

THE HISTORY AND DEVELOPMENT
OF SHIPS' BILGE PUMPS, 1500-1840

A Thesis

by

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ABSTRACT

The History and Development
of Ships' Bilge Pumps, 1500-1840 (May, 1984)
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The fate of a ship and the lives of those on board depended on keeping the vessel afloat. Contemporary sources discuss the nature of leaks and how to find and plug them. Accounts of shipwrecks relate the effect of the disaster on those aboard and their response to the situation.

From the period of 1500-1840, the three main types of pumps used on ships were the burr pump, the suction or common pump, and the chain pump. The burr pump was in general use in the 16th century, but declined in the first quarter of the 17th century in favor of the common pump. The large separate foot valve at its base must have made it difficult to repair. This type of pump can be associated with large holes cut in the mast steps of three 16th-century wrecks.

The common pump first appeared in Italy in the early 15th century. By the end of the 16th century, it was in general use on ships and remained so well into the 20th

century. As long as the common pump valves were made of wood, their shape and form remained the same. In the 18th century, lead, copper and bronze were introduced into the construction of ships' pumps. Iron appeared only in the 19th century. With the use of metals, other designs of the common pump appeared. Common pumps were also used for washing decks and fighting fires.

The chain pump was used on ancient ships, but had disappeared by the Middle Ages. In the early 15th century the type was reintroduced from eastern Europe into western Europe, where it found application in the mining industry. The chain pump was in use on English ships in the late 16th century, and by the 18th century all navies except the French were using it. In the last half of the 18th century, the English redesigned this pump, which became standard equipment on all British Navy ships. In the first quarter of the 19th century, the chain pump was gradually being replaced by the common pump in all smaller and some larger warships. However, they did make a comeback in the 1830s.

All wooden ships leaked to some extent; therefore the bilge pump was the device on which the safety of the ship and its inhabitants depended.

DEDICATION

A.M.D.G.

for my parents

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CHAPTER I

INTRODUCTION

Sailing ships played a very important role in the establishment and maintenance of European expansion. They were self-contained societies on the high seas, carrying with them all of the equipment, materials, food, and other necessities of life. One of the more important items necessary for the efficient operation of the ship was the bilge pump. All wooden ships leaked; therefore, some means of ridding the hull of excess water was needed. In small open boats a bailing bucket or scoop was sufficient. However, when a vessel had a deep draft and/or when a deck enclosed the hold, it became difficult, if not impossible, to raise the water over the bulwarks. At this point, a pump became more efficient, if not necessary.

Although important on ships, pumps are very mundane devices. However, most modern sources on ships and seafaring make only passing commentary on the pumps and do not go much beyond a general description of the different types. While an abundance of information exists about guns, sails, rigging, ship construction, and other such topics, little attention has been focused on ships' bilge

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pumps. Yet, they were the most important pieces of equipment on board ship, more so than the anchor or rudder, because the pumps maintained the buoyancy of the hull by eliminating excess water.¹

This thesis is a compilation of available information on the three main types of pumps (all hand operated) used on European ships from the post-Medieval period to just prior to the commercial development of steam--1500 to ca. 1840. The end date of 1840 was chosen because patent records survive from this time, the manufacture of pumps was becoming industrialized, and in some cases pumps were being operated by the steam power plant of the ship.

During this period, the burr pump, the suction or common pump, and the chain pump were the three principle types of pumps used. The construction and design of each of these pumps will be examined in detail and related to the contemporary technical environment. Information is presented on the relationship of the crew to the pumps; that is, the number of men required to work them and the length of their work periods. In addition, descriptions of pumps adapted to the secondary functions of pumping seawater for washing or for fire fighting will be given.

Historical information on pumping machinery is scarce. Ewbank's book, A descriptive historical account of hydraulic and other machines for raising water (1842), is a comprehensive text on all types of hydraulic

machines. Ewbank had access to a wide selection of 18th- and 19th-century texts, and he footnoted most of his references. In addition to these, he included observations of his own on a number of ships' pumps. Because of these points, his text has been a primary source of information and references.

Usher, in his discussion of "Machines and mechanisms" (1957), uses pumps to show the development of technology in the 16th and 17th centuries. He points out the increasing use of metals (lead, copper, and iron) during this time, but notes that the technology of metal working proceeded slowly and that cost was an important factor.

There are several other sources from which information has been drawn. Contemporary marine dictionaries are very useful in supplying definitions, descriptions, and dates of use. When editions from different years are available, they can be compared to show changes in pump use through time (Blanckley, 1732 and 1750; Boteler, 1634; Falconer, 1776, 1780, and 1815; Manwayring, 1644; Smith, 1627). Other contemporary texts give additional information on material, design, and accounts of routine use (Agricola, 1556; Belidor, 1737-1753; Diderot, 1766; Hutchinson, 1794; Treatise, 1793). Information has been gathered from books, reports, and museum collections (Boudriot, 1974; Bugler, 1966; Cederlund, 1981 and 1982; Longridge, 1955; Edlin, 1949;

Rose, 1937; Prager and Scaglia, 1972).²

Only a few useful items of archival and patent information were obtained from American and English sources. (The use of archival and patent information has been limited because of access and cost.) A brief survey of material available in the U.S. National Archives yielded only one description of pumps and several shipyard account ledgers of repairs, which mentioned the purchase of pump leather and pump nails.³

Copies of a number of plans of ships' pumps were purchased from the National Maritime Museum, London, and these were very helpful by showing chain pumps, new designs of suction pumps, and arrangements of wash pumps. Additional information is in the Admiralty Collections, Letters from the Navy Board in the National Maritime Museum, Greenwich. Gardiner (1976) based an article on these and other letters. British patents, as well as other European Naval Archives and Patent Offices, should offer a great deal of information to those who have access to them and the opportunity to search them properly.

Finally, shipwreck accounts are useful sources since they can offer some idea of how pumps were operated in cases of extreme emergency (Duffy, 1955; Huntress, 1974).

CHAPTER II

OF LEAKS AND MEN

Before speaking of bilge pumps, a discussion of leaks would be in order. Hutchinson (1794: 258-9) noted that in some instances crews left their sinking ships too soon. Although these ships appeared to be in imminent danger of foundering, they were found hours later, still afloat. There were two reasons for Hutchinson's statement. First, as water rose in the hold, the distance between the piston and the surface of the water (the critical distance) decreased, making it easier to work the pump. Second, as the water in the hold rose and covered the leaks, the flow of water from those leaks was reduced (Hutchinson, 1794: 259; Treatise, 1793: 86-7).⁴ At some point, the water entering the hull would equal the water being pumped or bailed out. Therefore, it was possible to have a great amount of water in the hold, yet to keep the ship afloat with continual bailing and pumping. Some accounts of ship disasters relate that serious conditions were held in check until the ship could reach shore (Wright, 1964: 1-16; Duffy, 1955: 58, 91-3; Boxer, 1959: 56-58).

