often came from significantly different contexts, on the same deck, or from entirely different decks altogether. Thus it could be assumed with some confidence that the majority of these rebuilt casks did not represent actual objects from 1628, but rather "mongrel" casks pieced together by museum staff in the 1980s. To make matters worse, all of the *fyndbricka* had been removed from these casks, making it difficult to re-identify individual items. Fortunately, the notes in the 1988 file allowed most of the components to be re-identified and resorted into their original find contexts. The decision by museum staff in the 1980s to rebuild a significant proportion of the cask collection with little to no regard for archaeological context remains perplexing, until one considers the institutional environment in which it occurred. "Museums have focused on exhibitions, and…the result of this attitude has been that preservation and storage often get a low priority, although this is one of the most important tasks for the museums" (Lindblom 2003: 196). As a successful museum more focused on exhibitions than research, the decision to mix material from different contexts to create objects for display seems slightly less confusing and reprehensible. In addition, there is significance in the very fact that staves and head pieces from different areas of the ship could be joined together, as it indicates a certain amount of regularity in the collection. Despite these



STATENS SJÖHISTORISKA MUSEUM
Wasavarvet
Dokumentationsavdelningen
Konserveringslaboratoriet

ANTECKNINGAR TILL
KONSERVERINGSRAPPORT

FÖREMÅL: Laggkärl (vatten) fr Wasa
NR: 12159

INK. / 198 FRÅN

LEVERERAD / 198

BESLUTADE ÅTGÄRDER:

TILL

VIDTAGEN ÅTGÄRD	MATERIAL	SIGN/DATUM
~~OBS! Innerställningen är ej rötskydd då impregnerad m. t. ex Hylosan, måste göras vid senare tillfälle~~ P.E 6/11 1987 Hylosan behandlad Dec -87 PE. -Vid slutmonteringen ersattes stav 11 (12188, med 12498) och stav 2 (12166, med 12994) 21/4-88 H.A, P.E	Tunnan kommer fr kasett XII-A Stavarnas nr är: 12159+12161-162+12164-66+12169+12171+12174+~~12188~~ 12498+12192-193+12197-198-199. En ny stav har gjorts. Lockbitar har nr: 12177-12179 plastremsa på mittbit till lock tryckt VAGDA. med nr 12178 Botten (det 2:a "locket") har nytillverkats. De nytillverkade delarna har märkts "KOPIA 1987"	K-Å.K PE 4/11

FIGURE 12. Example of a page from the conservation file recording how casks were reassembled between 1986 and 1988, often with pieces from different areas of the ship. In the above example most staves are from the lower gundeck, with the exception of one stave from the hold. Luckily, these notes allowed most objects to be re-identified and resorted based on find location. (Courtesy of the Vasa Museum, Stockholm.)

criticisms, the collection of casks from *Vasa* remains one of the best and most complete assemblages of historic cooperage. Every multigenerational project suffers similar setbacks. For example, many of the casks from the *San Juan* (1565) were reburied at Red Bay and remain inaccessible (Loewen 1999: 7), while most of the casks from *Mary Rose* (1545) remained in wet storage and were unavailable for study (Rodrigues 2005: 409).

During the course of this study, all of the cask material in Room 141 was reorganized, and stored based on find location. The goal was to keep all of the cask material from the same find contexts together in an effort to re-establish the total number and type of staved containers on board. Objects were organized based on the deck-beam-side system used for recording all find contexts within the ship. Complete casks or groups of items identified as part of the same cask were kept together whenever possible. Sometimes, groups of staves were linked together in the museum's artifact database, Marketstore, without being explicitly identified as a cask or *tunna*. These groups were also kept together. When possible, groups of loose staves which appeared to match each other, and were from the same or similar find locations, were grouped together, as they could be part of the same container. Staves and head pieces were also sorted based on the type of wood they were made of, generally either oak or pine with a few possible beech objects. Casks on display were removed from their cases for study and then replaced. Museum staff assisted the author in removing the twenty-two casks hanging from the ceiling. Whenever possible, rebuilt casks corresponding to notes in the 1988 file were taken apart, and their individual components renumbered and sorted based on original context. A total of twenty-four rebuilt casks were disassembled. Figure 13 shows Room 141 in the storage magazine after reorganization. Staves and head pieces are still stored on wooden pallets with wooden spacers, but are now kept in smaller units that are slightly easier to access. A great improvement, however, is the resorting of the collection based on context. Each pallet is clearly labelled with the deck and beam numbers where the objects were found, and each individual object on a pallet is listed on the label. For the first time this has made it possible to look up a specific cask part in Marketstore, note the context, and then actually retrieve that object. Rebuilt casks which could not be identified in the 1988 file or likely represented actual containers from 1628 were kept intact, and stored on tiers of shelves in Room 141. Shot kegs remained in their original location, along the top of cabinets in Room 146.

FIGURE 13. Room 141 in the storage magazine after final reorganization in May, 2011. Heads and staves are still stored separately, but are clearly organized by find location and are kept in smaller, easier to handle units. (Courtesy of the Vasa Museum, Stockholm.)

Methodology

The goal of this study was to record the casks and cask parts from *Vasa* in detail, examine the distribution of casks on the ship, and finally to interpret the casks in a wider North European perspective. A detailed recording of each cask and individual element formed the basis for the secondary and tertiary levels of analysis. It was decided to use paper proformas or recording templates to record each complete cask, individual stave, and individual head piece. Other researchers at the Vasa Museum had used proformas to successfully record collections such as the blocks, or to assist in recording the structure of the ship. The decision as to which attributes of each element to record was based in part on a review of previous studies, especially Brad Loewen's work on the casks from Red Bay (2007), as well as a consideration of what information was required to answer specific research questions. For example, knowing the volumes of different sizes of casks would be crucial both for establishing a typology, as well as understanding seventeenth century Swedish metrology. In order to calculate volume, the distance between the croze grooves as well as the diameter at the midsection and ends of the cask would be required. With over 2,000 loose elements and dozens of complete casks to record it was necessary to keep the proformas as streamlined as possible, but without omitting important data. Kimberly Smith (2009) created proformas for recording cask material as part of her comparative study of historic casks from wreck contexts, but these had never been tested. While comprehensive, Smith's proformas seemed excessively long – nine pages to record a complete cask, and four pages each for an individual stave, head piece, or hoop (Smith 2009: 247-270). The proformas eventually developed for use with the casks from *Vasa* were limited in length to two pages for a complete cask, and a single page for an individual stave or head piece. Since there were fewer attributes to record on hoop fragments, these data were entered directly into an

Excel spreadsheet without recourse to proformas. The proformas were created using Excel software. Their eventual form employing clearly delineated subheadings and multiple check boxes was inspired, in part, by the context recording sheets used by Parks Canada historic archaeologists in Ontario, Canada. The proformas were reviewed and improved through the attentions of Brad Loewen at Université Montreal, and Fred Hocker, the Director of Research at the Vasa Museum. While certain elements are shared by each form, they also feature unique fields specific to the object being recorded. The completed sheets were stored in binders and divided by find location or container number, if it was determined that multiple loose objects belonged to the same cask. One copy of all the notes is kept by the museum, while another is in the possession of the author.

All measurements were recorded in millimeters (mm), using either a flexible hand tape or digital calipers for the thicknesses of objects. The find number of each object was checked in the museum database, Marketstore, to determine if the object was identified as part of a larger container, or if other finds were linked to the object. Small sketches were made of noticeable tool marks, incised markings or *bomärker*, and the position of any holes in the object. This record was supplemented with photography using a digital Nikon SLR belonging to the museum, to illustrate both typical and atypical features of the casks. The three types of proforma are explained in detail, below.

Complete Cask Recording Form (Figures 14-15)

- At the top of each proforma the find number (FNR) of the artifact was noted, as was the date on which it was recorded. Complete casks usually have a head number or *huvudnummer* which encompasses all the objects composing or related to that cask.

Context

- This section records the find context of the object, using the deck-side-beam coordinates. "Breadth" refers to the location of the object measured as an offset from the centerline of the ship, a measurement which appears occasionally, albeit infrequently, in the find records.
- "Related finds" refers to other objects associated with the cask, as recorded in Marketstore. These can include either parts of the cask itself, or objects found within the cask.

Condition

- "No. of heads" records how many heads remain in the cask, as many of the rebuilt examples are missing one or both heads. Sometimes the end of a cask was left open, while in other cases reproduction pieces (*kopier)* filled in the gaps.
- "No. of original heads" is related to the preceding field, and records how many of the existing heads are original, or copies. Reproduction pieces are stamped with the words *Kopier* and the date of production, ususally 1988 or 1989.
- The presence of original hoops was noted, although this occurred in only a handful of examples.
- "No. of staves" – the number of staves in the cask were counted. Staves were numbered clockwise for ease of recording. The bung stave was counted as the first stave when the cask was sitting upright, with Head 1 uppermost. This created a frame of reference, as most of the individual staves in the rebuilt casks lacked FNR discs. The presence of any *kopier* staves was also noted, in the field "No. of original staves."

Diagnostic Features

- The style of bung hole was noted in the "Bung shape" field. A bung was considered "square" if the height and width were within two or three mm of each other.
- The thickness of the staves was recorded using digital calipers and entered in the "Average stave thickness – middle" and "Average stave thickness – ends" fields.
- For the purposes of recording, one end of the cask was arbitrarily labelled "Head 1," and the opposite "Head 2," since there is really very little to distinguish between the two ends otherwise. The diameter, thickness, number of pieces, and edge bevel style of each head was noted.
- The types of edge bevel or bite exhibited by the head pieces in the collection are summarized in Figure 39, in Chapter 4. These are schematic sketches of the external edges of head pieces, showing their profile. The names of the bite style are slightly idiosyncratic, as they were developed by the author. Research into historic cooperage has yet to reveal a specific terminology for this feature.
- The number, style, and dimensions of croze grooves present were then noted. Three styles of croze groove were identified:

  Scratch – a very faint shallow groove, no more than 2mm wide by 2mm deep

  Vee – a V-shaped groove, usually at least 4mm wide by 2mm deep, and found almost exclusively on pine containers.

  Square/ hawksbill – A groove generally with straight sides, but slightly deeper and more defined than the scratch groove, usually at least 3mm wide by 3mm deep.

Dimensions

- The measurements recorded in this section are mostly concerned with calculating the volume of the container. The number of the croze groove corresponds to the number of the head, so that "Diameter at croze groove 1" would be measured at Head 1, and vice versa. The "calculated volume" fields were left blank in the end, as it was decided to use Rhinoceros NURBS modelling software as the most accurate method to determine volume.

Photographs

- Any photos taken of the object were recorded here. Photos were numbered using the FNR of the objects plus the suffixes a,b,c etc to identify multiple images of the same object. When existing good quality photos of the cask already existed in Marketstore, the notation "photos in MS" was made. Copies of photos taken were given to Fred Hocker and Irene Lindblom for uploading to the Marketstore database.

Comments

- In this section, my tentative identification of the type of wood was noted, usually either oak or pine. Wood identification was done visually, and again it should be stressed that the identification is not definitive given the author's lack of experience on this particular subject. The author was briefly instructed in wood identification by Fred Hocker, an experienced maritime archaeologist. It seems clear, however, that the casks are definitely made out of two distinct species of wood
- Any other comments about the appearance, unusual features, or provenience of the item were also made in this section.

Complete Cask Recording Form – Sheet 2

- A second, blank sheet supplemented the information on the first sheet. Here a diagram of the individual, numbered staves was drawn, and the presence and dimensions of any holes in the staves and head pieces recorded. *Bomärker* and tool marks were also noted in this section.

VASA MUSEET	Complete Cask Recording Form	FNR: 15903 Sheet 1 of 2	Date: 20 Apr, 2011

Context

Deck:	HS	Side:	SB	Beam:	23-24	Breadth:	—
Related finds?		□ yes □ no		Verified in Marketstore?		☑ yes □ no	

Related FNRs: Heads: 15915, 15917. Staves: 15903, 15904, 15905, 15906, 15907, 15908, 15909, 15910, 15911, 15912, 15913, 15914, 15933 – loose stave, 15934, 15935. Other:

Condition

No. of heads	□ 0 □ 1 ☑ 2	No. of original heads	□ 0 □ 1 ☑ 2	Original hoops?	□ yes ☑ no
No. of staves	14	No. of original staves	14		

Diagnostic Features

Bung shape	~~□ circular □ square □ rectangular~~	Bung dimensions	—		
Avg. stave thickness - middle	8	Avg. stave thickness - ends	9		
Head 1 diameter	371	Head 1 thickness	19	No. of pieces in Head 1	2	Head 1 bite style	V-bite 1
Head 2 diameter	364	Head 2 thickness	11	No. of pieces in Head 2	3 (2 orig.)	Head 2 bite style	bevel
Croze grooves present	□0 □ 1 ☑ 2	Croze groove style	scratch	Max width of groove	2	Max depth of groove	2

Dimensions

Height overall	623	Max stave length (following curvature)	624	Distance between grooves	558	Diameter at booge	441
Diameter at croze groove 1	367	Diameter at croze groove 2	370	Calculated volume			

Photographs

Photo number	Description
	photos in MS.

Comments

Oak ?.
Medium-sized rebuilt oak cask in Magasin Rm. 141.
Listed in 1988 file, but appears to be a GENUINE cask, as all the parts listed are from the same context.
Could be missing one stave, as 15933 is loose, but linked to Tunna 15903.

Staves numbered COUNTERCLOCKWISE as in 1988 file

FIGURE 14. Sample of Complete Cask Recording Form, page one (Author).

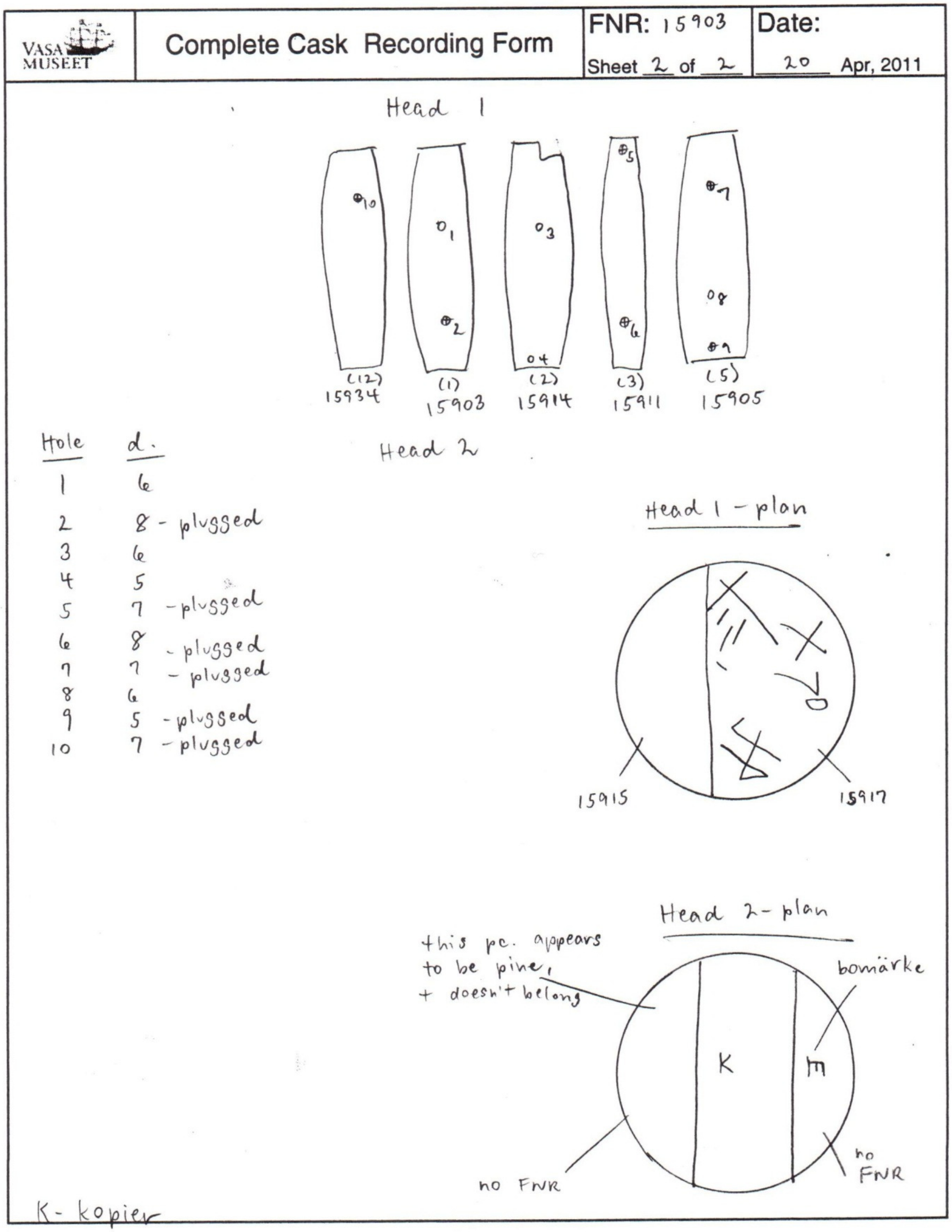


FIGURE 15. Sample of Complete Cask Recording Form, page two. In complete casks the staves were numbered from the bung stave, in a clockwise direction, with Head 1 uppermost (Author).

VASA MUSEET	Individual Stave Recording Form	FNR: 11974	Date: 21 Apr, 2011

Context

Deck:	UB	Side:	BB	Beam:	10-11	Verified in MarketStore?	☑ yes ☐ no
Item part of larger container?	☑ yes ☐ no	If yes, FNR for container:	11980				
Associated FNRs:							

Condition

☑ complete ☐ incomplete	Croze grooves present	☐ 0 ☐ 1 ☑ 2	ID Portion	☐ end ☐ middle

Diagnostic Features

Bung stave?	☑ yes ☐ no	Bung shape	☐ circular ☐ square ☑ rectangular	Bung dimensions	84w. 80h. X
Croze groove style			☑ scratch ☐ vee ☐ square/hawksbill ☐ other		

Dimensions

Length overall (or max surviving length)	750	Max width	114	Width at end 1	99	Width at end 2	98
Thickness at middle (booge)	10	Thickness at end 1	10	Thickness at end 2	10		
Distance between grooves	654	Max width of groove	2	Max depth of groove	2		

Other Features

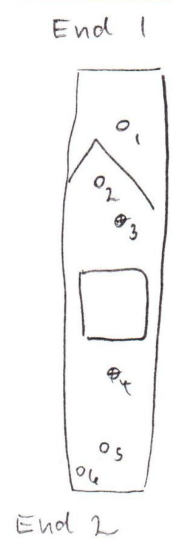
Tool Marks

Marks present?	☐ yes ☑ no
Description:	

Holes

No.	Diameter	Plugged?
1	9	no
2	8	no
3	10	yes
4	10	yes
5	10	no
6	6	no
7		

Sketch



Bomärkes

Markings present?	☑ yes ☐ no	No. of markings?	1

Sketch:

Photographs

Photos taken?	☑ yes ☐ no	Photo number:

Comments

Oak?
Bomärke previously recorded in entry for 11961, when 11974 was part of rebuilt cask 09495.

Bomärke extends onto another stave.

FIGURE 16. Sample of Individual Stave Recording Form (Author).

VASA MUSEET	**Individual Head Piece Recording Form**	**FNR:** 20407	**Date:** 24 Mar, 2011

Context

Deck:	VB	Side:	SB	Beam:	10-11	Verified in MarketStore?	☑ yes □ no
Item part of larger container?	☑ yes □ no	If yes, FNR for container:	13702				

Associated FNRs:

Condition

☑ complete □ incomplete	ID Portion	☑ cant □ middle □ centre □ head

Diagnostic Features

Bite style	□ v-bite 1 ☑ v-bite 2 □ flat □ rebated □ lip □ bevel □ chamfered				
Dowel holes in edge?	□ yes ☑ no	No. of dowel holes	□ 0 □ 1 □ 2 □ 3	Dowels present?	□ yes □ no

Dimensions

Length overall (or max surviving length)	410	Max width	289	Thickness	17	Overall Head Diameter	410

Other Features

Tool Marks

Marks present?	☑ yes □ no

Description: Adze marks on both faces.

Holes

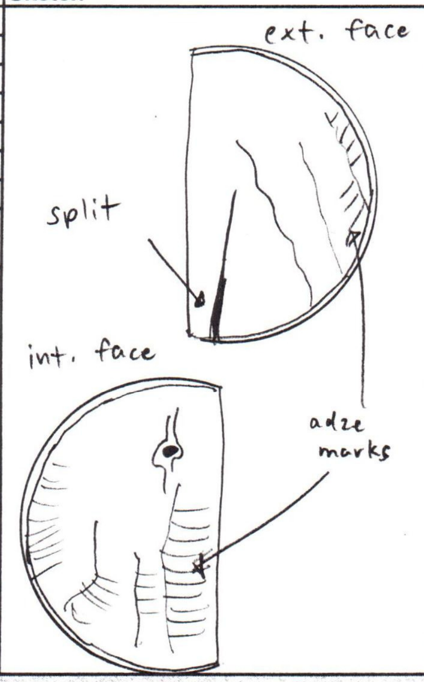
No.	Diameter	Plugged?
1		
2		
3		
4		
5		

Bomärkes

Markings present?	□ yes ☑ no	No. of markings?	

Sketch:

Sketch



Photographs

Photos taken?	☑ yes □ no	Photo number: 20407a - S

Comments

Pine?
Distinct adze marks on both faces sugg. tool had a blade about 40w. Stop marks about 10 from one another.
See photos.

FIGURE 17. Sample of Individual Head Piece Recording Form (Author).

<u>Individual Stave Recording Form (Figure 16)</u>

- This form shares many of the same fields as the Complete Cask Recording Form.

Context

- The "Item part of a larger container?" field records if the stave is part of a known cask, or just an isolated find. Although obviously all of the staves on the ship were once part of a larger container, this box was only ticked "yes" if the object was specifically linked to a cask or group of staves in Marketstore. If a range of staves was linked together in Marketstore without ever being explicitly identified as a *tunna* or similar container, the lowest FNR of the group was used as the head number for the entire range.

Condition

- A stave was generally considered to be complete if both croze grooves were present, even if the ends were slightly fragmentary or eroded.
- If the stave was incomplete, the identifiable portion or "ID Portion" was recorded as either an end or middle piece, or left blank if the stave was nearly complete.

Dimensions

- The widest point of a stave was recorded as the "Max width," usually but not always at the midsection or booge. Some staves have asymmetrical shapes, with the widest point closer to one end than another, while the pine staves were almost completely straight from end to end.
- As with the heads in the complete casks, one end of a stave was arbitrarily labelled "End 1" and the opposite as "End 2," for the purposes of recording. If the stave was incomplete, the complete end always became "End 1" for the sake of consistency.

Other Features

- The presence of tool marks, *bomärker*, and holes were noted and recorded in this section. If any of these features were present, a small sketch was made to give an approximate idea of their location. Holes were indicated by small circles, bisected by a cross if they were plugged. Their diameters were measured with digital calipers.

<u>Individual Head Piece Recording Form (Figure 17)</u>

- Most of the fields on this form are similar to those used for complete casks and individual staves, and so do not need to be explained again. The exceptions are the fields for recording the edge joinery of the head pieces, under the Diagnostic Features sub-heading. Most heads were made of several individual pieces joined together with wooden dowels along their interior edges. The presence and number of dowel holes was recorded, and if any of the original dowels remained.

The sheer size of the cask collection meant that this methodology, while fairly simple and straightforward, proved rather time consuming in the end. An initial assessment of the collection in July and August of 2009 provided baseline data on the extent and major features of the collection, and it was estimated that a total of three months would be required for comprehensive recording. This began in October, 2010, at which time it was discovered that many of the rebuilt casks were not in fact original objects, but rather pieced together from different contexts. The time required to disassemble these casks and re-identify their components delayed the research program, which ended in mid-December, 2010, and a second period of study was required. The remaining pieces in the collection were organized and recorded between March and May, 2011. In total, approximately five months was spent ordering and recording the cask collection from *Vasa*.

Chapter 4 – The Techniques and Terminology of Cooperage

A cooper is someone who makes staved wooden containers held together with wood or metal hoops (Salaman 1976: 155). It is possible the word derives from the Latin *cuparius*, one who builds wooden casks or *cupals* (Nightingale 1997: 28). Cooperage can refer variously to the process of constructing and repairing staved containers, the objects themselves, or the workshop where coopers work (Loewen 1992: 81). There are three branches of coopering: wet or "tight", dry or "slack", and white. Wet coopers make bulged casks to hold liquids, dry coopers make bulged casks to hold dry goods, and white coopers make straight-sided, open ended containers such as buckets and tubs. Wet coopering is generally considered the most demanding, as the parts of the cask need to fit precisely to hold liquids. There are variations within each type, such as the "dry-tight" casks used for herring (Kilby 1971: 42-43). While wooden casks may seem simple, their components and construction employ a specific terminology which it is necessary to understand in order to appreciate the methodology and findings of this study.

The Origins and Advantages of Casks

Iconographic and archaeological evidence suggest wooden casks originated in northern Europe during the Roman period. A relief on Trajan's Column from ca. A.D. 113 shows casks transported by river craft on the Dacian frontier (Figure 18) (Lepper and Frere 1988: 15). Approximately fifteen casks were found at the Roman site of Silchester in the UK, used as well linings. These containers were nearly 2 m high and likely contained wine. They seem typical of most Roman casks in that they were large, made of softwood, and used almost exclusively for the long distance transport of wine (Boon 1974: 263-265). In much of Europe casks seem to have replaced amphorae as the major container for shipping bulk goods by the seventh century AD. Casks reduced transport costs since the container itself occupied less cargo space than clay amphorae (Unger 1980a: 51-52). Further advantages of wooden casks over amphorae included a better volume-to-weight ratio, easier handling, and the ability to use a single container for fermentation, transport and dispensing. These improvements were slightly offset by the higher costs of making casks and a shortage of timber in certain areas of the Mediterranean (Wilson 2011: 228-229).

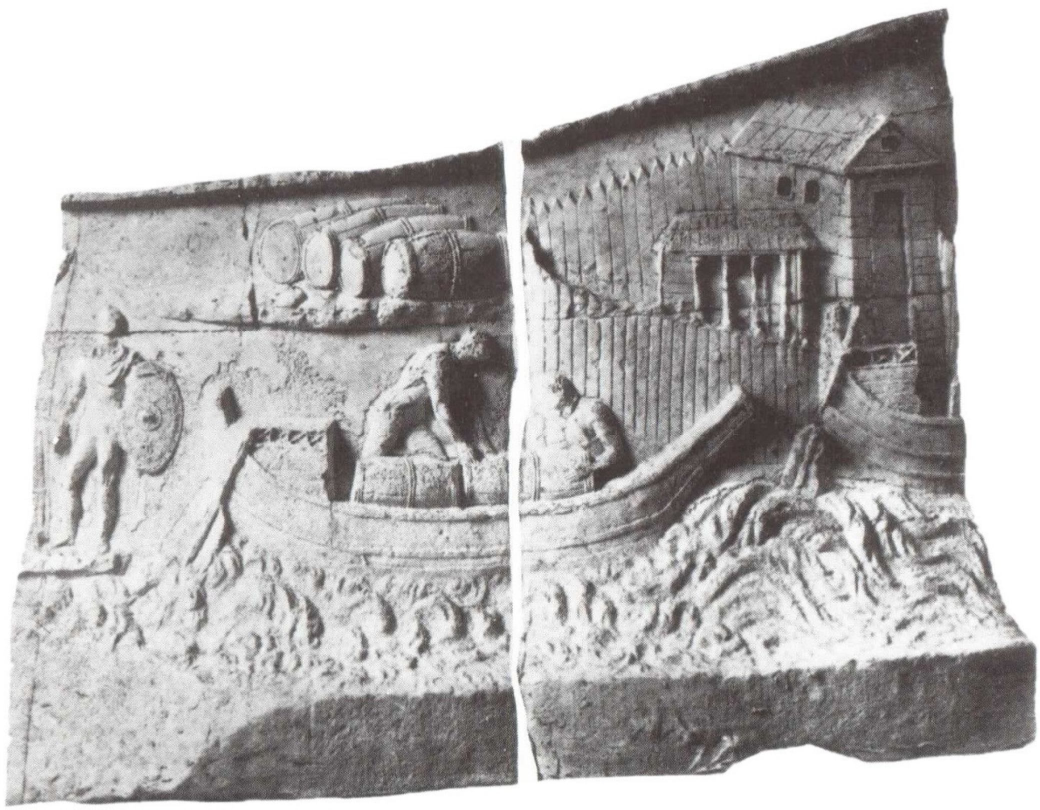


FIGURE 18. Some of the earliest iconographic evidence for wooden casks is found on Trajan's Column in Rome, ca. A.D. 113. Here casks are transported by river craft on the Dacian frontier (Lepper and Frere 1988).

The bulged form of the cask is extremely important. When joined together, the staves act as a double arch, a very strong shape. On its side, only a small portion of a cask touches the ground. This reduces friction and allows a heavy container to be easily handled, rolled, or pivoted by a single individual. The chime, or ends of the stave, act as a handle for upending a cask (Hankerson 1951: 14). Twede explains the widespread use of casks by reference to nine "universal principles of shipping containers," namely: (1) the package shape and weight facilitate material handling productivity, (2) the geometry facilitates transport, (3) materials and technology are readily available and low cost, (4) construction protects from handling and transport forces, (5) packaging trade associations cooperate to set standards for quality control and work with government to regulate standards, (6) graphics identify product and 'brand,' (7) shelf-life of food products can be extended, (8) closure permits easy filling and closing, and (9) containers are widely used or recycled (Twede 2005: 262-263). Brad Loewen has pointed out that many of the considerations which apply to the study of ceramic vessels also apply to casks (2014: 1). Both are tools for storage, transformation, and transport (Rice 1987: 208). Casks prolonged the life of stored food and drink, and were crucial for transforming fermenting liquids into alcohol. The form of a storage container is influenced by its contents, either liquid or dry (Rice 1987: 225). Casks for liquids are more robustly built than those for dry goods. Containers used for long term storage often have larger volumes than those used for short term storage (Rice 1987: 236). The production and use of wooden casks over many centuries in many regions, however, means that care must be exercised when interpreting historic cooperage.

Virtually every study of historic casks (Ross 1985; Shackelford et al. 1988; Rodrigues 2005; Loewen 2007; Smith 2009; Fawsitt 2010) cites Kenneth Kilby's *The Cooper and His Trade* (1971), and this study is no exception. His influence is difficult to overstate. Kilby worked as a brewer's cooper in the UK for approximately a quarter century, beginning as a fourteen-year-old apprentice in 1941 (Kilby 1971: 15-17). He undoubtedly was a skilled craftsman and knowledgeable about his trade, but some idea of the context in which he wrote will clarify the strengths and limitations of his work for understanding historic casks. Kilby was heir to a tradition of craftsmanship that was in steep decline by the time his book was published in 1971.

In a sense, *The Cooper and His Trade* can be seen as a lament for a vanishing industry, and in this respect is similar to Bob Gilding's *The Journeyman Coopers of East London* (1971). Geoffrey Crossick cautions that the "historical study of artisans must take account of the myths which successive generations have woven around them and which they indeed wove around themselves – myths that were about the past" (1997: 1). While valuable, Kilby's work is nostalgic, Anglocentric, and idealizes the role of the individual artisan in craft history. Brad Loewen asserts "that the cooperage technology which survived into the twentieth century, and is described in contemporary literature, is not representative of the bulk of historical cooperage " (Loewen 1992: 86). Specifically, Loewen believes that the use of the drawknife and the modern standard of wet cooperage are not attested to archaeologically (Loewen 1992: 85-86), claims which the current study supports. Some reference to Kilby is made throughout this study, but where possible the reconstruction of the steps involved and tools employed in constructing a wooden cask are inferred from the *Vasa* material and similar historical contexts.

Timber Selection and Conversion

The first step in constructing a wooden cask is selecting and acquiring timber. The choice of timber is based on the type of cask desired, and the availability and price of different species of wood. Oak and other hardwoods are generally preferred for liquid or tight casks, while softwoods are more often used for dry or slack casks (Kilby 1971: 69). Oak is a desirable material for casks whenever strength and impermeability are required. The outer layer, or sapwood, of the oak is removed to leave only the heartwood beneath. The heartwood undergoes the process of tylosis, which clogs the pores of the wood and makes it denser (Loewen 2007: 12). Ideally, oak used for casks is straight grained and free of knots. Softwoods are generally cheaper than oak and easier to work with, but offer less strength.

Timber felling is normally a seasonal activity, for several reasons. Trees are easier to fell in the fall and winter before sap rises up the trunk in the spring. Individuals might also work as woodsmen in the winter before returning to a different occupation for the remainder of the year. Once a tree was felled, it was converted into usable timber by splitting it with wedges or a froe (Kilby 1971: 72). The process of timber conversion is shown in a detail from this German work from 1596, below, part of a series depicting the annual labour cycle. The fact that timber felling is shown for the month of November reinforces the seasonal nature of this work.

FIGURE 19. Detail of a German engraving from 1596, showing the process of timber felling with axes and splitting with wedges and mauls. The seasonal nature of the work is suggested by the depiction of woodsmen for the month of November (Seelig 2002: 70).

There are two ways to convert timber from the trunk of a tree: radially or tangentially. Radially converted timber is split or sawn from the centre of the tree outwards, with the grain, which maintains strength. Tangentially converted timber is divided across the grain, which offers less strength but is often a more economical way to use the wood. The different orientation of radially and tangentially converted timber is shown in Figure 20, below.

Once timber was cut and converted, it needed to be seasoned to ensure it would not shrink or warp when used. The wood was stacked outside in such a way that air could circulate freely between the pieces, which were left to season for as little as a year and as long as five years in some instances (Kilby 1971: 76). Timber for casks was sorted by quality and size before it was ready for sale. The trade in staves was often controlled by merchant middlemen who bought in bulk to supply individual workshops or specific trades. Evidence from the Biscay region in the sixteenth century and the nineteenth-century Baltic suggest the standard unit for trading in cask components was the *mille* of about 1,200 pieces. In sixteenth-century Brittany, a *millier* contained about 1,200 staves and 600 head pieces (Loewen 2007: 76), while Kilby claims that “staves were sold by the mille of 1200 pieces” (1971: 74).

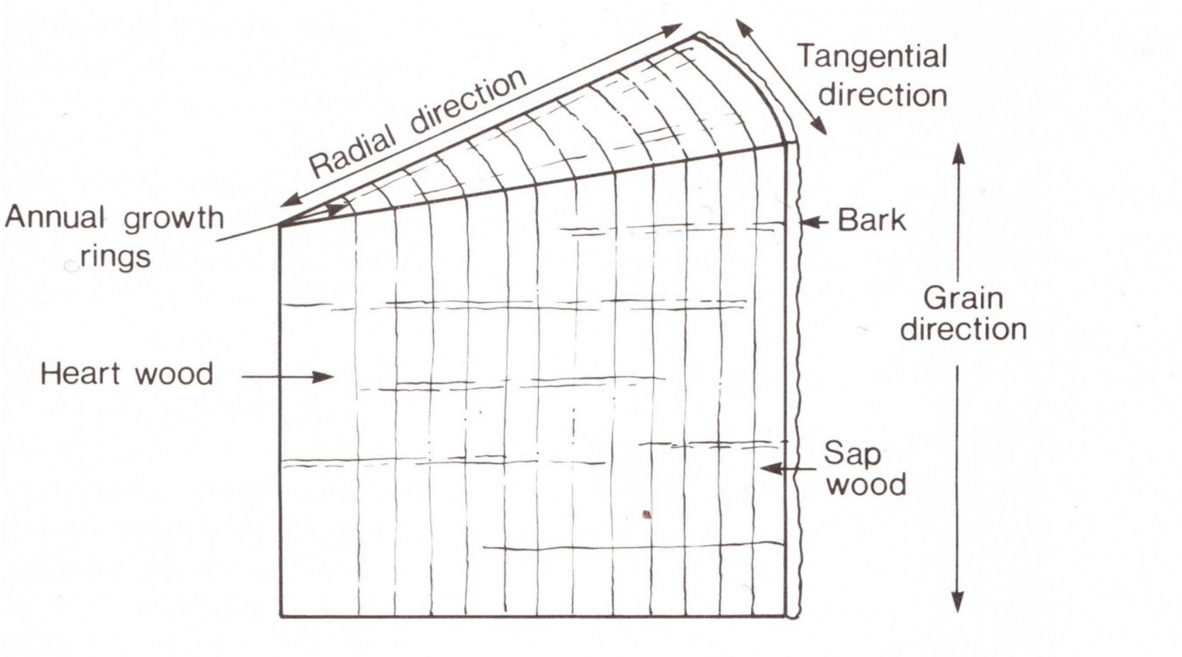


FIGURE 20. Diagram of a tree trunk, showing the boundaries between the heart and sap wood, and the difference between radial and tangential timber conversion (Cronyn 1990: 247).

The majority of the casks and cask parts from *Vasa* are made of oak, with the remainder made of pine, and a few isolated beech examples. There are 1,648 loose staves in the collection, of which 1,180 or 72% are oak. There are 437 loose pine staves, representing 26% of the total loose staves, while the remaining 2% is made up of 31 staves of an unidentified hardwood species, likely beech. There are 587 loose heads and head pieces in the collection, of which 384 or almost exactly two-thirds are oak. The remaining third of the loose heads and head pieces are pine. The remainder of the collection consists of 42 whole casks of various sizes, of which 33 are oak and nine are pine. These data are summarized in Table 1, below. The oak and pine timber was converted in different ways. All of the oak staves and head pieces appear to have been radially converted, while the pine staves and head pieces were tangentially converted. This difference is readily visible in Figures 21-22, which contrast a radially split oak stave, above, with a tangentially split pine stave, below. The use of radially converted oak timber agrees with modern standards of best cooperage practices (Hankerson 1951; Kilby 1971; Salaman 1976), and pine casks are found in numerous archaeological contexts (Loewen 1992: 82). The quality of the oak timber used in the *Vasa* casks is excellent. It is straight grained and almost entirely free of knots or flaws, with the exception of three pieces which have depressions where it appears knots might have been removed. In contrast, the pine staves and heads frequently exhibit knots. Knowledge of how pieces were converted, combined with dimensions of the head pieces allow some estimates to be made concerning the minimum size of trees required. The largest oak head piece has a maximum width of 450 mm, which when some allowance is made for removed sapwood, suggests oak trees with a minimum diameter of 100 cm were felled. The largest pine head piece has a maximum width of 535 mm, suggesting pine trees at least 54 cm in diameter were used. In a similar vein, we can estimate roughly how many milles of timber were required for the *Vasa* casks. There are 1,180 loose oak staves and stave fragments plus another 469 oak staves in the remaining thirty-three rebuilt oak casks, for a total of 1,649 oak staves in the collection. The 384 loose oak head pieces are augmented by a further 86 oak head pieces in the rebuilt oak casks, for a total of 470 oak head pieces in the collection. There are 557 total pine staves in the collection – 437 loose and 120 in the remaining rebuilt casks. When the 86 head pieces in the rebuilt oak casks are added to the 384 loose oak head pieces, we find there is a total of 470 oak head pieces in the collection. There are only 20 head pieces remaining in the rebuilt

Staves			Head Pieces			Whole Casks					
Oak	1180	72%	Oak	384	65%	Oak	Large	19	Pine	Large	2
Pine	437	26%	Pine	203	35%		Medium	2		Medium	6
Uniden.	31	2%					Small	8		Small	1
TOTAL	**1648**	100%	**TOTAL**	**587**	100%		Shot Kegs	4			
							Total	**33**		**Total**	**9**

TABLE 1. Wood use among *Vasa* casks (Author).

FIGURE 21. A typical oak stave from *Vasa*, showing radial conversion. Note the medullary rays at the end of the stave. (Photo by author, 2010.)

FIGURE 22. A typical pine stave from *Vasa*, showing tangential conversion. (Photo by author, 2010.)

pine casks, for a grand total of 223 total pine head pieces. The relationship of staves to head pieces can be expressed as a ratio, as 1649:470 for the oak pieces or 3.51:1, and 557:223 or 2.48:1 for the pine pieces. These numbers are likely slightly skewed by the inclusion of fragmentary pieces in the totals, but they do allow some observations to be made. If cask components were sold in units of milles in the seventeenth century Baltic, perhaps one mille or slightly more was required for the oak casks (taking into account fragmentary pieces), and half a mille was employed to construct the pine casks.

The origin of the timber used in the *Vasa* casks remains a mystery at the moment. No dendroprovenance study has been conducted, and few historical records exist regarding the casks. It is possible the timber originated locally in Sweden, as the kingdom was well known as a supplier of timber and forest products. In the description of Stockholm and the Mälaren region in *Civitates Orbis Terrarum* (1572-1617) the city is listed as an exporter of casks (Braun and Hogenberg 1955: 125). Many of the *Vasa* casks might have come from Norrköping, a major manufacturing centre in Östergötland province about 150 km from Stockholm. An individual named Sessman was responsible for supplying all the bread and beer consumed in the campaigns of 1626 to 1630, although this operation was curtailed by an outbreak of plague in 1629 (Ulrica Söderlind 2012, pers. comm.). It is possible, however, that timber for the casks originated in Poland, Russia, or Germany, areas recognized as major timber exporters. Sound Toll registers record the export of large quantities of small planks called *clapholt* from Poland to the Netherlands, which could be used for casks (Manders 2000: 326). More likely still is that timber for the casks came from a variety of sources, perhaps the oak from one source and the pine from another. This pattern of multiple timber sources is highlighted in the case of the ship itself. The Hybertsson brothers purchased timber for *Vasa* locally in Sweden, as well as further afield in Riga, Königsberg, and Amsterdam (Hocker 2011: 41-42). Hopefully a dendroprovenance study in the next few years will answer these questions more conclusively.

Preparing the Staves

Once coopers acquired timber that was the correct species, size, and condition for the desired casks, they could begin preparing the staves. The first task was to trim the interior and exterior faces of the stave using a cooper's axe. This was a specialized tool with an offset blade perhaps 30 cm long, ground only on one side. The offset blade allowed the user to grasp the handle near the blade for greater control (Salaman 1976: 51). The stave was held lengthwise away from the cooper, resting on its edge on a wooden block or bench while it was trimmed with the axe. This operation is visible in the background in Figure 23, which shows coopers at work in a Dutch series from 1635. Interestingly, the tool used by the cooper here lacks the characteristic offset T-shaped blade of the traditional cooper's axe. Instead, the tool he is using appears more like a cleaver. It is unclear if this is an example of artistic license or ignorance, or evidence of an early cooper's tool now forgotten. Brad Loewen states that the dressing of staves was a specific trade in France, where the practitioners were known as *doleurs* from their use of the cooper's axe or *doloire* (Loewen 2007: 16). It is unclear if this division of labor existed in northern Europe as well, or if coopers dressed their own staves as was common in the nineteenth and twentieth centuries (Kilby 1971: 21).

Evidence from this operation remains on some of the staves from *Vasa*. There are 42 oak staves with tool marks characteristic of those made by a cooper's axe. These marks occur only on the interior faces of oak staves, generally in groups of four or more clustered at each end. Stave 15631 from the aft part of the hold, below, exhibits these marks. Here there are four stop marks from an axe or similar tool with a blade about 20 cm long. The marks angle away from each other towards the end of the stave, and cut across the grain of the wood at an acute angle. This example suggests at least sixteen strokes of the axe were required to dress this stave – four at each end, on each face. No axe marks were observed on any of the exterior faces of the staves, suggesting they were removed by a subsequent planing or finishing operation. The pine staves also exhibited tool marks on their interior faces, but these were different than those observed on the oak staves. Twenty-four pine staves bore tool marks which ran almost perpendicularly across the stave (Figure 25). These marks were much shorter and suggest a tool with a blade only about 4 cm in length. It is surmised that these marks come from a cooper's adze similar to that wielded by the cooper in the foreground, below. On the whole, the pine staves and head pieces displayed a much cruder level of workmanship and finish than the oak pieces. The difference in workmanship between the oak and pine pieces might also result from an older tradition of woodworking in the northern countries, where oak pieces are finished one way, and pine another. Oak and pine components of the Skuldelev vessels were finished differently, although in this case the oak members still bore axe marks, while pine planks were planed smooth (Olsen and Crumlin-Pedersen 1967: 160-161).

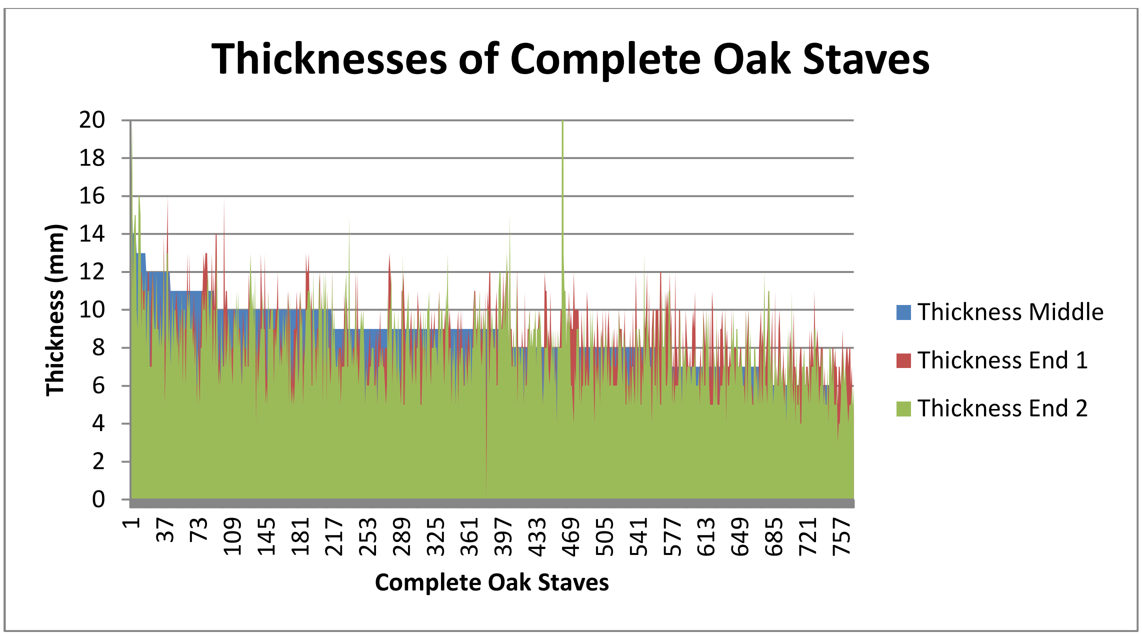
FIGURE 23. Coopers at work, from a Dutch series dated 1635. The cooper in the background is dressing a stave using a tool that resembles a cleaver more than a traditional cooper's axe. The cooper in the foreground is driving hoops using a hoop driver and a cooper's adze (Schuckman 1992: 182).