Leaks were more or less dangerous depending on their position in the hull. Because of the pressure created by the ship moving through the water, a leak was more serious in the bow than in the stern and more serious on the lee

side than on the weather side (assuming equal sized holes at equal depths on the hull).

The most common form of leak was at a planking seam where the oakum (the hemp or frayed rope used to caulk a seam) had worked loose by the motion of the ship. These leaks could be found by simply listening for them, often by using some object to augment the sound that was transferred through the planking. By placing the mouth of an empty earthen pot against the planking and putting one's ear to the bottom, the leak was heard as a low rumbling. A short stick or a trumpet could be used in the same way. The location of a leak was discovered by moving the listening device from plank to plank and finding where the noise was the loudest (Boteler, 1634: 22; Treatise, 1793: 88).

Once the leak was located, it could be plugged or stopped in a variety of ways, depending on its size, severity, position in the hull, the materials at hand, and the state of panic of the crew and passengers. In the best of situations, the captain would prefer to put his ship in drydock or to careen her in order to repair the bottom. However, leaks had a nasty way of appearing in the middle of a voyage, usually during a storm. Stop-gap methods were employed to eliminate or to control the leaks until a safe port could be reached.

Leaks could be plugged from the inside of the hull, especially in inaccessible areas, by "sinking down some tallow and coals mixed together." When the leak was very large, "pieces of raw beef, oatmeal bags, and the like stuff" were used to fill the hole (Boteler, 1634: 23).³

For leaks between wind and water, a piece of sheet lead could be nailed over the area (Boteler, 1634: 23). A double layer of canvas or leather, backed with oakum, was also suggested for use instead of lead because the latter tended to break due to the motion of the ship (Treatise, 1793: 89).⁴ Shot holes were usually stopped with a canvas covered wooden plug which was driven into the hole (Boteler, 1634: 23).

Leaks were stopped from the outside of the hull by covering the area with a sail sewn with oakum or by passing a bag or net of oakum down on a line until it passed over the leak. The suction of the water passing through the hole in the ship drew strands of oakum into the hole, thereby stopping the leak. This method worked best if the leak was in the bow or midship area (Boteler, 1634: 23; Treatise, 1793: 88-9).

Life aboard a sailing ship was far from glamorous. Living conditions were poor and hygienic conditions even worse. The accumulation of filth and garbage in the hold polluted the bilge water. Although a health hazard, it did permit quick recognition of whether the hull was

"tight:"

When a ship is staunch, that is takes in but little water into her hold, she is said to be tight. And this tightness is best known by the very smell of the water that is pumped out of her; for when it stinketh much, it is a sign that the water hath lain long in the hold of the ship; and on the contrary, when it is clear and sweet, it is a token that it comes freshly in from the sea. This stinking water therefore is always a welcome perfume to an old seaman; and he that stops his nose at it is laughed at, and held but a fresh-water man at best. (Boteler, 1634: 239)

The seamen certainly didn't enjoy the smell of the bilge, they just accepted it as a part of their life:

For when that we shall go to bedde,
The pump was nygh our beddes hede;
A man were as good as dede
As smell thereof the stynk.
(Duffy, 1955: 106)

Foul bilge water was also a very good reason for using a dale to conduct the water directly to the ship's side.

There is an interesting and important point involving the kinetics of a sinking ship which nautical archaeologists should keep in mind. That is, as the water rose in the hold, many items of the ship's cargo and equipment that were stored in the hold began to float. This applies especially to ships which took a long time to sink and has important implications on stratigraphy, the identification of in situ or secondarily deposited materials, the interpretation of interior structures, and

the primary break-up of the hull. The HMS Centaur, a 74-gun 3rd-rate, was returning to England in a leaking condition from the West Indies after the Battle of the Saints in 1782. Struck by a storm in the Atlantic, she was dismasted and lost her rudder. With her leaks worsening, the rolling hulk slowly filled with water and suffered an extreme example of what floating debris can do:

All the rum, twenty-six puncheons, and all the provisions of which there was sufficient for two months, in casks, were staved having floated with violence from side to side until there was not a whole cask remaining: even the staves that were found upon clearing the hold were most of them broken in two pieces. In the fore-hold, we had a prospect of perishing: should the ship swim, we had no water but what remained in the ground tier; and over this all the wet provisions, and butts filled with salt water, were floating, and with so much motion that no man could with safety go into the hold. . . .What I have called the wreck of the hold, was the bulkheads of the after-hold, fishroom, and spirit rooms. The standards of the cockpit, an immense quantity of staves and wood and part of the lining of the ship were thrown overboard, that if the water should again appear in the hold, we might have no impediment in bailing. . . . At this period the carpenter acquainted me the well was staved in, destroyed by the wreck of the hold, and the chain pumps displaced and totally useless. There was nothing left but to redouble our efforts in bailing, but it became difficult to fill the buckets from the quantity of staves, planks, anchor-stock, and yardarm pieces, which now washed from the wings, and floating from side to side with the motion of the ship. (Huntress, 1974: 69-72)

In concentrating on the details of design, dates, and changes of materials, one should not lose touch with the human factor. What does one think on hearing the phrase "to have a sinking feeling?" Today it means to have a depression or an uncomfortable feeling in the pit of one's stomach. In the age of sail, it would have meant the abandonment of all hope, to have become resigned to one's fate at the hands of a turbulent ocean. The words of an eye-witness can best convey the feelings of those who travelled on these ships:

All this night they passed in great trouble and distress, for everything they could see represented death. For beneath them they saw a ship full of water, and above them the Heavens conspired against all, for the sky was shrouded with the deepest gloom and darkness. The air moaned on every side as if it was calling out 'death, death' . . . Within the ship nothing was heard but sighs, groans, moans, and prayers to God for mercy . . . Between the decks it seemed as if the evil spirits were busy, so great was the noise made by the things which were floating about and bumping against each other, and crashing from side to side, so that those who went down below fancied that they beheld a likeness of the last judgement. (Boxer, 1959: 57-8)

The physical activity of working the pumps or bailing the hold with buckets perhaps gave the passengers and crew a sense of control of their own fate, or perhaps it just distracted them for a little while from their own fears. The common and present danger of one's ship sinking was a great leveller of social distinctions:

Our governor . . . had caused the whole company, about 140, besides women, to be equally divided into three parts and, opening the ship in three places . . . appointed each man where to attend; and thereunto every man came duly upon his watch, took the bucket or pump for one hour, and rested another. Then men might be seen to labor, I may well say, for life; and the better sort, even our governor and admiral themselves, not refusing their turn and to spell each the other, to give example to other[s]. The common sort . . . kept their eye waking and their thoughts and hands working with tired bodies and wasted spirits three days and four nights, destitute of outward comfort and desparate of any deliverance, testifying how mutually willing they were yet by labor to keep each other from drowning, albeit each one drowned whilst he labored. (Wright, 1964: 10)

As the danger of the situation increased, measures were taken to improve the stability of the ship. The masts might be cut down if the ship had gone on her beam ends, guns might be jettisoned, but most commonly, the cargo was thrown overboard. Here the social order was respected again, for the first things to be cast out were the belongings of the poor, the soldiers, and the common seamen. Next came the richer cargoes of the merchantmen, officers, and nobles. If all else failed, Crown and/or Church property was the last to be discarded (Duffy, 1955: 112).