FIGURE 24. The interior end of an oak stave with four stop marks left by a cooper's axe or similar tool. (Photo by author, 2010.)

FIGURE 25. This pine stave from the Orlop deck shows the characteristic tool marks found on pine staves, different than those found on oak staves. These marks are also found only on the interior face, but are much shorter and run across the stave at less of an angle. They were made by a tool with a blade only about 4 cm wide, perhaps a cooper's adze. (Photo by author, 2010.)

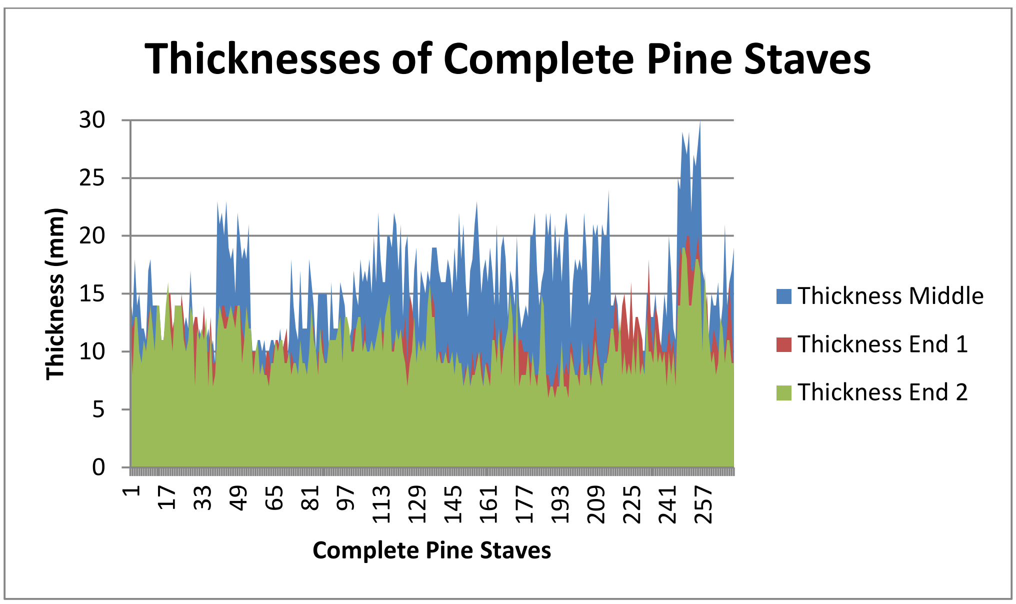
Once the faces of a stave had been dressed with the cooper's axe, the same tool was used to list the edges. This operation involved trimming the edges of the stave so that it was wider in the middle and narrower at the ends. This allowed the distinctive bulged shape of the cask when the staves were assembled. Evidence for this action is visible in the shapes of the staves. The oak staves are always wider in the middle than at the ends. The pine staves appear to have been listed little or not at all, as they are quite straight with little taper and difference in width between the middle and the ends. In modern cooperage staves are backed and hollowed out after listing. The purpose of backing and hollowing the stave is to create parallel curved surfaces that will be easier to bend when the cask is raised up. Backing the stave involves shaping the exterior face or back of the stave with a drawknife. Long staves are held in position between the cooper's body and the block, a large lump of wood used as a chopping block. Smaller staves are held firmly using the cooper's "horse," a specialized workbench with a foot operated lever to hold items in position. Care is taken not to remove more wood than is necessary, so portions of unmodified wood are left as a "witness" (Kilby 1971: 22). Once the stave was backed it was flipped over so that the interior face could be hollowed out, again using a drawknife. This is the process as described by Kilby, and practiced by traditional coopers at Williamsburg, Virginia and Henne, Denmark (Fawsitt 2010: 34).

Brad Loewen has raised doubts as to the antiquity of this practice, claiming that the drawknife is "a tool which is not found in archaeological cooperage" (1992: 86). The oak staves from *Vasa* support this conclusion, and were not backed or hollowed out. The tool marks on the oak staves indicate they were shaped instead mainly with the cooper's axe. Graph 1, below, summarizes the thicknesses of 771 oak staves, which were sufficiently complete that their thickness could be measured in the middle and at both ends. The blue block in the background represents the thickness in the middle of the stave, at its widest point, while the green and red areas represent the thicknesses at the ends of the staves. The fact that the green and red peaks often rise above the blue blocks indicates staves where one or both ends are thicker than the middle. This suggests the cooper wedged or held the stave away from himself while listing it, and angled the axe inwards to remove more material from the center of the stave. Leaving more wood at the ends of the stave also imparted increased strength to the chime area of the cask, the area most subject to shocks and strains during handling. Generally the oak staves had one end that was noticeably thicker than either the middle or the opposite end. This graph also indicates the general thinness of the oak staves overall. The majority seem to range between about 6 and 12 mm thick.



GRAPH 1. The thicknesses of 771 complete oak staves, measured in the middles and ends (Author).

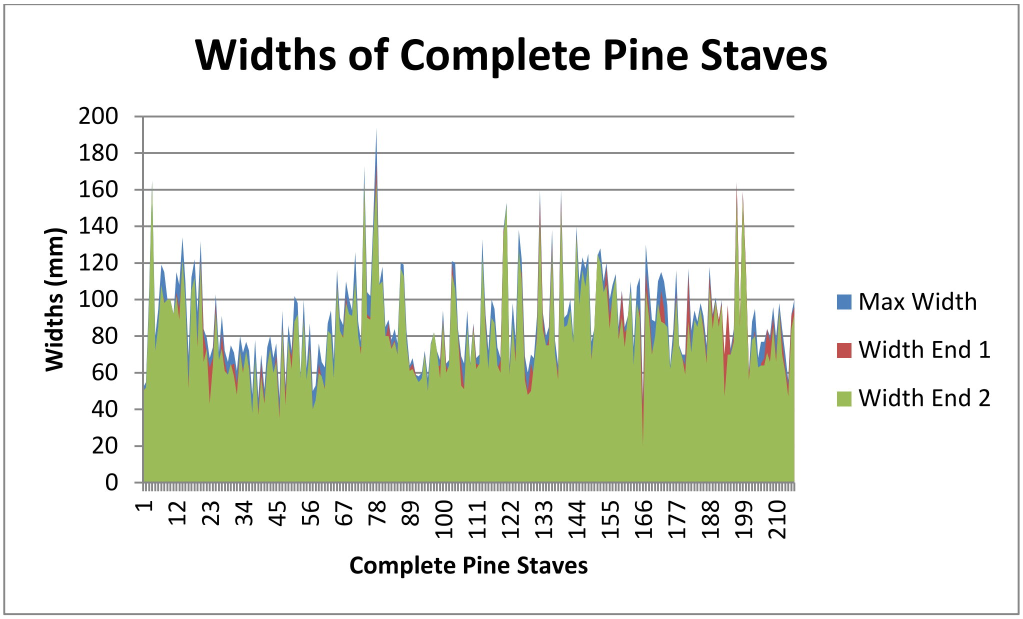
The pine staves from *Vasa* conform to the accepted understanding of archaeological cooperage, in that they are thickest in the middle and become thinner towards the ends. This was the pattern observed on the staves from the 24M wreck at Red Bay, which led Loewen to hypothesize that staves were dressed solely with the cooper's axe without recourse to a drawknife (Loewen 2007: 15-16). The pine staves from *Vasa* lack the characteristic long, striated marks left by the cooper's axe or *doloire*, however. The short tool marks running across the staves suggest a different method of dressing the staves, perhaps simply using the cooper's adze or a standard axe. This would accord with the general appearance of the pine pieces from the *Vasa* casks, which appear crude and unfinished alongside oak examples. The overall impression of the pine pieces is of expediency rather than a concern with finish. Graph 2, below, summarizes the thicknesses of 271 pine staves that were sufficiently complete to measure at the middle and both ends. Here the peaks representing the thickness in the middle of the staves (blue) are always higher than the red and green peaks representing the thicknesses at the end



GRAPH 2. Thicknesses of 271 complete pine staves (Author).

of the staves, confirming that the pine staves are always thickest in the middle. Areas where the three colours meet indicate staves that are of nearly uniform thickness, without much appreciable difference between the middle and ends of the object. The graph also shows that the pine staves are much thicker than the oak examples, with an average thickness of 15.83 mm in the middle and 10.85 mm and 10.51 mm at the respective ends.

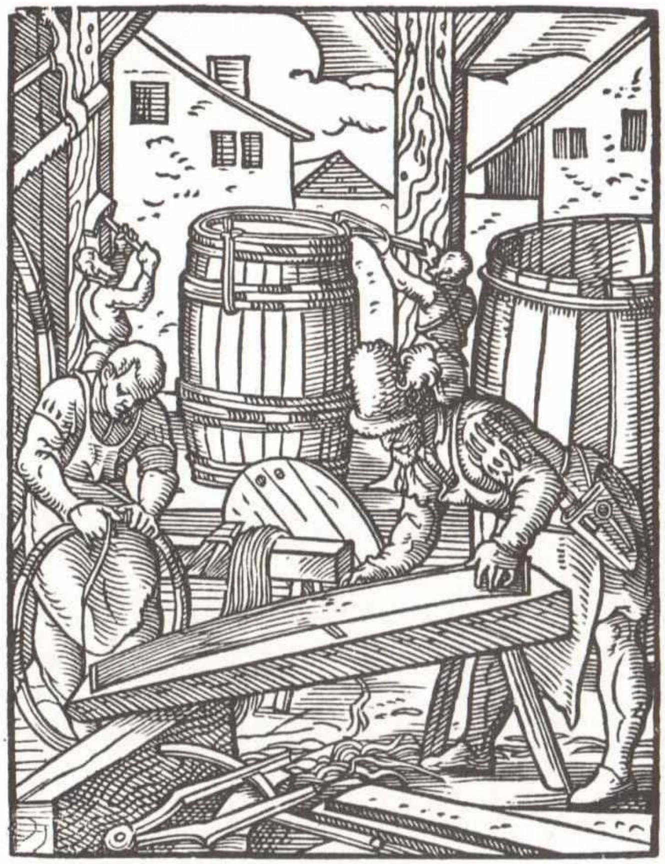
In contrast with the oak staves, which taper considerably from their widest point at the middle towards the ends, the pine staves are nearly straight sided. Graph 3, below, compares the widths of 217 complete pine staves at their midsection and ends. The three values almost entirely overlap, indicating very little difference in width between the middle and ends of the staves. This confirms that the pine staves were not listed like the oak staves. The straight pine staves produced almost straight-sided cylindrical casks, without the noticeable bulge found on the oak casks.



GRAPH 3. Widths of 217 complete pine staves (Author).

Once the staves were dressed and listed, the next step was to "joint" them, or trim the long edges of the stave. This was done using a tool called the "jointer," a plane about 1.5 m long turned on its back, and resting at an angle. Producing the correct angle along the edges of the staves was important, so the staves fit tightly together and would not leak, and to ensure that the dimensions of the cask were correct both in the middle and at the ends. Jointing was done purely by eye, and the ability to produce the correct joint was the mark of a capable cooper. The jointer was simple to operate in theory; staves were pushed along the sole of the jointer and the

Der Bůtner.



Ich bin ein Bůtner / vnd mach stoltz/
Auß Förhen / Tennen / Eichen Holtz/
Badwañ/Schmaltzkůbl/scheffel vñ geltn/
Die Bůtten vnd Weinfässer / weltn/
Bier Fässer machn / bichen vnd binden/
Waschzůbr thut man bey mir finden/
Auch mach ich Lägl / Fässer vnd Stůbch/
Gen Franckfurt / Leiptzig vnd Lůbig.

a ij Der

FIGURE 26. Likely the most widely reproduced image of historic cooperage, from Amman and Sachs *Ständebuch* of 1568. The cooper in the foreground is jointing a stave on the jointer, while other workers make hoops and lever them onto a cask with hoop dogs. Other tools visible include the wing compass in the foreground for tracing the circumference of heads, and what looks like a pair of shears for cutting hoop bindings, on the sawhorse in the middle ground (Amman and Sachs 1568: 98).

away part of the edge (Kilby 1971: 23). This operation is shown in Figure 26, above, where the cooper in the foreground is jointing a stave and producing long wooden shavings in the process. This image comes from Jost Amman and Hans Sachs's *Ständebuch* or *Book of Trades* of 1568, and is likely the most reproduced image of historic cooperage. The text beneath translates as "the Cooper uses Scotch pine, fir and oak to make barrels, tubs, beer and wine casks, which are shipped to Frankfurt, Leipzig and Lübeck" (Amman and Sachs 1568: 98). This brief caption suggests the range of wood species employed by coopers, variety of products produced, and provides some indication of the use of casks in regional trade.

The edges of the *Vasa* staves suggest they were shaped on a jointer. The oak staves have an evenly curved, smooth transition from the widest point at the midsection towards the ends, characteristic of the shape produced on a jointer. This contrasts with the staves from Red Bay, whose faceted joints suggested to Loewen that they were shaped instead with an axe (2007: 17). The edges of the oak staves slope inwards, although the staves were often so thin at their midsection (usually between 6 and 10 mm) that little of the joint survived. The joints on the oak staves were more pronounced at the ends of the stave where the wood was thicker. The pine staves, although generally straight sided, were thicker and the joints were often better preserved than those of the oak staves. These joints also sloped inwards, although the exact angles were not measured.

Raising and Firing the Cask

Once the necessary staves were prepared, they were ready to be "raised up" into a "case", a cylinder of staves without head pieces (Ross 1985: 3). The staves were stacked in a circle and secured with a temporary hoop over their upper ends, forming a cone shape (Figure 27). The staves were still straight at this point, and needed to be bent to form the bulged shape of a cask.

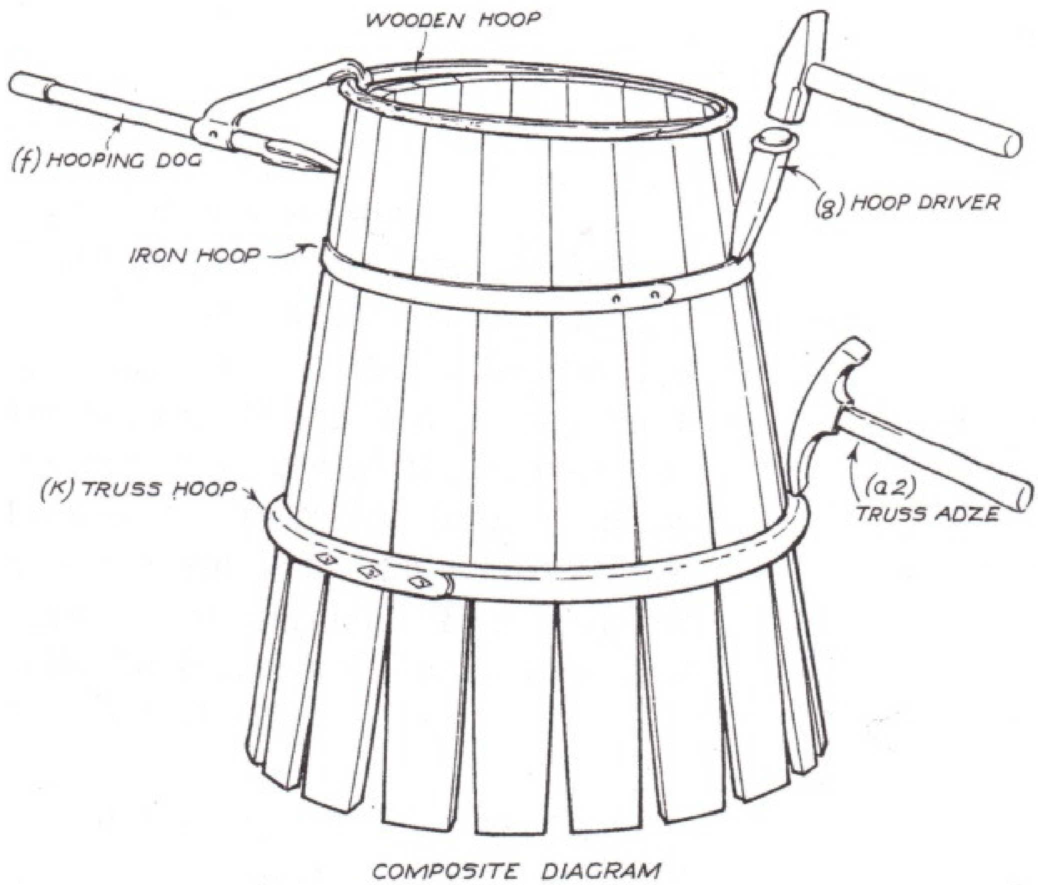


FIGURE 27. The process of raising a cask using a truss hoop and drivers (Salaman 1976: 164).

A fire was made out of old wood shavings and placed in a small iron brazier, known as a cresset. When the case was placed over the cresset the heat softened the wood fibres and made them easier to bend. After the case was heated for some time, a special wooden hoop known as a truss hoop was forced down the cone of staves to bend them inwards, to the proper size. The truss hoop was driven downwards with the aid of a hoop driver, a piece of wood with an iron tip, struck by a maul or cooper's adze. Often multiple coopers would drive the truss hoop in unison to force it downwards. As the truss hoop was driven downwards, permanent wooden hoops were driven or levered behind it to hold the staves in place (Kilby 1971: 26-27). The operation of driving hoops seems to be the one most clearly associated with coopers in iconographic evidence of their trade, as seen in many of the figures so far. After the top end of the case was secure, the lower end could be bent using a windlass. This was often simply a rope fastened round the staves and tightened with a lever, similar to a Spanish windlass. Through a combination of heat from the cresset and pressure from the windlass, the splayed end of the case could be slowly bent inwards and held in place with hoops (Loewen 2007: 18). Evidence for this operation is visible in the bulged form of the oak casks from *Vasa*, which are noticeably wider at their midsection than at the ends. Cask 12601 from the lower gundeck, for example, is almost 27% wider at its midsection than at its ends. This pronounced curvature could only be achieved by bending the staves through a combination of heat and pressure.

The pine staves were almost completely straight, but preserved another sort of evidence for the process of firing and raising a cask. The fire burning in the cresset needed to be hot enough to make the staves flexible, but not so hot that it set the cask on fire. On occasion the insides of casks were deliberately charred in a process Kilby calls *pompeying* (perhaps in reference to the Roman town?) to speed the maturing of beer or wine (1971: 35). Charred casks kept water fresher than those that were not charred (Diamond and Farrer 2005: 548). A total of 54 pine staves from *Vasa* were charred on their interiors. None of the oak staves were charred. It appears this charring (Figure 28), was deliberate rather than accidental, since it extended across the entire interior surface of the staves. Staves burned during the firing process would likely be burned only at one end (Brad Loewen 2012 pers. comm.). Deliberate charring suggests these pine casks might have contained either alcoholic beverages or water. Along with driving hoops, the burning cresset seems to be one of the features most often associated with contemporary

FIGURE 28. A charred pine stave from *Vasa*, evidence of the process of firing a cask. (Photo by author, 2010.)

FIGURE 29. A Dutch cooper at work, 1627. Notice the cresset burning to the cooper's left. The hoop driver and adze in his hands suggest he was in the process of raising a cask before the interruption by the well-dressed visitors (Keyes 1980: 201).

depictions of coopers. A flaming cresset is visible to the left of the cooper in the Dutch work from 1627, above. The adze and driver in the cooper's hands suggest he is in the process of raising a cask after firing it.

Cutting the Chiv and Croze Grooze

The next step after a cask was fired and raised was to finish the ends, preparing them for fitting the heads. First, the ends of the staves were trimmed with an adze to ensure they were level. Then a bevel was cut around the interior ends of the case. This area is known as the chime. It reduces the amount of the wood in contact with the ground when the cask is stored on end, slowing rot, and also provides a sloping surface that facilitates the fitting of heads. Then the cooper used an adze to cut a concave depression around the interior ends of the cask, below the chime. This area is known as the chiv, and provides an even surface upon which to cut the croze groove, the groove where the head is seated. Figure 30, below, indicates the position of these features on the stave. The croze groove is cut with a tool called a croze, (Figure 31), a type of specialized plane designed to slide around the cylindrical interior of a cask. The croze was adjustable, so both the position of the croze groove relative to the end of the stave and the depth of the groove could be controlled. The position of the two croze grooves in relation to one another was very important, since it was one of the major attributes affecting the volume of the cask. After the groove was cut at one end, a pair of folding measuring sticks known as diagonals could be used to determine the position of the second groove (Kilby 1971: 34).

Evidence for these operations is found on almost all of the cask material from *Vasa*, as cutting the chime, chiv, and croze grooves were prerequisites for fitting heads at either end of the case. The chimes on the oak staves was generally clearly defined, (Figure 32), but the

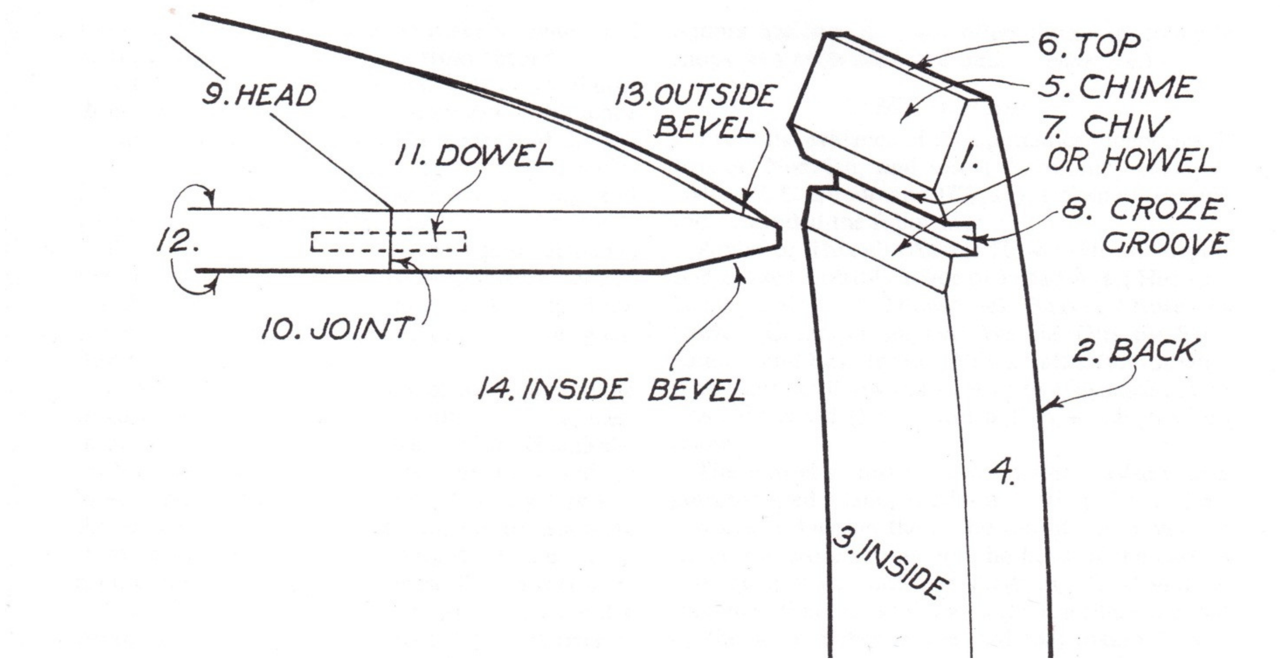


FIGURE 30. Landmarks on staves and head pieces (Salaman 1976: 156).

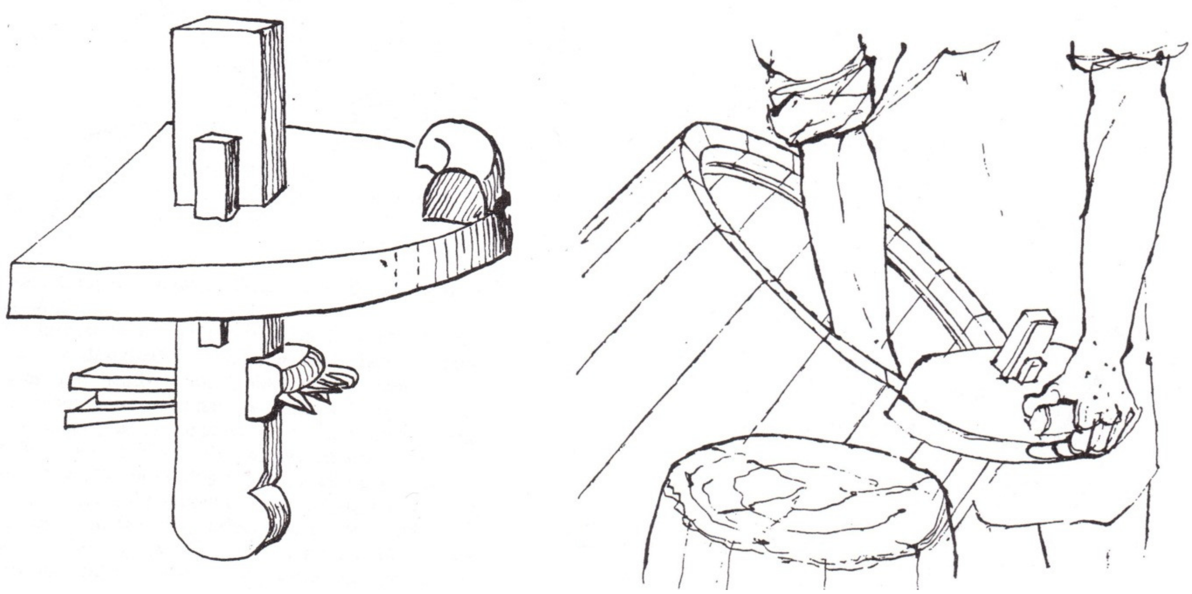


FIGURE 31. The croze (left) is a specialized tool for cutting the croze groove near the end of the cask, (right) (Salaman 1976: 320-321).

chivs were not. This is likely a factor of the shape of the oak staves, which were often thinner at the middle and became slightly thicker towards the ends. The ends of the pine staves presented a different picture, (Figure 33). The chivs were large and clearly defined, although crudely cut, and sloped towards the end of the staves.

FIGURE 32. Profile of the end of an oak stave, showing the clearly defined chime, poorly defined chiv, and square croze groove. (Photo by author, 2009.)

FIGURE 33. End of a pine stave, showing the large, sloping chiv and V-shaped croze groove. The chime here is deformed. (Photo by author, 2010.)

Three types of croze groove were observed on the *Vasa* casks: scratch, square, and vee. Scratch grooves were poorly defined and measured no more than 2 mm wide by 2 mm deep. Square grooves were slightly larger than the scratch grooves and more defined, with a square cross section. A groove needed to measure at least 3 mm in one direction to be classed as "square." Vee-shaped croze grooves were found almost exclusively on pine pieces. They have a V-shaped profile, wider at the top of the groove than at the bottom. Table 2, below, summarizes the frequencies of the various styles of croze groove observed on the *Vasa* casks. Croze grooves could not be observed on staves with both ends broken off, a not infrequent occurrence, but 1,032 oak staves and 363 pine staves retained at least one groove for measurement. The data in Table 2 shows that the scratch grooves on the pine staves were slightly smaller than those on the oak staves, although the reverse was true for the square style grooves. The three vee grooves noted on the oak staves seem so infrequent as to be an aberration in the data. The table also shows that scratch style grooves accounted for approximately two-thirds of all croze grooves observed on the loose oak staves, with the remaining third composed of the slightly larger square

Oak Staves – Croze Grooves				
Number	**Style**	**Avg. Width (mm)**	**Avg. Depth (mm)**	**% Total**
678	scratch	1.94	1.72	65.70
351	square	3.00	2.61	34.00
3	vee	4.67	2.33	0.30
1032 total				
Pine Staves – Croze Grooves				
Number	**Style**	**Avg. Width (mm)**	**Avg. Depth (mm)**	**% Total**
194	scratch	1.79	1.42	53.40
75	square	3.23	2.92	20.70
94	vee	4.78	2.67	25.90
363 total				

TABLE 2. Frequencies, styles, and average dimensions of croze grooves observed on *Vasa* staves (Author).

grooves. It is possible that the relatively small difference between the scratch and square grooves observed on the oak pieces (about 1 mm) reflects post-depositional erosion and the obfuscating effects of the PEG conservation treatment, rather than a genuine, distinct difference in style. The square and vee-shaped grooves on the pine pieces, however, are unequivocally much larger and indicate that at least two crozes or croze irons were used to cut the grooves on the *Vasa* casks. A croze iron is the cutting blade of a croze, which can be adjusted or replaced depending on the style and size of the groove desired (Salaman 1976: 319). Double croze grooves, that is, two grooves at each end or two grooves opposite a single groove, were observed on a number of staves. Fifteen oak staves and nine pine staves exhibited double croze grooves (Figure 34). The presence of double croze grooves is an indication either of cask reuse, or of a miscalculation on the part of the cooper. The only definite evidence of a mistake by the cooper is shown in Figure 35, where it appears the croze slipped while cutting the groove.

FIGURE 34. Example of a double croze groove at the end of an oak stave, evidence either of reuse, or a miscalculation by the cooper when cutting the groove. Also note the plugged hole above the groove. (Photo by author, 2010.)

FIGURE 35. The only definite evidence of an error on the cooper's part when cutting the croze groove. This oak stave shows where the croze slipped while cutting the groove. (Photo by author, 2010.)

Constructing the Heads

Once the case was complete it was time to construct the two heads to seal the ends of the cask. Heads are usually made of multiple pieces of wood edge-joined together with dowels. The interior edges of the head pieces are planed on the jointer to ensure they fit snugly together. Then the cooper bored holes in the edges of the pieces using a brace and bit, and inserted hardwood dowels to join the pieces. The cooper determined the required dimension of the head using a compass, and marked the circumference of the head on the joined pieces before cutting it out with a saw or axe. Next he cut bevels around the edge of the head with a very sharp drawknife, known as a heading knife. Figure 36 shows a German cooper from 1642, with a brace and bit, wing compass, and drawknife on the wall of his workshop. The top bevel is called the outer bevel, and the lower bevel the inside bevel, as shown in Figure 37, below. Typically the inner bevel is larger than the outside bevel (Kilby 1971: 40), a pattern observed on the *barricas* from

Red Bay (Loewen 2007: 24). The edge where the bevels meet at an angle is known as the bite, the portion of the head that actually fits inside the croze groove. The hoops on the ends of the cask, known as the chime hoops, were removed so that the heads could be wedged in. The cask was essentially complete once the heads were fitted and chime hoops replaced.

The different pieces making up a head have specific names, depending on their position. These are identified in Figure 37, below. The longest piece forming the center of the head is known, not surprisingly, as the center. Pieces which flank it on either side are called middle pieces, while the two curved pieces forming the outer edge of the head are called cants. These last are important as diagnostic elements, since there can never be more than four cants in a given cask. The heads from *Vasa* are not like those from Red Bay, or as described in modern sources on cooperage. Rather than being made up of five or more generally symmetrical pieces, the *Vasa* heads are usually made of two to four asymmetrical pieces. The heads from *Vasa* also lack reinforcing barres to hold the pieces together, with the exception of Head 23534 from a questionable context outside the ship. Figure 38, below, illustrates a typical oak head from *Vasa*.

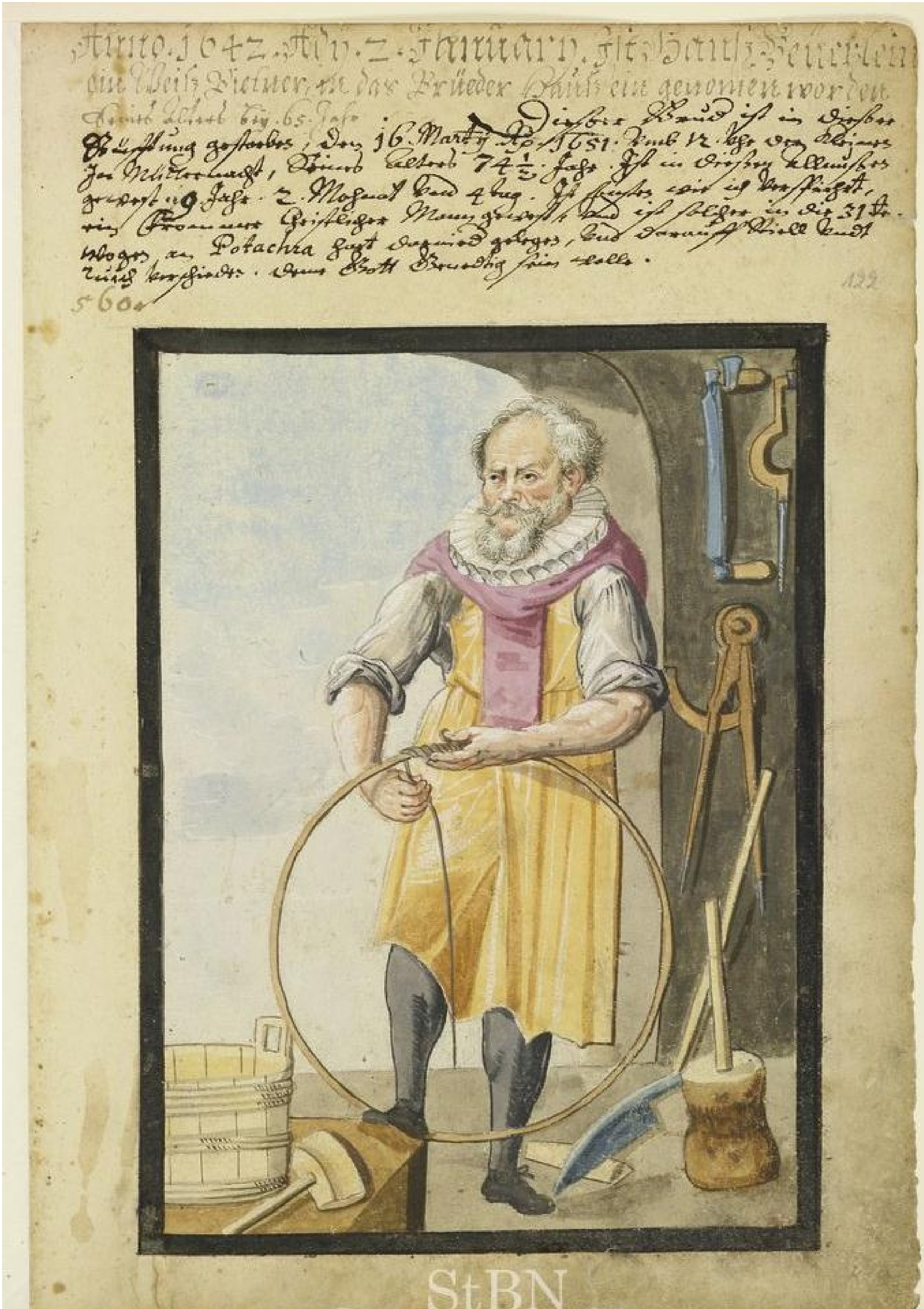


FIGURE 36. Cooper Hans Beuerlein of Nuremburg, shown at age 65 in 1642. Notice the drawknife on the wall behind him, along with a brace and bit and wing compass. These are tools for making heads (Mendelschen Zwölfbrüderstiftung, Vol. II).

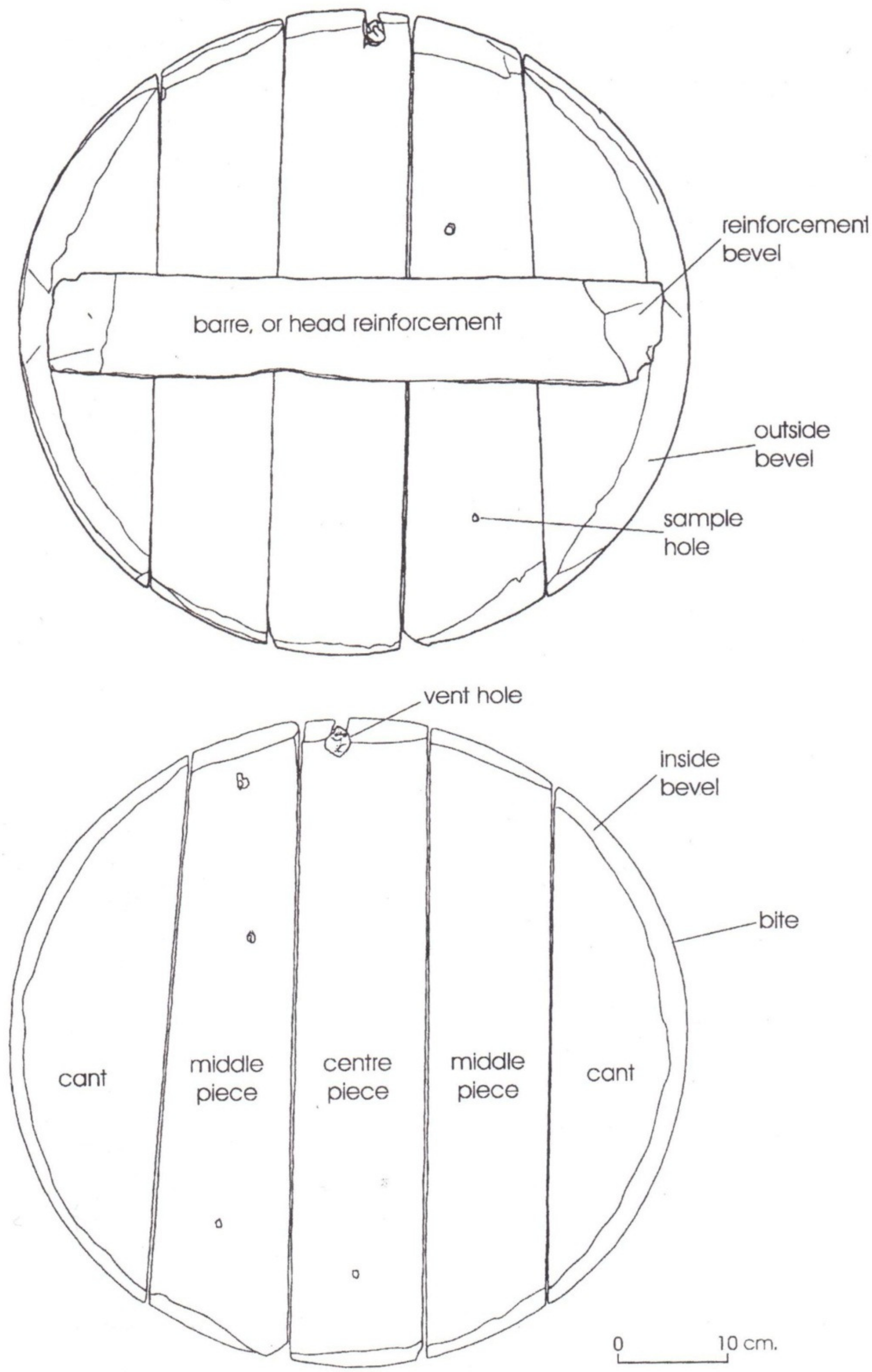


FIGURE 37. The parts of a head. This example comes from Red Bay, which features a reinforcing barre, but otherwise the terminology is the same for the heads from *Vasa* (Loewen 2007: 9).

FIGURE 38. A typical oak head from *Vasa*. Despite a diameter of 45 cm, it is made of only two large cants joined together with two dowels. (Photo by author, 2011.)

Despite a diameter of 45 cm, Head 15467 is made of only two large cants. This deviation from the norms of cooperage as recorded historically and archaeologically suggests a distinct tradition of cooperage, or an abundance of inexpensive timber. Using fewer, larger, pieces to make a head rather than five pieces and a reinforcement barre was a less economical use of timber. Perhaps this was offset by savings in labor, as fewer pieces needed to be shaped and joined for each head. A cooper making the *Vasa* casks could shape as few as four head pieces to complete a container, while a cooper making heads in the *barrica* style might need a dozen or more pieces.

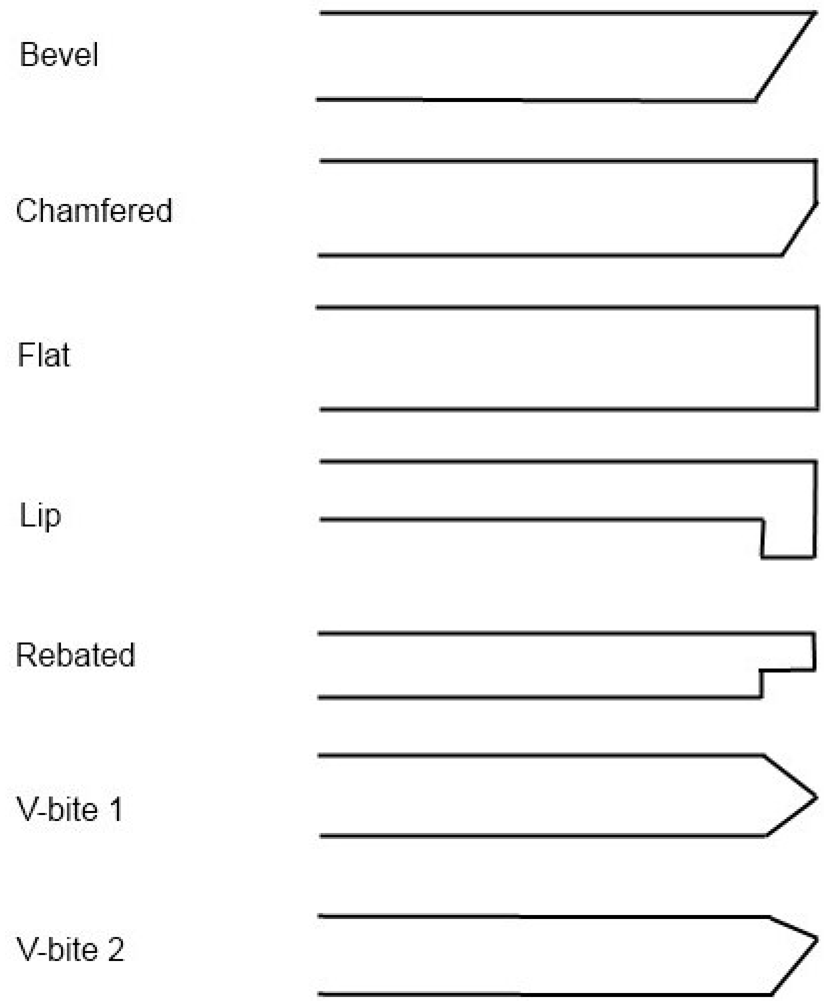
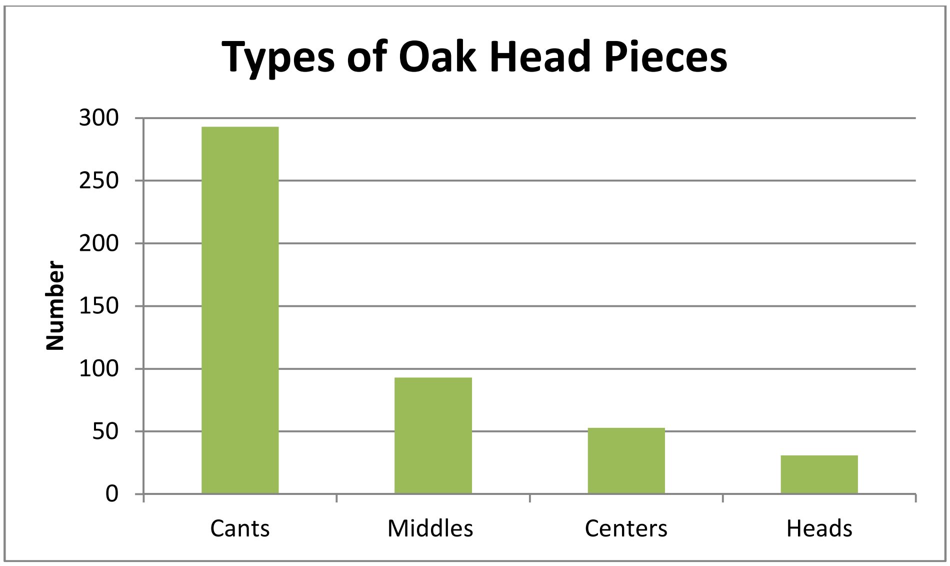


FIGURE 39. Schematic diagram of edge profile styles of *Vasa* head pieces. Not to scale (Author).

Seven different styles of edge bevels were observed on the head pieces from *Vasa*. Schematic profiles of the different edge styles are shown in Figure 39, above. The names of the edge styles are idiosyncratic and specific to the author, as the existing literature on cooperage does not seem to classify the edges on head pieces beyond "inside" and "outside" bevels. The exception to this are the styles identified as "v-bite 1" and "v-bite 2," which should more properly have been called "v-bevel 1" and "v-bevel 2." The bite is the part of the edge which fits inside the croze groove, so in this case only the point where the two beveled edges meet is actually the bite. The author was unaware of this during the course of his research, which led to this slight error in nomenclature. The v-bite 1 and 2 edge style are fairly typical of cooperage overall, but the lip and rebated styles are more unusual, and not recorded in archaeological or historic contexts. These latter types of edge are found on pine pieces, and have a clear function. They are removable lids for casks used to store personal possessions or other material that needed to be easily accessed. The v-bite and bevel styles seem to come from casks that were opened less frequently, or whose contents could be accessed through bung holes.



GRAPH 4. Type and frequency of oak head pieces from *Vasa* (Author).

There are a total of 693 head pieces and fragments of head pieces in the *Vasa* collection. Oak pieces account for 470 of the total, while the remaining 223 pieces are pine. The oak pieces are composed of 384 loose examples and another 86 pieces in the remaining rebuilt casks. Cants are the most common remaining oak head piece. There are 293 oak cants, 93 middle pieces, 53 center pieces, and 31 complete heads made of multiple pieces. This data is summarized in Graph 4, above. The style of edge bevel observed on the 384 loose oak heads and head pieces is summarized in Table 3, below. Only the loose heads and head pieces are included in this summary. While the edge bevel styles of heads in the rebuilt casks were recorded, this data is not as reliable. The heads were often wedged in so tightly that they could not be removed, so only the outer bevel was visible for examination. The loose pieces, in contrast, could be observed from all angles and as a result the record of features observed is much more accurate.