When the people saw that they could no longer hope to save the ship or their lives, they would frantically try to save their souls:

Those on board . . . stormed around the priests . . . In their confused animal madness all of them wanted to confess at once and began to speak their sins so loudly that they were heard by all. . . . As the desperation grew, one crazed individual, seeing that he could not soon receive confession, began to shout his sins above the tumult of everyone, sins that were so enormous a priest put his hand over the man's mouth. (Duffy, 1955: 117)

Others desperately tried to find a place in one of the few ship's boats. Others, still, resigned themselves to their fate:

The people . . . now seeing their efforts useless, many of them burst into tears and wept like children. . . . Some appeared perfectly resigned, went to their hammocks and desired their messmates to lash them in . . . but the most predominant idea was that of putting on their best and cleanest clothes. (Huntress, 1974: 72)

As there are many people, so there are many reactions:

In the midst of despair and confusion, a slave was so delighted to see himself separated from his master--who was one of the first to get into the lifeboat--that he made no attempt to save himself. He ate sweets from the neglected barrels of provisions, swam gaily around the broken sides of the Santiago, and sang out that he was a free man. For a few hours the slave, of his own free will, was able to trade his chances of survival for the sudden privileges of a freedom created by disaster. (Duffy, 1955: 123-4)

As a ship slowly sinks, the water entering it follows certain physical laws, such that the rate at which the water enters the ship decreases as it sinks. At some point the output of the pumps may equal that of the water entering the ship, which will give the crew time to locate and plug the leak. Leaks were found by listening for them. They were plugged, both from within and without, with anything at hand that would suit.

The pumps, supplemented in severe cases with bailing buckets, were the last defense, hope, and salvation of the lives on board. If one were on a sinking ship and had the choice of having working sails and rudder, but no pumps, or of having no sails or rudder, but working pumps, which would one choose? The pumps were the most important pieces of equipment on a ship.

CHAPTER III

THE CONSTRUCTION OF WOODEN TUBES

Wooden pumps for ships differed little from those made for land use, and the procedures for making the tubes were exactly the same. The major difference was in the shaping of the exterior and the lower end.

Elm was the most popular wood because of its durability in a wet environment. In addition to elm, other woods with similar properties such as larch, beech, and alder were also used (Rose, 1937: 78-9; Edlin, 1949: 56; O'Sullivan, 1969: 107; Waddell, in press; Ohrelius, 1962: 110-1).

The first task in making a wooden pump tube was to find a suitable tree, the trunk of which was straight and free of knots and side branches. Such a tree might be difficult to find since some branches may have been trimmed in the past and their knots covered with new bark (Rose, 1937: 79). Trimming of the outside of the log to its final shape might have been done at this point, or it may have been delayed until after the log was bored.

The pumpmakers marked longitudinal guidelines down the length of the trunk and located the centers of each end using plumb bobs and rules. These lines precisely positioned the auger shaft in both the vertical and horizontal planes ensuring that the hole was bored down

the center of the tube (O'Sullivan, 1969: 107-9; Rose, 1937: 80).*

After being marked, the log was set up on a platform or supports of some kind, the horizontal and vertical guidelines were replumbed, and the tube was fastened securely to the platform (Fig. 1). The log might have been secured by rope or chain, but another common method was to use "dogs." Dogs were lengths of iron 12-18 ins long with the ends bent at right angles and the tips sharpened, much like large staples. One end was driven into the log and the other into the support to securely fasten one to the other (O'Sullivan, 1969: 108; Rose, 1937: 80-1; Horsley, 1978: 230, fig. 96; Salaman, 1975: 297, fig. 444a).'

In order to achieve the desired bore size, a series of augers was used. The bits in these sets might number from three to six or more. Each bit was made to cut a slightly larger hole. The first was a long bit with straight, parallel sides. The cutting edge was on the end and at right angles to the body (Fig. 2). The first bit, also called a quill bit (O'Sullivan, 1969: 105) or a nose, pod, or split nose auger (Salaman, 1975: 39), cut the pilot hole through the tube. Since the shell augers had no points, a small hole had to be made in the exact center of the log so that the first bit started in the proper spot. Modern screw-pointed augers were not used for this

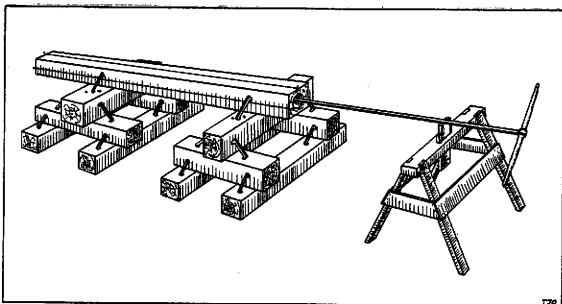


Figure 1. Boring a wooden tube. The log is set up on a platform and is fastened by dogs. The auger shaft is supported by the auger stool.

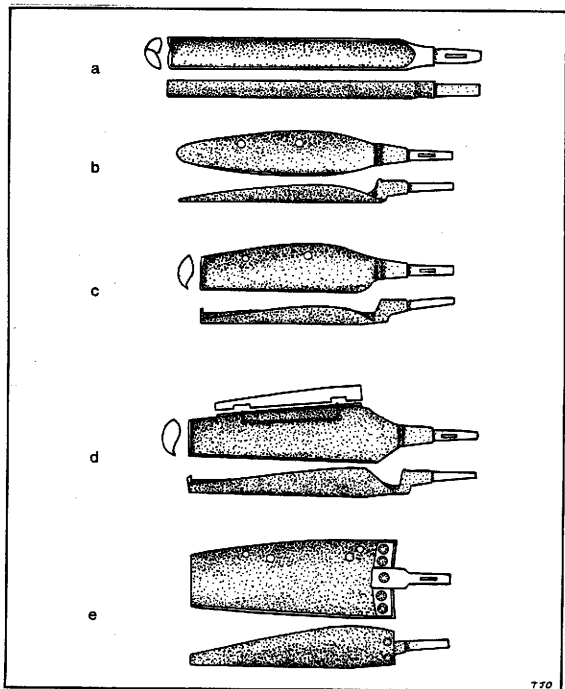


Figure 2. Auger bits. a. quill auger, b. spoon auger, the remainder are shell bits, c. third bit, d. fourth bit with an iron strap attached, e. sixth bit. (After O'Sullivan, 1969: 104)

work because they tended to follow the grain of the wood (Rose, 1937: 82-3). If a screw auger hit an undetected knot or shift in the grain, it caused the bit to veer off its proper course and come out the side of the log.

Once the pilot hole had been drilled with the first bit, the size of the bore was increased by the use of successively larger bits. These bits were tapered shell augers which had a sharpened cutting edge on one side as well as on the end. This type of tool is more efficient and less labor intensive, especially in the larger bit sizes (Salaman, 1975: 39). On the other side of the larger bits, a strap of iron or a piece of wood was tied to the outside of the bit through two holes intended for that purpose (Fig. 2d). This increased the bore to a diameter larger than that bit, but smaller than the next larger bit (O'Sullivan, 1969: 105).

The auger shaft was 12-15 ft long. At one end was a wooden handle three or more feet long. At the other was a square socket into which the bits could be fastened with a key that fit through the shaft and the bit. To support the auger shaft, an auger stool was used. This was essentially a stable platform with an adjustable rest for the auger shaft. The stool was positioned and the shaft adjusted so that the latter lined up with the two longitudinal guides (Fig. 1). Two men, facing each other with the handle between them, turned the auger in quarter

turns while a third man pulled the shaft against the log.

Because the bit quickly filled with shavings, it was often turned in reverse, withdrawn, and cleared. When the handle came near the stool, the next bit was put on and the hole enlarged. When the auger handle again reached the stool, the first bit was put on again, the stool was moved forward, the alignment of the shaft was checked, and the boring began once more. An auger shaft at the Mercer Museum at Doylestown, Pa., has markings in feet along the shaft so that the pumpmaker could tell at a glance how far he had gone. A hooked bar was kept at hand to clear shavings from the bore (O'Sullivan, 1969: 109).

In the case of tubes over 15 ft in length, the boring was done from both ends toward the middle. It was not necessary that the holes meet perfectly. Also, the diameter of the hole might differ between the top and the bottom of the tube. This was to compensate for the volume of space taken up by the pump rod (Boudriot, 1974: 146) and so that the lower box could seat at the constriction where the diameters changed and not fall down the tube. The boring continued until the desired bore size was reached.

Pumps used on land were often made of two, and sometimes three, short section of tube rather than one long one. A ship's pump was usually a single, long tube, although for the early part of the study period two

sections may have been used. Two pieces of a pump tube from the San Juan, a 16th-century Basque whaling ship which sank in Red Bay, Labrador, in 1565, have been recovered. These did not fit together because of erosion of the wood, and it could not be determined whether both sections had come from the same tree (Waddell, pers. com.). In the case of the Machault, a French frigate which sank in battle in the Restigouche River in Canada in 1760, the tubes of three different pumps were recovered intact. The overall length of one was 7.6 m (ca. 25 ft) in length. In most shipwrecks, all that remains of the pumps are the lower parts of the bottoms of the tubes.¹⁰

Although most tubes were made by hand, a few machines were designed to do the same work. Leonardo da Vinci drew a pipe boring machine in 1500 (Salaman, 1975: 296), and Belidor (1737-1753: vol. II, pl. 5) shows a pipe boring machine powered by a water wheel. A mill was set up to bore pine tubes in England in the 1770s. Another was in operation in London boring tubes of elm (Edlin, 1949: 57, 126).

The fabrication of tubes required a specialized set of tools. Ships generally did not carry these items with them, though they might have carried a spare tube for emergencies (Bugler, 1966: 80). A method of making a pump tube without the proper bits was described in 1687 by

William Dampier (1729: 443-4):

And our Pumps being faulty, and not serviceable, they did cut a Tree to make a Pump. They first squared it, then sawed it in the middle, and then hollowed each side exactly. The two hollow sides were made big enough to contain a Pump-box in the midst of them both, when they were joined together: and it required their utmost skill to close them exactly to the making a tight Cylinder for the Pump-box; being unaccustomed to such Work. We learnt this way of pump making from the Spaniards; who make their Pumps that they use in their Ships in the South-Seas after this manner. . . .

As in Dampier's case, this method, born of necessity, produced serviceable pump tubes when traditional tools were not available. Two examples of such a pump were found on a Spanish wreck near Port Royal, Honduras, in the early 1970s. Although the wreck was given a tentative date of 1515 based on olive jars, the ship also carried "straight sided rum bottles" which were probably of 18th-century date (Berrier, pers. com.). The Spanish, therefore, were using this type of pump tube in the West Indies and possibly in Europe, as well as in the Pacific in the 17th and 18th centuries.

Another alternative to a bored tree trunk was a tube constructed from planks. The planks were shaped so their edges fit snugly, the seams were caulked, and the whole tube was bound at intervals with straps. Not only the tube, but also the upper and lower valve boxes were

square. Such tubes were used to some extent by the U.S. Navy in the first part of the 19th century (1820) (Petrejus, 1970: 109).''

Hutchinson (1794: 256-7) invented a type of diaphragm pump which used square tubes built of planks. He referred to this type of tube as though it were nothing new. It was certainly simple enough to have been in both naval and merchant service for a long time, but the necessity of caulking the four seams probably kept them from being used on a permanent basis because of the added maintenance. A pump made of elm staves firmly bound together with ash hoops and lined with cowhides was devised by a Mr. James Brindley (1757-1812) (Björling, 1890: 21); again, such a tube probably did not become popular because of its complicated construction.

The bottoms of tubes used in land wells were treated differently than those used on ships. On land the bore was plugged at the bottom, and small holes were drilled into the sides a short distance from the bottom. This was done so that sediment and other material on the bottom of the well would not be sucked up the tube. This was a necessary precaution in pumps made for drinking water, but not in those on ships, which were discharging foul salt water.

For a ship's pump, the heel of the tube might be fashioned so that it would fit securely in the bottom of

the hull. The specific way in which this was done was probably the prerogative of whomever installed it. The manner of seating each type of pump will be dealt with in each respective chapter.

The methods and tools used in boring wooden tubes for pumps changed little over the centuries. Tubes for ships' pumps were fabricated in the same way as those for land pumps. The tools conformed to the same basic pattern (auger shaft, bit set, stool, platform, etc.) and were used in the same way. Alternatives to bored logs existed in tubes made of planks and in hollowed halves of a log.

CHAPTER IV

THE BURR PUMP

The first of the three pump types to be discussed is the burr pump. Besides the tube, the parts included the foot valve and the spear with the burr valve attached (Fig. 3). The foot valve acted not only as the lower valve, but also as the base of the pump. A short section of wood was bored through like the tube, and at its top was a claque valve. The pump tube was secured on top of this base (Agricola, 1556: 176). The burr valve was made from a pole of sufficient length with a thickening of wood (the burr) at one end and piece of leather, sewn in the shape of a cone. The leather cone, the base of which equalled the bore diameter, was attached to the burr (Agricola, 1556: 176; Manwayring, 1644: 78).

Once the pump was primed with water, the rod was moved up and down in the tube; the leather cone closed on the downstroke, opened on the upstroke, much like an umbrella, and thus lifted water above it. At the same time, water was drawn up through the foot valve. To strengthen the leather cone, strips of leather were sewn at one end to the base of the cone and fastened to the spear at the other end (Ewbank, 1842: 214).