Bevel Style	Cants		Middles		Centres		Heads	
	Number	% of Total	Number	% of Total	Number	% of Total	Number	% of Total
Bevel	74	31.9	23	27.7	20	44.4	14	58.3
Flat	1	0.4	1	1.2	0	0.0	0	0.0
V-bite 1	98	42.2	30	36.1	13	28.9	4	16.7
V-bite 2	59	25.4	29	34.9	12	26.7	6	25.0
Total	232		83		45		24	

TABLE 3. Frequencies of edge bevel styles observed on 384 loose oak head pieces (Author).

Table 3 suggests trends in the edge bevel styles of the 384 loose heads and head pieces. Only three styles of edge bevel out of the six styles identified were found on the oak head pieces, if one discounts the two flat examples as outliers. The bevel style of edge, composed of a single large interior bevel or a large interior bevel and extremely small outer bevel, was one of the most common styles observed. It was found on 58.3% of the complete heads, 44.4% of the center pieces, 27.7% of the middle pieces, and nearly a third of the loose cants. This agrees with cooperage practices observed archaeologically (Loewen 2007: 24) and recorded historically (Kilby 1971: 40), in which the interior bevel is always the largest. The bevel edge style takes this to an extreme by eliminating, or almost entirely eliminating, the outer bevel. Perhaps this is another labor saving technique, as it requires the cooper to cut only a single bevel on each head. The incidence of flat edge profiles among the oak head pieces was so low as to suggest either the species of wood or the artifact itself was incorrectly identified. The v-bite 1 edge profile, where both bevels are of equal size, was the most common style observed on cants and middle pieces and appeared on more than a quarter of the loose center pieces. The v-bite 2 style of edge is the type which corresponds most closely with the accepted norms of archaeological and historical cooperage, in that it has a larger inner bevel and smaller outer bevel. Approximately a quarter of the loose oak cants, center pieces and heads and a third of the middle pieces exhibited this style. Studying the different types of head piece as separate elements might be slightly misleading, however. Rather than an edge style distinct to each head, it is possible in certain cases that the edge style changes across the head, from piece to piece. The cants on a given oak head might have the v-bite 2 bevel style, which shifts to the v-bite 1 or bevel style on the middle or center pieces in the center of the head. The existence of different edge bevel styles is significant, as it suggests multiple cooperages supplying the casks, or the hands of different coopers. Journeyman cooper Jon Hallman at Williamsburg, Virginia, states that the shapes of the edge bevels on head pieces are due in part to personal preference (Jonathan Hallman 2010, pers. comm.).

As with the oak staves, the level of finish and quality of workmanship on the oak head pieces is excellent. The vast majority of tool marks were obliterated, as the interior and exterior faces and edge bevels of the pieces were smoothly finished. Tool marks were only observed on seven loose oak head pieces and one oak head. These consist of striations approximately 5 to 8 cm long running across the grain, and usually found in groups of two or three near the edges of the piece. Three of these marks can be seen in Figure 40, below, towards the left of the cant. It is possible these marks were made by an axe used to trim the faces of the head pieces, before the surfaces were smoothed with a plane or similar device. No tool marks were observed around the edge bevels, suggesting the heads were first cut out with a saw or axe before being finished with a heading drawknife.

FIGURE 40. Oak cant 15916, one of the rare examples of an oak head piece with tool marks remaining. Here there are three stop marks towards the left of the piece, perhaps from an axe or adze used to trim the piece before finishing. (Photo by author, 2011.)

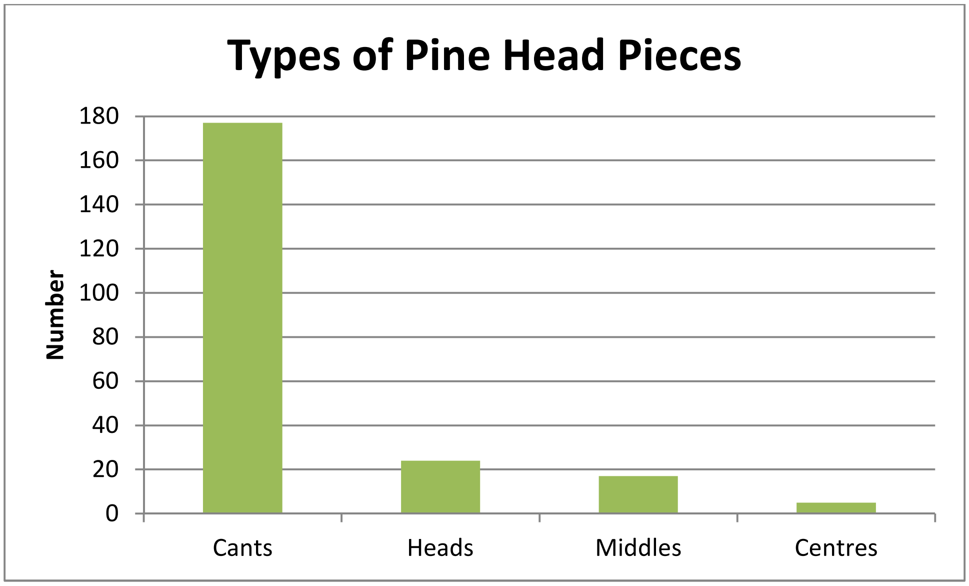
The vast majority of oak heads from *Vasa* were edge-joined using dowels, (Figure 41). The number of dowel holes found on each type of oak head piece is summarized in Table 4, below. Only complete head pieces are included in this data, since they preserved all of the dowel holes. What is immediately apparent is that the majority of pieces are joined with only two dowels. This is true for 83% of the loose cants, 60% of the middle pieces, 97% of the center pieces, and 75% of the loose oak heads. The five loose heads without any dowel holes were all from small casks or shot kegs with diameters less than 22 cm. The 16 cants without any dowel holes show that edge-joinery, while common, was perhaps not the only technique used for making heads. With the lack of reinforcing head barres, it can only be speculated that these pieces were simply wedged into position. Many of the middle pieces were asymmetrically shaped, with one edge longer than the other. Fifteen of these pieces featured two dowel holes in the shorter edge, and three in the longer edge. Pieces with three dowel holes were rare, and only one instance was recorded of a piece with four dowel holes along its edge. Dowel holes were circular and measured approximately 8 mm in diameter, and extended approximately 1.5 cm into each edge. The dowels themselves survived on many, but not all of the pieces. Often they had been snapped in half and the ends remained in the dowel holes. The dowels were cylindrical in cross-section, and facets along their length showed where they had been carved with a knife or a cooper's adze.

Dowel Holes in Edge	Cants	Middles	Centers	Heads
0 holes	16	5	0	5
1 hole	3	0	0	0
2 holes	150	39	29	18
2-3 holes	0	15	0	0
3 holes	10	5	1	1
4 holes	0	1	0	0
Total	180	65	30	24

TABLE 4. Edge joinery on *Vasa* loose oak head pieces (Author).

FIGURE 41. Typical edge joinery on an oak cant. Also note the plugged bung hole to the left. (Photo by author, 2011.)

The remainder of the head pieces in the collection are made of pine. There are 223 pine head pieces, 203 of which are disarticulated. As with the oak pieces, the majority of the pine head pieces are cants. There are 177 pine cants, 24 pine heads, 17 pine middle pieces, and 5 pine center pieces. These data are summarized in Graph 5, below. The large difference between the number of cants compared to other head pieces indicates that many of the pine heads were made of only two cants. Most pine heads with more than two pieces were large heads designed to be easily removed, with lip or rebated edge styles. The pine pieces are distinctive for having a much cruder standard of workmanship than the oak head pieces. Tool marks survive on 39 pine head pieces, over 17% of the total. These marks consist of axe marks along the edge bevels, (Figure 42), and axe or adze marks along both the interior and exterior faces of the pieces, (Figure 43). Marks along the edge bevels suggest they were trimmed with an axe or cooper's adze, rather than being finished smooth with a drawknife as the oak pieces were. Tool marks along the faces of pine head pieces suggest the process of production. It is hypothesized that the pine head pieces were split from a log or larger piece of timber before the faces were thinned out and shaped. Stop marks about 4 to 5 cm long might have been produced by a cooper's adze or a small axe, and appear in parallel rows. This creates rippled facets along the face of the head piece. The pine head pieces are thicker than the oak head pieces. Pine head pieces measure on average 21.6 mm thick, while the average thickness of oak head pieces is only 13.0 mm.



GRAPH 5. Type and frequency of pine head pieces from *Vasa* (Author).

FIGURE 42. Detail of edge bevel of pine cant 07589, showing axe or adze marks. (Photo by author, 2011.)

FIGURE 43. Plan view of pine cant 18971, showing a series of adze marks running in parallel rows. (Photo by author, 2011.)

It should be noted that the data on pine head pieces is likely slightly skewed by the inclusion of some bucket parts in the collection. This study is focused solely on closed staved containers, or casks, and does not include white cooperage such as buckets and tubs. Whenever possible, intrusive material stored with the casks parts was identified and removed. These items included parts of trucks for gun carriages, wooden plates and the bottoms of tankards. Most of these objects were readily identifiable and their function already recorded in the museum Marketstore database. Many bucket parts posed more of a challenge, however. Staves with single exceptionally large, square croze grooves (at least 5 mm wide) and sawn ends were clearly parts of buckets, as were head pieces with flat edges designed to fit into these large square grooves. Bucket head pieces with edge bevels that tapered to an angled bite remain almost impossible to distinguish from pine head pieces from casks, however. One possibility would be to consider all pine head pieces not edge joined with dowels to be bucket parts. This assumption might not be entirely correct, as there are styles of cooperage in which the head pieces are not edge joined, but rather wedged in place and secured with pegs or a reinforcing barre above them. With this caveat in mind, any future study of the white cooperage from *Vasa* should reexamine the pine head pieces in the cask collection to attempt to identify any remaining bucket parts.

Bevel Style	Cants		Middles		Centres		Heads	
	Number	% of Total	Number	% of Total	Number	% of Total	Number	% of Total
Bevel	39	24.2	4	25.0	2	50.0	2	9.5
Chamfered	4	2.5	0	0.0	0	0.0	0	0.0
Flat	7	4.3	2	12.5	0	0.0	2	9.5
Lip	7	4.3	1	6.3	0	0.0	4	19.0
Rebated	43	26.7	1	6.3	0	0.0	5	23.8
V-bite 1	23	14.3	0	0.0	1	25.0	1	4.8
V-bite 2	38	23.6	8	50.0	1	25.0	7	33.3
Total	161		16		4		21	

TABLE 5. Frequencies of edge bevel styles observed on 202 loose pine head pieces (Author).

The pine head pieces exhibited a greater diversity of edge bevel styles than the oak head pieces, summarized in Table 5, above. The bevel and v-bite 1 and v-bite 2 styles remained common edge styles, but the pine head pieces were unique in exhibiting the chamfered, flat, lip, and rebated styles. The latter two styles definitely come from heads designed as removable lids, usually on casks full of personal possessions. The lip style, (Figure 44), was cut to fit over the end of a cask. The head would be slightly wider than the end of the cask, so that the lip could secure it in place. The rebated style performed a similar function, but on these heads a channel was cut around the inner edge of the head so that it could rest on top of a cask. It appears that many of the removable pine heads with the lip and rebated style were used with oak casks, an unusual example of mixing wood species within a single container. This might suggest the reuse of an old oak cask with a locally made pine head. The chamfered and flat styles of edge bevels appear only on pine head pieces. Their edge profiles are problematic, as they are much too large to fit into any croze grooves in the cask collection. It is possible they are misidentified objects with a different function. Alternatively, they might be another sort of removable lid. The chamfered and flat edge styles, however, would seem to be less effective than the lip and rebated styles for securing a removable head in place during the motions encountered at sea.

FIGURE 44. Interior of pine cant with lip edge style. These heads were designed as removable lids. (Photo by author, 2011.)

FIGURE 45. Detail of interior edge of pine cant with rebated edge style, another method of creating a removable lid. (Photo by author, 2011.)

Dowel Holes in Edge	Cants	Middles	Centers	Heads
0 holes	77	5	0	13
1 hole	1	0	0	0
2 holes	45	5	2	5
3 holes	8	0	0	3
4 holes	2	0	0	0
Total	133	10	2	21

TABLE 6. Edge joinery on *Vasa* loose pine head pieces (Author).

Some of the pine head pieces were edge joined with wooden dowels. The number of dowel holes in each type of loose pine head piece is summarized in Table 6, above. What is striking about these data is that the majority of pine head pieces do not exhibit any dowel holes at all. It is possible the pine head pieces were wedged into place and secured by the pressure of the staves and hoops around them. The number of pine head pieces without dowel holes might be artificially inflated by the inclusion of bucket bottoms, as discussed above. The thirteen pine heads without any dowel holes are mostly composed of single piece heads from smaller casks. Also absent are any pine middle pieces with three dowel holes on the longer side and two on the shorter, as seen in the collection of oak head pieces.

Chapter 5 – Attributes of the Casks

Production processes common to all of the casks were discussed in the previous chapter. This chapter focuses on specific attributes of the casks, including bungs and bung holes, additional holes, hoops, and markings. A cask was nearly complete once it was raised and fired, with heads and hoops affixed, but holes were needed to access the contents. These are known as bung holes, which are secured with a bung. Smaller holes allowed sampling of the contents or vented the cask. Wooden hoops held casks together and protected the staves. Carved markings on casks served a variety of purposes, from the coopers who made them to the eventual owners, but generally prove difficult to interpret conclusively.

Bung Holes and Bungs

Two major types of bung hole are found on the *Vasa* casks: rectangular or square, and circular. The former type are found solely on oak staves. Circular bung holes are found on pine staves and oak head pieces. The rectangular or square bung holes found on the oak staves are unusual, with few archaeological parallels. The earliest cask with a square bung comes from a thirteenth-century well in Viborg, Denmark (Daly 2007: 190). *Mary Rose* had at least one square bung cask aboard when it sank in 1545(Rodrigues 2005: 416). Casks with square bung holes appear frequently in Dutch art of the sixteenth and seventeenth centuries, and are discussed in detail in Chapter 8. Most of the square bung holes in the oak staves are actually rectangular, in that one dimension is slightly larger than the other. As this difference is usually a centimetre or less and difficult to detect visually, this type of bung hole will be referred to as “square” for convenience. Holes were only recorded as “square” on the recording sheet, however, if the width and height fell within one or two millimetres of each other. There are seven bung holes whose width and height matched exactly or closely enough to be considered square.

The stave into which the bung hole is cut is known as the bung stave. There is normally only one bung stave per cask, so they serve as useful diagnostic elements for estimating the number of casks in a collection. There are a total of 61.5 oak bung staves in the collection. This figure includes 15 complete examples in the remaining rebuilt casks, 38 complete, loose bung staves, 11 half bung staves, and the bung staves on four small kegs. The half bung staves are only counted as 0.5 of a full bung stave, so the 11 halves become 5.5 full bung staves for the purposes of calculation. Two of four small oak casks have square holes, while the remaining pair has circular bung holes. These are the only two circular bung holes found on oak staves. The surviving square bung holes on 53 oak bung staves measured 76 mm wide by 73 mm high on average. The largest measured 93 mm wide by 104 mm high, while the smallest was 66 mm wide and 55 mm high, excluding bung holes on small kegs. Figure 46, below, shows stave 12015 with and without its square bung 12016. In this case it appears that the bung has been cut from a piece of pine, although the stave itself is made of oak.

Only nine square bungs survived. With the exception of 12016, the remaining eight appear to be made of oak. Bung 18201 is unusual in that it is mounted on a larger piece of wood, (Figure 47). This technique was also used on Cask 16525, which is unique in having two square bung holes on the same stave. The bungs for this cask are mounted on a special curved half stave. While the remaining bungs fit fairly snugly in their holes, it is not entirely clear how they were secured. The larger backing on bungs 18201 and 16525 might have allowed some kind of cordage to be passed around the cask to tie the bung in place. Stave 11861, (Figure 48), has three smaller holes drilled around the edges of the square bung hole. These small holes are angled in such a way that they might have been used for pegs to secure the bung in place. This example appears unique in the collection, however, so it remains unclear as to how the remainder of the

FIGURE 46. Stave 12015 without (left) and with (right) its bung. Also note the six sample or vent holes drilled along the length of the stave. (Photo by author, 2011.)

FIGURE 47. Interior view of Bung 18201. This is one of only two examples mounted on a larger piece of wood. This demonstrates one method of securing a square bung in place. (Photo by author, 2010.)

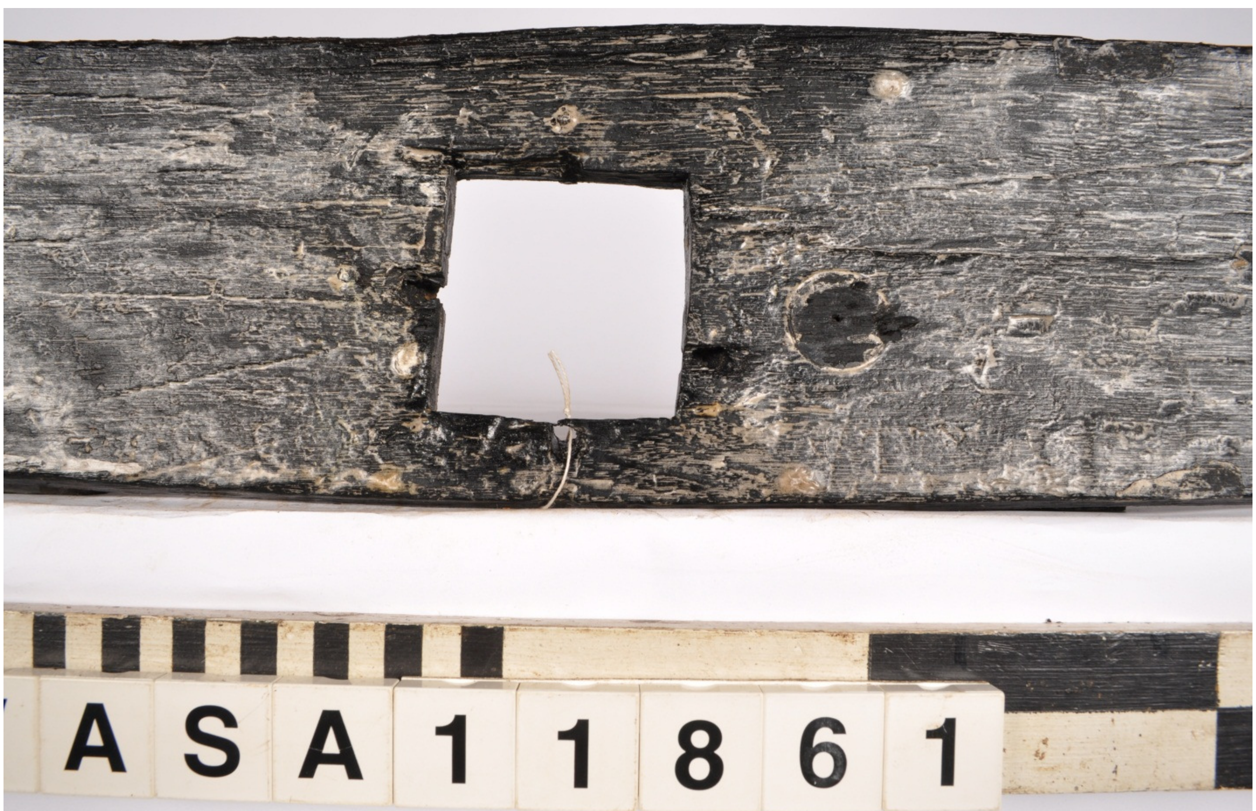


FIGURE 48. Interior view of oak stave 11861, showing three smaller holes around the square bung hole. These smaller holes might have been used for pegs to secure the bung in place. (Photo by author, 2011.)

square bungs were secured.

Circular bung holes were found on oak casks, but only on head pieces. Circular bung holes, (Figure 49), appeared on 17 oak cants, 22 centre pieces, and 12 middle pieces, for a total of 51 circular bung holes. These holes ranged from 11 to 24 mm in diameter, with an average diameter of 17 mm. It is noteworthy that the circular bung holes were most frequently found on centre pieces. On each head piece, the bung hole is usually located near a beveled edge. This makes sense if the casks contained liquid that could be drained either by removing a wooden bung, or by turning a spigot. A bung hole in the centre of a head would not be very effective unless the cask was stood on its end. Even though circular bung holes appear on 16 oak cants, these are usually large oak cants that form half or a third of a head. It appears the majority of circular bung holes on the oak head pieces were simply sealed with wooden plugs when not in use. A more elaborate tap in the shape of a rooster was recovered, (Figure 50), one of two brass spigots found amongst personal possessions. This was apparently a popular style in the seventeenth century. The rooster or “cock” design was a play on words, as it signified both the fowl and a stop cock to access liquids (Fred Hocker 2010, pers. comm.). One possible small square bung hole was found on fragmentary center piece 18113, which was plugged and measured 18 by 14 mm.

FIGURE 49. An oak cant with a circular bung hole. Also note the plugged hole below and to the right of the open bung hole, two other smaller plugged sample or vent holes, and the two exposed dowel holes along the lower edge. (Photo by author, 2011.)

FIGURE 50. One method of accessing the contents of a cask through a circular bung hole: a spigot in the form of a fowl. This piece is currently on display. (Courtesy of the Vasa Museum, Stockholm.)

The vast majority of bung holes found on pine casks were circular, plugged with simple carved wooden bungs. There are a total of 20 pine bung staves in the collection, 16 loose bung staves and four in the remaining rebuilt casks. All of the bung holes are circular, with the exception of one small square example measuring 17 mm on a side. The bung holes range from 9 to 22 mm in diameter, with an average diameter of 16 mm. There are only two pine heads with circular bung holes; one cant and one middle piece. There were three pine bung staves that appeared to have two bung holes, one at either end. Perhaps the cask could be drained standing on either end. Figure 51, below, shows the circular bung hole on pine bung stave 14070. A pine bung is shown below that, (Figure 52). Bung 18765 is typical of those in the collection. It is carved by hand and is wider at one end to allow a firm grip, while the narrower end fits snugly into the hole. No traces of leather or fabric gaskets to fit around the bungs were found on *Vasa*. While the square bung holes on the oak staves were always found in the middle of the stave, the bilge or booge area, the circular bung holes on the pine staves were sometimes found towards the end of the stave.

FIGURE 51. Detail of pine stave 14070, showing circular bung hole and incised *bomärke*. (Photo by author, 2011.)

FIGURE 52. Bung 18765, used to plug a circular bung hole on a pine cask. (Photo by author, 2011.)

Additional Holes

Many of the staves and head pieces had additional holes drilled in them. These holes were generally circular and much smaller than the bung holes. Drilled holes could be distinguished from empty knot holes by examining the wood grain around the hole. The grain bends around knots. The oak timber used for the *Vasa* casks was almost completely free of knots anyways, although knots were present on many pine pieces. Additional holes were found on 389 staves and 67 head pieces. There are a total of 1,037 such holes, which range in diameter from 3 mm to 19 mm. The average diameter of these holes is 8 mm. Approximately half of these holes are sealed with wooden plugs – 499 are plugged, while the remaining 538 holes are open. It is likely that these holes were originally plugged as well, but the plugs might have been lost during excavation or conservation. Holes occur more frequently on staves than head pieces, and are much more common on oak than on pine pieces. Holes are much more likely to be found on bung staves than on regular case staves.

There are 347 oak staves with extra holes, which includes every oak bung stave in the collection. The number of extra holes on individual oak staves runs from a maximum of 14 to single examples. On average, four extra holes were found on oak bung staves, but only two holes on standard case staves. The frequency of extra holes on bung staves is significant, as it provides clues about stowage. If the casks were stowed on their sides, with the bung stave uppermost, this would be the logical place to drill holes for sampling or venting the contents. The diameters of the holes tapered inwards from the exterior face of the staves, suggesting they were drilled with a tapered auger or gimlet rather than a brace and bit. This also suggests the holes were drilled from the outside of the staves inwards, once the cask was already complete. Figure 46, above, shows an oak bung stave with seven of these extra holes. The 347 oak staves with extra holes represent 21% of the total of 1,649 oak staves, so approximately one in five oak staves has at least one extra hole.

There are 62 oak head pieces with extra holes: 30 cants, 15 centres, 15 middles, and 2 complete heads. This represents approximately 13% of the 470 total oak head pieces. There are between one and seven holes per piece. As with the staves, head pieces with bung holes are more likely to have extra holes. Oak head pieces with bung holes have an average of three extra holes, as opposed to only two holes found on standard oak head pieces. There are a total of 125 extra holes on the oak head pieces. They range from 4 mm to 13 mm in diameter, with average diameter of 8 mm.

Extra holes occur infrequently on pine staves and head pieces, compared to the oak pieces. There are only 34 pine staves with extra holes, which represents only 6% of the total of

557 pine staves in the collection. There are between one and three extra holes on the pine staves, with an average of one extra hole per stave. The 48 extra holes on the pine staves range from 3 mm to 19 mm in diameter, with an average diameter of 8 mm. In contrast to the oak bung staves, pine bung staves were not more likely to feature extra holes than regular case staves. There were only five pine head pieces with extra holes, which is a mere 2% of the 223 pine head pieces in the collection. The five pine head pieces have between one and three extra holes, which range from 6 mm to 14 mm in diameter.

Although the vast majority of extra holes are circular, there are some square examples. There are 16 loose staves with square holes – 8 oak staves, 3 pine staves, and 5 staves of an unidentified wood species, perhaps larch. Pine cask 15304 also has 9 square holes on 7 of its 17 staves. Figure 53, below, shows pine stave 14084 with two empty square holes. The reason for cutting a square hole rather than a round one is unknown. Perhaps it indicates the hands of different coopers or a different cooperage than those which produced the majority of *Vasa* casks.

FIGURE 53. Pine stave 14084 with two square holes. Square holes were much less common than round ones. (Photo by author, 2010.)

Most of the 499 plugged holes are sealed with wooden pegs which fit the hole tightly and are cut flush with the interior and exterior faces of the stave or head piece, producing a smooth surface. There are some pieces, however, in which the pegs are longer than the thickness of the

FIGURE 54. The interior of oak cask 12601 soon after excavation in 1961, with 14 holes plugged with long pegs that extend into the interior of the cask. (Courtesy of the Vasa Museum, Stockholm.)

stave. These protrude from the surface of the stave rather than being cut flush. There are nine staves with long pegs, eight oak and one possible larch stave. There is one oak center piece with a long peg. The pegs range in length from 18 mm to 35 mm, with an average length of 26 mm. There is one pine cant with a plugged knot hole, with a plug 66 mm long. Figure 54, above, shows an oak cask soon after excavation. There are 14 holes in this cask plugged with long pegs that extend into the interior of the cask. Seven of the holes are on the bung stave, with the remaining seven opposite the bung stave. These pegs are cut flush with the exterior surface of the cask. The function of these holes is unknown, but some conjectures can be made. If the holes were bored to sample some of the cask contents, then it would be necessary to reseal the holes. A peg could be jammed into the empty hole and then cut flush with the exterior surface of the cask.

FIGURE 55. Sampling wine from a cask through a sample hole, from a seventeenth century Dutch engraving. Also note the cooper's adze on the cellar floor (Schuckman 1990: 35).

Extra holes in casks have been explained as either sample, vent, or worm holes. Bob Gilding describes the process of sampling alcohol from a cask using a "vallinche," a long, metal tube used as a drinking straw (1971: 33). This sampling could be either authorized, ordered by merchants or customs officials, or unauthorized. In the nineteenth and twentieth centuries illicit sampling by coopers, dockworkers, or sailors was known as "sucking the monkey" (Gilding 1971: 39). The pegs used to seal sample holes are called, not surprisingly, sample pegs (Ross 1985: 9). Figure 55, above, shows an individual sampling wine from a cask. Vent holes were drilled through bung staves or head pieces near the bung stave, allowing air to escape during filling (Ross 1985: 8). Vent holes also improved the flow of liquid out of a cask (Hankerson 1951: 32). Loewen states that there were 23 repaired worm holes on the casks from Red Bay, apparently caused by beetle larvae. These holes had been plugged, but Loewen inferred they were caused by insect damage since they were located in areas normally covered by hoops (2007: 37). Since the holes on the *Vasa* casks are not located beneath hoops, it seems unlikely they were caused by insects.

While it is possible that many of the extra holes in the *Vasa* casks are sample or vent holes, there are holes located *above* croze grooves which clearly serve a different function. There are 114 of these holes on 91 oak staves. Most staves have only one or two holes above the croze groove, although there is one oak stave with three such holes. Figure 34 in Chapter 4 shows an oak stave with a plugged hole above the croze groove. Holes above the croze goove are less common on pine staves, occurring on only 17 examples, 9 of which come from pine cask 15304. The location of these holes above the croze groove means they cannot be sample or vent holes, as they do not penetrate the interior of the cask. It is more likely they were used for pegs to help retain heads or chime hoops in place, although there are examples such as Figure 34 in Chapter 4. Here the peg in the hole has been cut flush with both faces of the stave. If the holes above the croze grooves were for head restraining pegs, it might explain the almost complete lack of reinforcing barres in the collection.

Hoops

Hoops are the wooden or metal bands used to hold casks together. Each hoop has two hoop tips which are fastened together to form a hoop join. Notches cut into wooden hoops helped link the ends together, and were reinforced with hoop bindings made of vegetal material (Ross 1985: 8). In addition to holding a cask together, hoops also protected the staves and ends of the cask from damage during handling and transit (Loewen 1990). All of the hoops on the *Vasa* casks are wooden, but this does not mean that iron hoops did not exist in 1628. Iron hoops are found on some Saxon cooperage. Martin Frobisher carried iron hooped casks of beer on his northern voyage of 1577 (Conway 1999: 479). Evidence for iron hoops in Iberian cooperage comes from a cask used as a well liner at the sixteenth-century colony of Santa Elena, and from the 1622 wreck of the *Atocha* (Loewen 1990). Conversely, as late as 1841, the brig *William Salthouse* still carried many casks hooped in wood (Staniforth 1987: 26).

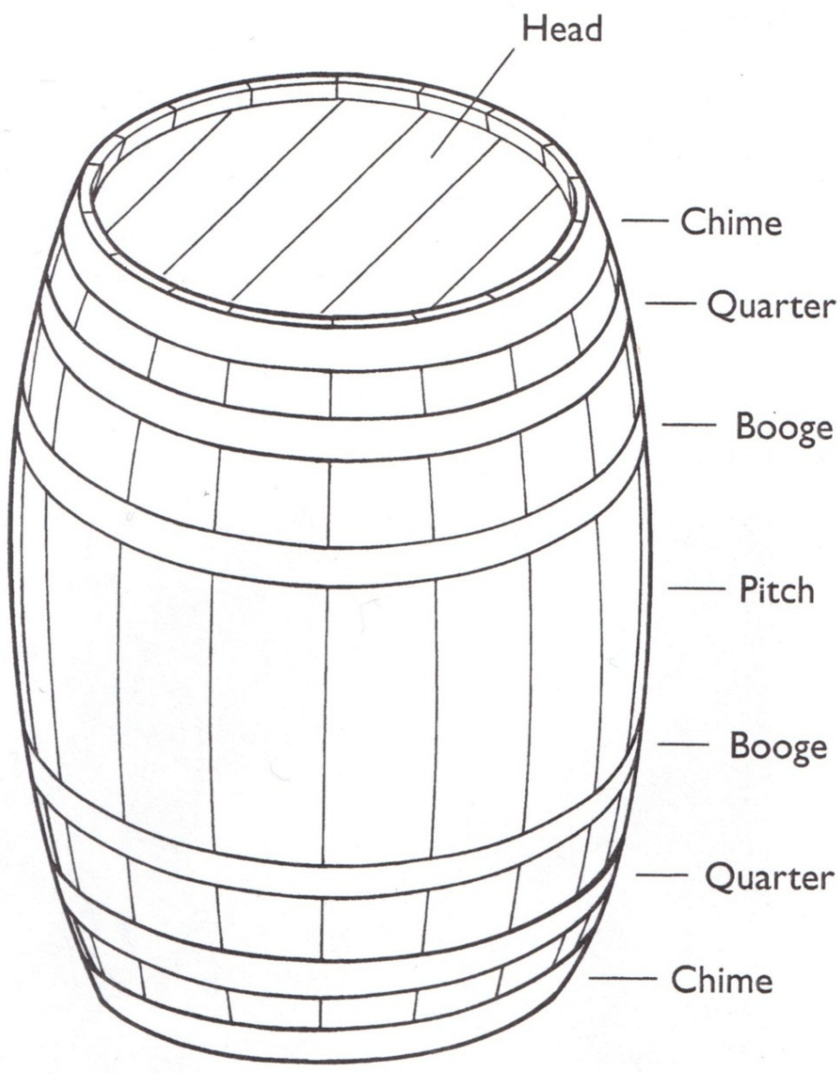


FIGURE 56. Schematic diagram of hoop locations (Rodrigues 2005: 415).

Iron hooped casks were stronger and more durable than those with wooden hoops (Howard 1996: 436), but more expensive. Although iron hoops became increasingly common in the eighteenth and nineteenth centuries, both types coexisted until the use of casks declined in the twentieth century.

Hoops are named based on their position on the cask, (Figure 56). Booge or bilge hoops are driven a third of the way down the cask and divide it into three roughly equal parts. Chime hoops on the ends of the cask are important for protecting the fragile chime area, which is most likely to get damaged. On larger casks, quarter hoops are fitted between the chime and booge hoops (Kilby 1971: 37). Hoops are driven onto a cask using a driver, an iron or iron tipped wooden rod which is hit with a maul or hammer. The driving of hoops is a pose characteristic of coopers and is shown in Figures 23 and 29 in Chapter 4. Fitting and driving wooden hoops onto a cask was also accomplished with a lever known as a "hooping dog," visible in Amman's 1568 woodcut, Figure 26 in Chapter 4. Hoops were not always evenly spaced along the exterior of a cask. The *barricas* common in western France and northern Spain featured many hoops clustered at either end of the cask, completely covering the ends (Loewen 1990).

Evidence for hoops on the *Vasa* casks comes from three sources: the surviving hoop fragments themselves, differential preservation on the casks, and photos taken during the 1961 excavation. All of the hoops are wooden, but the species has yet to be identified. Traditionally hazel and chestnut saplings were preferred for hoops, although alder was also used on the casks from Red Bay (Loewen 2007: 13). Figure 57, below, shows oak cask 12601 soon after excavation in 1961. These black and white photos are very useful for assessing the placement and number of hoops on the casks, prior to conservation and storage. Here nine hoops are visible, in four distinct groups. There are three hoops clustered together on the upper quarter, although it is possible one or two have slipped down from the chime. Below these there are two booge hoops, two quarter hoops, and two chime hoops at the bottom. It appears that the wooden hoops were grouped in pairs and fairly evenly spaced along the exterior of the cask, in accordance with the diagram in Figure 56, above. This style of hoop placement is different from the French and Basque cooperage found on the Drogheda Boat, *San Juan*, or *La Belle*, where the hoops are tightly clustered at either end (Ross 1985: 20; Meide 1997: 137; Fawsitt 2010: 37). The casks

FIGURE 57. Oak cask 12601 soon after excavation in 1961, showing hoop placement. (Photo courtesy of the Vasa Museum, Stockholm.)

from *Mary Rose* have evenly spaced hoops, however (Rodrigues 2005: 414). Other photos from the excavation of the interior of *Vasa* in 1961 suggest that the hoop placement seen in Cask 12601, above, is fairly typical of the casks as a whole. The casks seem to have between four and six bands of hoops, often with two hoops to a band. This means that an individual cask might have had anywhere from four to twelve hoops, based on the number and position of hoop bands, and if hoops were placed singly or doubled. The position and condition of the hoop joins in Figure 57 is noteworthy. The observed practice in archaeological and historical cooperage has been to place the hoop joins and ligatures (if using wooden hoops) in line with the bung stave (Rodrigues 2005: 414). Here the hoop joins are not in line with bung stave, although it is possible the hoops slipped when the cask was moved. The ends of wooden hoops are fastened together with vegetal ligatures or osiers, normally made from willow shoots one to two years old (Loewen 2007: 13). There are a variety of techniques to tie the ligatures. The wooden hoops from *Vasa* were certainly joined with some kind of binding, but none of this material seems to have survived. It is not visible in excavation photos, nor are any samples stored at the museum, to the author's knowledge. Hocker and Wendel state that these bindings likely decayed at a faster rate than the other cask components, allowing the casks to fall apart (2006: 49).

Information on hoop placement on *Vasa* casks also comes from staves with differential preservation. These staves have raised areas across their width where hoops, now missing, preserved the wood beneath. This "hoop ghosting," (Figure 58), is found on 22 staves, 18 oak and 4 pine. The majority of these staves are incomplete, and preserve between one and three raised bands across their widths to indicate where hoops once rested. The location of the raised areas confirms the pattern seen in Figure 57, above, of more or less evenly spaced hoops in the chime, quarter, and booge positions. There are a total of 44 raised areas of hoop ghosting on the

22 staves. These raised areas range in width from 16 mm to 45 mm, with an average width of 24 mm. This suggests that hoops were placed both singly and in pairs, as seen on Cask 12601.

FIGURE 58. Detail of oak stave 09459 showing two raised areas of "hoop ghosting," indicating the position of missing hoops. The area of lighter colored wood to the right is from a wooden spacer used to separate the staves during conservation. (Photo by author, 2011.)

The third source of evidence for the hoops on the *Vasa* casks comes from the remains of the hoops themselves. The complete hoops visible in the excavation photos from 1961 generally did not fare well in conservation, and most are broken into small fragments today. Most of the rebuilt casks do not have original hoops, with the exception of Cask 12601 which still retains six original hoops. There are approximately 745 hoop fragments in the collection, plus another 40 complete, loose hoops. The total length of the surviving loose hoops is 26.27 m. This is only enough hoop material for a fraction of the casks in the collection, so it seems that most of the original hoops have disappeared. The hoops are between 8 mm and 47 mm wide, with an average width of 19 mm. They range from 3 mm to 24 mm in thickness, with an average thickness of 10 mm. The large variation in hoop width and thickness is likely related to the size of cask they held together, with smaller hoops for small casks and larger hoops for full size casks. Most of the hoops were made by splitting small saplings in half down their length, producing two usable halves. These hoops have a semi-circular cross section, so that the flat interior of the hoop can rest against the cask surface. Some of the hoops were made of nearly whole small saplings or branches, however. These hoops used smaller branches. Rather than being split evenly in half, only part of the wood was removed to produce a flat surface, leaving the majority of the branch intact.

FIGURE 59. Interior view of a hoop end, showing the notch used to join the two ends together. (Photo by author, 2011).

It appears that two methods were used to create the hoop joins. The first employed two interlocking notches, one at each end of an individual hoop. One of these notches is shown in the above figure. This was by far the most common style. The notches were cut with a knife approximately half way across the width of the hoop, and then trailed off into a tail. The notches are cleverly cut with a gentle curve, more pronounced near the vertical face of the notch and then slowly returning to the original width of the hoop near the tail. A total of 99 notches survived sufficiently complete to measure. These notches varied in length from 19 mm to 195 mm, with an average length of 94 mm. They ranged in width from 4 mm to 24 mm, with an average width of 14 mm. The depth of the notches fell between 5 mm and 24 mm, with an average depth of 12 mm. This method of hook closure was apparently quite popular in North America (Loewen 1992: 83). The casks from the late sixteenth-century Dutch Scheurrak SO1 wreck also used hook hoop joins. Here Martijn Manders called them *vissenbekje* or "fish mouth" style (Manders 1996:

46). The second method of hoop joinery on the *Vasa* casks was simpler. The ends of the hoop were trimmed with a knife to form a pointy end, or tail. These tails were then crossed over each other and presumably bound with osiers. There are 55 such tails in the collection of hoop fragments. The plates from the entry on cooperage in Diderot and Alembert's *Encyclopédie* show several methods of hoop joinery, (Figure 60). It appears the notched hoops from *Vasa* correspond to Diderot's Figure 27, while the hoops with overlapping tails are shown as Figure 28.

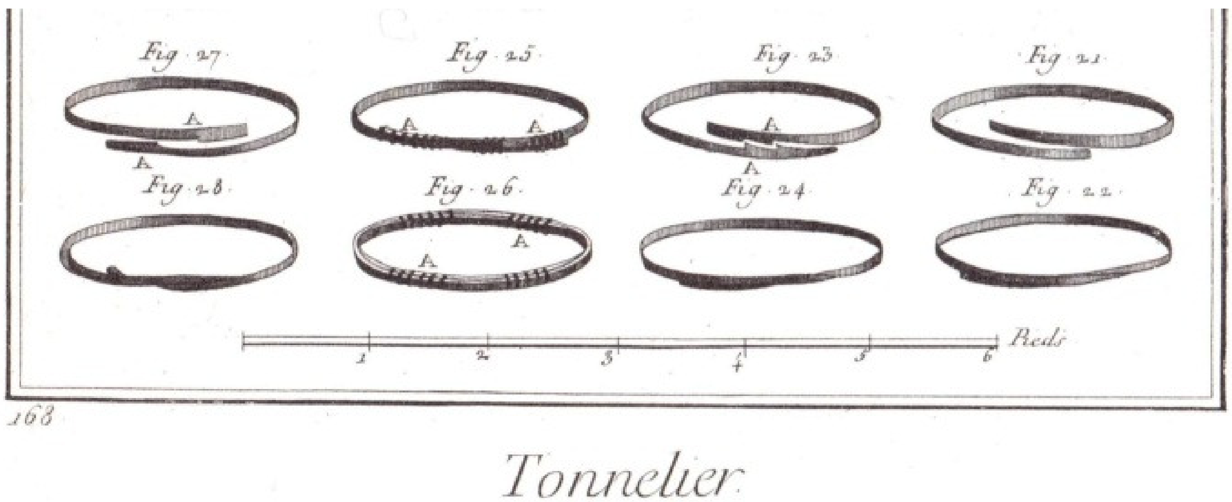


FIGURE 60. Different styles of hoop joinery, as shown in Diderot and Alembert's *Encyclopédie* of 1751-1772 (Diderot and Alembert 1772: 168).

Bark remained on 26 hoop fragments, (Figure 61). It is uncertain if this reflects expediency or haste in production, standard production practices, or merely differential preservation. Bark removal would seem prudent to reduce the possibility of rot or insect damage. The lack of bark on the majority of hoops, however, suggests that this was generally stripped away prior to fabrication. A total of 13 holes were observed on the hoop fragments, ranging from 3 mm to 9 mm in diameter. It is uncertain if they were used as attachment points for osier bindings, or more likely, natural flaws in the wood.

FIGURE 61. Bark survived on 26 hoop fragments. (Photo by author, 2011.)

Markings (*Bomärker*)

Many of the *Vasa* casks have markings carved into them, known as *bomärker* in Swedish. There are a total of 184 such marks on 147 staves and head pieces. There are 121 marks on oak pieces, and 63 marks on pine pieces. Marks are more commonly found on head pieces than staves. There are 83 marks visible on oak head pieces, compared to only 49 marks carved into oak staves. *Bomärker* occur on other objects in the collection, mostly personal items such as boxes, wooden tankards, plates, and spoons. It seems likely that most of these markings indicate ownership of an object, and the similarity of the cask markings suggests they too are personal or owner's marks. The precise meanings of individual marks likely vanished with the demise of their creators, and thus remain essentially unknowable. The marks on the *Vasa* casks form a language of their own, since "signs are, as it were, programmed messages," but "we do not grasp all signs spontaneously. We have to get to know them. We have to learn to read what has been written in sign language" (Bühler-Oppenheim 1971: 9). As noted symbologist Carl Liungman observes:

> The meaning of a sign thus is something collective. A human being…acquires the meanings of the signs used for communication in its culture, as well as a whole series of conventions…Graphic structures rely upon these conventions for their various meanings (2004: 501).

Without knowledge of the specific symbolic conventions used and understood by individuals aboard *Vasa* in 1628, it is difficult to interpret the precise meanings of the *bomärker*. The exception would be cases where guild, notarial, or legal archives preserve the marks and names of specific individuals. Research in Swedish archives might yield some results in this area. More information will be forthcoming from Irene Lindblom, collections manager at the Vasa Museum, who is conducting a detailed study of the *bomärker*.

Marks are made on casks by those involved in their production and use. In England legislation from the medieval period onwards required coopers to mark their work, as a means of enforcing standards of quality and metrology (Kilby 1971: 113:115). Coopers or forestry workers might mark timber intended for casks, to sort staves into different groups based on size (Loewen 2007: 18). If casks were disassembled or "shook," then long lines scratched across all the staves and head pieces served as a guide for reassembly (Ross 1985: 9). Examples of thirteen late-sixteenth and early seventeenth-century cooper's marks are preserved in Bordeaux notarial archives, (Figure 62) (Roborel de Climens 1896). Loewen believes these marks are crude representations of a cooper's horse (Loewen 2007: 36). This is plausible, as the other artisan marks in the Bordeaux Archives generally consist of either the characteristic tool of the trade, or the finished product. Thus individual butchers used a cleaver as their mark, carpenters used a small drawing of an axe, and hatters an image of a hat (Roborel de Climens 1896). While a

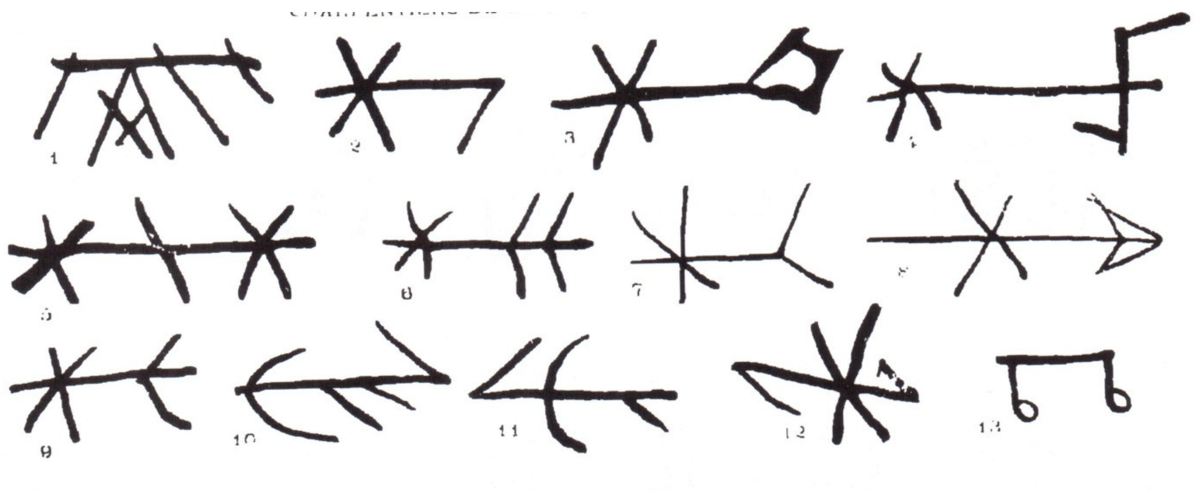


FIGURE 62. Coopers marks from Bordeaux, France, from the period 1593-1608 (Roborel de Climens 1896).

cooper or a carpenter might mark their finished product, a butcher would not mark a cut of meat. Rather, these marks or house signs were used in lieu of a signature in an era of limited literacy (Bühler-Oppenheim 1971: 47).