There were many ways to impart an up and down motion to the spear. The simplest was to grasp the spear and

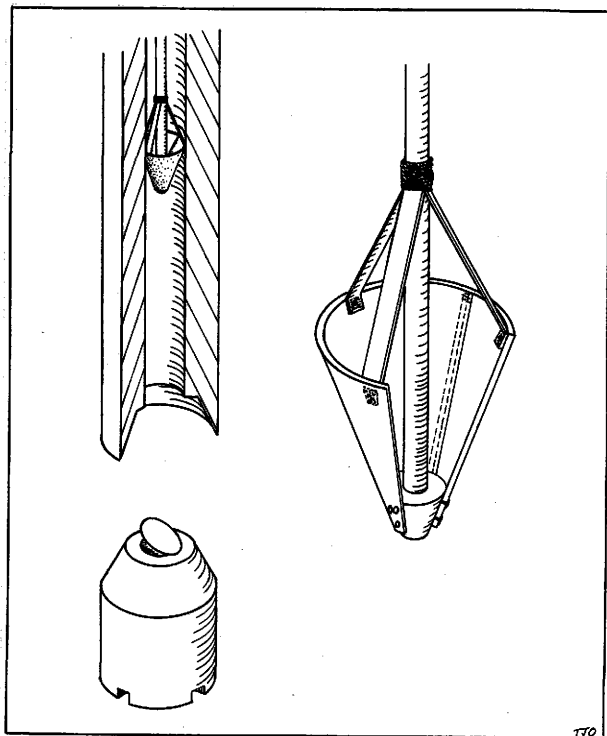


Figure 3. A burr pump. Left: The tube with the burr valve in place and the foot valve below it. Right: A detail of the burr valve.

move it up and down, perhaps by a short cross piece at the top of the spear used as a handle. Another way was to have a standard pump brake, which was a lever bar with a fulcrum point at a yoke set on or near the pump head (Agricola, 1556: 176-8). Manwayring and Boteler describe a different system used on ships in the early 17th century. Two men stood on either side of the pump head to push the spear down; to raise it up, a rope was seized to the middle of the spear by which six to ten men could haul the spear up again (Boteler, 1634: 71-2; Manwayring, 1644: 78-79).

A burr pump was found on the Basque whaling ship San Juan (1565). Portions of the tube, the foot valve, and the spear and burr valve were recovered. The foot valve, in the shape of a stepped cylinder, had a valve claque made of six layers of leather fastened together. Two layers had broad tails which were nailed to the base in a recess cut for that purpose. The tube fit over the top part of the base and rested on the step. The San Juan's burr valve differed from the standard description. Instead of having a leather cone attached to the spear, the valve consisted of 21 leather discs in two sizes fit over the end of the spear. The discs were held in place by an iron pin (Waddell, in press).

Although no other examples of burr pumps have been found on 16th-century wrecks, a similarity in the pump seatings exist among the San Juan and two wrecks discovered in England. The seating on the San Juan's pump had been made by cutting a semicircular hole in the port-aft side of the main mast step which was an expansion of the keelson. A floor timber below the keelson, which was also in the way, also was partly cut away (Waddell, in press). A similar seating was found in a ship dated to the 16th century discovered near Rye, Sussex (Lovegrove, 1964: 117-8). It had a semicircular hole cut into the keelson 11 ins from the expanded portion forming the mast step. The Cattewater wreck in Plymouth, also dating to the 16th century, had an elliptical hole cut in the center of the mast step (McKee, Ellis, and Carpenter, 1974: 5 and fig. 3). These pump seatings share the traits of being ca. 12 ins in diameter and having circular or semicircular holes in the mast step, which gives the pump a position on or near the centerline of the ship (Fig. 4). With the San Juan example, an association can be made between the burr pump and this type of seating.

Waddell noted that the hole of the seating was cut in a rough or crude manner, suggesting that the placement of the pump was regarded as an afterthought. He also pointed out the contradiction in expanding the keelson to form a stronger mast step and then cutting into it to form the

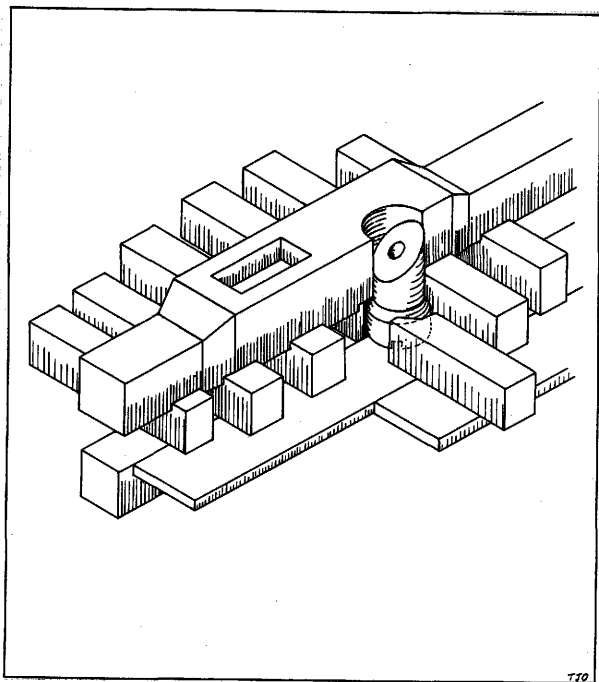


Figure 4. A 16th-century burr pump seating. This represents a generalization of a burr pump seating in the mast step of a 16th-century ship.

pump seating (Waddell, in press). Most probably the seating took this form in order to fix the base of the pump securely.

When and where the burr pump appeared is not certain. It is cruder in design than the suction pump, suggesting that it may have been a precursor of the suction pump. The earliest reference found by the author showing this type of pump is in Agricola (1556: 176-7), where it is discussed along with the common pump and is said to be inferior to it.

By the beginning of the 17th century, the burr pump had fallen out of general use. Marine dictionaries of the period mention this type and state that it was no longer in use on English ships, but could be found on Dutch and Flemish ships. The latter had broad, flat bottoms, and their pumps were placed at the ships' sides in order to expel the water that collected at the turn of the bilge when the ship heeled (Boteler, 1634: 71-2; Manwayring, 1644: 78; Smith, 1627: 8-9). However, the burr pump does show up from time to time because it was a simple machine and was easy to construct (Ewbank, 1842: 214-5). A burr pump was recently found on a wreck which sank in the 1840s or 50s near Isle La Motte in Lake Champlain. Another burr pump was found on the General Butler (built 1860), a canal schooner that also sank on the Lake (Kevin Crisman, pers. com.). These later burr pumps were modified in that the

large foot valve had been replaced by the lower valve arrangement of the common pump.¹²

A possible reason why the burr pump fell out of use may have been the difficulty in servicing it. To replace, repair, or clear the leather flapper valve, the entire tube had to be lifted off the base. This would have been difficult at sea in the close confines of the well, especially during rough weather or if a few feet of water had collected in the hold. The common pump had a definite advantage in this respect.

Both Boteler (1634: 72) and Manwayring (1644: 79) state that the burr pump drew up far more water and was less labor intensive than the common pump at that time. If such a statement were true, one wonders why the burr pump fell out of use. However, it was replaced in time by the suction pump.

The burr pump was a very simple machine that was used on ships in the early 16th century and probably for some time before that. Its use was waning by the late 16th century, and it had almost entirely disappeared by the early 17th. The standard seating arrangement for the burr pump was a single pump stepped on or near the centerline of the ship in a hole cut into the expanded mast step/keelson. The San Juan's pump has confirmed that the purpose of the holes in the mast steps of other 16th-century wrecks accommodated the bases of the pumps.

The San Juan's pump has presented a very different example of the burr valve than previously was known.

CHAPTER V

COMMON PUMPS

The common pump is so generally understood, that it hardly requires any description. It is a long wooden tube whose lower end rests upon the ship's bottom, between the timbers, in an apartment called the well, inclosed [sic] for this purpose near the middle of the ship's length.

This pump is managed by means of the brake, and the two boxes, or pistons. Near the middle of the tube, in the chamber of the pump is fixed the lower-box, which is furnished with a staple, by which it may at any time be hooked and drawn up, in order to examine it. To the upper-box is fixed a long bar of iron, called the spear, whose upper-end is fastened to the end of the brake, by means of an iron bolt passing through both. At a small distance from this bolt the brake is confined by another bolt between two cheeks or ears, fixed perpendicularly on top of the pump. Thus the brake acts upon the spear as a lever, whose fulcrum is the bolt between the two cheeks, and discharges the water by means of valves, or clappers fixed on the upper and lower boxes. (Falconer, 1780, 221) [Fig. 5]

The earliest representation of a common or suction pump was a drawing made by the Italian engineer, Mariano Jacopo Taccola, in 1433. The drawing shows a tube only a few feet in length; this is interpreted as showing that the limitations of the pump had not yet been discovered. Drawings of this pump continued to appear in later engineering texts. But by the second quarter of the 16th century, the suction pump had practical application in the

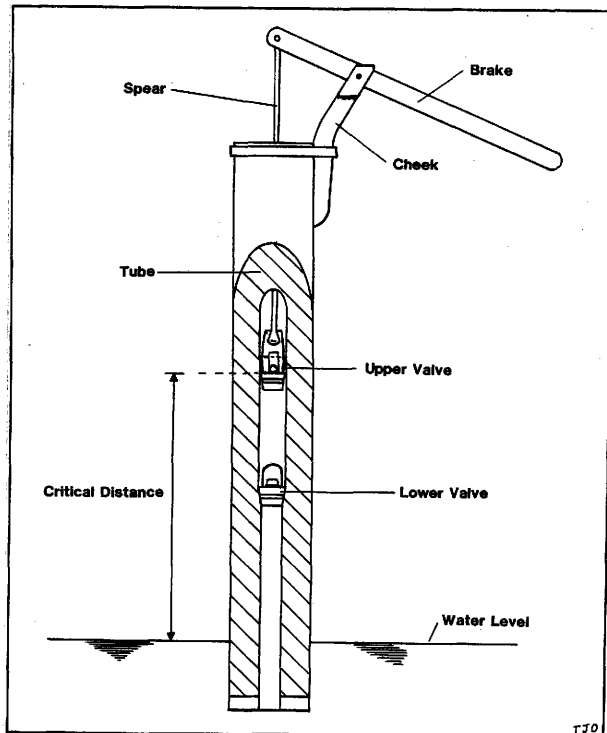


Figure 5. A common pump. This schematic shows the different parts of a common pump and the critical distance between the water and the claue of the upper valve at the top of its stroke.

mining industry in Germany (Shapiro, 1964: 571-4, and fig. 4). The use of suction pumps on ships probably began sometime in the late 15th or early 16th century.¹³

The height to which a common pump can raise water by suction is dependent upon the physical laws relating to barometric pressure. A rule of thumb is that suction can raise a column of water in feet equal to the barometric pressure in inches of mercury. That is, at a barometric pressure of 30 inches of mercury, it is theoretically possible to raise a column of water 30 feet high. However, due to friction and loss of efficiency in the pump, the height is usually 28 feet. This critical distance is measured from the surface of the water to the claue of the piston valve at the top of its stroke (Fig. 5). The force of the atmosphere on the surface of the water pushes it up the tube as the pressure is decreased within the tube during the priming process.¹⁴ The water is lifted by the piston once it is above the valve claue.

On ships, the length of the pump tube was determined by the depth of the hull. Tube lengths in excess of 28 feet were entirely possible because the boxes could be placed anywhere within the tube, usually toward the center, thereby decreasing the critical distance.

A description of wooden tubes and their manufacture has already been given. The shapes and proportions of the different styles of valves were well known to pumpmakers.

As long as the valves were made of wood, they had very recognizable and unvarying shapes. Those from the early 18th century were identical in overall shape and form to those produced by Irish pumpmakers in the first part of the 20th century.¹⁵ Generally, valves were turned on a lathe and were usually made from elm. Scribe lines around the valves were added at points where significant features began or ended on the body.

The lower valve (Fig. 6) was about as tall as or a little less than it was wide. The large hole through the center through which the water passed was usually oval, but was sometimes round. The two holes on either side of the center hole received the ends of the staple which was secured by riveting the ends over roves at the bottom of the box. The staple was for retrieving the lower box to inspect and to repair it. For this purpose, a long pole with a hook on the end was always kept on board. This feature gave the common pump a decided advantage over the burr pump in that only the lower valve, and not the entire tube, had to be removed in order to replace the valve leather. Another style of staple was attached to a basal ring. The staple and ring fit into grooves on the outside of the wooden valve (Howard, 1979: 193, fig. 295).¹⁶ The claue valve was a piece of leather large enough to cover the central hole. A small block of wood was attached to one side as a weight. A groove encircled the outside, and

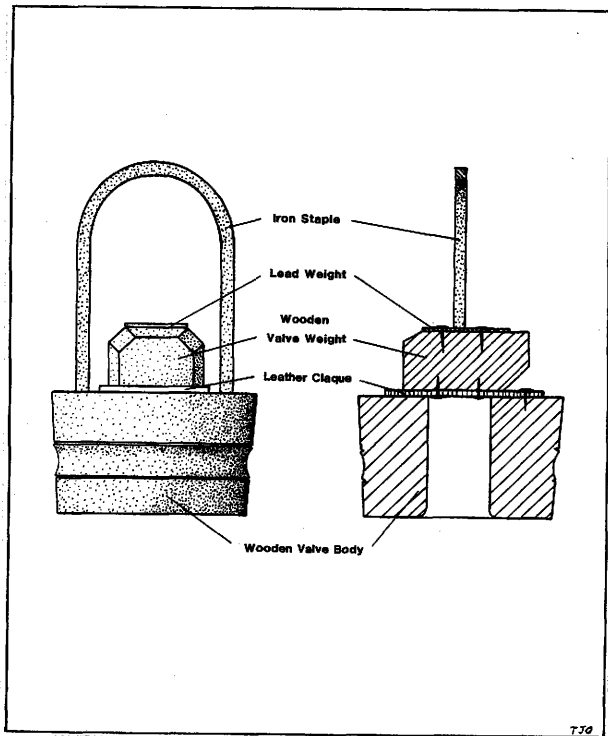


Figure 6. A lower valve. This represents a generalized form of a lower valve box. The hole through the center was sometimes circular, sometimes oval.

here a wrapping of flax, yarn, wool, or such stuff ensured a watertight seal around the box (O'Sullivan, 1969: 111-3; Boudriot, 1974: 146).