Merchants also marked casks as a way of identifying their property. Merchants' or shippers' marks are commonly found on historic casks. Merchant or house marks can have angular, geometric forms like the majority of marks found on the *Vasa* casks, but more often combine angular lines with letters and curvilinear forms. A merchant's mark was like a monogram, and often incorporated the initials of the merchant (Loewen 2007: 36). House marks were used by generations of the same family, each of whom slightly modified the original mark (Koch 1930: 76). Figure 63, below left, provides examples of wine merchants' marks from Haarlem, from 1707. These marks are characterized by combinations of letters. Figure 64, below right, shows how merchant marks were used on cargo such as casks and bales to denote ownership. Lester Ross claims that merchants preferred to mark cask heads since they could be more easily replaced if the container was reused, while coopers apparently marked the bung stave since it was generally the most robust stave (1980: 10). Customs inspectors also marked

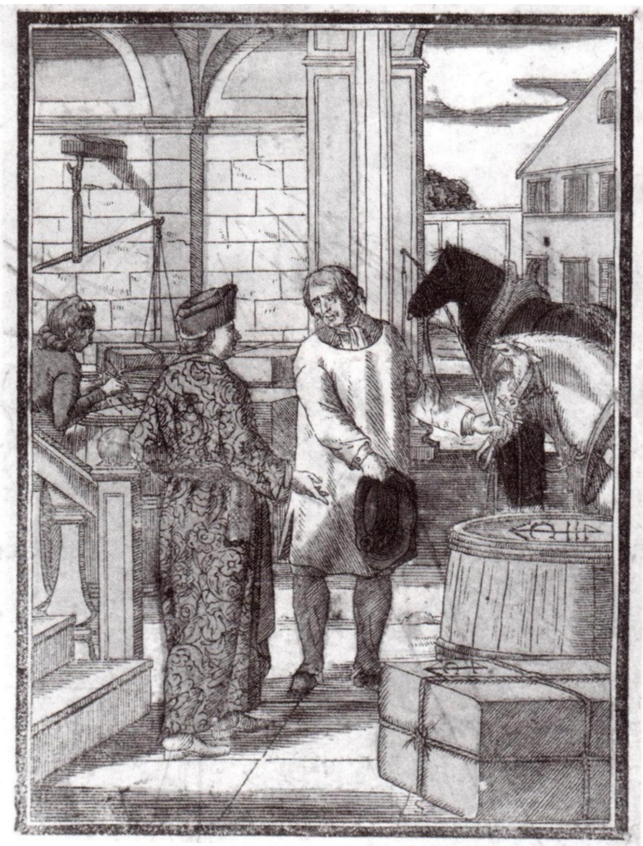
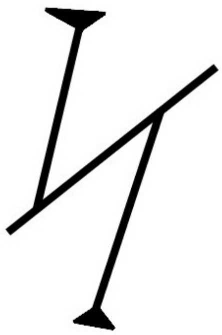


FIGURE 63 (left). Examples of merchant or house marks used by wine merchants in Haarlem, 1707 (Schuckman 1991a: 185)**. FIGURE 64 (right).** Merchant marks applied to a cask and bale of goods, ca.1690-1710, from *Curioser Speigel*, Nuremburg (Notarp 2000: 60).

casks to confirm that standards of quality and economic regulations were enforced (Frandsen 2004: 163).

The marks on the *Vasa* casks can be classified stylistically into three types: letters and curvilinear forms, geometric shapes and angular lines, and scrawled lines. Complete examples of each type are presented below. The drawings were made by tracing photos of the marks, since many of the marks are quite eroded and faint.

Type I – Letters and Curvilinear Forms



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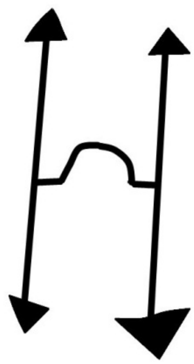

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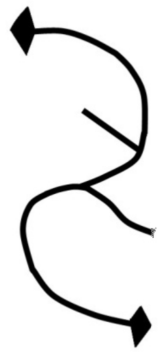

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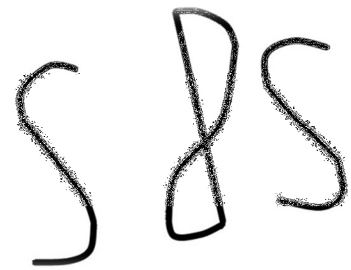

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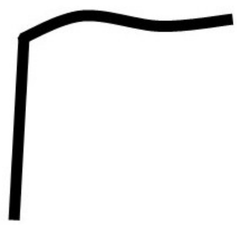

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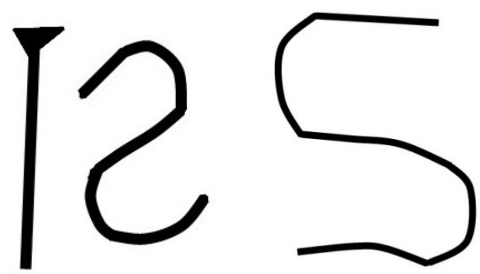

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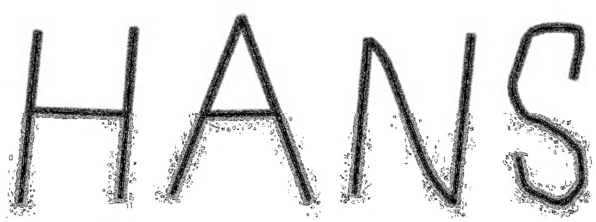

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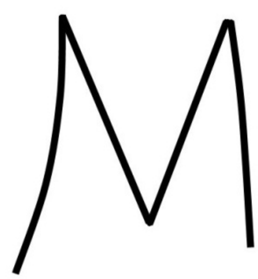

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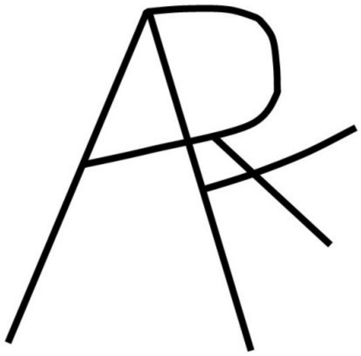
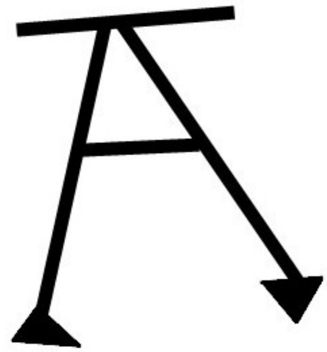


13256



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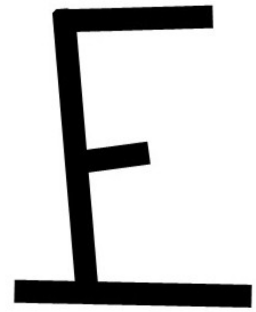

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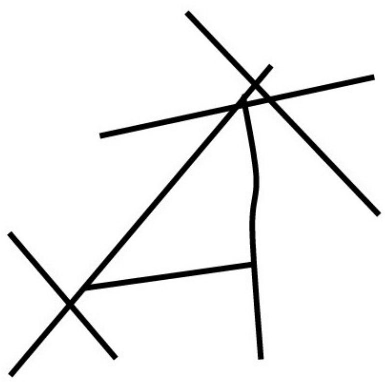

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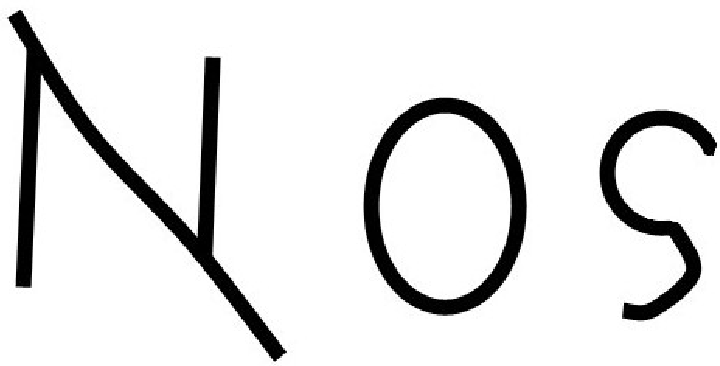

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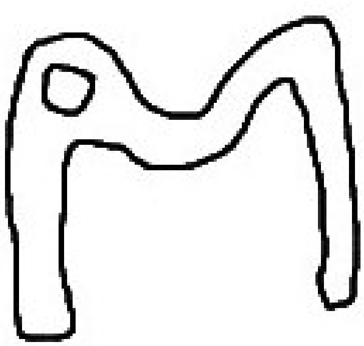
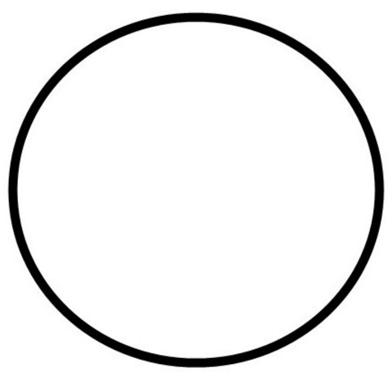
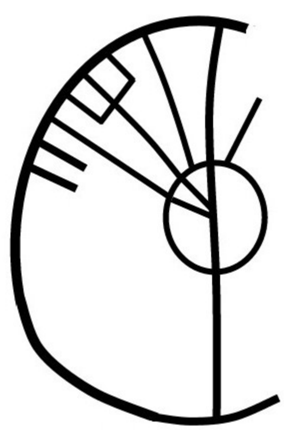


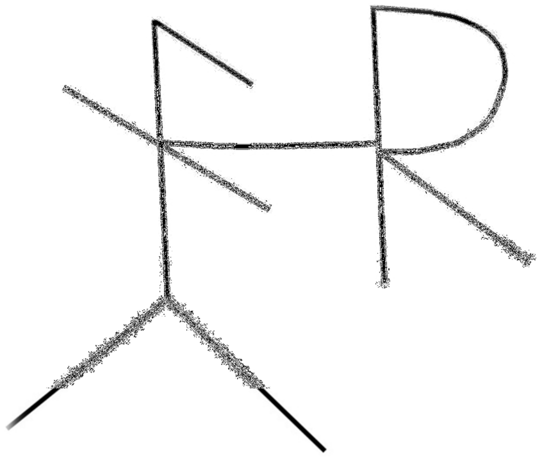
No FNR



17205



14069



No FNR

There are a total of 18 markings that employ letters or curvilinear forms, above. Eight of these marks occur on pine heads with rebated or lip style edges, indicating they are removable lids for casks full of personal possessions. It is likely then that many of these marks are the personal marks of the owners of the objects within. Occasionally, more than one set of marks occurs on a cask lid. In this case, perhaps more than one individual was sharing a cask in place of a sea chest. The multiple marks might also indicate reuse. A third explanation is simply that the marks are graffiti, carved by bored sailors with time on their hands. This is the explanation given for the markings on a box lid from *Solen*, (Figure 65), a Swedish warship sunk off Danzig only a year before *Vasa*. It is entirely possible that some of the marks on the *Vasa* casks are also graffiti, an explanation not likely to enamour archaeologists fond of over interpretation. The "HANS" *bomärke* is striking, but was almost not recorded at all. Found on an oak cant, the mark was so eroded as to be almost invisible to the naked eye. Luckily, Irene Lindblom noticed a photo of excavation supervisor Per Lundström holding the object, from a 1961 newspaper clipping. When the excess PEG was removed from the object , the letters were very faintly visible. Mark 13256 was found on an oak bung stave, and strongly resembles a traditional merchant's mark. It appears to combine the letters "A" and "R." The mark illustrated on the page above also appears to combine the letter "R" with some angular lines. It, too, resembles a merchant's mark.

FIGURE 65. Marks on a wooden box lid from the Swedish warship *Solen*, sunk off Danzig in 1627. These marks are explained as graffiti (Villner 1986: 50).

An unusual aspect of the *Vasa* cask markings is that very few seem to employ the circles or half circles characteristic of a cooper's scribe. This is a tool used by coopers to mark casks. It consists of a central point and one or more extremely sharp curved bits, (Figure 66). It produces perfect circles and can score lines as well. Fawsitt refers to this tool as a rase-knife (2010: 62). Cask markings on *Mary Rose*, *San Juan*, and *La Belle* frequently featured individual and interlocking circles made with a cooper's scribe (Rodrigues 2005: 419; Loewen 2007: 34-35, 2014: 31). This style of mark is almost entirely absent from the *Vasa* collection, with the exception of mark 17205. This is a circle found on a half bung stave, possibly made with a cooper's scribe. The remainder of the marks appear to have been cut with a knife or possibly a burin.

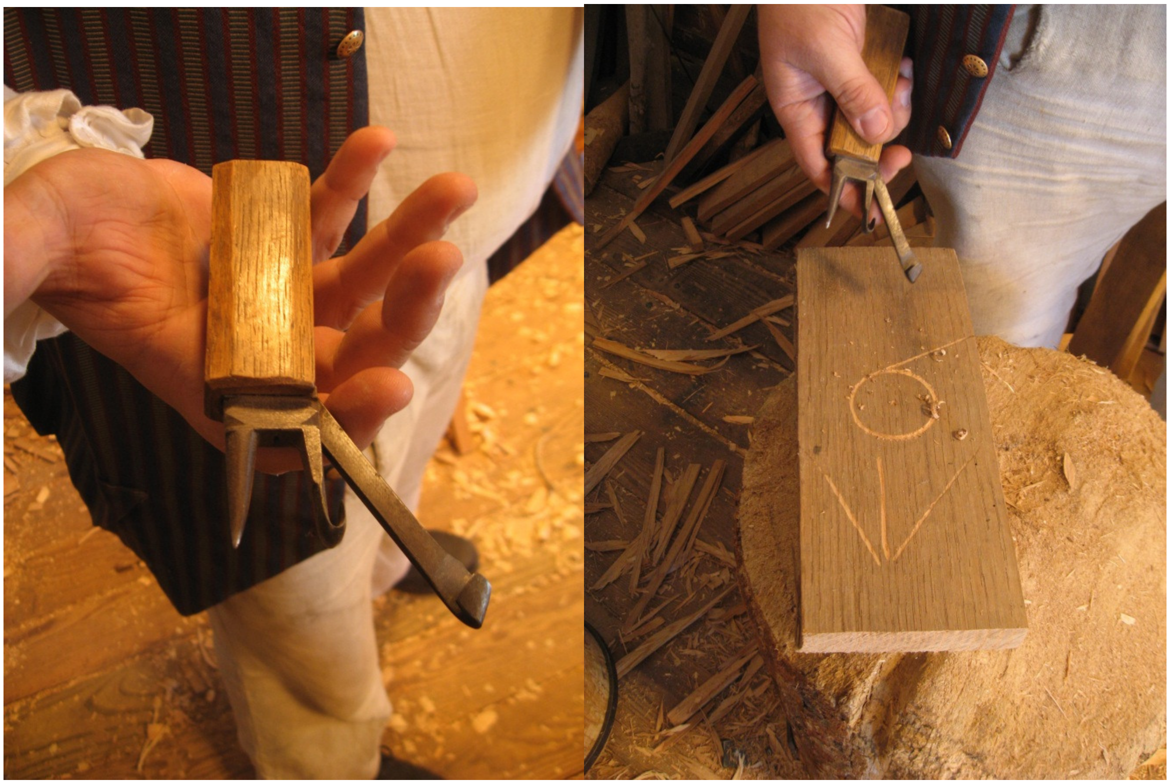
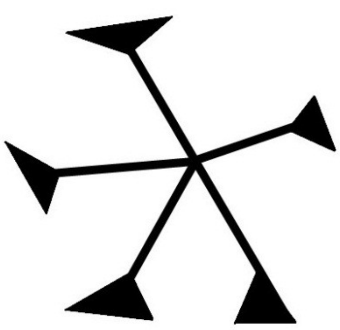


FIGURE 66. Cooper Jon Hallman holds a cooper's scribe, left, and demonstrates its use, right. The marks on the *Vasa* casks are unusual in that they do not appear to have been made with this tool, in contrast to examples of historic cooperage from other sites. (Photos by author, 2010).

Type II – Geometric Forms



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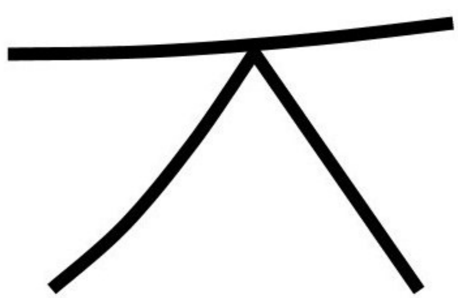

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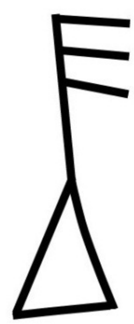

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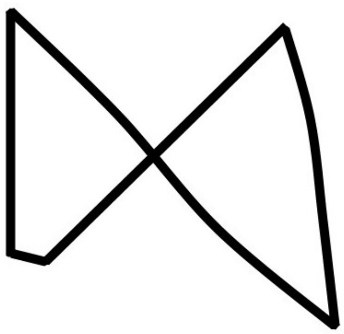

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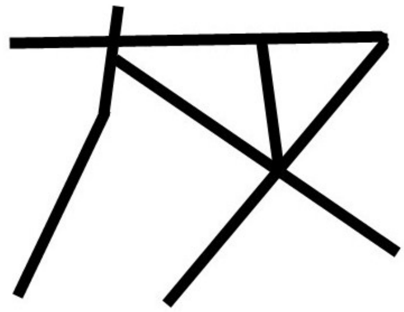

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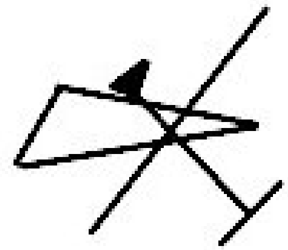

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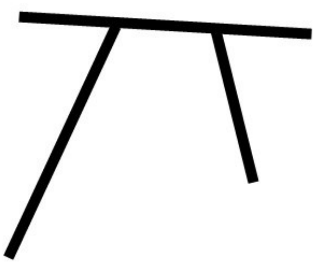

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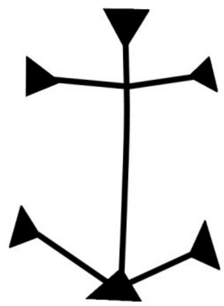

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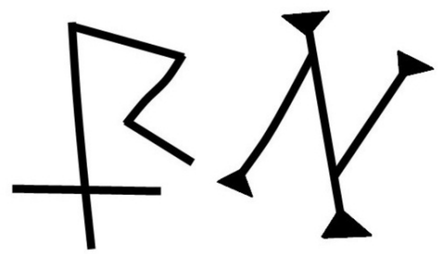

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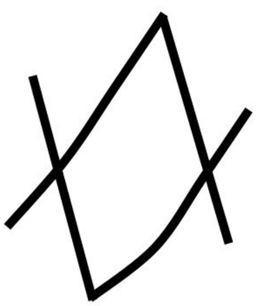

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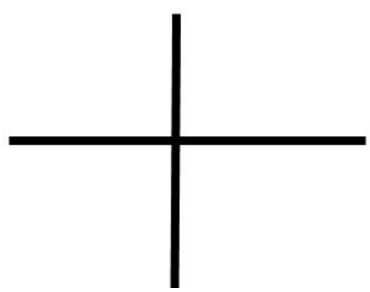

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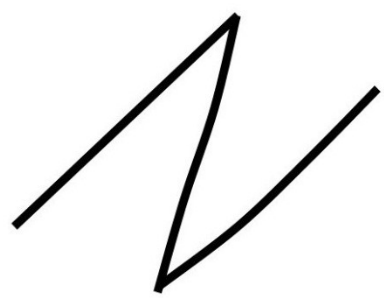

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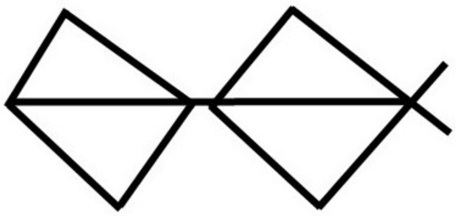

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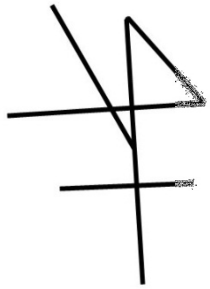

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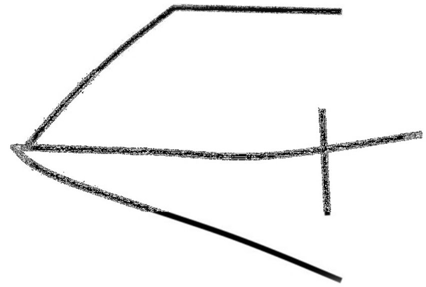

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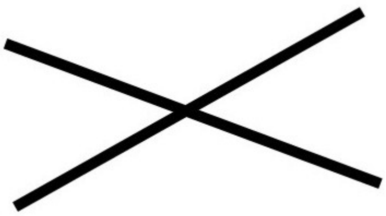

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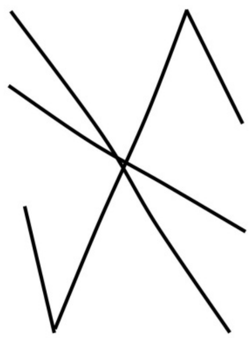

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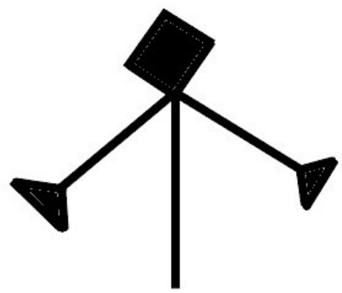

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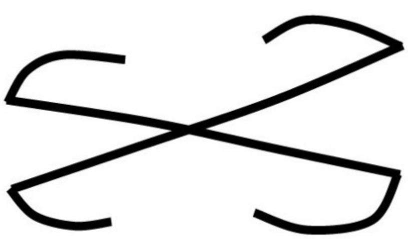

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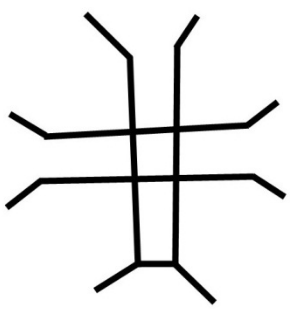

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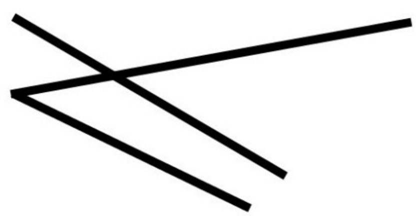

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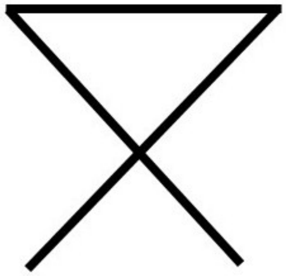

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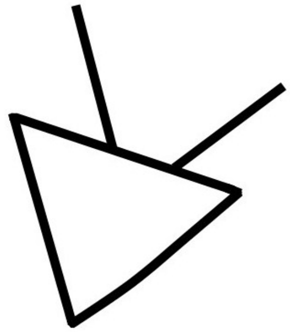

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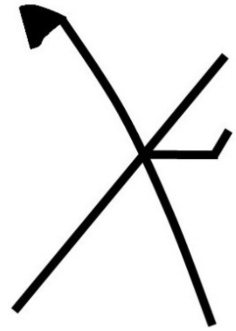

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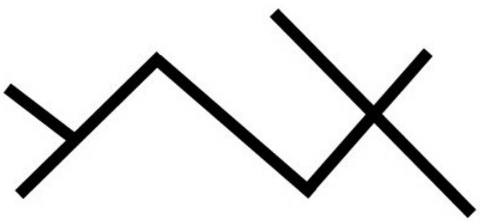

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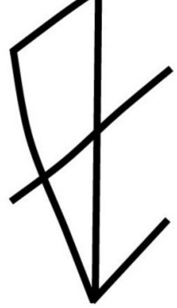

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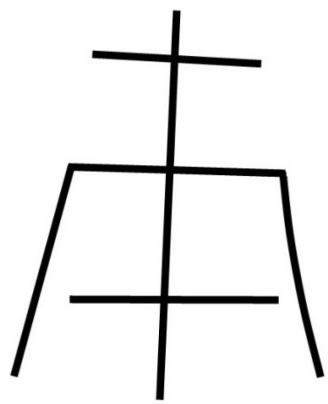

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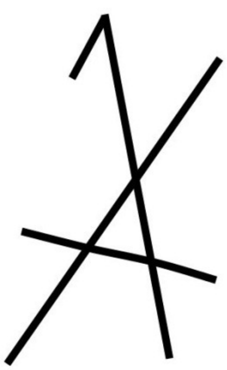

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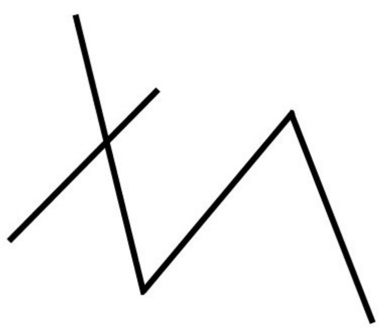

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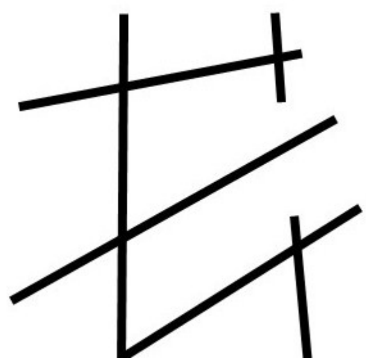

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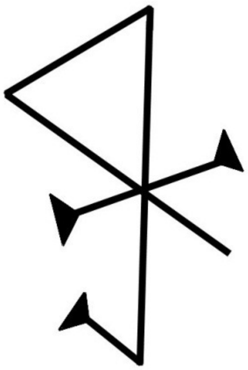

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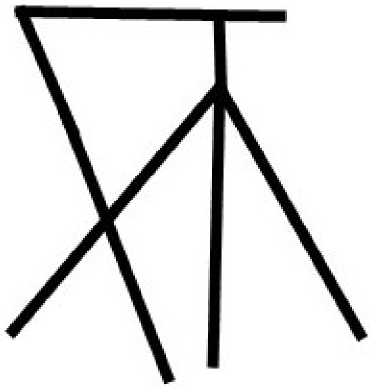

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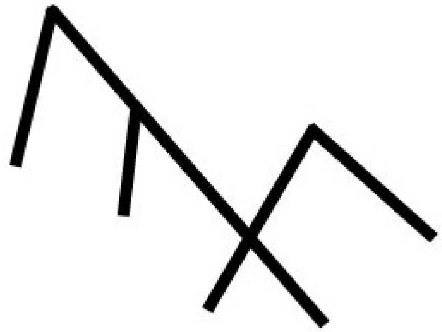

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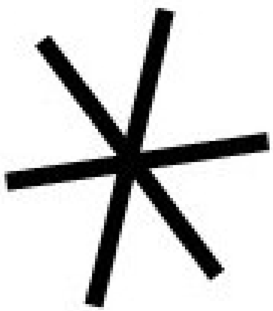

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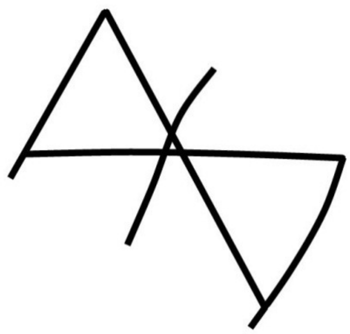

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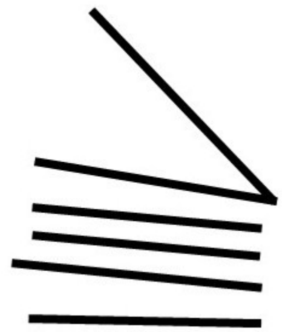

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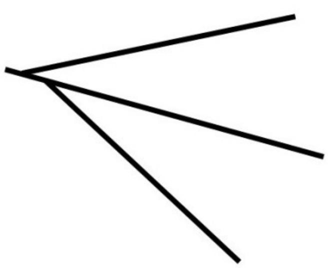

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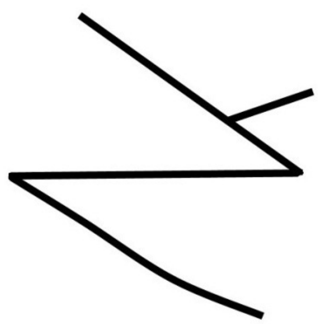

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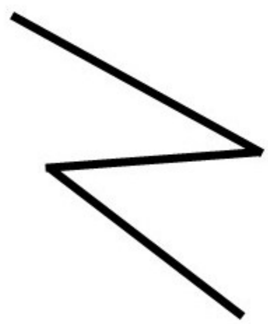

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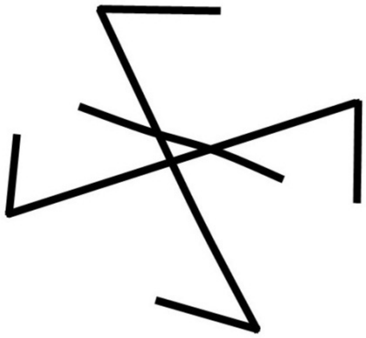

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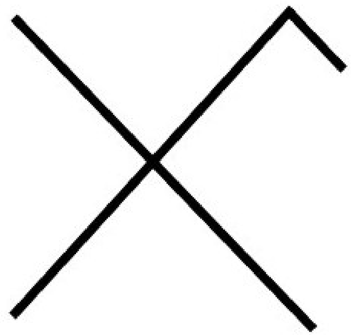

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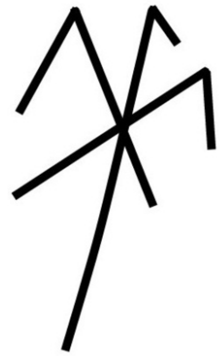

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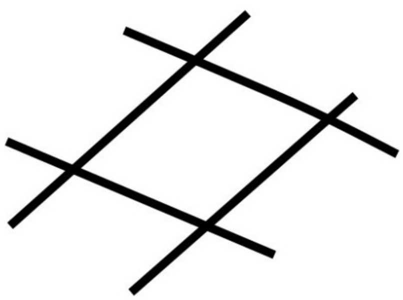

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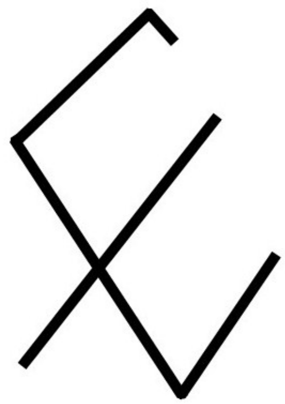

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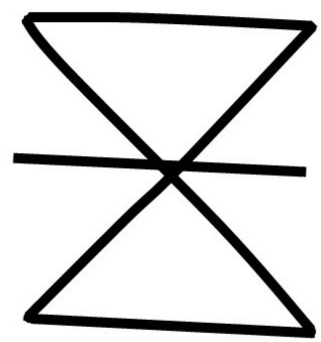

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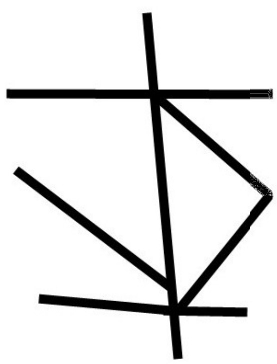

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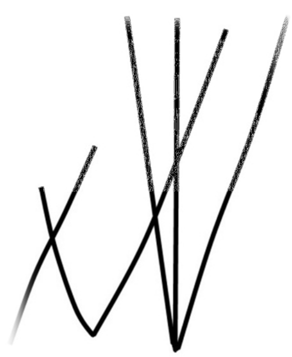

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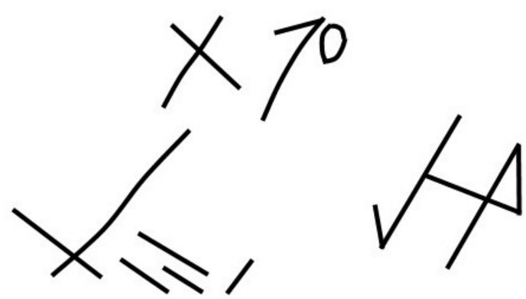

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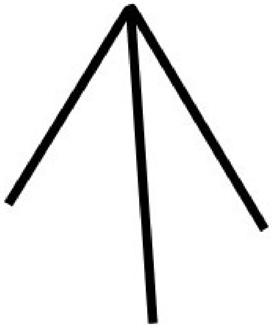
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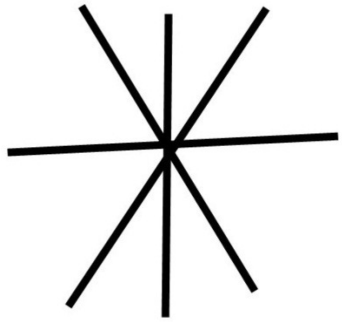
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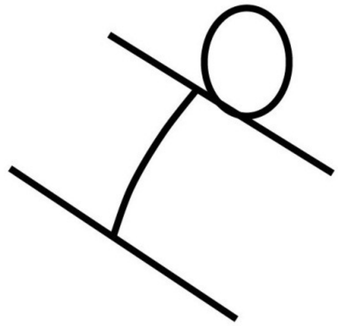
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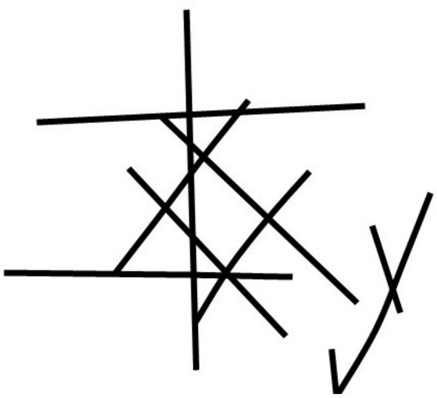
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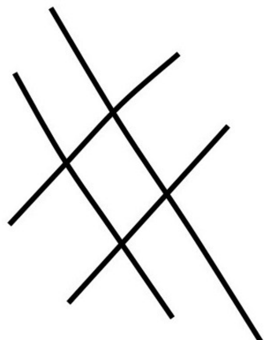
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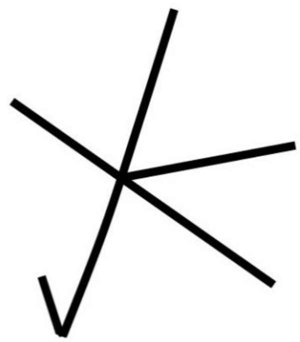
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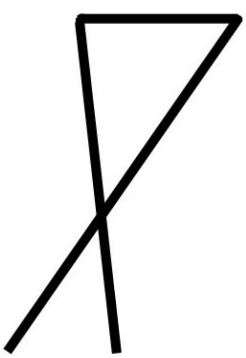
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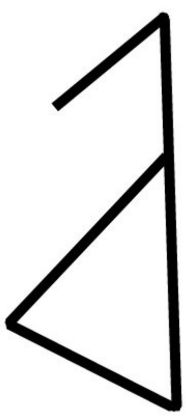
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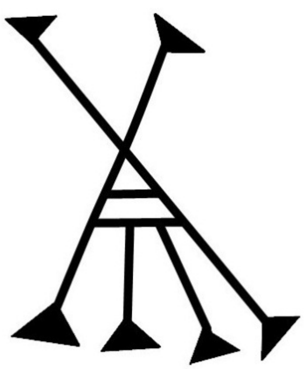
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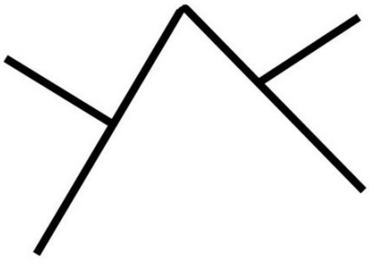

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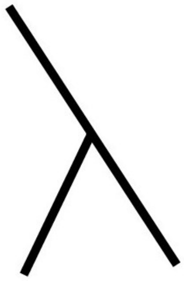

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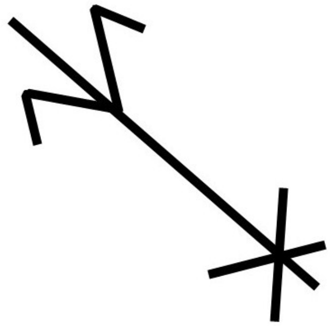

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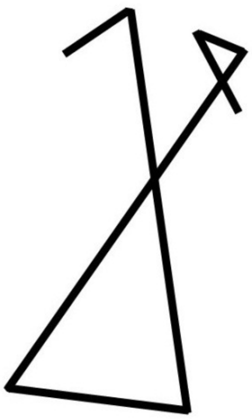

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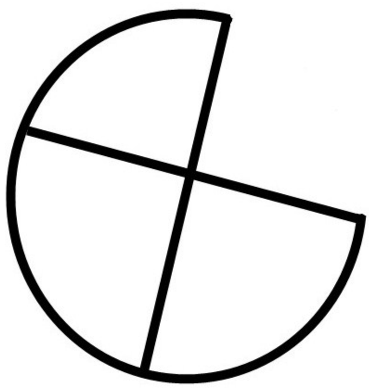

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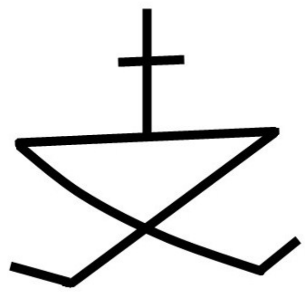

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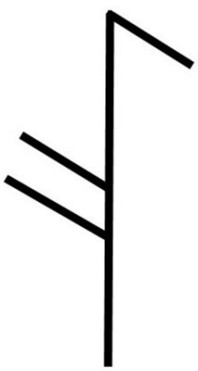

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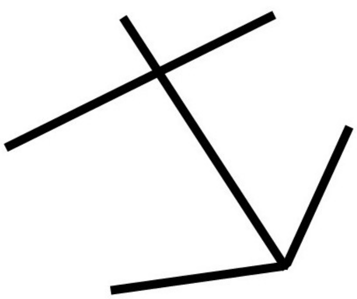

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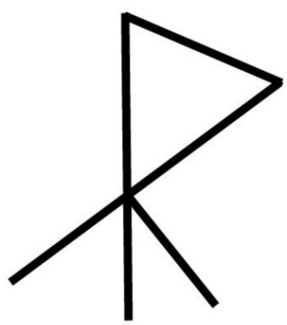

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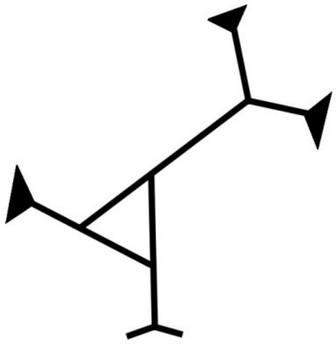

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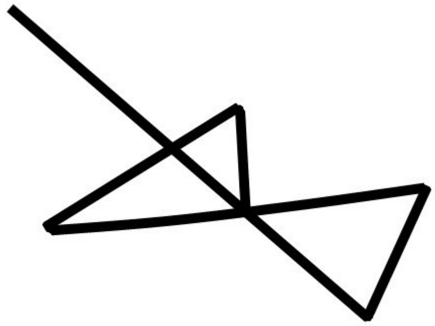

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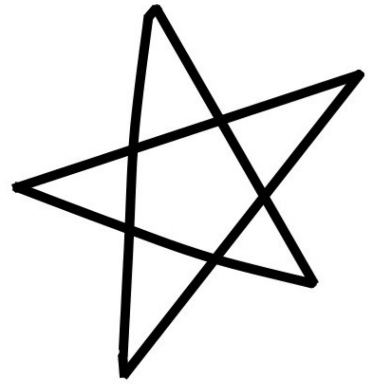

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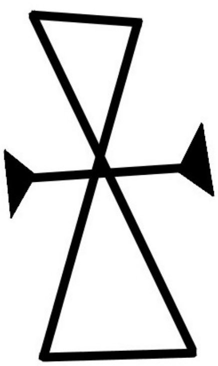

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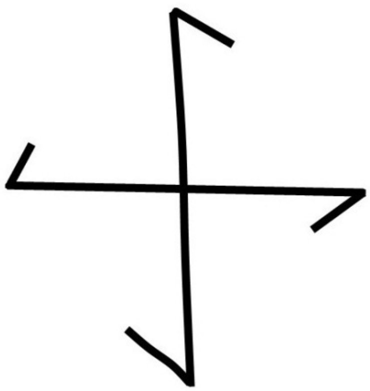

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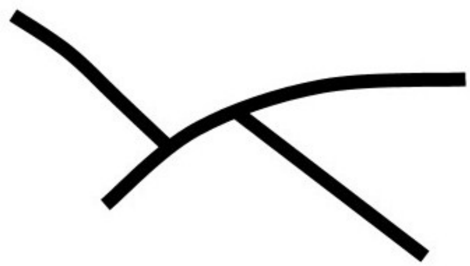

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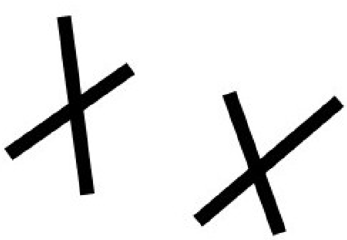

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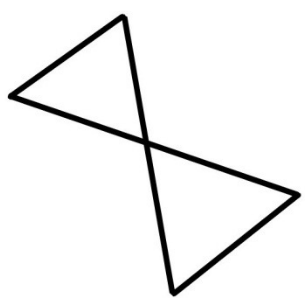

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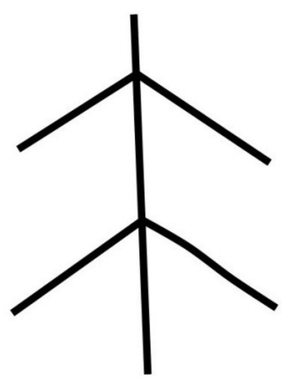

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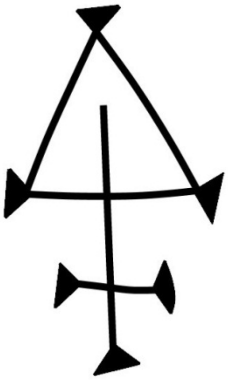
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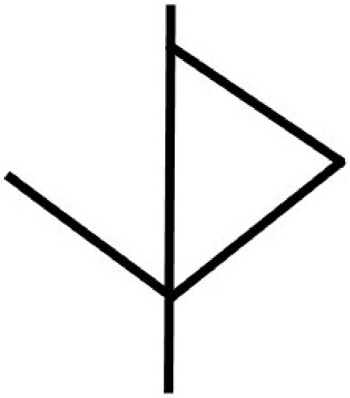
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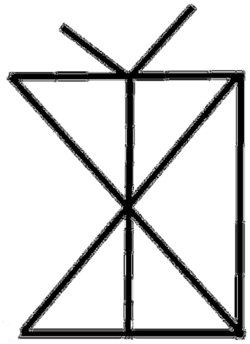
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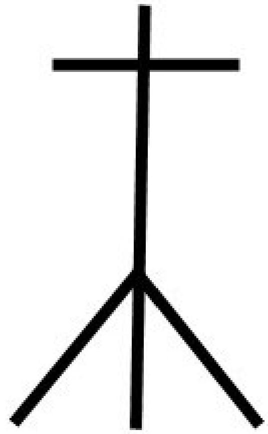
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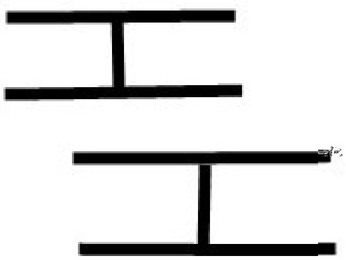
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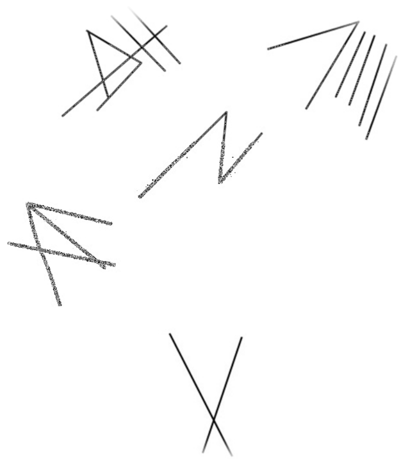
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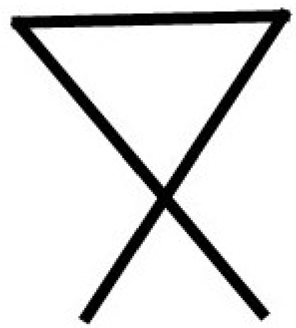
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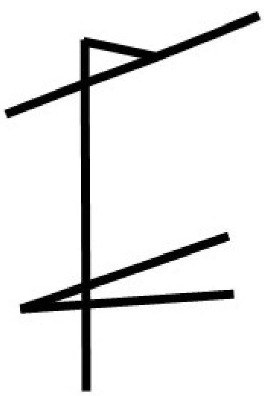
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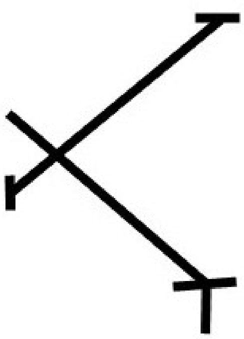
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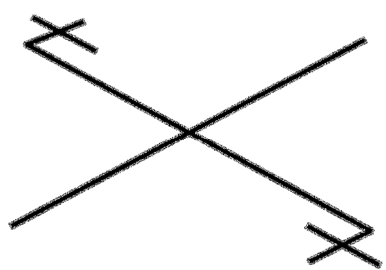
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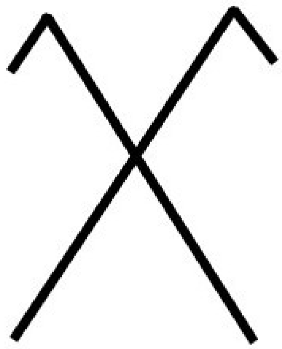

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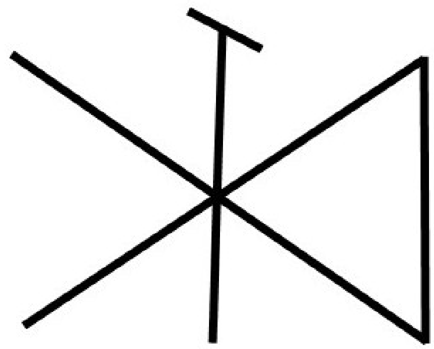


No FNR

The geomeric shapes are the most common type of mark found on the *Vasa* casks. There are 147 marks of this type in the collection, of which 107 are unique and are not repeated on other casks. This diversity is one of the most conspicuous features of this group, and suggests they are neither coopers nor merchants marks. If these marks were made by coopers or merchants there should be fewer types of marks repeated more frequently. A similar diversity of marks was found on the casks from Red Bay, which had over 60 unique marks. This led the excavators to conclude that the marks belonged to individual crewmen, and indicated ownership of shares of the cargo (Loewen 2007: 36-37). The geometric marks on the *Vasa* casks likely had a similar function, to indicate ownership. There are many instances where multiple marks appear on the same cask, (Figure 67). In this instance, the contents of Cask 08218 remains unknown, so it is unclear if the multiple marks indicate shared ownership, or several cycles of reuse. The location of the marks here is significant. Clustered near the bung, they suggest the cask was stowed with the bung facing outwards so that the marks would be visible. The geometric marks were carved with a knife or burin. They lack the circles and curvilinear forms typical of marks made with a cooper's scribe, found on most other examples of historic cooperage. Similarly to

FIGURE 67. Detail of Cask 08218, taken soon after excavation in 1961. The multiple marks on a single cask might indicate shared ownership, or alternatively several cycles of reuse. (Courtesy of the Vasa Museum, Stockholm.)