The upper valve (Fig. 7) consisted of the body and the valve claque. All piston bodies held certain features in common. A circular hole was cut through the center from the bottom and joined a large rectangular hole cut through the diameter. The valve claque was placed over the center hole. On the outside, a groove was cut a short distance from the base. Although similar to the groove on the lower box, no source mentions a wrapping around the body at this point. At the level of the valve claque, an indentation was made where a piece of leather was wrapped around the body of the valve to ensure that no water leaked past the sides. The lower edge of the leather rested on the ledge formed by the indentation. The leather was tacked around the bottom, and the butt ends were tacked to the side of the body.

The top of the valve body was shaped according to the type of spear that was used. Two sides of the valve body were shaped to a point, and a metal spear with a flattened forked end fit over the point and was nailed in place. For a wooden spear or a metal one with an eye or flat end, a slot was cut from the top of the body to a little way above the rectangular hole. Holes were then drilled across the slot through which the spear was bolted or

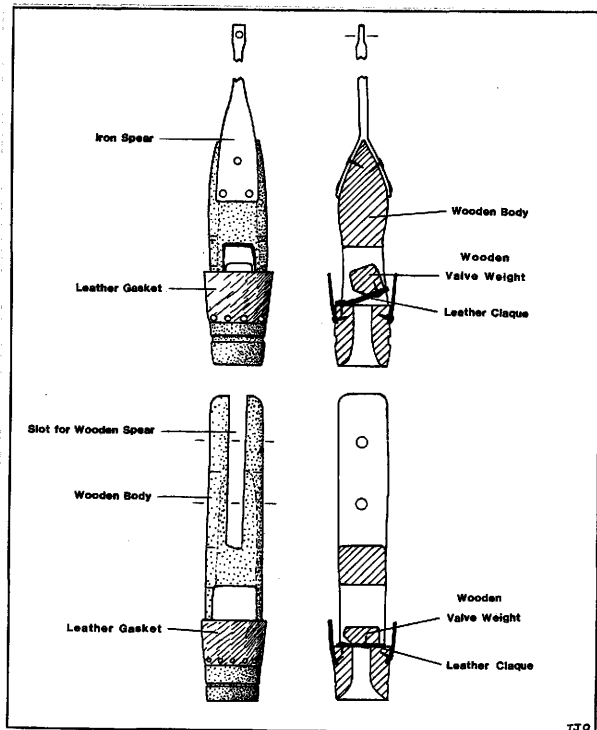


Figure 7. Upper valves. Top: An upper valve shaped to fit a forked iron spear. Bottom: An upper valve slotted at the top for attachment to a wooden spear. (After O'Sullivan, 1969: 112)

pegged. When the spears were made of wood, fir or pine was preferred (Ewbank, 1842: 224; O'Sullivan, 1969: 116; Boudriot, 1974: 146; Cederlund, 1981: pl. XXIV; Cederlund, 1982: 97).

All of the above types of upper and lower valves, made of ash and elm, were recovered from the Machault. They match very closely those depicted in O'Sullivan (1969: figs. 7-10, and 12). A few of those found on the Machault were probably spare valves because there were no nail holes where the leather valve clagues should have been tacked down. A fragment of a lower valve was discovered in the Defence (1779) collection. Several lower valves were recovered from the San Jose y las Animas, a ship of the Spanish Plate Fleet of 1733, which wrecked off the Florida coast (Levy, pers. com.). Piston valves from the Swedish shipwrecks at Jutholmen (17th century) and Älvsnaben (ca. 1730), although slightly different in appearance, still display all of the major features discussed (Cederlund, 1981: pl. XXIV; Cederlund, 1982: 97). Other valves, which came from land pumps of the late 19th century, are in the Mercer Museum and in the Pump Museum, Saco, Me. The similarity that all these valves bear to one another, coming from such different times and locales, is striking.

The handle on a common pump was usually a wooden bar bolted through supports of "cheeks" that were cut out of

the tube itself or attached as a second piece. In photographs from the Scourge (1813) (Nelson, 1983: 297), the cheeks are quite obvious and are formed out of part of the tube. The top of the spear can be seen next to the cutlass in the port pump. The brakes are not mounted, but the square timber stuck down the bore of the starboard tube may be one of them. In one of the pumps from the Machault, the brake was found in the bore, next to the spear. Presumably, it was placed there for storage, being a handy, easy-to-reach spot. The spear could not have fallen very far down the tube because of the lower valve. In addition, the brake handle would have wedged itself between the spear and the tube wall.

Examples of attached cheeks can be seen on the Vasa's pump, a decoratively carved cheek with a tenon from the Jutholmen wreck, and a cheek piece of iron on the Victory (Harland, pers. com.; Cederlund, 1982: 108; Bugler, 1966: pl. 21).

Another form of brake was a long lever arm attached to the mast above the pumps with a temporary lashing. A rope attached to one end led to the spear, and a number of lines were attached to the other end so that as many men as there were lines could work the pump. An object, which was possibly one of these overhead lever arms, was found on the Jutholmen wreck (Cederlund, 1982: 123-4). Instead of forcing the spear down again by hand, weights were

attached to the top of the spear. Boudriot shows cannon balls (presumably imperfect, and therefore useless as shot) bound in iron straps with an eye for attachment to the spear (Boudriot, 1974: 146, figs. 184 and 186). The water usually exited the tube through a hole in its side near the top. Since the water in the bilge had its own distinctive odor, it was common to have a conduit that attached to the opening and guided the bilge water to a scupper at the side of the ship rather than allow it to spill out onto the decks. This conduit, called the dale, was made of canvas or planks and could be removed when not in use. Lead pipes were sometimes used as permanent dales.

As mentioned in Chapter I, the lower ends of ships' pumps were fashioned in a different manner than those used on land. The bore was left open at the bottom of the tube and, to allow water to enter the bore, four channels were cut at the base from the outside to the center. The heights and widths of these cuts varied from pump to pump.

In order to fix the heel of the pump securely in the bottom of the ship, one or more faces were cut on the lower end, permitting the tube to rest between and on top of the floors and/or the keelson (Fig. 8). Several examples of this form have been found in the archaeological record: the Defence, (1779), the Trinity Cove Wreck (mid-18th century), and the Machault (1760).