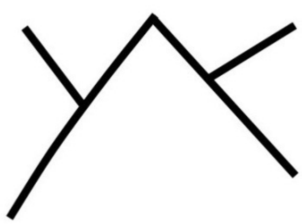
the letters and curvilinear forms found in Type I, many of the Type II marks have triangular serifs. The shape of the geometric marks is likely due to their method of production. Knives and burins lend themselves to the carvings of straight lines and angular rather than curvilinear forms. These shapes are easy to create and replicate, and are based on a limited repertoire of basic forms. In some respects they are similar to the signs used by modern vagrants, and fulfill similar requirements of ease of production and communication. The supposition that these marks are the personal marks of individuals is strengthened by comparison with similar symbols from different

FIGURE 68. Wooden panel from Davos-Monstein, Switzerland, dated 1694. The signs here are very similar to those found on *Vasa*, combining a limited number of basic geometric forms. Here the number of cattle each farmer sent to pasture is recorded beneath their house sign (Bühler-Oppenheim 1971: 93).

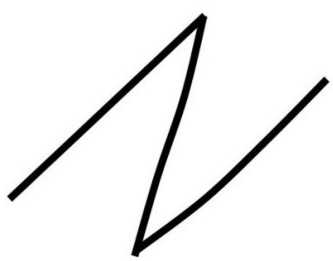
FIGURE 69. A fifteenth-century wooden statue of St. George from the island of Götland (left) is covered in markings (right). These are similar in shape to the Type II marks from *Vasa*, and suggest the latter are also personal marks. (Courtesy of the Götland Lansmuseum, Visby, Sweden.)

contexts. Figure 68, above, shows a wooden panel from Switzerland used to record individual peasant's use of pasture, while Figure 69 shows a fifteenth-century equestrian statue of St. George from the island of Götland. A closer look at the statue reveals that it is covered in marks similar to those from *Vasa*. The profusion of marks on the statue suggests they are personal marks, carved either as simple graffiti or perhaps as a more sincere devotional act. The overall shape of these marks from different contexts is remarkably similar to those from *Vasa*, combining a limited number of geometric forms to produce individual marks. Many of the marks are also accented by triangular serifs. While some of the geometric marks bear a strong resemblance to Nordic runes, "the suggestion that they owe their origin to the Runes is only to be accepted in rare cases" (Koch 1930: 76). The greater incidence of geometric marks compared to letter marks on the *Vasa* casks suggests a limited level of literacy amongst the owners and users of the casks, or at the very least a society where geometric house marks still enjoyed widespread currency.

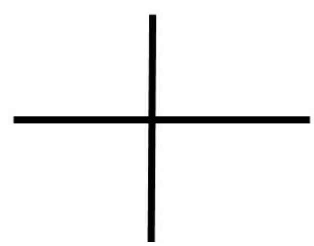
Not all of the Type II – Geometric marks on the casks were unique, however. There are 16 marks which reoccur at least twice on the casks. Many identical marks are also found on personal possessions such boxes, tankards, and tableware, but more research needs to be done to uncover the implications of these links. The marks which are repeated on multiple casks are presented, below. The first example is also the most significant. It reoccurs a total of seven times, and always on head pieces. This frequency might tend to support the hypothesis that it is a cooper's mark, if not for the fact that it reoccurs on a variety of personal objects.



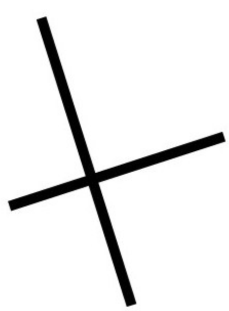
7 examples



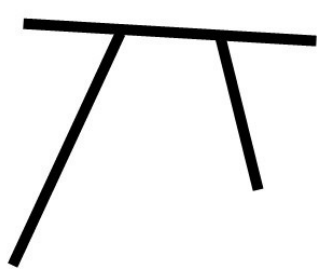
5 examples



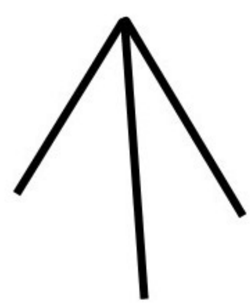
3 examples



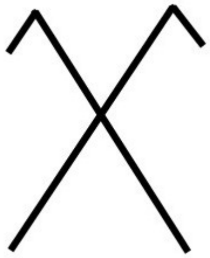
3 examples



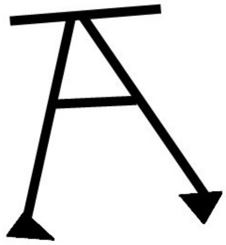
2 examples



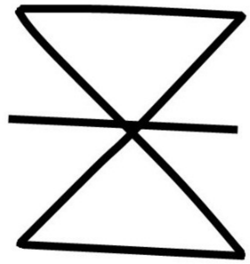
2 examples



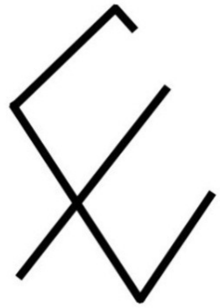
2 examples



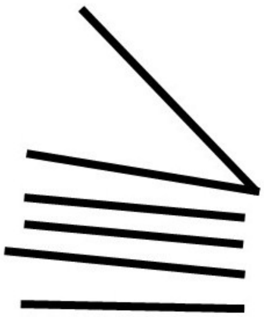
2 examples



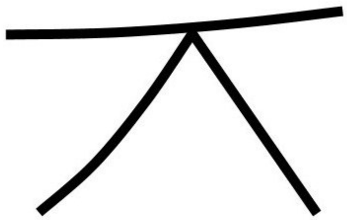
2 examples



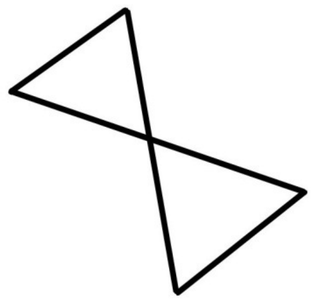
2 examples



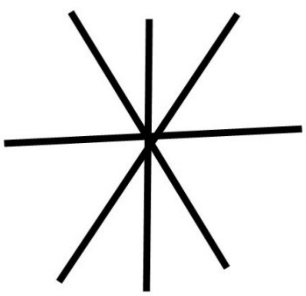
2 examples



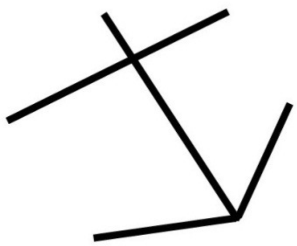
2 examples



2 examples

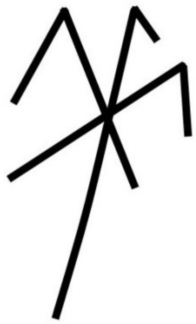


2 examples

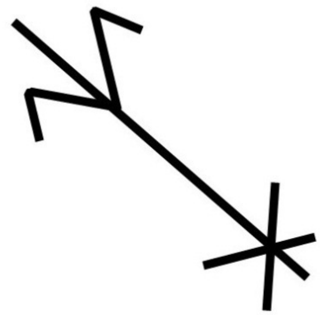


2 examples

There are only two marks which resemble the cooper's marks from Bordeaux, shown in Figure 62, above. The fact that these are isolated examples, however, suggests that they are not likely to be cooper's marks. These two marks are presented below.



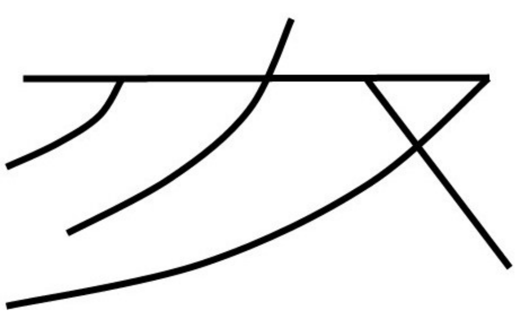
13497



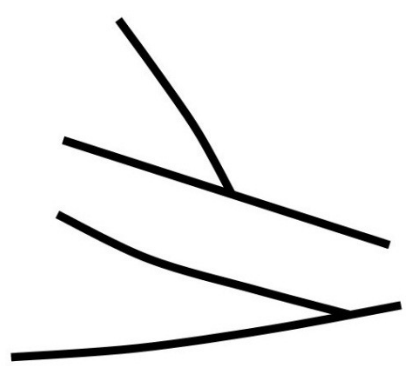
17452

Type III – Scrawled Lines

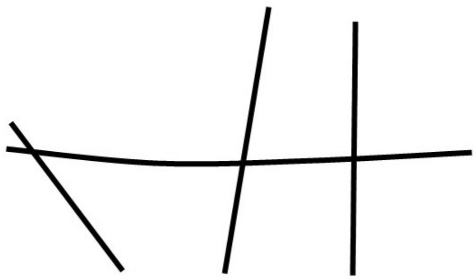
The third type of marking found on the *Vasa* casks consist of long, irregular lines which extend across multiple pieces. They are usually less well defined than the letter-based or geometric marks. These marks are considerably larger than the other two types. While it is possible the scrawled lines could serve as assembly marks, and in fact did help reestablish links between pieces, they seem unnecessarily complex for this purpose. All of the scrawled lines occurred on head pieces. There are 19 instances of scrawled lines on the casks, examples of which are presented below.



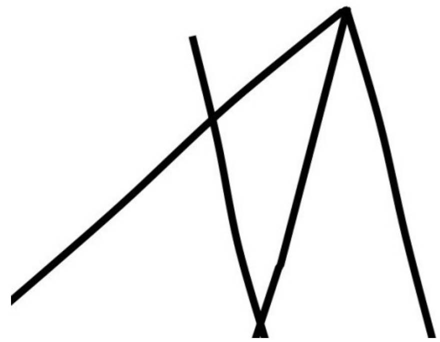
08221-08222



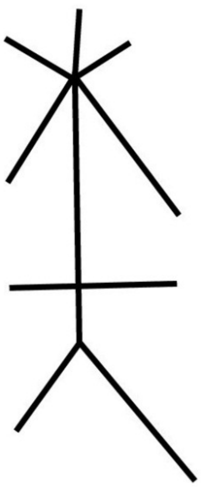
12031-12032



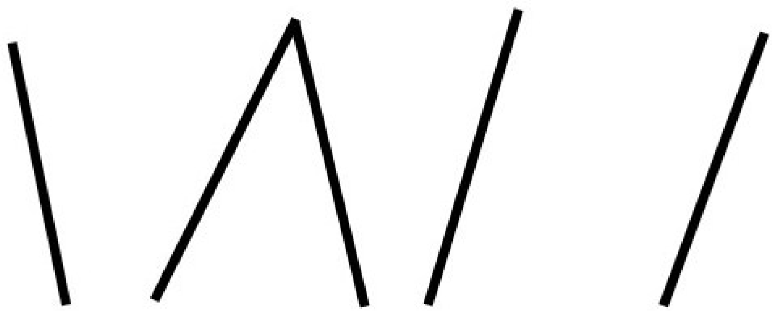
12156-12157



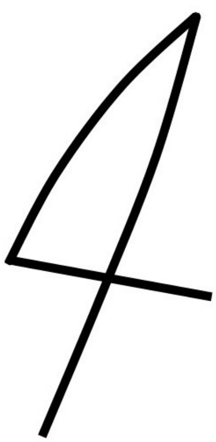
13131-13132



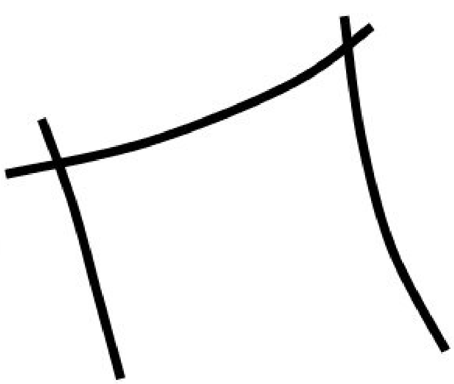
13499



16339



18947



B92

The square bung holes and numerous *bomärker* are some of the more interesting and unique features of the *Vasa* casks. The square bung holes have few parallels, as recorded archaeologically and historically. Iconographic evidence for this style of bung hole does exist, however, and is presented in Chapter 8. The *bomärker* are significant, as future studies can establish links between individual objects and specific casks. Further archival research might be able to associate markings with particular crew members, adding a further human dimension to the *Vasa* story. The oak casks were made of good quality timber, but the numerous sample and vent holes indicate that they had certainly undergone some use. Although iron hoops were used to bind some containers in the seventeenth century, all of the *Vasa* casks were hooped in wood. Hoops were evenly spaced along the casks, which is different from the Gallo-Iberian practice of clustering hoops at the ends of the container. Taken together, these attributes show that while the *Vasa* casks share features still common to cooperage today, they also preserve many unusual variations.

Chapter 6 – Typology

The preceding chapters dealt with specific attributes of the casks. This chapter aims to study the casks as whole containers, and create a typology of the collection. The division of archaeological collections into discrete types has a long history within the discipline (Trigger 1989: 156-161), and facilitates the description of artifacts as well as intersite comparisons (Rice 1987: 288). Classificatory schemes can themselves be categorized as either "devised" or "folk," with the former based on attributes identified by the archaeologist (Rice 1987: 282), and the latter founded on the customs of the actual users of the objects (Rice 1987: 277). The typology proposed here attempts to integrate these two systems. The *Vasa* casks are classified based on the material and construction of the container, volume and contents, as well as context. This data is compared with information on seventeenth-century Swedish metrology, in an effort to understand how the sizes of container might have been understood by those who produced and used them.

The *Vasa* casks are divided into five main types: oak casks, lidded casks, pine casks, small casks, and shot kegs. The oak casks were the true multipurpose container of the ship and seem to have been used to store a variety of provisions. When modified with the addition of a removable pine head they are classed as "lidded casks," often used by individuals to store personal possessions. Pine casks were significantly smaller than the oak casks and contained fish, among other items. Small casks were made of both oak and pine, but are defined here by their diminutive size. Examples range from almost 19 liters capacity down to the tiny "Micro Cask," which only held 0.3 L. The seven shot kegs found in the hold were also small, but are differentiated because of their unusual construction and known contents of approximately 9,000 lead musket shot.

Oak casks are the most common in the collection. There are likely 64 examples of this type. These containers are augmented by an estimated 26 lidded casks, 33 pine casks, 15 small casks, and the 7 shot kegs mentioned above, for an estimated 145 total casks on *Vasa*. This figure is significantly higher and more specific than the earlier estimate of "at least 100 barrels on board" presented to the public in the exhibit hall, but is a conservative estimate based on careful examination of the data. One method to calculate the number of casks aboard *Vasa* is to perform a minimum number of vessels (MNV) count, which is analogous to determining the minimum number of individuals (MNI) in an osteological or zooarchaeological collection (Rice 1987: 292). This method is based on counting diagnostic elements that occur only a limited number of times within the same individual, so in the case of a human skeleton a single left femur can be counted as one individual. Casks, too, have certain elements that are found only a limited number of times within the same container. Casks normally have only a single bung stave, so these can be used in a minimum number of casks, or MNC count. A cask with two heads will have a maximum of four cants, so these form the other diagnostic element in the MNC count. As mentioned in Chapters 4 and 5, there are 81.5 bung staves in the collection, as well as 580 cants of all types. When the 580 cants are divided by four (four cants per cask), we arrive at the figure of 145 casks. This means there was a *minimum* of 145 casks on the ship.

Taphonomic processes ensure that the exact number of casks on *Vasa* on August 10, 1628 will never be known with complete certainty. Some casks surely floated away as the ship foundered, while salvage efforts in the 1660s likely damaged or destroyed others, especially on the upper gundeck. Nonetheless, a more sophisticated estimate of the number of casks aboard might be possible with some methodological improvements. The author's study of the disarticulated cask components was conducted in the limited confines of the museum storage magazine, and in the public work space in the ship hall. Using a methodology more akin to that employed by investigators of airline disasters might yield significant results. Spreading the wreckage (cask elements) from similar find contexts in groups in a large open area like a warehouse would allow for an improved understanding of the elements which might have been part of the same original container, and thus a more accurate overall estimate of the total casks on board. The author employed this general process, but space was limited to only a few tables and a corridor where boxes of cask parts from different contexts could be temporarily stored.

The contents of a cask are an important attribute for the creation of a typology. Unfortunately, not as much is known about the contents of the casks as is desired. Information is generally quite good on personal possessions found in casks. Several of these were block lifted and later individually examined in the lab (Kaijser et al. 1982: 77-87; Cederlund 2006: 406-407). Significantly less is known about the provisions and stores kept in casks, which included biscuit and dried peas, salt meat and fish, beer, as well as gunpowder, lead shot, and presumably, naval stores like pitch and tar. To their credit, the 1961 archaeological team recognized the importance of sampling cask contents and did exactly that. The museum MarketStore database currently lists 111 *provs* and *slamprovs*, samples and sludge samples. Of these, only about 17 are related to cask contents. These are summarized in Table 7, below. Even this limited sample is largely incomplete, as no information exists on 11 of the 17 recorded samples. Some of the samples were studied soon after excavation by Ernst Abramson, but the majority of these proved to be inconclusive sludge full of sand and diatoms (Abramson 1965). It would be possible for specialists to reanalyze these samples, however, as portions of each remain in the museum freezer (Fred Hocker 2012, pers. comm.). Ulrica Söderlind discussed the faunal remains and provisions from *Vasa* in her 2006 book, *Skrovmål*, but was more concerned with discerning larger patterns of shipboard foodways than associating provisions with specific containers (Söderlind 2006).

Container	Type	Sample	Material	Deck	Side	Beam
08117	oak cask	08127	sheep, cow	OB	SB	14-15
19778	pine cask	19784	grains	TD	SB	3-4
19103	oak cask	19106	unknown	TD	BB	6-7
18765	pine cask	19024	herring bones	TD	BB	7
18236	oak cask	18021	unknown	TD	SB	20-21
18301	oak cask	18329	unknown	TD	SB	20-21
18352?	oak cask	18379	rye grain	TD	SB	21-22
17030?	oak cask	17098	unknown	HS	BB	1-3
11773	pine cask	14325	cod bones	HS	BB	10-11
08218	oak cask	08220	unknown	HS	BB	23-24
15841	oak cask	15861	grains, peas	HS	BB	24-25
16451	oak cask	16457	unknown	HS	BB	23-24
16431	oak cask	16494	unknown	HS	M	24-25
16525	oak cask	16524	unknown	HS	M	24-25
16502	oak cask	16599	unknown	HS		25
16502	oak cask	16600	unknown	HS		25
15304	pine cask	17074	unknown	HS	SB	24-25

TABLE 7. Cask contents based on sampling. The table is organized by find location. This list does not include casks of personal possessions or those containing musket shot (Author).

While frustrating, this situation is hardly unique. Casks from archaeological contexts are almost invariably damaged, and their original contents, if liquid or perishable, long gone or unrecognizably decayed. In part, contents can be inferred from cask construction and context. Chapter 4 discusses the differences between the three branches of cooperage, and mentions that casks for liquids are more stoutly built than those for dry goods, although the casks from *Vasa* do not necessarily support this premise. The volume of a cask is significant when trying to infer its contents, as certain commodities were strongly associated with specific sizes of container (Rees and Rees 2010: 199). The context in which a cask was discovered is also very important. Most of the casks of personal possessions were found on the gundecks. This makes sense, as it was the area where most of the sailors lived and worked. If a pine lid was found on the gundecks where many lidded casks were found, it is not unreasonable to assume that this lid comes from a comparable container. Similarly, a cask found in the provision storage area in the hold, near the galley, is likely to have held provisions even if not specifically recorded.

Metrology

The volume or capacity of a cask is very important. Sizes of cask became strongly associated with specific commodities, and were subject to repeated government regulation (Unger 2004: 73). Individual nations, regions, and trades employed unique metrological systems (Zupko 1977: 103-187), and as Peter Linebaugh observes, "the entire period of mercantilism has been defined by the fragmentation of measuring standards" (2006: 162). Coopers produced casks of known capacity by controlling four key dimensions: the distance between the croze grooves, the two head diameters, and the diameter at the booge, or bulging midsection of the cask. A pair of hinged rods known as "diagonals" allowed the cooper to determine the correct placement of the heads and ensure the cask was of the desired capacity (Rees and Rees 2010: 200-201). Governments, guilds, and merchants had a vested interest in enforcing metrological standards. Customs officials or "gaugers" measured capacities of casks either by weighing or with a specialized measuring stick known as a "gauging rod" (Rees and Rees 2010: 209). Figure 70, below, shows this process.

In 1628, Sweden employed its own system of metrology. King Karl IX issued decrees in 1605 attempting to regulate the size of casks across the kingdom, which remained in force until 1638 (Bruzelli and Carlestam 1999: 21). Different measures were used for dry and liquid goods, as well as specific commodities such as fish and tar. These measures are summarized in Table 8, below. Some of these measures correspond closely to the calculated capacities of the *Vasa* casks, and provide another tool for inferring their contents, and even the naval supply process.

FIGURE 70. The process of gauging a cask, using a graduated gauging rod. The woodcut comes from Nuremburg and dates to the first half of the sixteenth century (Zijlma 1991: 266).

Measure	Equals	Vol (L)	Purpose
Oxhuvud	70-90 kannor	183.00-236.00	wine or oil
Spannmålstunnan	56 kannor	146.60	grain
Tunna (lakegods)	48 kannor	125.60	pickled goods
Tunna (tjära)	48 kannor	125.60	tar
Heringband		120.00	fish
Halvtunna	2 ankare	73.25	dry or liquid
Spann		72.00	grain
Ankare	15 kannor	39.25	liquids
Kagge	12 kannor	30.00	fish?
Kanna		2.62	multipurpose

TABLE 8. Seventeenth century Swedish measures (Jansson 1995).

The volumes of the *Vasa* casks were calculated using Rhinoceros software. This approach was pioneered by Sarah Fawsitt, at the suggestion of Fred Hocker (Fawsitt 2010: 5). Using CAD software for volume calculations is more accurate than earlier methods, although the principle is much the same. Jane and Mark Rees observe:

> …the volume can be determined by measuring the three principal dimensions: the bung diameter, the head diameter and the cask length. From these the volume could be calculated. The hurdles to be overcome with this method were numerous – taking accurate measurements; determining the stave and head thicknesses; assessing the variety of the cask and choosing the formula, which included some method of adjustment for the variety (2010: 209).

Earlier studies of historic cooperage relied on mathematical formulae for calculating the volume of a cylinder (Rodrigues 2005: 418; Loewen 2007: 32; Loewen 2014: 4), although Loewen notes this tends to underestimate the cask volumes as it does not account for the bulging midsection (2007: 32). While many of the "hurdles" as described by Rees and Rees remain, volume calculations based on Rhinoceros are more accurate than those based on the cylinder formula, since Rhino accounts for the bulging shape. The dimensions used to calculate *Vasa* cask volumes were the distance between the croze grooves, the diameters of the heads, and the diameter at the booge. This data was used to create three-dimensional wire frame models of the casks in Rhino, (Figure 71), whose volume could then be determined using the "Analyze" function. Sarah Fawsitt provides a useful guide on how to create these models in her study of the Drogheda Boat casks (Fawsitt 2010). Measurements for volume calculations were derived primarily from existing, rebuilt casks judged to be genuine objects, and not "mongrel" reconstructions from the 1980s. The calculated volumes of these rebuilt casks are summarized in Table 9, below. Individual elements and incomplete casks could then be compared to the dimensions of these complete casks, to determine what type the incomplete examples might belong to and suggest an approximation of their volumes. Generally volume calculations were not made using incomplete or fragmentary casks, although Fawsitt (2010) and Loewen (2014) have performed these calculations by using booge-to-chime ratios.

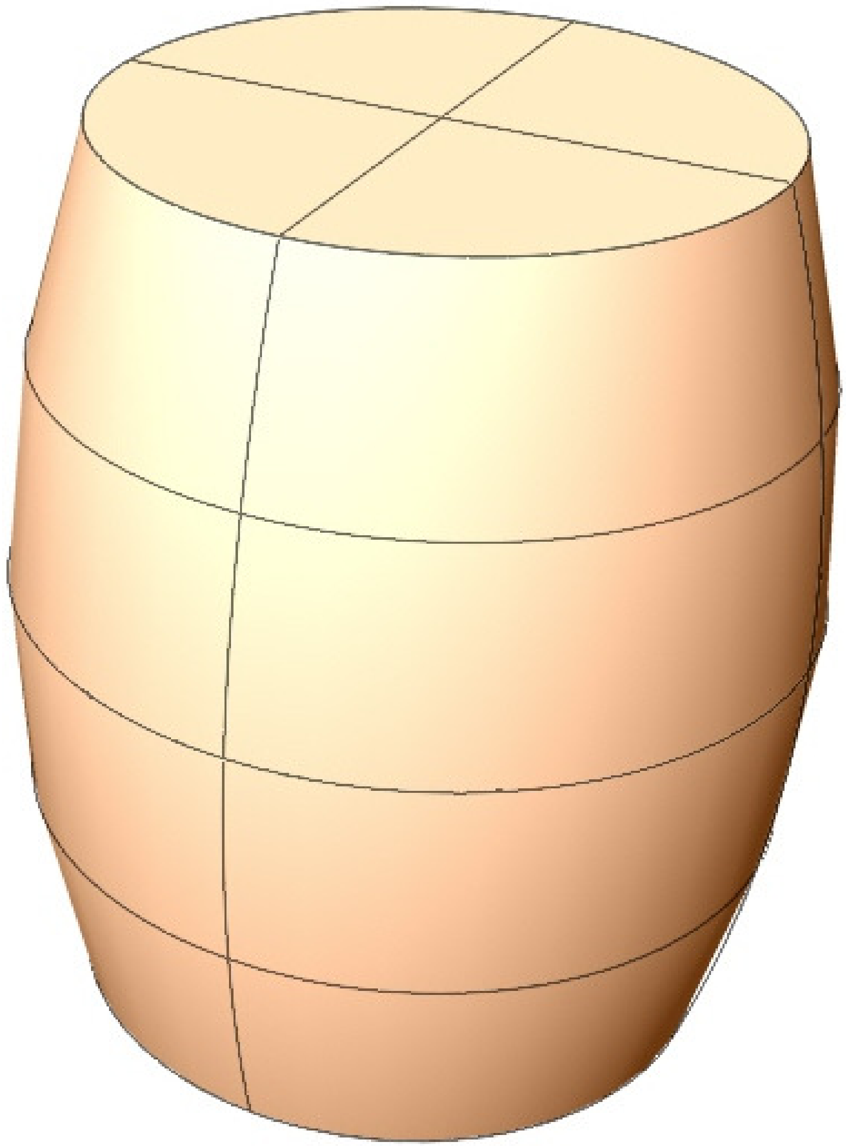


FIGURE 71. A Rhinoceros model of the interior surface of oak cask 08218, used to calculate its volume of 136.7 L (Author).

Table 9, below, summarizes the volumes and attributes of 28 complete casks used as the basis for the cask typology. Rhino models were created for each of these casks to determine their volumes. The four key dimensions used to calculate the volume are also listed for each of these casks. “Dist Bt Gr” refers to the distance between the croze grooves, while “D Booge” is the diameter at the widest point, or booge. “D H1” and “D H2” refer to the diameter at the two heads. The cask measures are recorded in millimeters, and the volumes in liters.

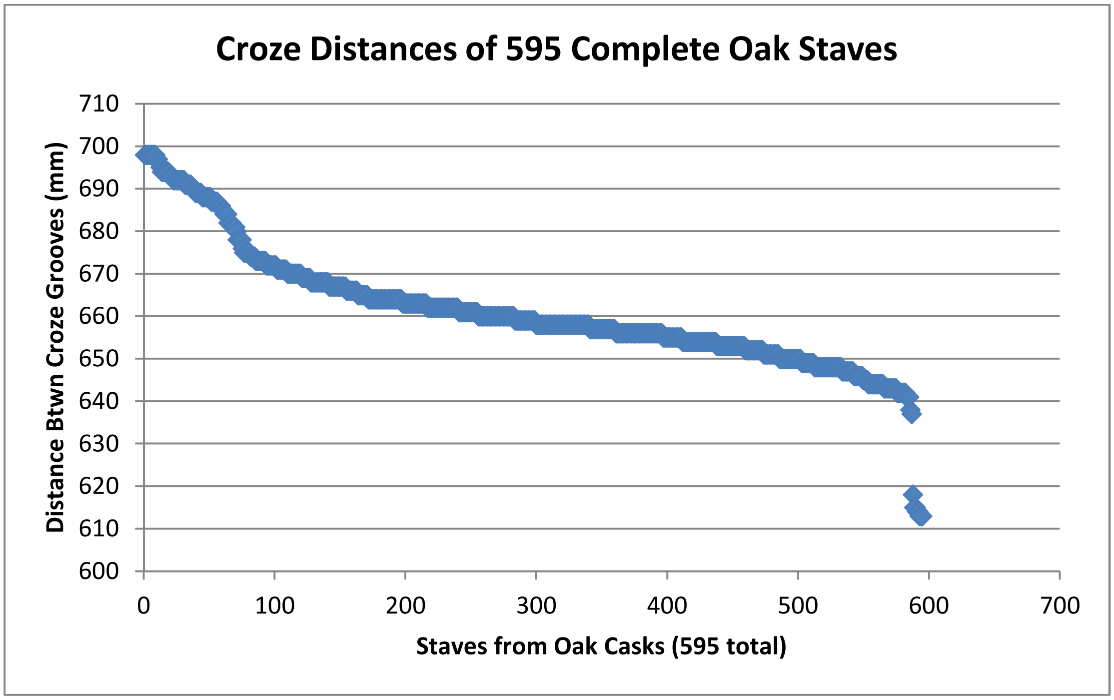
FNR	Type	Wood	Bung Shape	Dist Bt Gr	D Booge	D H1	D H2	Vol (L)	Contents
18135	cask	oak	rectangular	690	559	435		146.4	unknown
17030	cask	oak	rectangular	680	551	440	450	142.9	unknown
08680	cask	oak	rectangular	648	563	445	453	141.5	personal possessions
08224	cask	oak	rectangular	648	559	450	460	140.7	water?
08218	cask	oak	rectangular	641	556	450	448	136.7	unknown
12601	cask	oak	rectangular	595	570	451	450	132.1	unknown
13279	cask	pine	none	656	519	444	445	126.5	unknown
none	cask	pine	none	672	502	455	465	125.9	unknown
15903	cask	oak	none	558	441	367	370	76.6	unknown
16525	cask	oak	square	527	448	372	367	74.0	unknown
15841	cask	oak	none	540	427	350	349	68.7	grains, peas
11773	cask	pine	circular	500	336	298	298	41.1	cod
23547	cask	pine	none	425	353	320	333	39.8	unknown
18850	cask	pine	rectangular	491	336	282	285	39.3	unknown
15304	cask	pine	circular	472	325	287	288	36.4	unknown
none	cask	pine	circular	482	329	269	268	36.4	unknown
18765	cask	pine	circular	475	325	285	273	36.2	herring
16951	cask	oak	none	401	357	295	296	36.0	unknown
17222	small cask	oak	rectangular	320	296	232	222	18.8	unknown
16883	small cask	oak	circular	314	299	224	222	18.7	unknown
08117	small cask	oak	rectangular	323	242	192	191	13.0	unknown
17325	shot keg	oak	none	228	264	237	216	11.3	musket shot
00477	small cask	pine	circular	306	240	160	165	11.1	unknown
17305	shot keg	oak	none	236	247	211	188	10.0	musket shot
23562	small cask	oak	none	275	213	163	157	8.4	unknown
08207	small cask	oak	circular	195	161	128	128	3.5	unknown
14886	mini cask	oak	none	118	110	77	78	0.9	unknown
07643	micro cask	oak	none	86	72	62	58	0.3	unknown

TABLE 9. The volumes and key attributes of the 28 complete casks used as the basis of the typology, ordered by volume (Author).

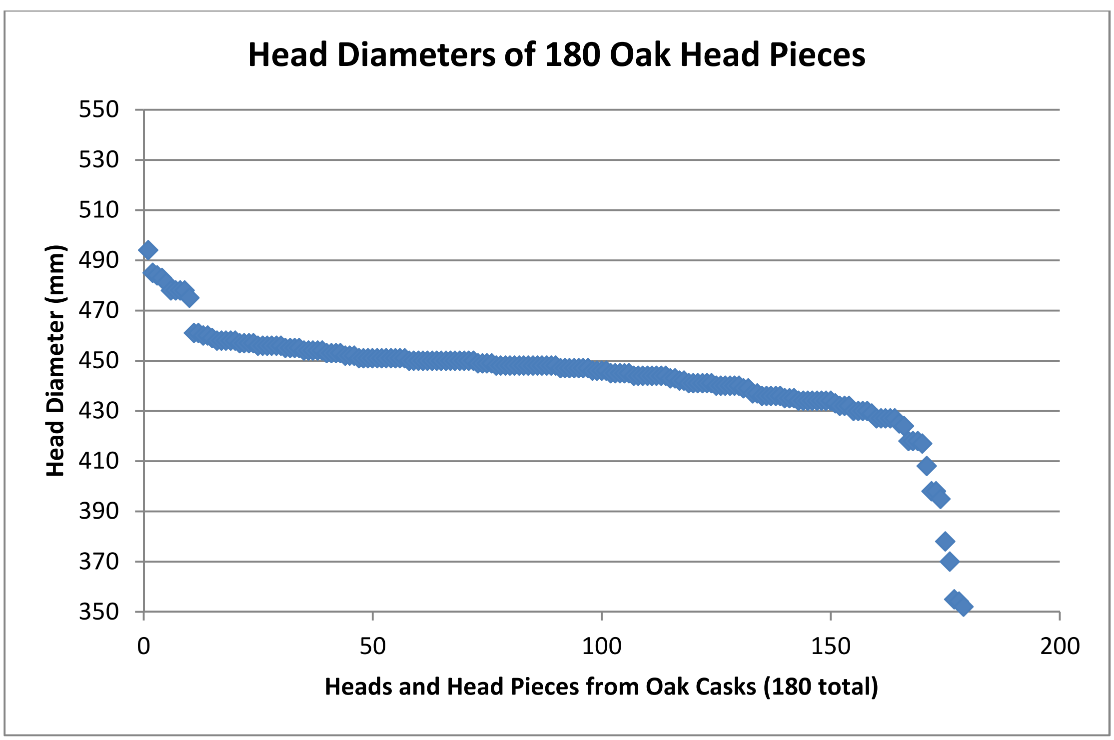
Oak Casks

Oak casks are the most common type in the collection. It is estimated that there are at least 64 examples, or 44 % of the estimated total of 145 casks. This type is primarily defined by its construction, built of oak staves and head pieces. This type subsumes a variety of sizes, ranging from approximately 36 liters all the way to the largest casks in the collection of 140 to 146 liter capacity. The oak casks have several characteristic features, discussed in Chapters 4 and 5. They have square or rectangular bungholes, and are generally composed of between 14 and 17 staves. The staves vary in width within a single container, from as little as 100 up to 180 mm wide at the booge. Heads are generally made of two to four large, irregular pieces, usually edge joined with two dowels per joint. Heads often feature bung or sample holes, and fit into croze grooves between 2 and 3 mm deep and wide. Additional sample or vent holes occur on the staves. Hoops are notched to join together, and evenly spaced at the chime, quarter, and bilge positions.

There is significant regularity in the dimensions of the oak casks, as seen in the disarticulated elements. Graph 6, below, summarizes the distance between the croze grooves of 595 complete oak staves. Although the graph is a scatter plot, the individual points are so close together as to form a continuous line. This shows that most oak casks had a height between croze grooves of between 640 and 675 mm, with a few outliers. Graph 7, below summarizes the head diameters of 180 oak heads and head pieces. It too is a scatter plot, and shows that the majority of oak casks have heads with a diameter of between 430 and 460 mm. Oak casks 18135, 17030, 08680, 08224 and 08218, listed in Table 10, above, have similar dimensions, with croze distances between 641 and 690 mm, and head diameters of between 435 and 460 mm. This suggests that the majority of the oak casks had volumes of approximately 136 to 146 liters.



GRAPH 6. Distances between croze grooves of 595 complete oak staves (Author).



GRAPH 7. Scatter plot of the head diameters of oak casks, based on 180 oak heads and head pieces (Author).

The dimensions of the oak casks, as seen in Graphs 6 and 7 above, are significant, as they appear to correspond to multiples of the seventeenth century Swedish foot. In 1628, the Swedish foot measured 297 mm and was divided into 12 inches (Hocker 2011: 43). Table 10, below, summarizes multiples of the Swedish foot which are similar to the dimensions of the oak casks. Cask 12601 is one of the best preserved examples of an oak cask from *Vasa* (Figures 54 and 57, Chapter 5), and is stored in a special wooden carrier in the storage magazine. It measures 595 mm between croze grooves and has a head diameter of 450 mm and calculated volume of approximately 132 liters. The distance between the croze grooves is the equivalent of two Swedish feet, while the head diameter is approximately 1.5 Swedish feet. Slightly larger multiples of Swedish feet correspond closely to the observed distances between croze grooves of the 595 complete oak staves presented in Graph 6, above. Two and one-sixth Swedish feet (2.16 feet) equals 643 mm, while two and one-fifth (2.20) and two and one-third feet (2.30) equal 653 and 683 mm respectively. These are dimensions which reoccur repeatedly in the collection of oak cask and cask elements. One and a half Swedish feet equals 445 mm, which is the approximate dimension of the majority of oak head pieces which could be measured to determine head diameter. These figures suggest that the coopers who made the *Vasa* casks were using Swedish units of measure, and thus were either Swedes themselves or working to standards mandated by the Swedish administration. This supports earlier archival research which indicates that all the bread and beer (shipped in casks) for the campaigns of 1626-1630 came from Norrköping (Ulrica Söderlind 2012, pers. comm.). The metrological data from the oak casks suggests a provisioning system which relied on resources from within the kingdom, and based on Swedish units of measure. In contrast, the Dutch foot in 1628 measured 281 mm (Hocker 2011: 43). Multiples of this measure do not match any of the *Vasa* oak casks.

	Swedish Feet	Equiv in mm
Croze Distance	2.00	594
	2.16	643
	2.20	653
	2.30	683
Head Diameter	1.50	445

TABLE 10. Possible measures used in the construction of the *Vasa* oak casks (Author).

Although little is known about the contents of these oak casks, they seem to have been a multipurpose container. Oak casks in Compartment H3 in the Hold likely held salt beef and pork, as many bones of this type were found in the area. *Vasa* was not fully provisioned when she sailed in August 1628, however, since the men were responsible for providing their own food within home waters (Hocker 2011: 117). Although the backgrounds of the officers and the division of space within the ship did not promote an excessively rigid hierarchy (Hocker 2011: 111), there remained clear differences in the quantity, type, and presentation of food provided to officers and seamen. Officers on *Vasa* ate in cabins off pewter dishes and drank out of glass tumblers. The crew ate in messes of five to eight men, and shared wooden tableware and tankards (Söderlind 2006a: 260). The basic provisions in the Swedish Navy of 1628 consisted of dried peas, cereals, bread, salt meat, salt fish, salt, dairy products, water, and beer (Söderlind 2006b: 153). This list of foods is almost identical to those carried by the contemporary Royal Navy, with perhaps a greater emphasis on peas. The types of food served aboard ship reflected not only the conservative and bland diet most sailors were accustomed to, but foods which could be preserved for lengthy periods (Rodger 1998: 318). Provisions on *Vasa* were likely controlled by the steward (*skaffare*) and prepared by the cook (*kock*) (Hocker 2011: 104). The galley was located amidships in the vessel, in Compartment H5. The large iron cauldron found there had a capacity of about 180 liters (Cederlund 2006: 375), and confirms that the peas, salt meat and fish would be prepared by boiling. This was standard practice on most warships (Rodger 1988: 85-86), and ensured that the cook did not require a high level of culinary skill. Cooks were often injured sailors unfit for other duties, and their frequent shortcomings were summed up in the saying “God sends the food, but the Devil provides the cook” (Scammel 1987: 366).

All personnel received peas, bread and beer daily, augmented by salt meat and fish on alternate days. Regulations indicate that two meals were served daily, the first around noon and the second later in the afternoon. No mention is made of breakfast, but it is assumed the men saved some of their daily ration for a morning meal (Söderlind 2006b: 154). The peas were likely turned into a thick pea soup (Hocker 2011: 117), a dish which remained popular among mariners into the twentieth century (Villiers 1937). The bread was a hardtack-like biscuit baked hard so that it would last in the damp environment of a ship. Ratings received rye bread while wheat bread was reserved for officers (Ulrica Söderlind 2012, pers. comm.). Söderlind’s research shows what percentage of each group’s daily caloric intake was provided by each of the six main categories of provisions, shown in Table 11, below. While data exists for the regulation provisions for ratings in 1628, the earliest comparable data for officers dates from 1638.

Provision Type	Ratings 1628	Officers 1638
Bread	45	24
Meat	14	10
Fish	11	24
Dairy	0	7
Peas, Cereals	16	17
Beer	14	18
Total	100	100

TABLE 11. Daily caloric intake for ratings and officers, based on provision types (Söderlind 2006b: 157-158).

Table 11 shows that bread or biscuit provided the bulk of the food served to the men. Biscuit accounted for almost half of the ratings’ daily caloric intake, but only a quarter of the officer’s daily intake. It appears the officers also received more fish than the men, but otherwise the numbers in the different provision categories are fairly similar. It should be remembered, however, that these figures are based on regulations and represent more of an ideal than reality. They do not take into account shortages due to mismanagement or spoilage. The full ration set down for ratings in 1628 would theoretically provide over 4,000 calories, ample for men engaged in strenuous physical activity. The ration for officers in 1638 would provide over 6,000 calories daily. Even assuming an extremely high spoilage rate of 50 percent, these figures suggest men in the Swedish navy were adequately provisioned (Söderlind 2006b: 156). The condition of the *Vasa* casks, discussed in Chapter 4, suggests that spoilage rates were not nearly so high. The oak casks have a high standard of workmanship, and are made out of sound timber. If properly packed, stowed, and maintained, the oak provision casks would adequately preserve food.

Compartment H3 in the Hold is known as the "Meat Locker" because of the large number of casks and animal bones found there, and appears to be one of the main provision storage areas on the ship. This area likely held at least 13 oak casks with square bung holes and one pine cask. If these casks held salt meat, then their capacity might theoretically match the "cask for pickled goods" cask size listed in Table 8, above, which is about 125 liters. This does not seem to be the case, however. Oak Cask 08224 was found in this area, and has a distance between croze grooves of 648 mm, a booge diameter of 559 mm, and head diameters of 450 to 460 mm. The contents of this cask are unknown, although it is referred to as the *Vattentunna* or "water barrel" in excavation notes for some reason. The dimensions of this cask are not unusually large or much larger than most of the disarticulated elements found in the Meat Locker, and yet the volume of this cask is calculated as approximately 140 liters. This suggests that many of the casks holding salt meat had a volume closer to 140 liters, which is nearer the 146 liter size of the seventeenth century grain cask (Table 8).

While it is known that *Vasa* carried biscuit and peas, it is difficult to identify most of these casks with certainty. Several of the complete oak casks have volumes in the range of 140 to 146 liters (Table 9), which approximate the size of the 146 liter grain cask known from studies of Swedish historical metrology (Table 8), but the two oak casks directly associated with grains and peas through sampling of contents (Table 7) do not necessarily fit this pattern. Traces of rye grain were found in cask 18352, a cask of personal possessions found in compartment T4 on the orlop. This area is known as the "Carpenter's Store" because of the chest of tools found here, so it is likely the traces of rye grain here represent a small store of individual food. Cask 15841 is a medium-sized oak cask found in compartment H8 in the hold, an area associated with high status items and considered as an "officers' storeroom" (Lindblom 2002). Analysis of sludge samples from this cask yielded traces of wheat, oats, and peas (Abramson 1965). It is interesting that traces of wheat were found here, as wheat bread was reserved for officers and this compartment contained high status items. Cask 15841 has a removable lid, and a calculated volume of 68.7 liters. This volume is about five liters less than the *halvtunna* or "half barrel" of 73 liters, and is approximately half the volume of the larger oak casks in the 140 to 146 liter range. Cask 15841 does not have any visible bung hole. The only other cask directly associated with grain provisions is pine cask 19778, from the forward portion of the orlop. Compartment H8 or the "Officers' Storeroom" yielded another oak cask of unique type, cask 16525, (Figure 72). This has two square bung holes in a single bung stave, and is divided in half by an interior partition at the booge. The holes were sealed by a double bung mounted on a curved plank. The calculated volume of this cask is 74 liters, so each half of the cask would hold about 37 liters. The volume of 74 liters closely approximates that of the *halvtunna* (73 liters) recorded historically, while each half of the cask might approximate one *ankare*. The contents of this cask, unfortunately, remain unknown. To the author’s knowledge, this cask is completely unique and has no parallels either archaeologically or historically.

FIGURE 72. Oak cask 16525, from compartment H8 in the hold. Its calculated volume is 74 liters, approximately one *halvtunna*. The contents are not known. (Photo by author, 2011.)

Some of the oak casks likely held beer and water. Water was carried aboard vessels in the Swedish Navy, but was rarely listed on provision lists since it was free (Söderlind 2006a: 258). Beer was an important part of the men's daily rations, providing 14 percent of their daily caloric intake in 1628 (Table 11). In addition to its well-known alcoholic effects, beer was a popular drink since it was inexpensive and kept better than water. While it might be nominally rationed, already by the eighteenth century other European navies allowed their men to drink as much as they liked, by "ancient custom" (Rodger 1988: 92). A good supply of beer kept the men happy, but excess could affect discipline. Robert Monro led a regiment of Scottish mercenaries in Swedish service, and commented on this fact in 1637. "This regiment in nine yeeres time…had ever good lucke to get good quarters…and great quantity of good beere…but oftimes I did complaine and grieve at their plenty, seeing they were better to be commanded, when they dranke water, then when they got too much beere or wine" (Monro 1637: 47). Monro also comments on the qualities of different regional beers such as those from Hamburg and Rostock, although he himself was partial to "Serbester" beer (Monro 1637: 47).

The author's initial assumption when examining the *Vasa* casks was that the oak containers with square bung holes must have held only dry goods. The large, square bung holes and relatively light construction seemed to indicate "slack" cooperage unfit for liquids. A more thorough understanding of the collection, however, combined with study of period art, seems to suggest otherwise. Figure 73, below, shows a German wine cask from about 1425. A square bung is clearly visible on top of the cask, yet the liquid is being tapped at one end. This indicates that casks with square bungs could hold liquids. Many of the oak casks with square bung holes have heads with multiple plugged holes. These holes might have been for taps to draw off beer or other liquids. A large square hole offered several advantages to brewers. It provided an outlet for foam produced during fermentation, and convenient access for publicans and others to doctor the brew with herbs, eggs and other additives (Richard Unger 2012, pers. comm.). Swedish barrels for liquid measures in 1628 were supposed to contain 117.5 liters (Söderlind 2006a: 263); but again, this is smaller than the calculated volumes of many of the *Vasa* oak casks.

FIGURE 73. This illustration from a German manuscript of about 1425 shows that casks with square bung holes could contain liquids. The example here is likely a wine cask, and the red and white pennant above suggests it contains Austrian wine (Mendelschen Zwölfbrüderstiftung, Vol. I).

Lidded Casks

The second type of cask in the collection is the "lidded cask." The material and construction of these casks is almost identical to the oak casks, but lidded casks are differentiated by their contents and unique removable lids. Most lidded casks held personal possessions. There is estimated to be approximately 26 casks of this type in the collection, although only ten examples are identified with certainty. The presence of the remaining 16 possible lidded casks is inferred mainly from finds of pine lids and artifact clusters. The majority of lidded casks were found on the two gundecks, which makes sense since this is the area where the crew lived and worked. The casks are made of oak, with the exception of lidded cask 21101, which is made of a softwood otherwise unrepresented in the collection. Fred Hocker has examined this cask and believes it may be larch. The cask contents were accessed via removable pine lids. The pine lids have either rebated, lip, or flat edge styles, described in Chapter 4. Many of the pine lids have grooves cut into their edges, and across the top surface, Figure 74. These grooves, combined with instances of iron staining suggest the lids might have been held together with some sort of iron strapping, or perhaps had hinges and hasps. The frequent *bomärker* found on the pine lids (Chapter 5) likely identified the owner(s) of the cask.

Most of the lidded casks have dimensions almost identical to the oak casks. Lidded cask 08680, for example, has a calculated volume of 141.5 liters (Table 9). Most lidded casks have two croze grooves and one oak head fixed in position, suggesting they were reused. The mixing of wood species in a single cask is unusual and further evidence of reuse. It suggests individuals obtained used oak casks and then combined them with pine lids. Lidded cask 13702 from the lower gundeck has two croze grooves at one end, suggesting at least two cycles of use. Lidded casks provided an alternative to sea chests, which were also found on *Vasa*. Perhaps these casks were cheaper than chests, or at least offered more space. The fact that some of the casks might have been locked locked is significant. A ship is a floating community and dependent on trust for good relations among its members. Nothing destroys this trust faster than a thief, and longstanding tradition among seamen holds pilfering from a fellow crewmember's seachest as one of the most despicable shipboard crimes (Villiers 1937). In fact, three of *Vasa*'s crew were charged with stealing a German sailor's chest on the day after the ship sank (Fred Hocker 2012, pers. comm.).

FIGURE 74. A pine lid from a lidded cask. The groove in the right edge of the lid might have been for metal strapping, or perhaps a hinge or hasp. The raised area to the left of the lid supports this idea. Although most of the metal from the ship has vanished, raised areas indicate where metal once rested. (Photo by author, 2011.)

FNR	Deck	Side	Beam	Previously Published
07843	OB	BB	0-3	Not published
08680	OB	BB	2-4	Cederlund 2006 p.407
14101	UB	SB	2-3	Cederlund 2006 p.407 Kaijser et al. 1982 p.83-84
21101	UB	SB	2-3	Kaijser et al. 1982 p.85
13599	UB	SB	8-9	Cederlund 2006 p.406
13702	UB	SB	10-11	Cederlund 2006 p.407
12865	UB	SB	11-12	Kaijser et al. 1982 p.77-78
18669	TD	SB	9-10	Kaijser et al. 1982 p.79-82
19251	TD	BB	22-23	Kaijser et al. 1982 p.85
17277	HS	BB	4-5	Kaijser et al. 1982 p.86-87

TABLE 12. Securely identified lidded casks (Author).

The ten lidded casks identified with certainty are summarized in Table 12, above. The majority of these have been described in Kaijser et al.'s *Ur sjömannens kista och tunna* (1982), and some are mentioned briefly in Chapter 15 of *Vasa I* (2006). The contents varied from cask to cask but generally consisted of the same type of finds. These consisted of spare clothing and footwear, wooden tableware, tankards and spoons, small bentwood boxes, sewing equipment, bits of leather and string, buttons, coins, and tools. These individual find categories are being studied separately. Jessica Smeeks from East Carolina University is studying the personal items associated with bodies found on the ship, while Stephanie Gandulla from the same institution is studying the wooden tableware (treen). The find of seven spoons stowed in a tankard within lidded cask 18669 on the orlop suggests that multiple individuals shared these casks on occasion. The seven spoons would have been enough for a single mess. It is possible to try and associate groups of lidded casks with specific groups of shipboard personnel. The estimated 17 lidded casks on the gundecks would belong to ratings and warrant officers, who messed and slept in this area. The two lidded casks found in compartment T4 in the orlop, known as the “Carpenter’s Store,” could have belonged either to the carpenter or to his mates. Figure 75, below, shows lidded cask 18669 during the 1961 excavation. Although the hoops have fallen away and allowed the staves to splay outwards, the contents remain largely in situ. This find indicates that the lidded casks were stowed vertically, on end, as do the pine lids. The lids might have rested loosely in place, alternatively the conjectured strapping might have been used to securely fasten the lid.

FIGURE 75. Lidded cask 18669 from the orlop, in situ. The hoops (visible as fragments to the left) have fallen away and allowed the staves to splay out. Visible at the bottom of the cask are a turned wooden bowl and a bentwood box. (Courtesy of the Vasa Museum, Stockholm.)

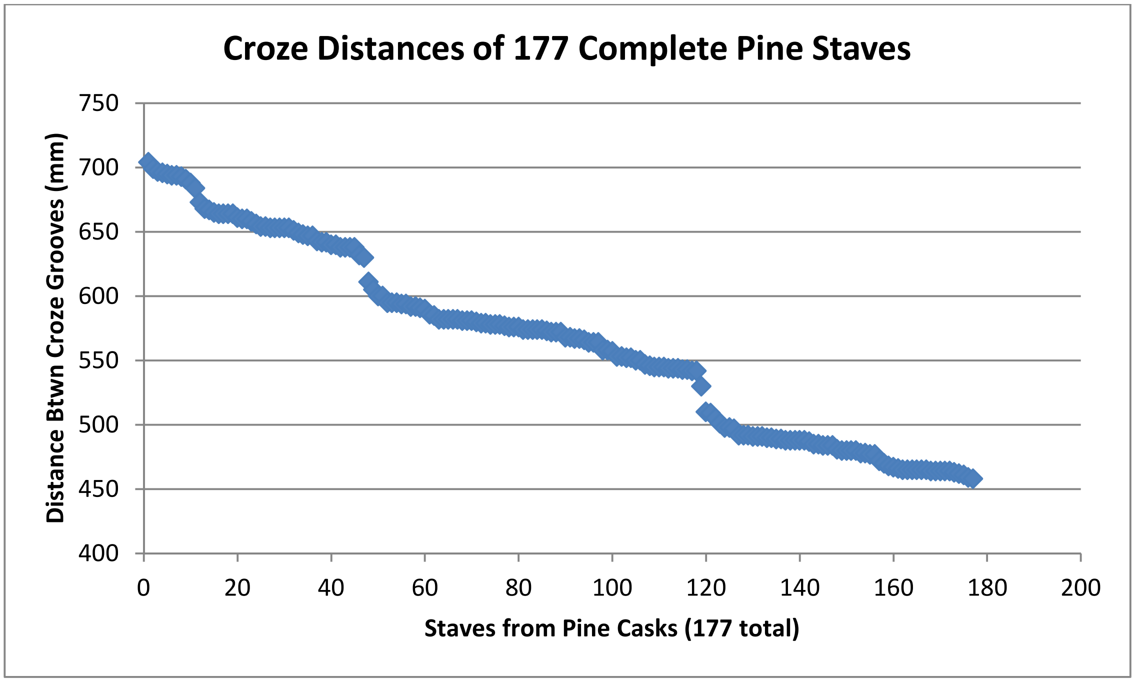
FNR	Type	Wood	Bung Shape	Dist Bt Gr	D Booge	D H1	D H2	Vol (L)	Contents
13279	cask	pine	none	656	519	444	445	126.5	unknown
none	cask	pine	none	672	502	455	465	125.9	unknown
11773	cask	pine	circular	500	336	298	298	41.1	cod
23547	cask	pine	none	425	353	320	333	39.8	unknown
18850	cask	pine	rectangular	491	336	282	285	39.3	unknown
15304	cask	pine	circular	472	325	287	288	36.4	unknown
none	cask	pine	circular	482	329	269	268	36.4	unknown
18765	cask	pine	circular	475	325	285	273	36.2	herring

TABLE 13. Dimensions and volumes of eight rebuilt pine casks remaining in the collection (Author).

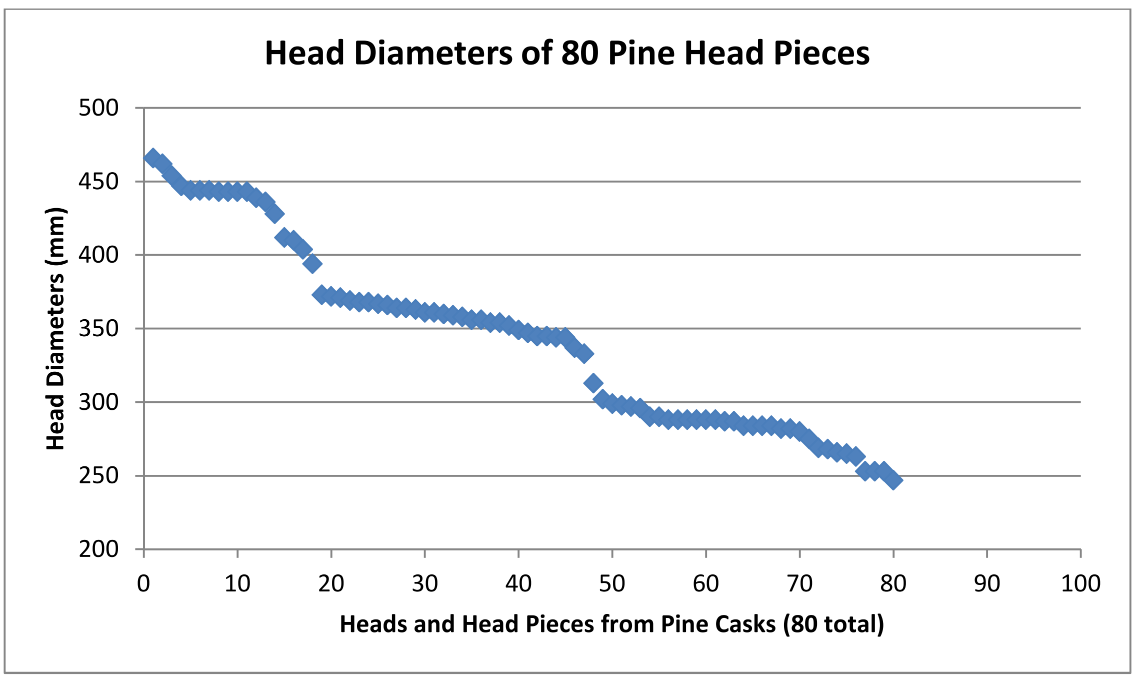
Pine Casks

The third type of cask in the collection is the pine cask. This type is primarily defined by the material used to construct the containers, pine, but also by the size of the casks. There are two large pine casks with calculated volumes around 125 liters, but many of the pine casks are considerably smaller, with volumes between 36 and 41 liters. Eight rebuilt pine casks remain, although it is estimated at least 33 pine casks exist in the collection. Data on these casks is summarized in Table 13, above. The shape of the pine casks was constrained by the qualities of the timber. While the oak casks have a noticeably bulging midsection, the pine casks are almost completely straight sided. This cylindrical profile is clearly visible in Figure 76, below, which shows pine cask 15304 from compartment H8 in the hold. Either the pine timber was less pliable than the oak, or the coopers who made the pine casks did not feel a bulging shape was required. Almost no sample or vent holes are found in the pine staves, but many knots are present. Heads for the pine casks are almost invariably one or two-piece only, but are not always edge joined. At least five of the pine casks were charred on the interior (discussed in Chapter 4). The number of charred casks does not include any of the eight rebuilt pine casks, whose interiors could not be examined. Bung holes on the pine casks are almost always circular, in contrast to the square or rectangular bung holes found on the oak casks. Most of the pine casks were found on the lower gundeck and orlop. The distribution of the casks is discussed in detail in Chapter 7. Fewer *bomärker* are found on the pine casks than on the oak casks (Chapter 5). Overall, the level of workmanship is much cruder than the oak casks, and tool marks more frequent. As discussed in Chapter 4, however, the rough finish of the pine casks might be deliberate rather than evidence of rushed production or lack of attention to detail.

FIGURE 76. Pine cask 15304, from compartment H8 in the hold. 15304 exhibits the characteristic features of the pine casks, including a straight, cylindrical overall shape and circular bung holes. Also note the pegged holes at the ends of the casks which might have been used to help retain the heads in place. The hoops are reproductions. (Photo courtesy of the Vasa Museum, Stockholm.)



GRAPH 8. Distances between croze grooves of 177 complete pine staves (Author).



GRAPH 9. Scatter plot of the head diameters of pine casks, based on 80 pine heads and head pieces (Author).

Graphs 8 and 9, above, summarize the key dimensions of the loose pine cask elements. The scatter plots show that the pine casks are divided into three main sizes, based on the three groupings seen in the plots. The largest size has a croze distance of about 650 to 700 mm and a head diameter of around 450 mm. This corresponds roughly with the two largest pine casks in Table 13, which have a calculated volume of about 125 liters. Interestingly, this is the size of a cask for pickled goods as recorded in the sources on historical metrology (Table 8). The medium size of pine cask appears to have a croze distance of between 550 and 600 mm, and head diameters between 350 and 375 mm. Little is known about this particular subtype. The smallest size of pine casks appears to have a croze distance of between 450 and 500 mm and head diameters of between 250 and 300 mm. Six of the eight remaining rebuilt pine casks appear to represent this subtype, with calculated volumes of between 36 and 41 liters. These small pine casks are roughly a third the size of the largest pine casks. The volumes of the small pine casks are similar to the *ankare* of 39 liters, for liquids, and are about a third the size of the 120 liter *heringband* fish cask (Table 8).

In fact, two of the three pine casks with known contents contained fish. Pine cask 18765 from the orlop contained herring, while pine cask 11773 from the "Meat Locker" in the hold contained cod. Salt fish was an important part of the naval diet in 1628. Ratings received an average fish ration of 338 grams in the period 1628-1692, while officers received 704 grams on average (Söderlind 2006b: 154). Naval records indicate a variety of types were issued, including herring, cod, pike, ling, salmon, and eel. Herring bones were the most common type found on *Vasa* (1,609 bones), but ling (336 bones), cod (256 bones), pike (86 bones), and burbot (69 bones) were also recovered. Study of these faunal remains suggest the herring, cod, and pike on *Vasa* were stored as salt or stockfish. Preserved fish could be stored for long periods of time, but required special preparation prior to consumption. The salt fish was first tenderized by pounding before being soaked in fresh water to remove excess salt (Söderlind 2006b: 161-162). Swedish per capita consumption of salted herring was among the highest in early modern Europe (Poulsen 2008: 101), so it was a food the crew of *Vasa* was already familiar with. Salt fish remained an important part of the Swedish naval diet until the final third of the seventeenth century, when fish rations declined. Söderlind speculates that the Admiralty board came to view salt fish as a "defective provision" leading to higher instances of scurvy (2006b: 155).

The author's initial assumption was that the herring on *Vasa* must have come from the Dutch North Sea herring fishery. Sources on early modern fisheries consistently emphasize the almost complete monopoly of the Dutch in this trade during the first half of the seventeenth century (Unger 1980b; Poulsen 2008). Richard Unger claims that "in the seventeenth century Dutch herring fishermen held a virtual monopoly" (1980b: 276). The rise of the Dutch herring fishery was based on technological and organizational innovation. From the fifteenth century onwards Dutch fishermen refined the technique of curing and pickling their herring catch at sea, allowing them to stay out longer and catch more fish (Unger 1980b: 255). The fish was gutted and packed with salt in casks. The speed at which the gutters worked (up to 2,000 fish per hour) meant that sometimes part of the stomach was left behind, with unintended but valuable consequences. The pyloric caecae contains a chemical called trypsin which helps in the curing process and improves the odor of the fish (Unger 1980b: 257). The herring packed at sea would shrink in the casks, and was repacked once it was landed. Generally 14 casks of herring packed at sea would be repacked into 12 casks ashore, which equaled one last (Poulsen 2008: 83-84). This process is shown in Figure 77, below. Organizationally, the Dutch herring fishery benefitted from regulation. In 1567, major fishing towns established the *College de Groote Visscherij* to license fishermen and regulate the industry. The College set standards of quality, which ensured Dutch herring sold at a premium (Unger 1980b: 261-262). The College also regulated the type and size of casks used, cask markings, and the salt used for pickling (Jenkins 1927: 74-75).

FIGURE 77. This engraving from 1608 shows the process of repacking salted herring into casks ashore. It is part of a series entitled *The Typical Employments of North Holland* (Schuckman 1991b: 207).

Despite the Dutch dominance in salt herring production during the seventeenth century, research on the fish remains from *Vasa* suggests the majority of the fish came instead from the Baltic. Söderlind claims the dimensions and morphology of the herring bones from *Vasa* indicate they came from the Baltic rather than the North Sea (2006b: 162). This is possible, since there are distinct morphological differences between the different regional varieties of herring (Jenkins 1927: 42). The cod and other fish species found on the ship could also have been caught in the Baltic, with the exception of ling which requires higher salinity (Söderlind 2006b: 162). Documentary evidence exists for small scale cod fisheries in the Stockholm area and southwest

Finland during the sixteenth and early seventeenth centuries (MacKenzie et al. 2007: 114). Local cod fisheries might have supplied the cod found in pine cask 11773. It is interesting that both fish casks identified on *Vasa* are pine, since this appears to go against the best practices recorded historically. A study of the sixteenth-century Bohuslan herring fishery claims that pine casks "imparted a disagreeable taste to the herring," so Dutch merchants imported their own oak casks in preference to the local pine containers (Frandsen 2004: 149). If Bohuslan peasants used pine casks to pack their fish in the sixteenth century, it is possible Swedish fishermen continued this practice in the 1620s. Perhaps pine was cheaper than oak or more readily available. It is possible the rough finish of the pine casks suggests expediency or semi-skilled production, which might reflect the work of smaller scale Swedish fisheries. If the fish in pine casks 18765 and 11773 came from Baltic, and possibly Swedish, waters, it is possible the casks were also manufactured locally. If the archival and zooarchaeological data is correct, than it appears the Swedish Navy relied primarily on resources from within the kingdom to provision *Vasa*.

Small Casks

The fourth type of cask in the collection is defined by the diminutive size of the containers, in comparison to the oak, pine, and lidded casks. There are at least 15 small casks in the collection, with a considerable diversity of sizes. The dimensions and key attributes of eight remaining rebuilt casks of this type are summarized in Table 14, below. The small casks range in size from about 18 down to only 0.3 liters. Small casks 17222 and 16883 have volumes of approximately 18 liters. This does not match any of the historical cask sizes in Table 8, but is equivalent to approximately 7 *kannor* of 2.62 liters each. This size of 18 liters is roughly half the size of the three smallest pine casks in Table 13, which have volumes of approximately 36 liters.

FNR	Type	Wood	Bung Shape	Dist Bt Gr	D Booge	D H1	D H2	Vol (L)	Contents
17222	small cask	oak	rectangular	320	296	232	222	18.8	unknown
16883	small cask	oak	circular	314	299	224	222	18.7	unknown
08117	small cask	oak	rectangular	323	242	192	191	13.0	Animal bones
00477	small cask	pine	circular	306	240	160	165	11.1	unknown
23562	small cask	oak	none	275	213	163	157	8.4	unknown
08207	small cask	oak	circular	195	161	128	128	3.5	unknown
14886	mini cask	oak	none	118	110	77	78	0.9	unknown
07643	micro cask	oak	none	86	72	62	58	0.3	unknown

TABLE 14. Dimensions and volumes of eight rebuilt small casks remaining in the collection (Author).

Little information is available on the contents of the small casks, but the construction of small cask 00477 suggests that it contained liquids. This cask is visible on the far right in Figure 78, below. It is made of pine and has a calculated volume of approximately 11 liters. This cask was one of the first objects recovered from the wreck site (indicated by its low find number) and was dubbed the "Aqavit" or spirit keg. Light hearted period photos show chief diver P.E. Falting pretending to drain the contents of the cask into a liquor bottle. The provenience of this small cask might be suspect since it was found outside the ship, if not for the strong resemblance it bears to three wooden canteens or *flaskas* from more secure contexts within the ship. The bung hole on small cask 00477 has a prominent raised wooden lip which is almost identical in construction to those found on the wooden *flaskas*. This suggests that small cask 00477 is indeed contemporaneous with the rest of the collection. It is also possible that the "aquavit" label attached to this particular cask is not incorrect. "Spirit casks" on HMS *Invincible* were approximately the same size as small cask 00477 (Bingeman 2010: 154), so it is possible this small cask also held liquor.

Fred Hocker and the author named the two smallest casks in the collection the "Mini" and "Micro" casks. In Figure 78, the Micro Cask is visible on the far left, while the Mini Cask is to its right. The Mini Cask was found in compartment H8 in the hold, and has a volume of only

0.9 liters. The Micro Cask is even smaller, and has a volume of just 0.3 liters. It comes from the upper gundeck. Neither of these casks have a bung hole, nor are the contents known. Miniature casks were found on HMS *Invincible* (1758), but these were much narrower and longer. It is believed these miniature casks were writing kits, since they contained ink residues and fine sand for blotting (Bingeman 2010: 152). At the moment, the function of the two miniature casks on *Vasa* remains a mystery.

FIGURE 78. Small casks. From left, Micro Cask 07643, Mini Cask 14886, small cask 08117, and the "Aquavit Keg" 00477. The function of these small casks remains unknown. (Photo by author, 2010.)

Shot Kegs

The fifth and final type of cask in the collection are the shot kegs. These are about the size of the small casks, but are differentiated by their known contents and unique construction. The shot kegs contained musket shot for small arms and canister shot, and were found in compartment H1 in the hold. There are at least six, and possibly seven, shot kegs in the collection. Table 15, below, lists the shot kegs and their contents. Six kegs are identified with certainty, but a small mongrel cask labeled "175B" might contain elements of a seventh cask.

The majority of the shot kegs are kept in the storage magazine and were examined there, with the exception of one example on display in the "Sweden 1628" exhibit. This shot keg is displayed in a large case with a halberd and was not recorded in detail. The shot kegs are made out of oak, and their contents are readily identifiable by the staining the lead musket shot produced on the interior. These casks have an unusual construction, visible in Figure 79, below. The bottom head is in a normal position, but the opposite head is located perhaps a third of the way from the end of the cask. This reduces the potential volume of the cask, perhaps to limit the weight to a manageable burden. No bungs are visible on the shot kegs, but cutouts are found on adjacent staves on opposite sides of the cask which might have served as handles. The six known shot kegs contained between 1,222 and 1,590 shot each, with an average of 1,449 shot per cask. Some of the kegs had broken open prior to excavation, so it seems likely that keg 17114 with 1,222 shot had lost much of its original contents. The volumes of the shot kegs varied between about 10 and 11 liters.

Shot Keg	Shot
17155	1590
17177	1475
17305	1437
17325	1488
17114	1222
17134	1483
Total	**8695**

TABLE 15. The six known shot kegs and the number of lead shot that each contained (Author).

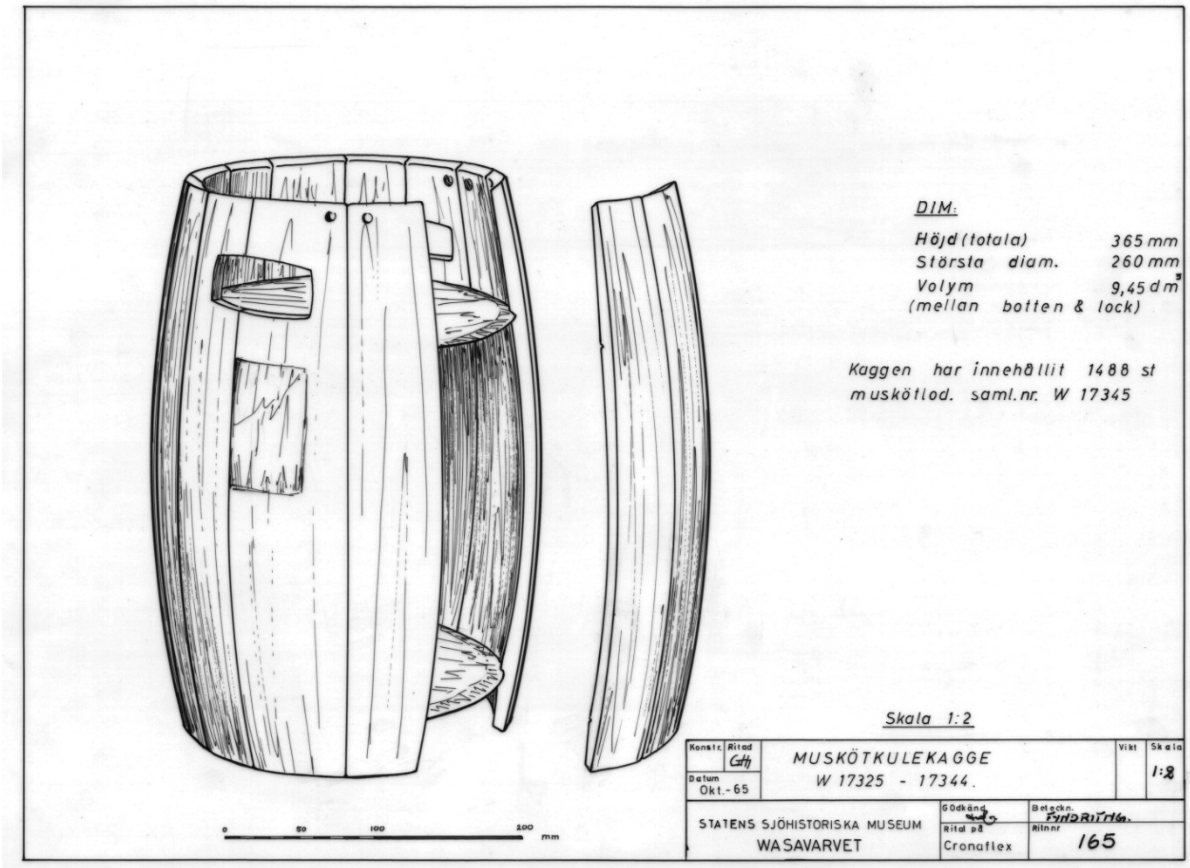


FIGURE 79. Cutaway drawing of shot keg 17325 showing unique construction. (Photo courtesy of the Vasa Museum, Stockholm.)

The large number of shot found in the kegs suggests that boarding remained an important tactic in naval engagements, although it is also possible the lead was intended to make up canister shot for the main guns. The ship was supposed to embark 300 soldiers once it reached Alvsnäbben. These men did not play any role in sailing the vessel; rather they were responsible for manning the guns and boarding enemy vessels. Only a few military muskets were found on *Vasa*. These are Swedish matchlocks or snaplocks based on Dutch patterns, firing lead balls of 18 mm diameter (.71 calibre) (Hocker 2011: 62-63). Robert Monro served in the Swedish army during the early portion of the Thirty Years' War. In his 1637 memoirs he includes an appendix, *An Abridgement of Exercise for the Younger Souldier*, which explains the ideal composition of a company in Swedish service. Monro's company consists of 150 men. There are 126 men-at-arms, divided into 21 *rota* of six men each, with the remainder of the company consisting of officers, NCOs, drummers, and other supernumeraries (Monro 1637: 183). Records indicate two companies were earmarked for *Vasa* (Skenbäck 1983: 21). According to Monro's scheme, these companies should have had a maximum of 252 musketeers, or 42 *rota*, although he includes pikemen in his ideal company. If these figures are correct, than there was enough musket shot in *Vasa*'s hold to issue approximately 35 rounds to each musketeer. Gustav Adolphus improved on Dutch linear tactics so that only six ranks could maintain volley fire (Parker 1988: 23), but it is unlikely that musketeers in the early seventeenth century could fire much more than one shot every two minutes (Parker 1988: 18). If *Vasa* reached the archipelago and embarked two companies of soldiers, there was enough ammunition in the hold for about 70 minutes of musketry at the maximum rate of fire. This assumes, however, that the infantry did not bring any ammunition with them, and that they actually could, or needed to maintain such a sustained rate of fire.

The 580 cants in the collection indicate there was a minimum of 145 casks on *Vasa*. These can be divided into five types: oak casks, lidded casks, pine casks, small casks, and shot kegs. Oak casks are the most numerous, and are primarily found in the hold. They contained provisions such as salt meat, and likely beer. Lidded casks generally held personal possessions, and most were found on the gundecks. Pine casks were found on the lower gundeck and orlop. Some contained fish, while charring on the interior of others implies they might have held water or spirits. The purpose of the 15 small casks in the collection remains difficult to determine, in contrast to the kegs full of shot. Although the casks exhibit diversity in materials and contents, division into discrete types is an effective method for understanding these containers.

Chapter 7 – Distribution

This chapter builds upon the typology previously outlined, to explain the distribution of casks throughout the ship. Although not fully provisioned, the cask distribution indicates that there was a clear plan for stowage and use of space aboard *Vasa*. The majority of oak casks were found in the hold. Many of these contained provisions. Most lidded casks came from the two gundecks, the area where the crew lived and worked. Pine casks were most frequently found on the orlop, an area used for storage. Small casks were found on the gundecks and the hold, while the shot kegs were clustered in compartment H1 in the hold. Basic trends in cask distribution are summarized in Table 16, below.

Cask Type	ÖB	UB	TD	HS	OUT	No FNR	Total
Oak Casks	3	11	1	43	1	5	**64**
Lidded Casks	11	6	6	1	1	1	**26**
Pine Casks	2	6	13	7	1	4	**33**
Small Casks	4	0	2	5	3	1	**15**
Shot Kegs	0	0	0	7	0	0	**7**
Total	**20**	**23**	**22**	**63**	**6**	**11**	**145**

TABLE 16. Basic trends in cask distribution on *Vasa* (Author).

Many casks exist only as disarticulated elements, but the division of space within the ship facilitated reconstruction of their original number and distribution. Space within *Vasa* is divided vertically by the five decks, which are connected by various hatches. Most material remains on its original deck, with the exception of some objects which fell down hatchways. Space on each deck is divided horizontally by various bulkheads, and the structure of the ship itself. The orlop and hold, especially, were largely undisturbed and finds on these decks can be plotted with a fair amount of confidence. Scale drawings of these decks made during the 1961 excavation assisted the plotting of individual casks. These drawings are reproduced, below, and areas where the locations of casks can be plotted with certainty are outlined in red on the distribution maps.

Otherwise, there is a certain amount of ambiguity in the cask distribution plan. There are no excavation plans of the two gundecks or the after half of the hold. Finds were recorded in relation to the deck beams overhead, later numbered from 1 near the stem to 27 near the stern. The space between each beam is known as a "room," which was further divided by the excavators into Port (BB), Midships (MS), and Starboard (SB) sections. So while it is possible to assign a certain cask to a specific room and section, it is difficult or impossible to say if the cask was originally flush with the ceiling planking, or perhaps closer to the centerline of the vessel. In these cases, inferences have been made; obviously casks could not stand in the space occupied by the guns. Students at the United States Naval Academy have developed a computer application which plots the finds in each "room" on *Vasa* using a randomizing program, which indicates the difficulty in plotting individual finds with accuracy in the absence of detailed photos and scale drawings.

Stowage

Study of cask distribution merits discussion of the process of stowage. Proper stowage of casks is important for both the integrity of the containers and the stability of the ship itself. Despite *Vasa*'s well known problems in the latter category, it is unlikely the number and placement of casks played a significant role in the disaster. Rather, the ship was too heavily built above the waterline (Hocker 2011: 134). The casks could have been loaded during the spring and summer of 1628, while the ship lay near the old Tre Kronor palace on Stadsholmen taking on guns (Hocker 2006: 47). If many of the oak casks came from Norrköping and some of the pine fish casks came from Swedish fisheries (Chapter 6), then these casks arrived on other vessels. They could be transferred directly to *Vasa*, ferried on lighters, or carried by cart if warehoused or produced locally. Loading the casks could have been accomplished by using the main or fore yards as a derrick, with blocks fastened to the end of the yard (Tipping 1994: 10). Tackle could also be rigged between the masts to lower casks through the hatches (Lavery 1987: 238). There are two ways to lift casks: canhooks and slings. Canhooks are iron hooks which grip the cask at opposite ends, in the space between the end of the cask and the head (Kemp 1976: 133). This stresses the chime area, and one would expect to see a higher instance of broken chimes among casks loaded this way (Fawsitt 2010: 56). Many of the loose staves in the *Vasa* cask collection have their ends snapped off at the croze groove, but it is difficult to tell if this damage occurred during loading in 1628, excavation in 1961, or during subsequent conservation and handling. An alternative to canhooks was to sling a line around the cask, which could then be lifted using a series of blocks.

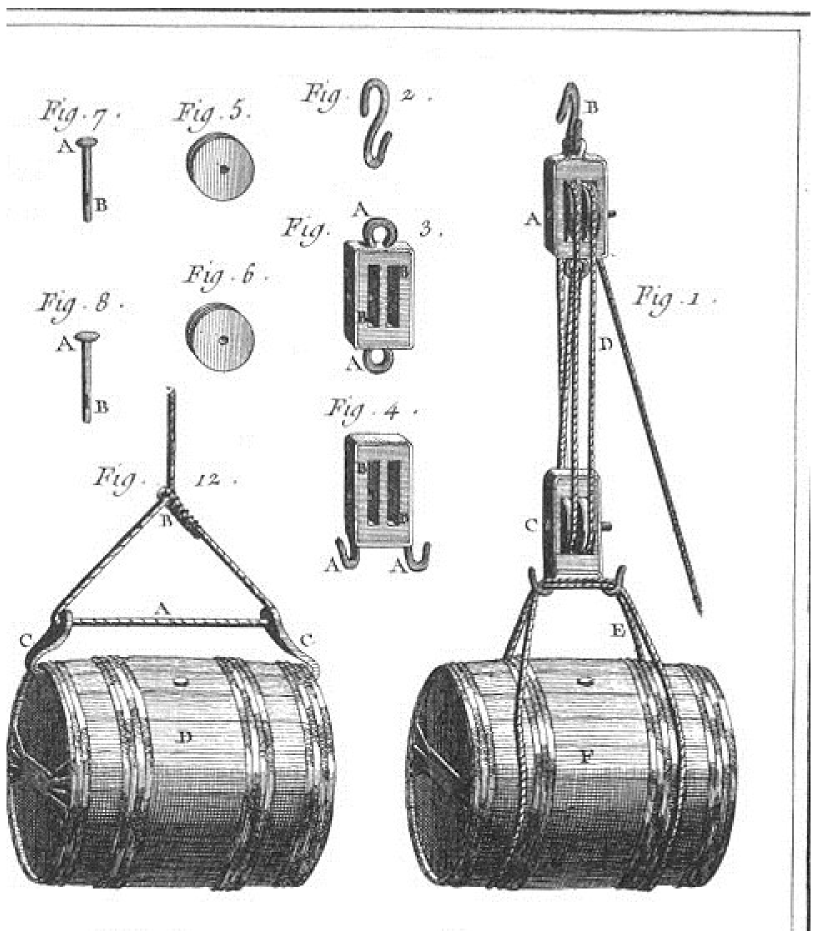


FIGURE 80. Two methods of lifting casks. Canhooks (left) and a sling (right) (Diderot and Alembert 1772: 174).

Regardless of the method used to attach the casks to the lifting line, heaving them aboard was heavy, hard work largely dependent on human muscle. The largest casks in the collection have a capacity of about 146 liters. If they contained a liquid with a density similar to water, which weighs approximately one kilogram per liter, then each cask might weigh as much as 166 kg (365 lbs) if we assume a weight of about 20 kg for the empty cask. Cooperative labor was necessary for lifting and stowing these weights, but injuries remained commonplace. Porters who routinely loaded and unloaded ships had a working life of little more than a decade, and were routinely crippled by hernias and broken bones (Linebaugh 2006: 167-168). Osteological examination of the fifteen skeletons found on *Vasa* shows that the men had a high incidence of healed fractures (Hocker 2011: 113). A loading gang might have worked under the direction of either the master (*överskeppare*), Jöran Matsson, or the boatswain (*högbåtsman*), Per Bertilsson and their mates (Hocker 2011: 102-103).

A series of hatches provided access to the interior of the ship. They allowed for communication between decks and let air and light into the lower decks. Hatches are almost always located along the centerline of the vessel, freeing up space for guns and reducing the possibility of flooding if the ship heeled excessively. The forward and aft edges of the hatches are usually defined by deck beams. Smaller hatches on the orlop are known as scuttles (Lavery 1987: 238-239). The number of hatches on *Vasa* decreases as one moves downwards. The weather and upper gundeck have the most hatches; the orlop has the fewest. There are 13 gratings down the centerline of the upper gundeck, which correspond to openings in the weather deck above. The lower gundeck has nine hatches, seven of which lead to the orlop. The orlop has eight hatches down into the hold below. There are three series of hatchways best suited for loading casks and cargo, one forward, one midships, and one aft. A hatch between beams 6 and 7 provides clear access from the weather deck down to compartment H2 in the hold. Hatches between beams 12 and 13 lead from the upper decks to compartment H5 in the hold. Moving aft, a third series of hatches between beams 20 and 21 provides access from the upper decks to compartment H7 in the hold. The main hatch between beams 13 and 14, which leads down to the galley, could also be used when a fire was not lit. With the exception of one small hatch or scuttle in the aftermost part of compartment T5 on the orlop, all of the hatches on *Vasa* are large enough to permit the passage of even the largest oak casks in the collection. The largest oak casks are only about 70 cm long by 60 cm wide, and all of the hatches exceed these dimensions with the one exception noted above. Casks could have been lowered down the appropriate series of hatches, based on their intended stowage location.

Once in their intended location, casks would be stowed either on end or on their side. Attempts to maximize cargo space were hampered by the shape of the vessel and shape of the containers. The ship has sloping sides, and the cylindrical casks do not stack as well as square containers. The preferred methods of stowage are known as “bilge and cantline” and “a-burton.” In the bilge and cantline method, the casks are stowed “bung up and bilge free.” This means the casks rest on their sides with bung uppermost, arranged in rows running fore and aft. Subsequent tiers of casks rest on the “canting” or “cantline,” the depressed area between four casks. The lowest level of casks is known as the “ground tier,” composed of the largest and heaviest casks least likely to be moved. Later sailing warships carried a ground tier of water or beer casks sunk into shingle ballast (Lavery 1987: 190). The a-burton method of stowage involves placing the casks in lines running athwartships, parallel with the deck beams (Smith 2009: 36). Space could be maximized by filling in gaps with smaller casks. Casks stowed bung up and bilge free required wedges and dunnage to keep them in place and reduce damage (Linebaugh 2006: 166).

Scale drawings and photos from the excavation indicate that casks on *Vasa* do not necessarily conform to these accepted patterns of stowage. Casks were found both on end, and on their sides. Lidded casks likely had to be stored upright, or the lid would fall off. Drawings of the “Meat Locker” in the hold show three oak casks resting on their sides, while forward in compartment H1 casks were found both upright and on their sides. *Vasa*’s ballast consisted of round stones with a floor of loose planking laid overtop, not shingle, so there is no ground tier of casks. There are numerous wooden wedges and blocks in the collection without signs of fasteners, many of which are simply recorded as *ospeciferat* (unspecified) or *formstycke* (a worked piece of wood). These might have been used as dunnage or billets. In his *Sea Grammar* of 1627 John Smith mentions “canting coines” and “standing coines” used to stabilize casks (1627: 33). The casks on *Vasa* were likely stowed both on end, and on their sides. It seems plausible that casks on the gundecks would be more likely to be stored on end, so they would not roll around, while those in the smaller compartment of the orlop and hold would be stored on their sides.

The following sections discuss the distribution of casks on each of the four decks. The five types of cask outlined in Chapter 6 are each represented by different coloured circles, (Figure 81). The circles are drawn approximately to scale, to provide a plan view of a cask standing on end. All casks are shown this way for the sake of consistency and convenience, even though some examples were actually stowed on their sides. Oak casks are represented as brown circles, while lidded casks are blue and marked with a prominent “L.” Pine casks are light yellow, small casks are red, and shot kegs are grey. The casks have been superimposed on the deck plans prepared by Fred Hocker and Jörgen Wallin,, published in *Vasa I* in 2006. Areas where casks could be plotted with certainty, based on scale drawings, are outlined in red.

FIGURE 81. Legend for cask distribution plans (Author).

The Upper Gundeck (ÖB)

It is estimated that the upper gundeck contained at least 11 lidded casks, 3 oak casks, 2 pine casks, and 4 small casks, for a total of 20 casks. The distribution of the casks is shown in Figure 82, below. Salvage efforts in the 1660s and 1950s meant that the two gundecks were the most disturbed areas on the ship. Cederlund admits "that the upper gundeck find layers were extensively disturbed by various forms of interference" (2006: 315), but this was offset by the fact that "a significant layer of cultural material remained under a dense layer of collapsed structural elements" (2006: 312). The upper gundeck was a large open space, from the stem aft to beam 22. The steerage between beams 22 and 23 held the whipstaff, while the Great Cabin and sterncastle were situated further aft (Cederlund 2006: 310-311). This large open space was needed for the 24 guns, plus the room to work them. The ship was designed as a floating gun platform. Anything that might impede this function was located along the centerline of the ship, including hatches and capstans. The guns at the ports divided this open space into smaller rooms, about 2 m long. Each mess would share one of these rooms, and sleep on the deck since hammocks were not yet commonplace (Hocker 2011: 110).

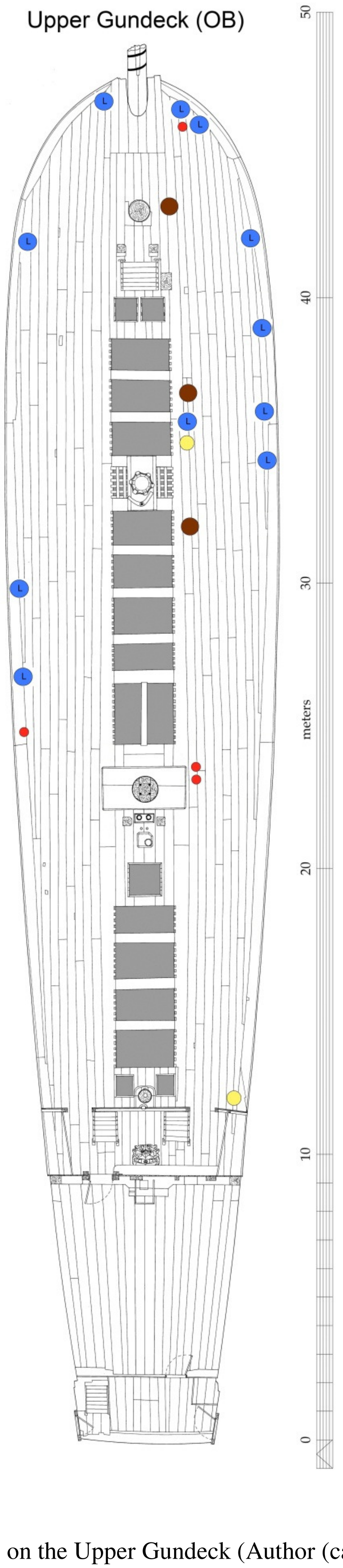


FIGURE 82. Estimated distribution of casks on the Upper Gundeck (Author (casks), Hocker and Wallin (deck plan)).

The most common type of cask found on the upper gundeck are lidded casks, with at least 11 examples represented. The high frequency of this type here is not surprising, as this was the area where much of the crew lived and slept. Only a few of the lidded casks on this deck were identified with certainty. Records clearly identify casks 07843, 08078, and 08680 as containers full of personal possessions. The presence of the remaining eight lidded casks on the deck is inferred largely from finds of the distinctive pine lids, found near groups of oak staves. It is possible to place a cask within a specific room, as defined by the deck beams and the division of the room into port, midships, and starboard sections. Within a room, however, the exact location of a cask must be inferred from knowledge of the fittings and function of the area, in the absence of scale drawings or photos showing casks in situ. Lidded casks have accordingly been plotted along the sides of the ship, in between the guns, or along the centerline. This would keep the containers out of the way, and provide sufficient space for working the guns and moving about the deck. It is possible the lidded casks on the gundecks are stowed in position for normal sailing, and would have been removed to lower decks before an engagement. All of the lidded casks on the upper gundeck are found forward of beam 18.

Only three oak casks were found on this deck, all on the starboard side between beams 2 and 9. Their contents are not known. A single pine cask was located between beams 22 and 24 on the starboard side, at the end of the gundeck. Four small casks were found on the upper gundeck. Small cask 08207 was found in a chest with other personal possessions near the bow, on the starboard side. This context suggests it belonged to an individual. It has a volume of 3.5 liters. The “Micro Cask” (07643) was found between beams 14 and 15 on the starboard side, as was small cask 08117 which is associated with cow and sheep bones. It is possible these small casks were also personal possessions, as they were found near several lidded casks. The fourth small cask on this deck was found opposite these two examples, between beams 14 and 16 on the port side. This cask was made of oak and has a volume of approximately 18 liters.

The Lower Gundeck (UB)

The lower gundeck held at least 23 casks: 11 oak casks, 6 lidded casks, and 6 pine casks. All of the casks on this deck were found forward of beam 15. The lower gundeck was divided into only two large areas. The deck forward of beam 23 was one large open space, divided down the centerline by hatches, masts and other fittings. A bulkhead at beam 23 partitioned the after part of the deck into a separate room, accessed via a sliding door. This was the gunroom, which held rammers and powder ladles (Cederlund 2006: 334-337). Overall, the find conditions on the lower gundeck were less disturbed than those encountered above. All of the gun carriages remained at their ports, although the guns had been salvaged in the seventeenth century. Personal possessions in chests and casks were found between many of the carriages (Cederlund 2006: 348-351).

Five of the six lidded casks on the lower gundeck have been identified with certainty. These are casks numbers 12865, 13599, 13702, 14101, and 21101. Five of the six lidded casks were found on the starboard side. The smaller number of lidded casks on the lower gundeck could mean that fewer individuals messed and slept on this deck. Perhaps the process of stowing personal possessions was incomplete, and the majority of lidded casks were temporarily stored on the upper gundeck prior to planned replacement on lower decks. Sailors on the lower gundeck could have used containers such as chests or sacks. It is also possible that space on the lower gundeck was set aside for the 300 soldiers scheduled to embark at Älvsnabben.

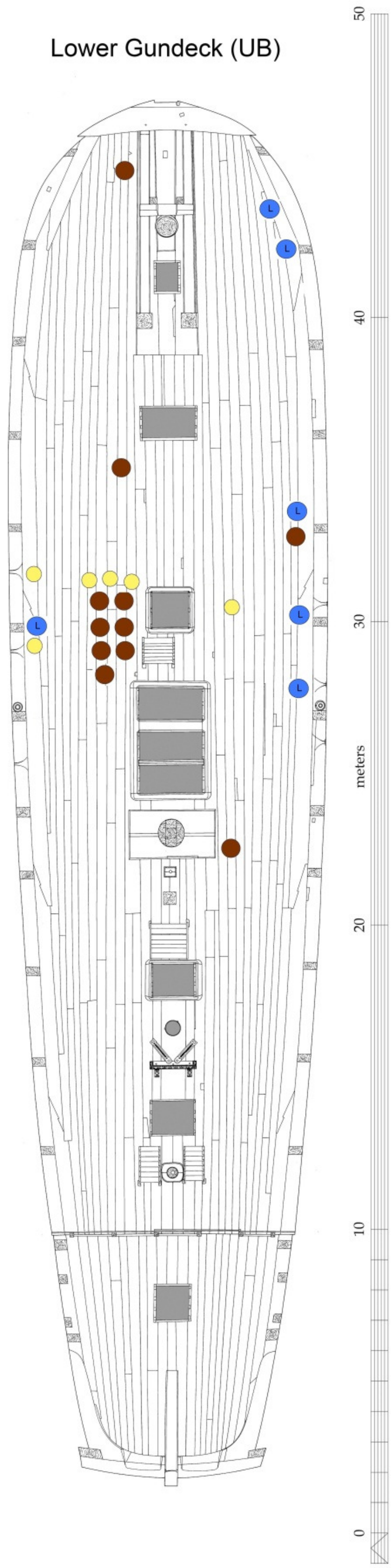


FIGURE 83. Estimated distribution of casks on the Lower Gundeck (Author (casks), Hocker and Wallin (deck plan)).

The major concentration of casks on the lower gundeck occurs on the port side, between beams 10 and 11. There are at least seven oak and five pine casks in this area. Oak cask 12601 comes from this area. This cask, Figures 54 and 57, Chapter 5, is the best preserved oak cask from the ship. It measures 595 mm, or almost exactly two Swedish feet (one *aln*) between croze grooves, and has a head diameter of 450 mm, or almost exactly 1.5 Swedish feet. Although its contents are unknown, the numerous holes in the bung stave plugged with long pegs suggests it contained a liquid. The fact that the pegs extend into the interior of the cask and were not trimmed flush with the interior suggests the pegs were inserted after the cask was complete and sealed. The volume of this cask is about 132 liters. One of the five pine casks in this area was charred on the interior, a feature often associated with casks containing spirits (Kilby 1971: 35). Perhaps the casks in this area held beer and spirits, and the concentration might represent a refreshment area, where crewmembers and their guests could enjoy a beer during the festive occasion. These casks could have been last minute provisions, waiting to be shifted down to the hold. Alternatively, the concentration of casks in this area could be a result of the sinking process, when the ship heeled to port and water flooded in. Unsecured casks might have rolled to port, although the hatch and companionway down the centerline would presumably have impeded casks from the starboard side shifting to port. Pine cask 11740 was found opposite the cask concentration in the UB BB 10-11 area. It contained a fatty substance that has yet to be conclusively identified.

The Orlop (TD)

Below the lower gundeck is the orlop, or *Trossdäck* (TD). This deck held at least 22 casks: 1 oak cask, 6 lidded casks, 13 pine casks and 2 small casks. The orlop was primarily a storage deck, and was only 1.5 m high on average (Cederlund 2006: 380-381). Traditionally, the orlop served to store cables, sails, and "other items which were neither heavy, valuable, nor dangerous" (Lavery 1987: 154). Indeed, excavators recovered a set of spare sails and a large mound of anchor cable on this deck. The orlop was the least disturbed of the four intact decks, and was the last to be excavated (Cederlund 2006: 386-388). The orlop was divided by bulkheads into five compartments, numbered T1 through T5 by Urban Skenbäck in the 1980s (Cederlund 2006: 356). Draughtsman Bo Wingren prepared detailed plan drawings of the find situations in the orlop, which allows casks to be plotted with considerably more confidence than those on the gundecks and in the after portion of the hold.

Compartment T1

The forwardmost compartment on the orlop, (Figure 85), extends from the stem aft to beam 4. It is accessed from above through a hatch measuring 95 x 75 cm, and a hatch of the same size leads to compartment H1 in the hold below. T1 could also be accessed via a sliding door in the bulkhead, 100 cm wide, leading aft to compartment T2 (Cederlund 2006: 380). T1 contained at least 6 casks: 1 lidded cask, 3 pine casks, and 2 small casks. These casks are visible in the plan drawing of the area. The presence of the lidded cask is inferred from pine lid 19560, found near a cluster of parrels and rigging hardware. Just aft of this two pine casks are visible, numbers 19763 and 19778. Pine cask 19763 was apparently stowed on its end, and the staves are visible splayed outwards. Pine cask 19778 is located approximately a meter to starboard. Sample

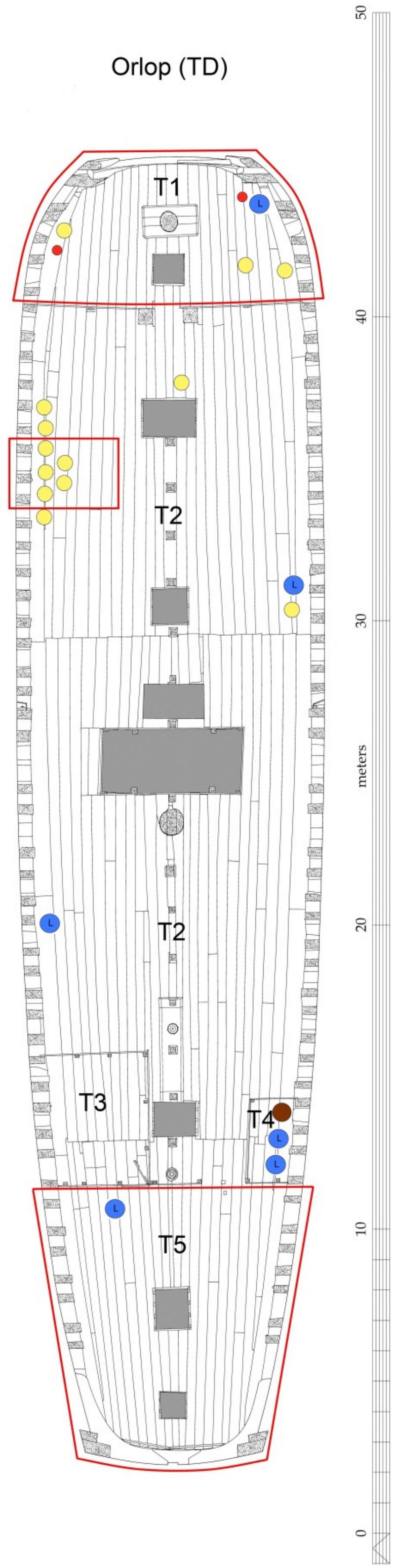


FIGURE 84. Estimated distribution of casks on the Orlop. Areas where casks can be plotted with certainty are outlined in red (Author (casks), Hocker and Wallin (deck plan)).

19784 indicates that this cask contained grains of some sort. If this is correct, than it appears some provisions were stored in areas other than the hold. A third pine cask was located on the opposite side of the compartment, between beams 2 and 3 on the port side. This might also have contained provisions, as a sample full of herring bones (19874) also comes from this area. Two small casks were found in compartment T1. Small cask 19853 is visible in the plan below, at beam 2 on the starboard side. It likely had a volume of around 13 liters. Another small cask was located on the opposite side of the compartment.

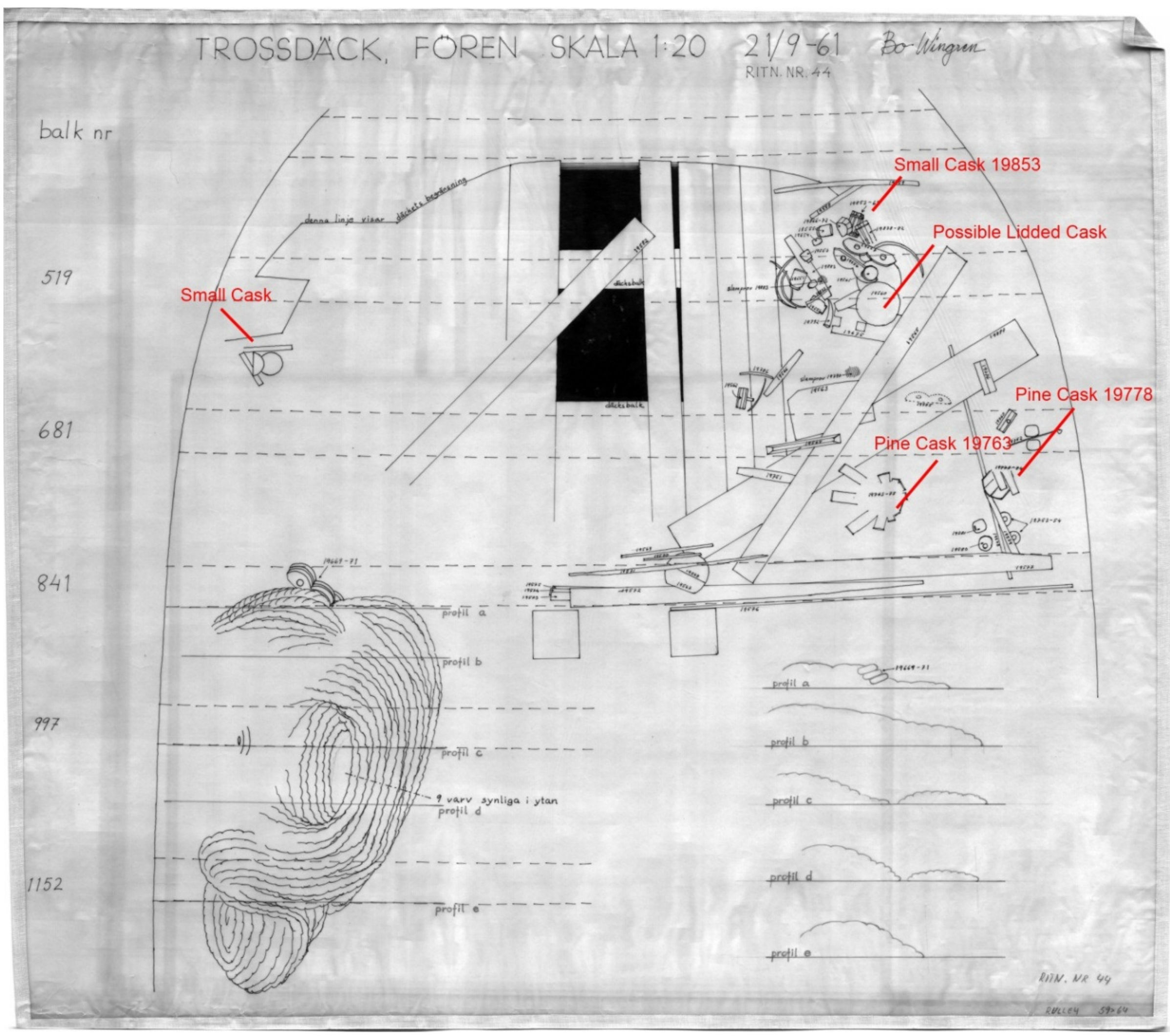


FIGURE 85. 1961 plan of find situation in compartment T1 on the orlop. A pine lid beneath beam 2 on the starboard side may indicate a lidded cask. A small cask is also visible in this area, while two pine casks are visible aft between beams 3 and 4. Little detail is available for the port side of the compartment, but a small cask may be shown. (Courtesy of the Vasa Museum, Stockholm.)

Compartment T2

The second compartment on the orlop was also the largest, and stretched from beam 4 aft to beam 22. T2 was accessed by five hatchways leading from the lower gundeck, which continue downwards into the hold. The hatch between beams 13 and 14, however, was walled off to create a smoke hood for the galley below. Movement in T2 would be restricted by the low height of the deck, only about 1.5 m high, as well as the riding bitts, hatches, mainmast, pump, and capstan block down the centerline (Cederlund 2006: 389). Compartment T2 held at least 12 casks: ten pine casks and two lidded casks. This is the highest concentration of pine casks in the ship. Eight of the pine casks were clustered between beams 6 and 9 on the port side. Half of these eight casks were charred on their interiors, suggesting they might have contained either spirits or water. Pine cask 18765 contained herring, and is visible on its side in a plan from 1961, (Figure 86). It has a volume of approximately 36 liters. Other pine casks in this area were larger and had volumes up to 60 liters. The presence of the herring cask and the possible spirit or water casks indicate that this area might also have been used to store provisions. Opposite this cluster of pine casks lidded cask 18669 was found between beams 9 and 10 on the starboard side. Pine cask 18433 was located just aft. It too was charred on the interior. A second lidded cask was located on the port side between beams 16 and 17. Stowing these casks in such cramped confines would have been difficult, and the casks must have been rolled on their sides by men bent over or kneeling. Pine casks 18765 and 18850 are shown on their sides in the excavation plan, but it is possible some of the fragmentary casks visible nearby were stowed on end. Forward of this cask cluster a large mound of anchor cable is visible. The presence of the anchor cable and oars, as well as the rigging hardware in T1, suggest that this would also be a logical place to store casks of naval stores such as pitch and tar. Unfortunately, the available samples do not identify any of these materials.

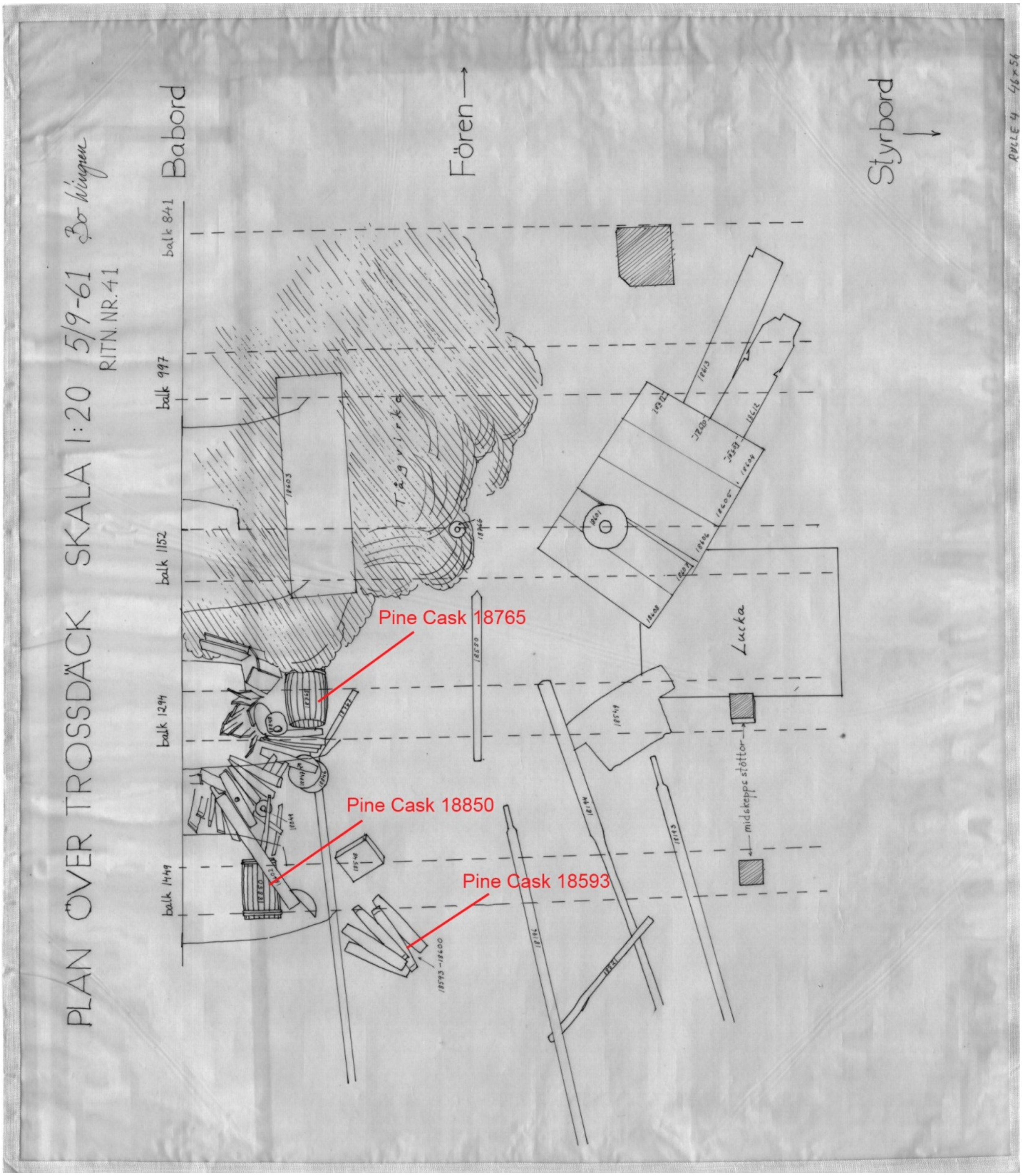


FIGURE 86. Find situation on the port side of compartment T2 on the Orlop, showing cask cluster aft of the anchor cable. (Courtesy of the Vasa Museum, Stockholm.)

Compartment T4

Compartment T3 was the sail room, and did not contain any casks. Compartment T4, opposite, is known as the "Carpenter's Store" because of the chest of carpenter's tools found here. This small compartment extends from beam 20 aft to beam 22, and was accessed via a sliding door leading to T2 (Cederlund 2006: 381). Compartment T4 contained three casks, in addition to the tool chest: two lidded casks, and one oak cask. It is likely these lidded casks belonged to the carpenter and his mates. *Vasa* would have carried up to four carpenters, or *timmerman* (Hocker 2011: 104). If the full complement of carpenters were aboard in August 1628, perhaps two carpenters shared each lidded cask in the Carpenter's Store.

Compartment T5

This is the aftermost compartment in the orlop, extending from beam 22 aft to the stern. It was accessed through an opening in the bulkhead leading to T2, or via a hatch to the tiller room in the gundeck above. Two hatches led to compartments H8 and H9 in the hold, below (Cederlund 2006: 381). T5 was pierced by two gunports in the transom, although no guns were mounted here. A number of gun carriage parts and artillery equipment were found in this compartment (Cederlund 2006: 398). Only one cask, a lidded cask, was found in T5. This is visible on its side in the 1961 plan, below. This is one of the largest casks in the collection, with a distance between croze grooves of 698 mm, and a head diameter of approximately 465 mm.

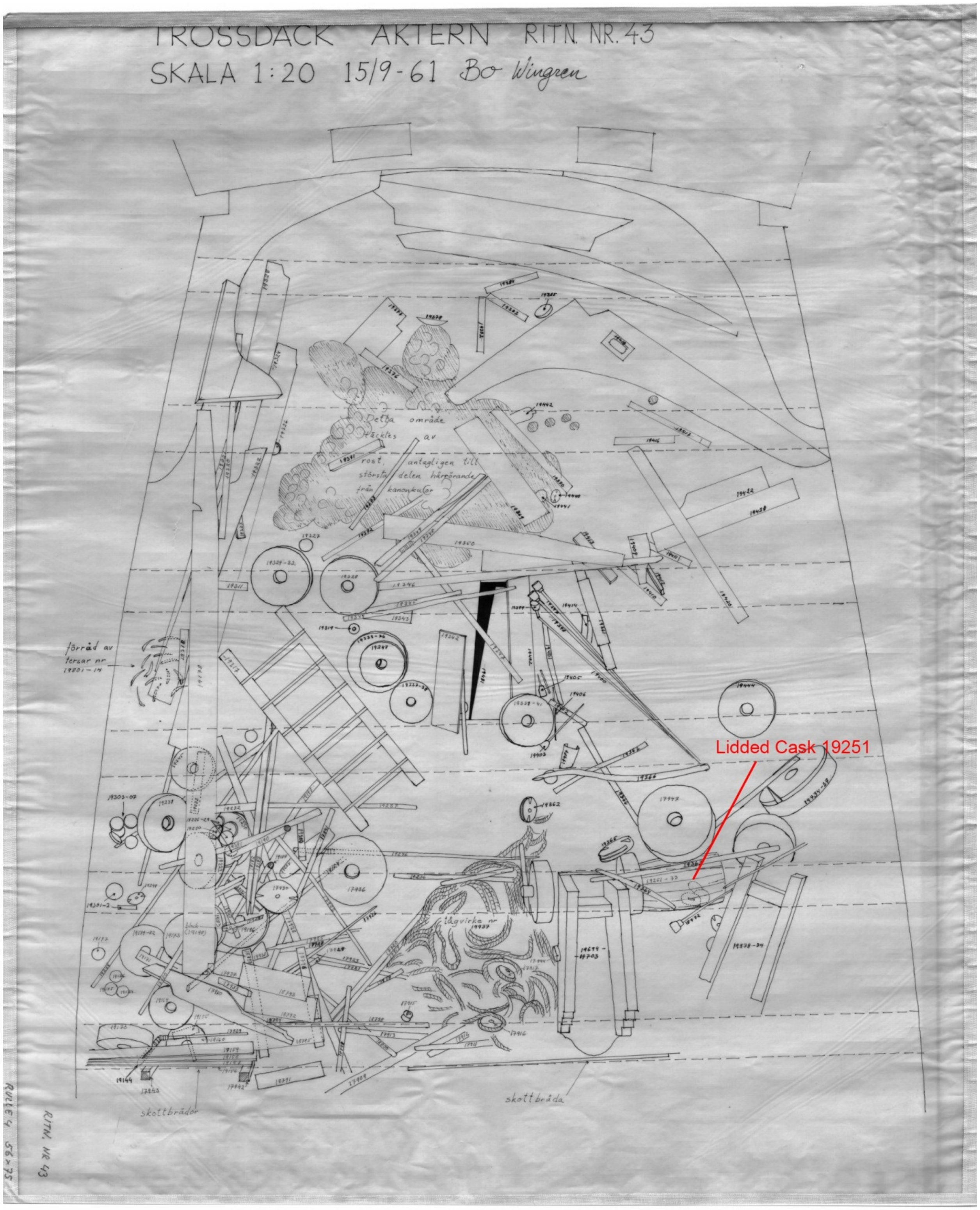


FIGURE 87. The find situation in compartment T5 on the orlop. The stern is at the top of the drawing. The only cask in this area, lidded cask 19251, is visible on its side between two gun carriages in the lower right. (Courtesy of the Vasa Museum, Stockholm.

The Hold (HS)

The lowest deck on the ship is the hold, or *Hålskeppet* (HS). It is divided by bulkheads into nine compartments, numbered H1 to H9. The find situation in the hold, like the orlop, was relatively undisturbed in comparison to the gundecks. Salvage operations had not affected this area, although some material moved between decks, especially around hatchways (Cederlund 2006: 379). *Vasa* carried 120 tons of round stone ballast, with a loose covering of planks laid overtop. During the sinking most of this ballast shifted to port and dislodged the plank covering. Removing this weight was a priority for the excavators, who decided to bypass the orlop in order to eliminate the strain on the ship's structure. The ballast was removed using an elevator constructed in the hatchway running down to the galley. Weight was also reduced by cutting a hole in the hull between deck beams 12 and 13, which drained the watery sludge filling much of the hold (Cederlund 2006: 359-360).

The hold contained the most casks of any deck. The hold held at least 63 casks: 43 oak casks, 1 lidded cask, 7 pine casks, 5 small casks, and 7 shot kegs. The distribution of casks on this deck is shown in Figure 88, below. Detailed plan drawings of the forward half of the hold allow the position of individual casks to be plotted with some confidence. Oak casks are the most common type found in the hold and occur in three major clusters, in compartments H1, H3, and H8, respectively. The clustering of casks in these areas shows that there was a clear stowage plan. It also shows that the ship was not fully laden when she sailed, as there remained ample room to take on additional stores and supplies once she arrived on reserve station in the Archipelago.

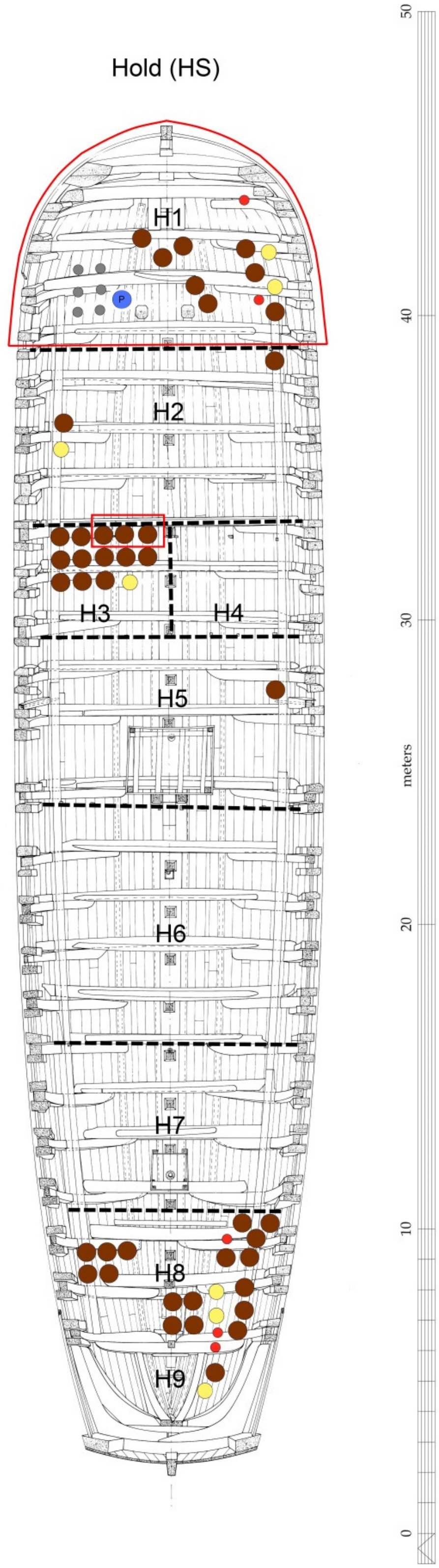


FIGURE 88. Estimated distribution of casks in the Hold. Areas where casks can be plotted with certainty are outlined in red (Author (casks), Hocker and Wallin (deck plan)).

Compartment H1

This is the forwardmost compartment in the hold, extending from the stem aft to beam 5. The only access to this area is through the hatchway to compartment T1 above (Cederlund 2006: 356). H1 held at least 20 casks: 8 oak casks, 1 lidded cask, 2 pine and 2 small casks, and 7 shot kegs. The find situation is shown in Figure 89, below. Oak cask 17030 is likely the cask visible on end with a beam jutting through the bung hole, near the stem and just to port of the riding bitts. This is one of the larger casks in the collection. It has a distance between croze grooves of 680 mm, a head diameter of 450 mm, and a volume of 142.9 liters. Further aft, oak cask 18135 is visible lying on its side, midships beneath beam 4. This, too, is one of the largest casks on *Vasa*. It has a calculated volume of 146.4 liters. This cask has 14 staves, which vary considerably in width. The narrowest is only about 100 mm wide, while the largest is about 170 mm in width. The additional six oak casks in this area vary slightly in size. Two have croze distances of about 650 mm, and thus likely a volume closer to 140 liters, while one has a croze distance of 660 mm, and two have croze distances closer to 690 mm, with a likely volume closer to 146 liters. The dimensions of the remaining oak cask cannot be established with certainty.

Two pine casks were present on the starboard side of H1. One rested between beams 3 and 4, while a larger example with a croze distance of 665 mm and a volume of about 105 liters lay between beams 4 and 5. One small cask is visible as a group of collapsed staves, beneath beam 2 on the starboard side. A second small cask was located further aft, between beams 4 and 5 on the starboard side. This cask, number 17222, featured a distinctive "A" mark on one head. It has a volume of 18.8 liters. Personal cask 17277 is visible as a group of disarticulated elements and personal objects spread out beneath beam 4 on the port side. The six shot kegs are clustered in a group on the port side, between beams 2 and 4. They contained nearly 9,000 musket shot, and are discussed in detail in Chapter 6. The presence of a seventh shot keg is inferred from rebuilt keg "175B," and other loose finds from shot kegs which cannot clearly be assigned to the six firmly identified shot kegs.

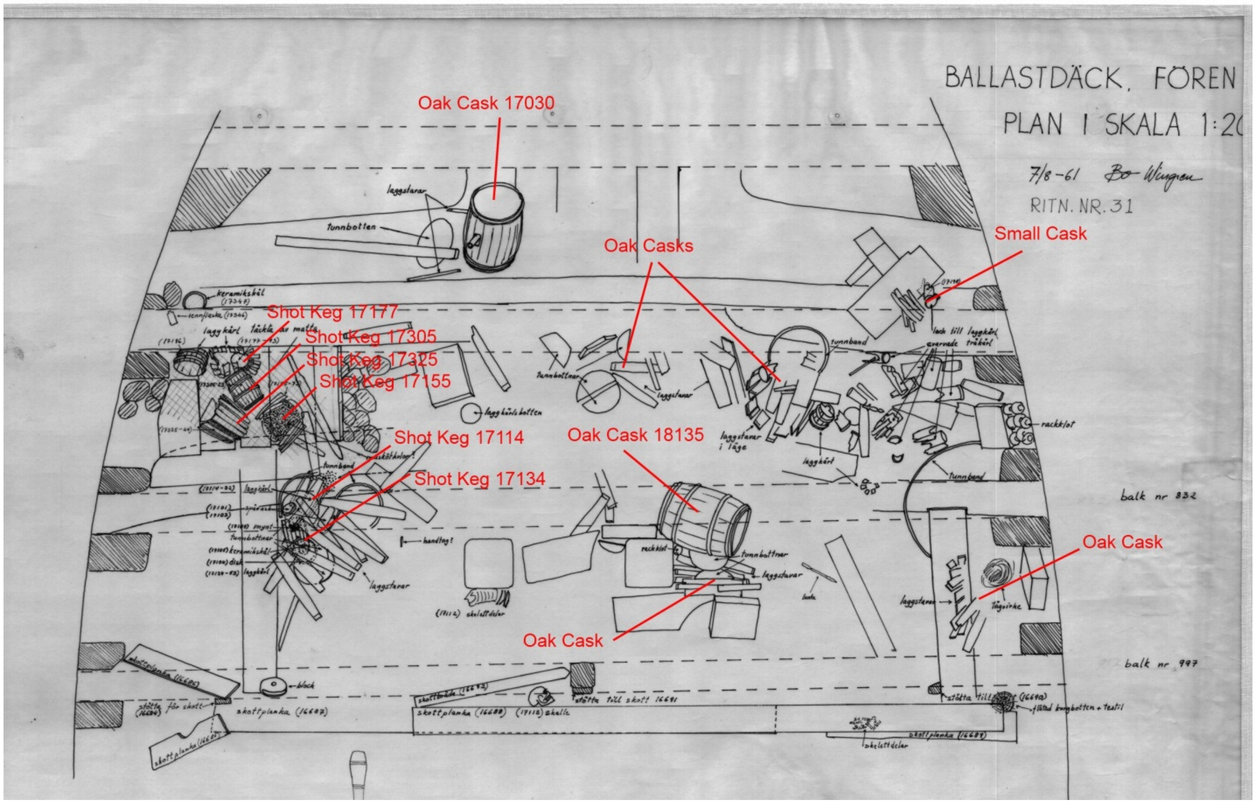


FIGURE 89. The find situation in compartment H1 in the hold. Oak cask 17030 is visible forward, near the bitts, while oak cask 18135 rests on its side beneath beam 4, midships. Shot kegs are clustered on the port side, between beams 2 and 4. (Courtesy of the Vasa Museum, Stockholm).

It is tempting to identify this area as the "proto-magazine," given the location of H1 within the ship, the presence of shot kegs, and the absence otherwise of any unequivocal formal magazine. Little is known about seventeenth-century magazines, but by the eighteenth century they were located in the forward part of the hold in British vessels, and in the after part of the hold in French ships. This kept them free of bilge water, which ran towards the center of the ship. The location of the magazine in the hold also reduced the effects of damp, and destruction by enemy fire. Brian Lavery believes, that during the seventeenth century, "there was nothing special about the magazine and that it was simply a part of the hold or orlop deck set apart from the rest, and kept locked to prevent the careless handling of powder" (1987: 144). Compartment H1 fits Lavery's criteria for seventeenth-century magazines, given its location in the forward part of the hold and the limited access.

The location of *Vasa*'s magazine is of interest, as it is known that she carried some powder, but the powder barrels have hitherto remained unidentified. Hocker's recent publication on *Vasa* states that the maximum charge for one of the 24-pounder guns was about 8 pounds (2011: 52), but the ship carried only enough powder for about 250 total shots (2011: 61). If these figures are correct, than the ship carried as much as 2,000 pounds of powder. This is still a substantial amount. Ideally, powder barrels needed to be constructed with special care so they would neither leak nor let damp in. Loose powder was dangerous, and damp powder would not burn effectively. Later British powder barrels were built of oak, with a combination of ash, hazel, and copper hoops to reduce the risk of sparks associated with iron hoops. These British powder barrels had a maximum height of 533 mm, and were organized by weight rather than volume (Razzolini 1978: 1-3). In contrast, the sixteen powder barrels from the 1686 wreck of the French *La Belle* were notable for their poor quality of workmanship and idiosyncratic combination of wood species (Loewen 2014: 30). The *La Belle* powder barrels fell into two groups based on size. Eleven of the powder barrels had capacities of between 58 and 66 liters, while the remaining five had volumes of between 32 and 38 liters (Loewen 2014: 21). The single powder barrel identified on *Mary Rose* had a croze distance of 650 mm, and an overall height of about 680 mm (Rodrigues 2005: 416). These figures are intriguing, as two of the oak casks in H1 do indeed have croze distances of about 650 mm, and four others have croze distances in the range of 680 to 690 mm. The volumes of these oak casks likely ranged between 140 and 146 liters. The location and dimensions of these eight oak casks in Compartment H1 suggest that they may in fact be the previously unidentified powder barrels. If this is correct, it is noteworthy because the oak casks in H1 do not appear to differ substantially from other oak casks in the collection in construction or markings. If these oak casks in H1 indeed held powder, than it confirms them as the true multipurpose container of the ship.

Compartment H2

Aft of compartment H1, compartment H2 extends from the aft side of beam 5 to the aft side of beam 9. The only access to this area is through a hatch to the orlop between beams 6 and 7 (Cederlund 2006: 356). The major finds in H2 were two large coils of anchor cable, visible in Figure 90, below (Cederlund 2006: 372). Only three casks can be identified in this area: two oak casks and one pine cask. The first oak cask was located between beams 5 and 6 on the starboard side. It has a croze distance of approximately 660 mm and a head diameter of 450 mm, so it might have had a volume of around 140 liters. The second oak cask was found between beams 6 and 9 on the port side. A fragmentary pine cask was also found here.

Compartment H3

During the excavation this area was known as the “Meat Locker” or “Larder” because of the large number of casks and remains of provisions found here. It represents the densest single concentration of casks in the ship, with at least 14 casks in an area of only about 15 m^2. Compartment H3 extends from the aft side of beam 9 to the aft side of beam 11, on the port side of the ship. Sliding doors in the bulkheads provide access to Compartment H4, to starboard, and Compartment H5, aft (Cederlund 2006: 357). Thirteen of the fourteen identified casks in this compartment were oak, while the remaining example was pine. Four casks are visible on their sides in the figure below, while Figure 91 provides another view of the find situation. This suggests that the casks here were stowed in the traditional bilge-and-cantline method, although

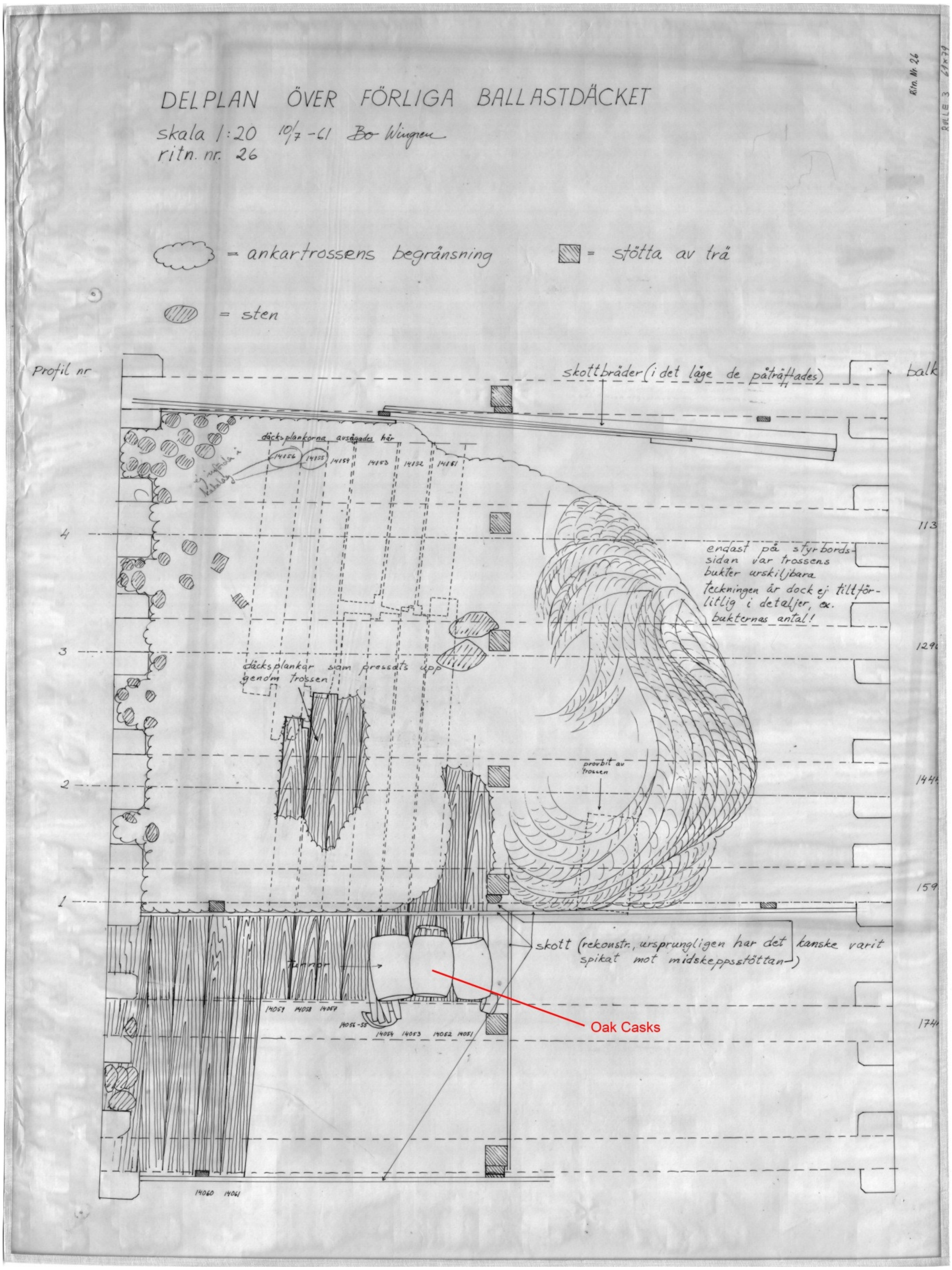


FIGURE 90. The find situation in compartments H2 and H3 in the hold. The anchor cable dominates H2, while three or four oak casks are visible on their sides in compartment H3. (Courtesy of the Vasa Museum, Stockholm.)

they are represented by simple circles on the author's distribution plan, in the interests of consistency. The large number of animal bones in this area indicate that these casks contained salted provisions, mainly beef, pork, and some mutton (Hocker 2011: 117). Intact pine cask 11773 was found in compartment H3. Sampling of the contents show it contained cod. It has a croze distance of 500 mm, head diameters of 298 mm, and a volume of 41.1 liters.

FIGURE 91. The jumbled mask of casks as found in compartment H3. (Courtesy of the Vasa Museum, Stockholm.)

Oak cask 08224 is one of the best preserved oak casks in the collection, and comes from this area. It has a croze distance of 648 mm, a head diameter of 450 mm, and a volume of 140.7 liters. Museum documents refer to this as the *vattentunna* or water barrel, but do not clarify this identification. The remaining dozen oak casks in H3 are represented by disarticulated elements. Excavators refined their normal recording methodology in this area, and divided the compartment into seven *fyndplats* or "find places," labelled A through G. The rationale behind this division remains unclear, however. Fyndplats C, D, and E contained only a few loose staves, not enough for complete containers. Fyndplats B, F, and G likely represent multiple containers as each group contains multiple bung staves. Fyndplats G alone contains five bung staves with square bungs, so it cannot represent a single cask. Neither the current director of research at the Vasa Museum (Fred Hocker 2011, pers. comm.) nor one of the few remaining members of the original excavation team (Carl Olof Cederlund 2011, pers. comm.) could recall how this variation on the recording system worked. If the individual *fyndplats* do not represent particular casks, perhaps they represent spatial divisions of the compartment as observed by the excavators. Unfortunately, notes on the organization of this system appear to be missing.

The contents, as well as the location and construction of compartment H3 are important for understanding provisioning on *Vasa*. The high concentration of casks and faunal remains here indicate this was the chief area for storing meat. If the 13 oak casks each had a volume of about 140 liters, and each contained salt meat, then about 1,800 liters worth of salted provisions were held here, in addition to the 40 liter cod cask. Access to the compartment was only through adjacent compartments H4 and H5. This limited access likely aided control by both the steward (*skaffare*) and cook (*kock*), and suggest these provisions represented official stores rather than food brought aboard by individuals. The concentration of provisions in H3 also makes sense, since the galley is located immediately aft in Compartment H5. This reinforces the idea that there was a clear plan for stowage aboard ship, as the bulk of the salt provisions were stored conveniently close to the galley. It also confirms that the ship was only partially provisioned, as a full complement of over 400 soldiers and sailors would require considerably more than 14 casks of salt meat and fish, not to mention bread, peas, beer and water.

Compartments H4, H5, H6, and H7

The compartment to starboard of H3 and the three compartments aft of it contained few artifacts. Only one cask can be identified in this area with any confidence, in compartment H5. Compartment H4 was almost empty, except for a few ballast floor planks (Cederlund 2006: 375). Perhaps this area was set aside for the loading of more stores once the ship reached the Archipelago. Compartment H5 contained the galley, a brick structure along the centerline of the ship between beams 13 and 14. It contained an iron cauldron with a capacity of about 180 liters (Cederlund 2006: 375), which suggests it could boil an entire cask's worth of salt meat at one time. Eric Ray from East Carolina University studied the galley in detail (Ray 2009). At least one oak cask was found in H5, between beams 11 and 13 on the starboard side. The find situation in this area is confused, as some material fell from upper decks, and other material was drained through a hole in the hull cut to eliminate excess weight. Coopered material in compartments H6 and H7 was too sparse and fragmentary to identify any containers with confidence. It is possible these compartments were also left largely empty on purpose, in anticipation of loading additional equipment.

Compartment H8

This compartment is located in the stern, between beams 22 and 25. Access is limited to a single hatch leading to the orlop, between beams 24 and 25 (Cederlund 2006: 358). Previous studies describe this area as an "officer's store," because of the high status items found within (Lindblom 2002). This seems a reasonable supposition, especially given the tightly controlled access which would aid security. Compartment H8 contained at least 22 casks, rivaling compartment H3 and the area between beams 10 and 11 on the lower gundeck in terms of density of cask concentration. It is estimated H8 held 17 oak casks, 2 pine casks, and 3 small casks. Unusual casks were found in this area, which supports the identification of H8 as a storeroom for special or valuable items. Oak cask 15841 is one of the only oak casks conclusively linked to vegetal contents. Sample 15861 from this cask contained traces of wheat, oats, and peas (Abramson 1965), suggesting that it may have held biscuit. Cask 15841 is only about half the size of the standard oak casks found on the ship, with a volume of 68.7 liters. Oak cask 16525 with the unique double square bung was also found in this area. These casks are described in Chapter 6. More typical is oak cask 08218, which has a croze distance of 641 mm (approximately 26 Swedish inches), a head diameter of 450 mm (about 1.5 Swedish feet), and a volume of 136.7 liters. Museum records identify this cask as a "water barrel," or *vattentunna*, but do not provide any more information.

Intact pine cask 15305 was found between beams 24 and 25 on the starboard side. It has a volume of 36.4 liters, although the contents remain unknown. Pine cask 15732 had similar dimensions and was charred on the interior, suggesting it may have held water or spirits. Miniature cask 14886 also comes from this area, with a volume of only 0.9 liters. Its contents remain unknown as well.

Compartment H9

The final compartment in the hold is labelled H9, and stretches from beam 26 aft. It is a tiny space reached only via a small hatch in the orlop above (Cederlund 2006: 358). Two casks can be identified in this area, one oak and one pine. The oak cask is number 16502. Sample 16599 was collected from this cask, but has yet to be identified.

Outside and Missing Provenience

The distribution discussed and illustrated above only includes casks which can be associated with specific areas of the ship. This distribution plan does not include casks found outside the ship, and those which have lost their find numbers and hence contextual information. It is estimated up to six casks were recovered by divers outside the ship: one lidded cask, two pine casks, and three small casks. Small cask 00477, also known as the "Aquavit Keg" is one of the more interesting casks from outside the wreck. It comes from the stern debris scatter, and is discussed in Chapter 6. Material judged to be intrusive, such as eight beech staves, is not included in the estimate of casks from outside the ship.

A portion of the cask collection lacks contextual information. Many of the rebuilt casks and individual elements have lost their identifying find number discs (*fyndbricka*) over the years. These containers can be studied and compared to the rest of the collection, but cannot be included in the distribution plan. It is estimated these casks and cask parts represent at least 11 containers: five oak casks, one lidded cask, four pine casks, and one small cask. This is about 7 percent of the total of 145 casks on board.

Chapter 8 – *Vasa* Casks in Northern European Iconography

Previous chapters have focused on the attributes of the *Vasa* casks, ordered them into a typology, and plotted their distribution across the ship. While reference has been made throughout to other examples of archaeological cooperage, this chapter aims to situate the *Vasa* casks within a wider early modern, north European context. This is accomplished through an iconographic study. A search through thousands of prints and images from the fifteenth through the seventeenth centuries has revealed dozens of examples of casks with similar attributes to those from *Vasa*. This is significant, as few archaeological parallels exist for these oak casks with square bung holes. Many images were also discovered of coopers at work, and the reuse of casks in secondary contexts. Pictures of casks similar to those from *Vasa* show the temporal and geographic scope of this type of container. Depictions of coopers offer clues about methods of production and organization of labor not always readily apparent in archaeological material alone. Images of casks used for purposes other than containers suggest the importance and utility of these objects in early modern European society.

Historical archaeologists have long turned to period art in an effort to interpret their finds. Ivor Noël Hume was one of the first to do so, in his study of the seventeenth-century Martin's Hundred plantation in Virginia (1982: 88-96). Hume also warned about the perils of interpreting early modern art too literally. He observed that celebrated British genre painter William Hogarth appeared to draw the same stock objects in the 1750s as he had in the 1720s, despite changing tastes in the intervening decades (Hume 1982: 94). Julia King expanded upon Hume's approach, in her study of tobacco use in the Chesapeake region. King makes several salient points about seventeenth-century Dutch art, noting that "the paintings mostly seduce modern-day viewers into believing that the images merely transcribed what was before the artist's eye. What may seem straightforwardly representational in Dutch art was usually deeply symbolic and not at all a mimetic view of everyday life in 17th-century Netherlands" (2007: 9). Despite this admonition, King admits that "the fiction of these representations does not necessarily invalidate their use for exploring early modern life in the Netherlands" (2007: 9), a claim which might be expanded to encompass the more general application of art for the understanding of archaeological material. Richard Unger has also commented on this subject. "Studying works of art as sources of information for the history of technology…means evaluating artists' reliability rather than their skill. Paintings are immediately denuded of any value for style. … So historians of technology seek in art the lowest level of meaning" (1991: 79). Even if students of the past seek only "the lowest level of meaning," meaning nonetheless remains. Art provides evidence that researchers ignore at their peril. The conventions employed and messages conveyed by artists offer clues to understanding past societies not always readily identifiable in the objects themselves. Sources of information should be complementary, not mutually exclusive.

The sources for this chapter were published collections of early modern prints, especially Dutch and German examples. *Hollstein's Dutch and Flemish Etchings, Engravings, and Woodcuts, ca. 1450-1700* (1949-present) and *Hollstein's German Engravings, Etchings and Woodcuts, 1400-1700* (1954-present) proved particularly useful. The corpus of cask images assembled by the author includes approximately 150 examples, but only a representative selection is presented here. The image corpus is by no means exhaustive or conclusive, as there are literally hundreds of thousands of published images from the period in question. Scholars such as Adam Bartsch (1757-1821) and F.W.H. Hollstein (1888-1957) devoted lifetimes to collecting and studying early prints, without ever assembling absolutely conclusive collections. The process of searching for images of early modern casks is painstaking, as images must be individually visually scanned. Using search terms in a database of catalogued prints is likely to yield poor returns, as most casks form part of the background detail rather than the chief subject or theme of the image. Once one does begin to look for images of early casks, they begin to crop up frequently, and in unexpected places. Casks appear more frequently in Dutch than in German art. This may be the result of a higher overall Dutch print output, however, as well as differing artistic and consumer tastes between the two regions. Unfortunately, the number of early images from Sweden is very limited, and only a single image from a Swedish manuscript is illustrated here. Casks almost always appear in urban rather than rural contexts, with the exception of some harvest or seasonal scenes. Casks never appear in religious scenes. While this statement may seem self-evident, many religious images of the sixteenth and seventeenth centuries show Biblical figures with contemporary dress and material culture. Casks are almost always associated with lower and middling individuals, peasants and artisans, and rarely with elites. They are commonly found in a number of genre prints, including peasant *kermis* or festivals, tavern scenes, seasonal scenes, workplace scenes, and harbor or maritime scenes. Examples of these appearances are presented below.

Casks with Square Bungs

The most common type of cask found on *Vasa* are oak casks with distinctive square bung holes. The earliest archaeological example of a similar cask comes from Viborg, Denmark, and dates to about 1270 (Daly 2007: 190). The earliest artistic representation of such a cask comes from a German manuscript of ca. 1425, shown in Figure 73 in Chapter 6. Another early example of a cask with a square bung hole comes from Hieronymous Bosch's *Wayfarer* painting of ca. 1488 (Dixon 2003: 68), shown below. Here the cask is standing near the doorway of the tavern or "House of Ill-Repute" visible in the background. A figure is urinating against the wall of the

FIGURE 92. An early depiction of a cask with a square bung hole. Hieronymous Bosch's *Wayfarer* of ca. 1488 (Dixon 2003: 68).

structure. Dixon observes that painters of the Northern Renaissance school were known for "interpreting sacred themes in everyday terms, and depicting the natural environment realistically," but "employed hidden meanings and symbolism to a greater extent than ever before" (2003: 35-36). Here we see the titular Wayfarer, likely a pilgrim, passing on his way and avoiding the worldly temptations of the House of Ill-Repute in the background. The two figures in the doorway perhaps represent Adultery, while the figure urinating might represent the sin of Drunkenness. In this context, the cask in front of the house might be an empty beer barrel, and the structure a tavern. The empty cask is associated with drunkenness, something to be avoided by the pious.

Other early examples of casks with square bungs come from German book illustrations of the late fifteenth century. The two examples presented below come from the herbal *Hortus Sanitatis* [Garden of Health], published in Mainz in 1491 (Schuler and West 2011: 1). The image on the left shows flies and cockroaches around an empty beer barrel. That on the right shows a figure collecting Cream of Tartar (potassium bitartrate) from a used wine barrel. These images demonstrate that casks with square bung holes could be used to hold liquids like beer and wine, and illustrate the importance of the trade in old casks. Another early image of a cask with a square bung is also the only example in the corpus from Sweden itself. Figure 94, below, shows one method of transporting a cask. Two men are carrying a wine cask slung on a pole, which rests on their shoulders. This is a detail from a manuscript dated 1502, in the Swedish national library (Jansson 1995: 194). These three images also reinforce the association of casks with square bungs with beer and wine. This is suggestive, and supports the possibility that some of the oak casks from *Vasa* held beer or other liquids. No liquid contents in the *Vasa* casks survived the centuries of immersion, so these contents must be inferred. The oak casks do not conform to Kilby's modern standard of liquid tightness, which requires much thicker staves and circular bung holes (1971: 21-41). The oak casks are much thinner than those described by Kilby, and have large square bung holes rather than smaller circular ones. The frequent association of square bung casks with beer and wine in early modern art suggests that some of the *Vasa* oak casks might also have held these beverages. The strongest evidence that some of the oak casks held beer, however, comes from a German print of 1601, (Figure 95). This shows brewery maids carting empty beer barrels back to the brewery (Unger 2004: 224). These casks seem almost

FIGURE 93. Two illustrations from *Hortus Sanitatis* [*Garden of Health*], published in Mainz in 1491. The cask on the left is an empty beer barrel (Schuler and West 2011: 8), while that on the right apparently contained wine (Schuler and West 2011: 137).

FIGURE 94. The only image of a cask with a square bung found from Sweden. Detail from a manuscript dated 1502, showing two wine sellers transporting a wine cask (Jansson 1995: 194).

FIGURE 95. This German woodcut of 1601 provides the closest artistic parallel to the oak casks from *Vasa*, and suggests some of the oak casks on the ship held beer (Unger 2004: 224).

identical to the oak examples from *Vasa*. They have square bung holes. The hoops are grouped at the chime and bilge positions, rather than clustered at the ends as seen on the *barrica* style casks found on the *San Juan* (1565) and *La Belle* (1686) wrecks. The heads in the woodcut are very similar to those from *Vasa*; they are made of only three pieces, and likely edge joined since no reinforcing barres are visible. Even the plugged tap or vent holes in the heads seem similar in size and location to those observed in the *Vasa* collection. These images suggest some of the oak casks on the ship likely held beer.

The association of square bung casks with drinking and alcohol continues into the realm of allegory. *The Demon of Drink*, below, personifies over-indulgence in alcohol as a fierce swine, wearing a cask with a prominent square bung hole. The hoops on the cask appear similar to those from *Vasa*, in placement and join style. The figure holds a large stein in one hand, and emits a noxious cloud. The sabre brandished in the demon's right hand might represent violence associated with drunkenness, while the wreath of playing cards on his head clearly symbolizes the gambling attendant to tippling. Dutch artist Cornelis Anthonisz Theunissen produced this striking engraving in the first half of the seventeenth century (Luijten 1986: 38). The allegorical use of square bung casks continues even in seemingly more straightforward works, and reinforces the need to interpret these images critically. Jan Steen's *The Dancing Couple* of 1663, (Figure 97), shows an apparently simple rustic scene. A cask with a square bung is prominent in the foreground, while another with a circular bung supports the table. The centrally situated square bung cask is apparently a reference to the Dutch proverb, "*Een vol vat en bomt niet*," or "a full barrel doesn't resound," illustrated in an emblem of 1614, (Figure 98). This saying means that foolish people make the loudest noise, like striking an empty barrel, while wise individuals remain quiet, like a full barrel (Chapman et al. 1996: 163-165). The inclusion of casks with two different styles of bung in the same image is also interesting, and suggests that different variations of casks existed contemporaneously.

FIGURE 96. Allegorical representations of casks with square bung holes associate these containers with beer and wine. Dutch print, first half of the seventeenth century (Luijten 1986: 38).

FIGURE 97. Jan Steen's *The Dancing Couple* (1663). The cask in the foreground likely represents the Dutch proverb "*Een vol vat en bomt niet*" (Kloek 2005: 56).

FIGURE 98. Emblem by Roemer Visscher, 1614. The saying "*Een vol vat en bomt niet*" translates as "A full barrel doesn't resound" (Chapman et al. 1996: 163-165).

Casks with square bungs appear frequently in peasant scenes. One of the earliest examples comes from a seventeenth-century copy of an earlier work by Peter Breughel the Elder. *The Fair at Hoboken*, below, shows a typical peasant kermis scene. Peasants are engaging in activities such as archery and dancing, and generally making merry. A cask with a clearly defined square bung hole is visible in the left foreground. This container is again likely associated with beer, wine, and over-indulgence in alcohol, as the Flemish verse beneath can be translated as "The peasants delight, during such feasts/ To dance, jump, and drink themselves blind-drunk like beasts…" (Klein 1963: 111). Breughel's work proved enormously influential, and many similar genre scenes of peasant kermis include one or more casks with square bung holes. A print by the Flemish artist Cornelis de Wael (1592-1667) from later in the century shows two peasants fighting in a courtyard, (Figure 100) (Schuckmann 1998: 195). A square bung cask rests slightly askew in the foreground. This cask is unusual in that the hoops are clustered at either end, rather than evenly spaced as in most other depictions of this type. A plugged tap, vent, or sample hole is visible in the top of the cask. This etching likely serves to illustrate the evils of alcohol, as a boisterous onlooker cheers on the combatants while raising a jug or bellarmine, while a woman attempts to restrain one of the fighters. Here the cask adds realism to the setting, suggesting a tavern milieu. These images can be seen as part of a larger genre of "peasants behaving badly" prints, portraying them as drunken, violent, foolish, and lusty to varying degrees. While these scenes imparted a moralizing message, they can also be viewed as a celebration of the simpler, earthy elements of life, ripe with humor and *joie de vivre*.

FIGURE 99. Peasant kermis scene, *The Fair at Hoboken.* Early seventeenth century copy of mid-sixteenth century original by Peter Breughel the Elder. A cask with a square bung hole is visible in the lower left foreground (Klein 1963: 113).

FIGURE 100. Peasants behaving badly – two men brawl beside a cask with a square bung. Etching by the Flemish artist Cornelis de Wael (1592-1667) (Schuckman 1998: 195).

FIGURE 101. Later seventeenth century image of a cask with a square bung, by Pieter Schenck (1660-1713) (Keyes 1981: 98).

These genre scenes remained popular in Dutch art throughout the seventeenth century, and provide numerous examples of casks with square bungs. A mezzotint by Pieter Schenck (1660-1713), above, shows a lecherous old man soliciting a young woman or barmaid. They are seated beside a cask, with the square bung hole facing the viewer. Hoops are evenly spaced at the chime and quarter positions, in groups of two. This is the same hooping pattern observed on the *Vasa* casks. Here the cask is used in a secondary context, as a makeshift table. One of the latest images of a square bung cask shows a similar scene, (Figure 102). Here a man sits enjoying a pipe, while his can of beer rests beside him on top of a cask with a square bung. The hoops on this cask are unevenly distributed – there are three at one end and only a single hoop at the opposite end, perhaps suggesting that this is an old, disused cask. The date of this image, 1694, is clearly visible on the lower part of the cask. This is one of the latest images of this type of cask in the image corpus. It is unclear if casks with square bung holes became less common in the eighteenth century. Certainly modern writers on cooperage such as Kilby do not indicate any knowledge of casks with this attribute, nor are these casks found in later archaeological contexts. The question remains as to whether square bung casks were still used as late as 1694, or if the artists employed deliberate or unconscious archaism, similar to the outdated material culture Hume spotted in William Hogarth's work. It is also interesting that none of the square bung hole casks shown in these works have an actual bung. The hole is always open, making these casks instantly recognizable. This suggests these are meant to be old, empty casks, a normal part of the seventeenth-century urban landscape eminently familiar to any who viewed these artworks. An empty cask was also much more symbolic of overindulgence than a full one. It is noteworthy, however, that very few bungs were recovered from *Vasa*, not nearly enough for the estimated 63 oak casks. There could be a correlation between the lack of bungs observed in period art and the paucity of bungs found on the ship, suggesting that these holes were often left open.

FIGURE 102. One of the latest images in the corpus, showing a cask with a square bung clearly dated 1694. It is unclear if this style of cask continued in use during the eighteenth century, or if artists employed archaizing tendencies, unconsciously or deliberately, to reinforce their messages (Naumann 1985: 275).

Coopers in Early Modern Art

The previous section illustrated several examples of casks with square bungs in early modern art. A large number of images also exist of coopers at work. A study of these images can shed light on workplace organization and the tools employed to construct casks, as well as the artist's, and hence the society they served, perception of these craftsmen. One of the earliest images of a cooper in Western art comes from Chartres Cathedral, (Figure 103). A series of stained glass windows show different craftsmen at work; these are known as the "trade windows." They likely date to the first quarter of the thirteenth century (Williams 1993: 16-17). The cooper in the window is shown in the characteristic pose of these craftsmen: driving hoops onto a cask, with a maul raised in the air. The thick window caming obscures some details, but the cooper is shown working on a large cask as high as himself. The large size of this container suggests it may be a wine cask. He holds a hammer or maul in his left hand, ready to bring it down on what appears to be a hooping dog or *tratoire* in his right. The wooden hoops are evenly spaced in the chime and bilge positions, and ligatures on the hoop joins are visible. While care should be taken not to over-interpret this medieval image, the posture of the cooper shown here became typical of almost all later representations. Coopers in early modern art are exclusively male, and are almost always shown standing, working alone or in small groups, driving hoops onto casks. Similar early depictions of coopers from religious contexts date from the twelfth century, from the Church of San Zeno in Verona, Italy (Webster 1938: 58-59), and the Monastery of Ripoll, Spain (Webster 1938: 84-85).

A rich source of images of coopers and early craftsmen comes from the house books of Nuremburg, Germany. In 1388, a wealthy merchant of that city, Konrad Mendel, built and

Figure 103. One of the earliest images of a cooper in Western art, from Bay 47 at Chartres Cathedral. The window dates to the first quarter of the thirteenth century (Whatling 2009).

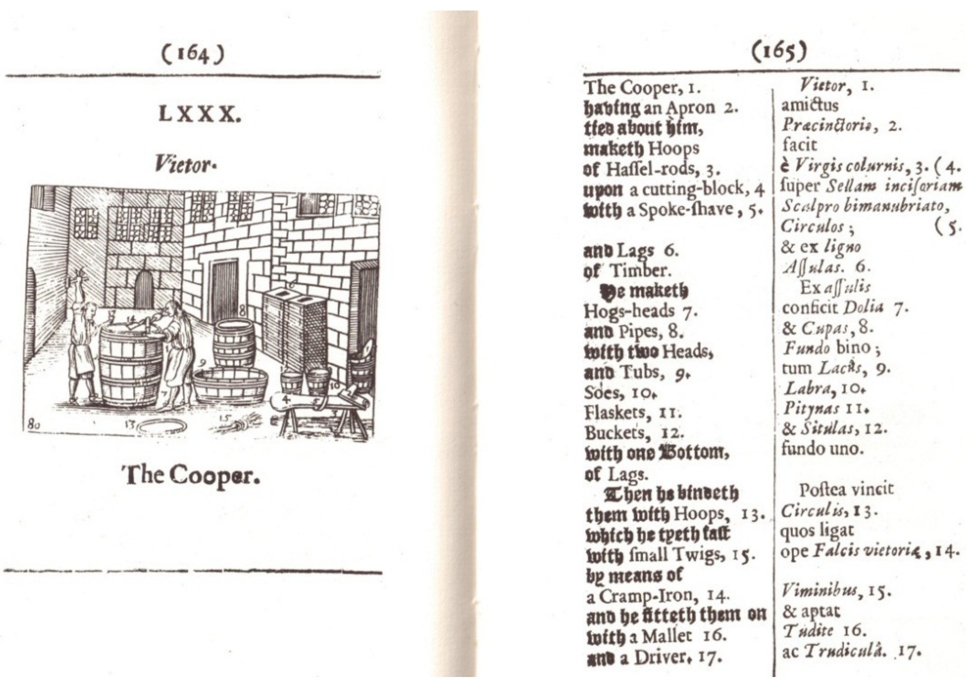
funded a retirement home for elderly artisans. The "House of the Twelve Brothers" was equipped to support a dozen aged artisans in perpetuity. When one died, another was admitted. After 1425, the name, occupation, and a brief biography of each inmate was recorded, along with a full page color image of that craftsman exercising his trade. This tradition continued until 1806. The Mendel house books are divided into three volumes, the first spanning the years from 1425 to 1549, the second from 1550 to 1791, and the third from that year until 1806. Mining magnate Matthew Landauer began a second "Twelve Brothers House" in 1511, which also operated until 1806 (Die Hausbücher der Nürnberger Zwölfbrüderstiftungen <http://www.nuernberger-hausbuecher.com.de>). Volume I of the Mendel series has four images of individual coopers, while Volume II depicts eight coopers. Four coopers are shown in the Landauer series. Figure 104, below, comes from the first volume of the Mendel house books and dates to 1478. It shows one of the brothers working at his trade of coopering. The pose is similar to that of the craftsmen in the earlier Chartres window. The cask is also of a similar size, about the height of a man, and so is also likely a wine cask. Much more detail is visible in terms of the tools employed, however. The cooper holds a hammer or cooper's adze in his right hand, ready to bring it down on the driver in his left. He wears an apron, and a cleaver is tucked into his belt, perhaps to cut withies for hoop bindings. An axe and block rest behind him, while extra hoops and a hooping dog lie on the ground. Of particular interest is the cooper's bench or horse visible behind him, apparently already in its fully developed form at this early date. The Nuremburg house books also show trades related to cooperage, such as tap maker Hieronymous Weib, shown at age 67 in 1631, (Figure 105). Metal spigots like those on the bench in front of Weib provided an alternative to simple wooden bungs when dispensing liquids. A similar tap, in the shape of a fowl, was found on *Vasa* and is shown in Figure 50**,** Chapter 5.

FIGURE 104. An unnamed Nuremburg cooper at work, 1478. The pose is almost identical to that seen at Chartres, 250 years previously, but the tool kit is much more detailed (Mendelschen Zwölfbrüderstiftung, Vol. I).

FIGURE 105. The Nuremburg house books are also a good source of images of trades associated with cooperage. Here tap maker Hieronymous Weib is shown at age 67 in 1631. A metal tap in the shape of a fowl was found on *Vasa* (Mendelschen Zwölfbrüderstiftung, Vol. II).

Images of coopers are useful for assessing the tool kits of these tradesmen. The tools shown in art can then be compared to actual archaeological material, to see if the tools inferred from marks on the wood are shown iconographically, and vice-versa. Images of coopers at work have already appeared in Chapter 4, in Figures 23, 26, 29, and 36. A woodcut from Jan Comenius's 1659 *The Visible World in Pictures*, Figure 106, is of interest, since individual tools are numbered and identified. Here two aproned coopers are working on a large cask in a courtyard, in the iconic pose of driving hoops. The cooper's bench or horse (4) is identified as a "cutting-block," while what appears to be a drawknife (5) is labeled as a "spoke-shave" for cutting hoops. The crudely drawn tool (14) is apparently a "cramp-iron" used to bind the hoops, although it looks more like some sort of cleaver. The mallet (16) and driver (17) are easily identifiable. These workplace scenes are fairly similar across time and space, focusing on the distinctive operations of driving hoops onto casks, working with hoops, and raising casks alongside flaming cressets. The tool kit shown in these works is much smaller than that described by modern writers on cooperage (Gilding 1971; Kilby 1971; Salaman 1976), likely a result of the increased specialization and diversification of tools from the nineteenth century onwards. Based on period art, a well-equipped seventeenth century cooper's tool kit could include a cooper's adze, axes, mallet and driver, bench, block, jointer, hand saws, brace-and-bit, hoop dogs, drawknives, knives and cleavers, shears, and a wing compass. The mallet and driver are by far the most common tools observed, followed by the cooper's adze and a general utility knife. Hoops and hoop dogs are also frequently found. Drawknives and drills (the brace-and-bit) are the least common tools observed, although archaeological evidence from *Vasa* and other sites confirms that these tools were required for constructing heads. Jost Amman's widely reproduced woodcut of 1568, Figure 26, in Chapter 4, also gives an idea of material frequently

The Cooper.



(164)

LXXX.

Vietor.

The Cooper.

(165)

The Cooper, 1.	*Vietor*, 1.
having an Apron 2.	amictus
ties about him,	*Pracinctorio*, 2.
maketh Hoops	facit
of Haſſel-rods, 3.	è *Virgis colurnis*, 3. (4.
upon a cutting-block, 4	ſuper *Sellam inciſoriam*
with a Spoke-ſhave, 5.	*Scalpro bimanubriato*,
	Circulos; (5.
and Lags 6.	& ex *ligno*
of Timber.	*Aſſulas*. 6.
He maketh	Ex *aſſulis*
Hogs-heads 7.	conficit *Dolia* 7.
and Pipes, 8.	& *Cupas*, 8.
with two Heads,	*Fundo* bino;
and Tubs, 9.	tum *Lacûs*, 9.
Soes, 10.	*Labra*, 10.
Flaskets, 11.	*Pitynas* 11.
Buckets, 12.	& *Situlas*, 12.
with one Bottom,	fundo uno.
of Lags.	
Then he bindeth	Poſtea vincit
them with Hoops, 13.	*Circulis*, 13.
which he tyeth faſt	quos ligat
with ſmall Twigs, 15.	ope *Falcis vietoriæ*, 14.
by means of	
a Cramp-Iron, 14.	*Viminibus*, 15.
and he fitteth them on	& aptat
with a Mallet 16.	*Tudite* 16.
and a Driver, 17.	ac *Trudiculâ*. 17.

FIGURE 106. A cooperage, from Comenius's 1659 Latin text, *The Visible World in Pictures*. Workplace scenes provide some clues as to the organization, dress, and tools used by early modern coopers (Comenius 1659: 164-165).

found in cooperages. This includes wood shavings, extra hoops, and hoop bindings. When compared with modern descriptions of cooperage, this suggests some essential qualities of the work that remained unchanged into the twentieth century. Bob Gilding worked as a London cooper at mid-century and always recalled the tremendous heat and smoky atmosphere of the cooperages, from the frequent firing of casks (1971: 18). He also believed that cooperage "was a trade noted for untidy yards and shops" where "most of them have wood shavings and sawdust scattered liberally around" (1971: 25). Despite the applications of machines to cooperage from the late seventeenth century (Loewen 2014: 35), and especially the nineteenth century onwards, aspects of Gilding's experience are reflected in early modern artistic representations of coopers. The piles of long wood shavings in the foreground in Amman's woodcut or aproned cooper standing over a flaming cresset (Figure 29 in Chapter 4) indicate some continuity in workplace conditions. Care must still be taken, however, not to create an idealized, static, view of artisans and labor in the past (Loewen 1992: 81; Crossick 1997: 1).

Workplaces scenes of coopers provide some evidence of workplace organization and dress. The number of workers shown is usually small, fewer than three, with the exception of some harvest scenes. Another exception is the engraving from Diderot and Alembert's *Encyclopédie* of 1751-1772, below, which shows no less than eight coopers. It is unclear, however, if this is meant as a literal, accurate representation of eight coopers working simultaneously or rather as a method of showing the different steps in creating a cask. The latter explanation seems the more plausible of the two. The workers are invariably male, although this may reflect artistic prejudice rather than reality. M.S. Ramona Vogel, a female cooper at historic Williamsburg, Virginia, claims to have found evidence for the existence of female coopers in the

FIGURE 107. Most artistic representations of coopers feature three or fewer workers, with the exception of this image from Diderot's *Encyclopédie*. This image, however, might show the different steps involved in cooperage rather than eight coopers working simultaneously (Diderot and Alembert 1772: 167).

past (pers. comm. 2010). Artists may have been loath to show female artisans in order to project an idealized view of labor and gender roles, where certain work was for men and other work for women. Early modern images of coopers certainly reinforce the idea that this trade was a "man's work," although this may not have been entirely correct. Julia King's study of tobacco use among women in the seventeenth-century Chesapeake confirmed that women smoked more frequently than Dutch art alone would lead one to believe (2007: 18). Similarly, the small number of coopers shown in each workplace scene may reflect artistic convention rather than reality, an effort to reaffirm the primacy of the small-scale artisan and guild system in the face of increasing proto-industrial production at sites like the Rochefort Arsenal (Loewen 2014: 44).

The dress of the coopers in workplace scenes is remarkably consistent, and likely less open to controversy than the validity of period art for assessing workplace organization and gender roles. While the cooper in the thirteenth-century Chartres Cathedral window wears a simple tunic similar to most peasants, the Nuremburg house books show aproned workmen by the fifteenth century. From then onwards coopers are almost invariably shown wearing aprons, often with an adze or cleaver tucked into their belt. A special type of tool belt with a triangular holster is also visible in many scenes, including Amman's 1568 woodcut and many of the Nuremburg house book images. It appears this holster contained a knife, and possibly other small implements. The dress of the workmen is usually plain, with the occasional adornment. One cooper in Amman's woodcut sports a feathered hat and tunic with slashed sleeves, while cooper Hans Beuerlein wears a lace ruff in 1642, Figure 36 in Chapter 4. On the whole, however, it appears that coopers were not a particularly affluent group.

Casks in Secondary Contexts

Early modern art also provides a wealth of information about the use of casks in secondary contexts, in contrast to their primary role as containers. Figure 95, above, shows the importance of the trade in used casks as old beer casks are carted back to the brewery. The material and labor that went into constructing them meant that casks were valuable containers with a resale or recycling value. The value of the cask was in part dependent on its quality, as a well-made liquid tight cask was more valuable than a cheaply made slack cask. The Drogheda Boat was carrying old wine casks repacked with fish when it wrecked in the Boyne River in the sixteenth century (Fawsitt 2010), while the oil casks found at Red Bay underwent several cycles of reuse (Loewen 2007: 12). In addition to normal reuse, old casks were recycled for a variety of other purposes. When the heads were removed, old casks became excellent well liners. Some of the oldest casks come from Roman wells in the UK (Boon 1974: 263-265), while the earliest example of a cask with a square bung comes from a thirteenth century-well in Denmark (Daly 2007: 190).

Art provides evidence of cask reuse that is not available archaeologically. The images of casks with square bungs shown with peasants in Section 8.1, above, almost always show casks in secondary contexts. These casks are not being used as containers; rather they form makeshift or expedient furniture. Old casks provide convenient surfaces for eating, drinking, and gambling in the absence of other tables, and appear a common fixture at taverns. These casks are empty, indicated by the unplugged square bung hole and the position of the cask on end. These old casks are visible in numerous peasant scenes as a background element, likely a familiar sight to the audience of these works, but also as an allegory for drinking and excess. Old casks also served as supports, for tables, as seen in Steen's *The Dancing Couple*, Figure 97, for stages, visible in the background in *The Fair at Hoboken*, Figure 99, and for scaffolds and other platforms. The uses of old casks in the early modern period were myriad. Liquid tight casks could be moored as buoys to indicate hazards, while Figure 108, below, shows casks with square bungs burned as beacons to celebrate the capture of Breda in 1637. Despite the problems inherent in artistic bias and interpretation, these works form a rich source of evidence that can both test and inform archaeological studies.

FIGURE 108. A cask with a square bung reused in a secondary context: burned as a beacon to celebrate the end of the Siege of Breda, 1637 (Scheffer 1982: 163).

Chapter 9 – Conclusion

The *Vasa* casks form one of the largest, most complete collections of historic cooperage anywhere in the world. If the estimate of a minimum of 145 total casks is correct, than the collection is one of the largest ever studied. The late sixteenth-century Drogheda Boat was only carrying 14 casks when it sank (Fawsitt 2010: 23-29). The 1686 wreck of the French *La Belle* contained 86 casks of various sizes (Loewen 2014: 6). *Mary Rose* likely held between 120 and 150 casks, although only 33 were studied in detail and published (Rodrigues 2005: 409). The *San Juan* originally held up to 345 *barricas* of whale oil, but only 83 were available for thorough study (Loewen 2007: 6). Although previous conservation treatments and collections management policies at the museum posed challenges at times, the *Vasa* cask collection offers the advantages of being largely complete and stabilized. The entire collection was accessible for study, an opportunity not available to many researchers who are forced to examine only a sample of casks from a given site.

The previous chapters have outlined the methodology used in this study, discussed the attributes of the casks and divided them into a typology, explained cask distribution on the ship, and compared them to examples seen in period art. This information can answer the research questions posed in the Introduction. Recording and studying the individual attributes of the casks showed there are two main types, those made of oak timber and those made of pine timber. This timber was converted in different ways. The oak staves and head pieces were radially converted, while the pine pieces were tangentially converted. Groups of striations on the interior faces of the oak staves suggest they were shaped with a cooper's axe, and not with a drawknife, as recorded in modern sources on cooperage. Oak heads differed from other examples of archaeological cooperage. They were made of two to four asymmetrical pieces edge joined together, and lacked the reinforcing barres seen on examples from the Drogheda Boat, Scheurrak SO1 wreck, *San Juan*, and *La Belle*. The oak casks have square bung holes measuring about 10 x 10 cm, in addition to smaller circular bung holes found in some head pieces. Smaller sample or vent holes are found on the heads, and frequently on the bung staves. Hoops were evenly spaced at the chime, quarter, and bilge positions, and occurred both singly and in pairs at each position. The wooden hoops were joined using carved notches, and presumably bound with vegetal ligatures. The oak casks were larger than the pine examples, generally with croze distances of between 640 and 680 mm and head diameters of about 450 mm. This translated into volumes of between about 117 and 146 liters. Pine casks were more crudely made than the oak examples, and more likely to exhibit tool marks. Pine staves lacked the distinct marks from the cooper's axe, and were thickest at their midsection. This suggests a different production process from that used to prepare the oak staves. Many of the pine staves were also deliberately charred on their interior. The bung holes on the pine casks were almost invariably circular, and the pine containers were much less likely to feature sample or vent holes. Pine casks were significantly smaller than oak casks on average, generally with volumes between 36 and 41 liters. Both types of cask exhibited carved markings. The diversity of these marks suggests that they are individual owner's marks, rather than merchants or coopers marks. There was enough regularity in the collection to create a typology of *Vasa* casks, divided into five major types based on construction, capacity, and contents. In addition to the oak casks and pine casks, the lidded cask, small cask, and shot keg groups were identified. Lidded casks were almost identical in construction to oak casks, but were modified with the addition of removable pine lids and used to store personal items. Small casks were generally made of oak, with the largest of this type only holding about 18 liters. The six or seven shot kegs were found in a group in the forward part of the hold, and contained about 9,000 small shot. Identification of the cask attributes and their division into a typology facilitated the study of how these containers were used on *Vasa*.

Data gathered by the author shows there are at least 145 casks in the *Vasa* collection: 63 oak casks, 26 lidded casks, 34 pine casks, 15 small casks, and 7 shot kegs. The hold, not surprisingly, contained the most casks. It held up to 63 casks, while 20 casks were found on the upper gundeck, 23 on the lower gundeck, and 22 on the orlop. Six casks come from outside the ship, while 11 have lost their provenience. These data are summarized in Table 16, Chapter 7. Little is known about the contents of these casks, but the limited samples available can be combined with inference to offer some ideas. Oak casks held a variety of food and drink, including salt meat, and likely beer. Examples from compartment H3 in the hold are associated with cattle, pig, and sheep bones, the remains of salted provisions. While records indicate the importance of dried peas and biscuit in the seaman's diet of 1628, the existing samples fail to provide much information on these important provisions. It is possible that some oak casks contained peas and biscuit. Artistic depictions of casks with square bungs associate these containers with beer and wine, so it is likely some of these thinly built casks also contained beer. Oak casks in compartment H1 in the hold might have held gunpowder. This area is located where specialized magazines were built in later vessels. The oak casks are also similar in size to a powder barrel identified from *Mary Rose* (Rodrigues 2005: 415-416). If these suppositions are correct, than the oak casks from *Vasa* served as multipurpose containers, storing dry and liquid provisions, as well as powder. Three of the pine casks definitely contained salt fish, another important component of the naval diet. Other pine casks were charred on their interiors, suggesting they might have contained either spirits or water. The distribution of the casks revealed a clear stowage plan. Lidded casks contained items such as extra clothing, wooden tablewares, sewing equipment, and snacks, and were concentrated on the gundecks, the areas where the crew messed and slept. Provisions were concentrated in compartment H3 in the hold, but were also found on the orlop. Small shot and possibly powder was kept in compartment H1. Compartment H8 contained unusual casks, which helps support its identification as an officer's storeroom. Much of the hold was empty, however, perhaps in anticipation of loading further stores at Älvsnabben. The overall quantity of casks and the extra space in the hold confirms that the ship was not fully provisioned when she sailed in August, 1628.

The cask volumes calculated during the creation of the typology shed some light on the possible origins of the containers. The Swedish foot in 1628 measured 297 mm (Hocker 2011: 43). Many of the oak casks have dimensions which correspond to multiples of this unit, summarized in Table 10, Chapter 6. This suggests the coopers who built these casks were Swedes themselves, or at least working with Swedish units of measure. A Swedish origin for the oak casks is supported by archival research, which indicates a merchant in Norrköping was responsible for supplying all the bread and beer for the campaigns of 1626-1630 (Ulrica Söderlind 2012, pers. comm.). Many of the pine casks might also have come from Sweden. Faunal analysis of the fish remains suggests they originated in the Baltic rather than the North Sea (Söderlind 2006b: 162), and documents record the existence of small scale Swedish fisheries during this period (MacKenzie et al. 2007: 114). Taken together, these different lines of evidence suggest a naval supply process largely dependent on local resources for provisioning.

An iconographic study revealed numerous examples of casks with square bung holes, similar to those from *Vasa*. These examples ranged in date from 1425 to 1694, with most images from the seventeenth century. Depictions of these casks associate them with beer and wine, and suggest many of the *Vasa* oak casks also contained beer. The frequency with which this style of cask occurs in seventeenth-century art suggests they would have been a common sight for the individuals aboard *Vasa*. In contrast to these examples from art, casks with square bungs occur only infrequently in archaeological contexts besides *Vasa*. One cask with a square bung was found in a well in Denmark, and dates to about 1270 (Daly 2007: 190). One cask full of naval stores on *Mary Rose* had a square bung, but was considerably thicker than the *Vasa* oak casks (Rodrigues 2005: 416). Thus the square hole oak casks from *Vasa* represent the largest collection of this type in the world. These casks differ in several respects from the French and Iberian cooperage found on the Drogheda Boat, *San Juan*, and *La Belle*. In addition to the square holes, the *Vasa* oak casks have evenly spaced hoops, and edge joined heads made of only two to four pieces. The casks from the three sites mentioned above have circular bung holes, hoops clustered in two groups at the ends of the cask, and heads made of more numerous, smaller pieces kept in place with a reinforcing barre. The *Vasa* casks are more similar to those found on *Mary Rose* (1545) and the Scheurrak SO1 wreck (ca. 1590).

Recently discovered wrecks have the potential to expand on the findings of this study, with new collections of seventeenth-century northern European cooperage. “The Ghost Ship” and “The Lion Wreck” are both deep, well preserved wrecks of seventeenth-century Dutch merchantmen which likely contain some casks in their holds (Eriksson 2012; Eriksson and Rönnby 2012). The Swedish first-rate *Kronan* (1676) is especially intriguing, as it offers Swedish comparative material from two generations later. While annual reports have been published in the Kalmar Lansmuseum yearbooks, excavation continues and a comprehensive publication is still many years in the future. The chief recommendation for further research on the *Vasa* casks, however, is to conduct a dendroprovenance study. Specialists will conclusively identify the wood species, and determine where the timber came from. Studies of this sort have been conducted on the Scheurrak SO1, *San Juan*, and *La Belle* casks, and were able to pinpoint the origin of the timber. While knowledge of the timber source does not necessarily mean the casks were made in the vicinity, it will offer a firmer footing for understanding the naval supply and provisioning process in 1628. Aoife Daly, an expert on European oak and dendrochronology, has expressed her interest in this project (2012, pers. comm.), which awaits only sufficient time and funding to get underway. Research in guild, government, and notarial archives in Stockholm also offers the possibility of uncovering more information on the origins and manufacture of the *Vasa* casks. Records might also preserve some *bomärker*, if they were used in place of a signature by certain individuals.

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Appendix – Glossary of Cooperage Terms

Barre – part of a head, a reinforcing bar which holds the other head pieces in place.

Barrel – a specific size of cask, whose volume depended on the commodity it contained. For example, a traditional British ale barrel contained 32 gallons, while a beer barrel contained 36 gallons.

Bite – the edge of a head, the angle where the interior and exterior edge bevels meet. This is the area which fits directly into the croze groove.

Bilge hoop – hoop located at the widest point of a cask, the booge or bilge.

Booge or bilge – the widest point of a cask, the bulging midsection.

Brace-and-bit – a hand operated drill, used to bore holes in the edges of head pieces prior to joining them with dowels.

Bung – plug used to seal bung hole.

Bung hole – hole cut into a cask to access the contents. Can be located on either a stave or head. Shape can be either circular or square.

Bung stave – stave pierced by the bung hole, usually the widest and thickest stave.

Cant – part of a head, the curved edge pieces. There are two cants per head, and four cants per cask.

Case – the body of a cask, before the heads have been inserted.

Case stave – any stave that is not a bung stave.

Cask - any staved wooden container, closed at both ends and bound with hoops.

Center piece – part of a head, the central, longest piece.

Chime – the end of a stave or cask, beyond the croze groove.

Chime hoop – hoop located at the end of a cask.

Chiv – the end of a stave, cut at an angle to reduce contact with the ground.

Cooper – someone who constructs staved wooden containers.

Cooper's adze – a tool with a curved blade to cut out the chime area, also features a hammer head to drive hoops.

Cooper's axe – a specialized axe with a narrow blade about 30 cm long, offset from the handle. Used for listing and dressing staves. Also known as a *doloire*.

Cooper's block – usually made out of an old log, a block to rest staves and head pieces on while shaping them.

Cooper's horse – a specialized workbench with a foot operated lever to hold staves and head pieces in place.

Cooper's scribe – a tool used for marking casks. It has a sharp point which form the axis around which a sharp, spade shaped bit can be rotated. Leaves characteristic curvilinear marks. Also known as a *rouanne* or rase-knife.

Cooperage – can refer to either: (1) the trade of manufacturing staved wooden containers, (2) a cooper's workshop, (3) the staved wooden objects themselves.

Croze – a specialized plane used for cutting the croze groove. The position, depth, and style of the croze groove can be varied by adjusting the height of the croze and the type of croze iron.

Croze groove – a groove cut into the interior face of a cask, near both ends. This groove holds the head in place.

Croze iron – the cutting blade of the croze.

Cresset – a small iron brazier used when firing a cask.

Diagonals - folding measuring sticks used to help determine the proper placement of the croze groove, and hence volume, of a cask.

Drawknife – a blade with handles at each end, set at 90 degrees to the blade. The tool is grasped with two hands and pulled towards the user to trim thin slices off a piece of timber. Used to carve edge bevels on head pieces.

Dressing a stave – trimming the interior and exterior faces of a stave so that it has the proper shape.

Dry or "slack" cooperage – casks designed to hold dry or semi-dry goods. More slightly built than wet cooperage.

Edge bevel – bevel cut around the interior and exterior edges of a head, to allow it to fit into the croze groove.

Firing a cask – making the staves in a cask more pliable through the application of heat, during the process of raising a cask. The case is placed over a small fire burning in a cresset.

Froe – a wedge shaped tool used for splitting timber.

Head – circular wooden end of a cask, usually composed of multiple pieces. Fits into the croze groove.

Hoop – Band, either wood or metal, which holds a cask together.

Hoop bindings – vegetal ligatures used to join the ends of hoops together. Also known as "osiers," willow shoots were generally preferred for this purpose.

Hoop driver – a piece of hardwood often tipped with iron, struck with a maul to drive hoops onto a cask.

Hoop join – the area where the hoop tips overlap, and are joined with a hoop binding.

Hoop tips – the ends of a length of hoop, which overlap to form a hoop join. The tips can be cut in a variety of different styles.

Hooping dog – a lever used to wedge hoops onto a cask. Also known as a *tratoire*.

Inside bevel – the interior edge bevel of a head, usually larger than the exterior bevel.

Jointer – a large, inverted, stationary plane, resting at about a 45 degree angle. Used to shape the long edges, or "joints" of a stave.

Listing a stave – trimming the exterior profile of a stave so that it is widest at the midsection, and narrows towards the ends. This will produce the bulged shape of the cask.

Middle piece – part of a head, middle pieces flank the center piece.

Outside bevel – the exterior edge bevel of a head.

Quarter hoop – hoop located between the chime and bilge hoops.

Raising a cask – assembling individual staves into a cask using a combination of heat and pressure.

Sample hole – a small hole bored in a cask to sample the contents.

Stave – vertical piece forming the sides of a cask.

Truss hoop – a specialized, reusable hoop driven over the case to bend the staves to shape.

Vallinche – a narrow metal tube used for sampling the contents of a cask, through a sample hole.

Vent hole – a small hole drilled in a cask to vent the contents and improve the flow of liquids.

Wet or "tight" cooperage – casks designed to be watertight, to contain liquids.

White cooperage – open ended containers, buckets and tubs.

Windlass – often a "Spanish Windlass," a rope looped around a case and then tightened with a lever, to draw the ends of the case together during the raising process.

Witness – portion of unmodified timber intentionally left on stave or head to show the cooper has removed only the necessary amount of material, and no more.

Worm hole – hole caused by insect damage.