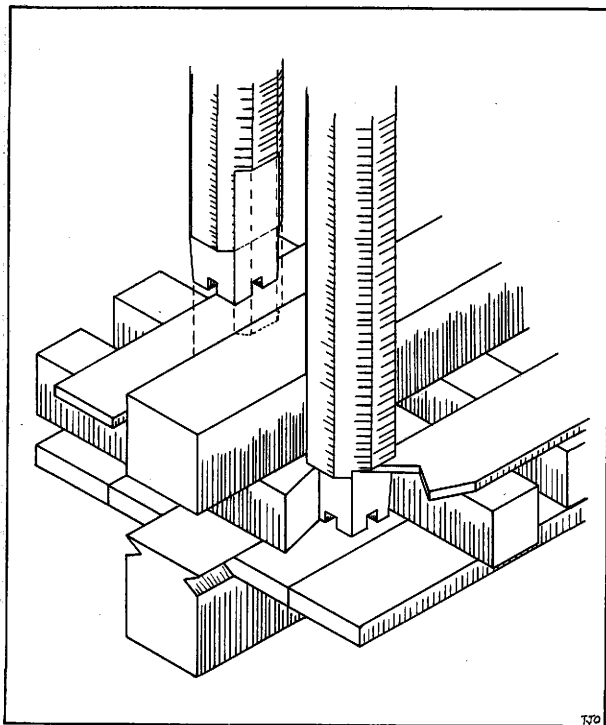


Figure 8. A common pump seating. The lower end of the pump tube is cut so it will fit between and on top of the keelson, frames, and ceiling planking.

A second way to seat the pump was to cut a circular hole a few inches deep into the tops of the floor timbers and to place the heel of the tube into it. In this type of seating, the channels were the only modification to the tube bottom, and they had to be taller than the seating was deep. The suction pumps of the HMS Charon, a 5th-rate 44-gun ship which was sunk in action in 1781, were seated in this fashion. The common pumps of the Santo António de Tanna, a Portuguese frigate which was sunk in the harbor of Mombasa, Kenya, in 1697, were set in between frames through holes in the ceiling planking.

One of the most common difficulties with pumps was that debris from the bilges could be sucked up their bores and become caught in one of the valves, thus preventing the pumps from working. To guard against this occurrence, sheets of lead or copper, called sieves, were sometimes placed over the ends of the pump. To date, the only examples found on shipwrecks are of lead. Scribed lines are sometimes found on the inside face, indicating the channel cuts. Within these lines, a series of holes are pierced through the lead. The tools used for this purpose varied from hot pokers to gouges. The sides of the sieve were bent up around the tube and nailed with large headed tacks. Several of these sieves have been recovered from wrecks. Of the two from the Machault, one is three-sided with thick sides and bottom, and the other is a thinner

sheet with small tabs that overlap the sides of the tube for fastening.

The lower ends of the two tubes from the El Constante, a Spanish ship which wrecked on the Louisiana coast in 1766, still had the sieves attached (Pearson, 1981: 20-1). A third pump, possibly a spare, was indicated by a third and much larger sieve (Fig. 9). All three sieves showed evidence of the grooves (discussed below) that ran down the sides of the two preserved tubes.

The cause of a clogged pump was not always "garbage." Certain items of cargo or ship's stores, when they became wet, could also affect the pumps. The Portuguese, on their return voyages from India, continually had problems with pepper clogging the pumps. When the peppercorns became soaked, they swelled and burst the sacks in which they were stored and migrated to all parts of the ship including the well and pumps. On the voyage of the São Thomé (1589), when the pumps became clogged with pepper, sheet tin was used to keep the pumps from being clogged again. Although it was not specified how the tin was used, it most probably was used as a sieve for the lower end of the tube (Boxer, 1959: 57 and fn. 1; Duffy, 1955: 59). Coriander, a spice about the size of peppercorns, was found between the valves in one of the preserved tubes from the Machault (Zacharchuk, pers. com.). During a voyage of the Sea Venture, an English merchantman bound

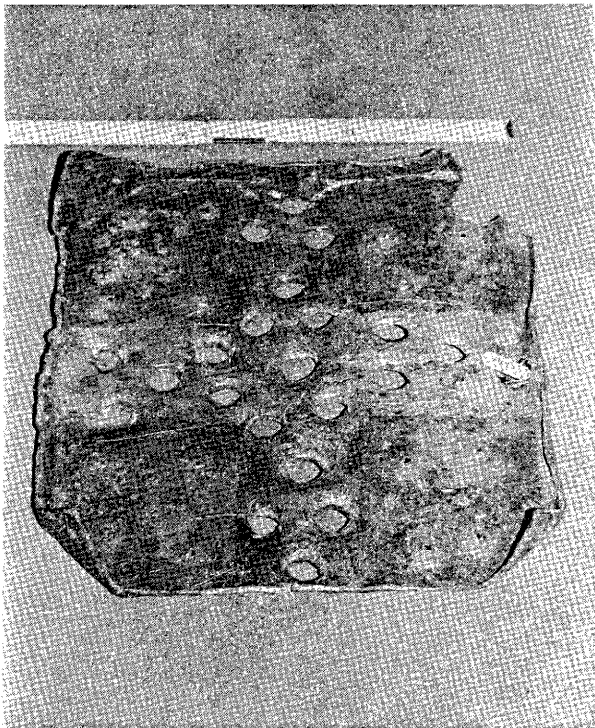


Figure 9. A common pump sieve. This sieve from the El Constante was fastened over the bottom of the pump tube to prevent debris from entering the tube and clogging the valves. Note the pattern of nail holes, larger holes, and scribed lines. (Photo by the author)

for Virginia in 1609, the ship faced a desperate situation in a storm when the pumps became clogged by "bringing up whole and continual biscuit" (Wright, 1964: 9).

The loss of the 3rd-rate HMS Centaur (1782) was in part due to a load of coal. Rising water allowed the coal to migrate to all parts of the ship. Once the lumps reached the pump well, they continually clogged the common pumps and damaged the chain and leathers of the chain pumps (Huntress, 1974: 69).

An unusual feature on the tubes from a few shipwrecks is a groove down the outside of the tube, the function of which has yet to be explained. Grooves were found on the tubes of the following wrecks: the Trinity Cove wreck, Newfoundland (Newfoundland Marine Archaeological Society, Annual Report, 1979: 16); two tubes from the El Constante (1766) (Fig. 10) and a third lead sieve¹⁷ with a small semicircular cut in one of the corners which indicated a third tube with a groove (Pearson, 1981: 20-1) (Fig. 9). A complete pump tube with the groove running the entire length and passing under several iron straps was found on the wreck of the Sydney Cove (1797) (Atheton and Lester, 1982: 15 and fig. 11). In the absence of literary references, we can only speculate on the purpose of these grooves. Suggestions include a pathway for water seeping in around the pump head at the deck; a slot with which to guide the pump into place when installing it or to lock



Figure 10. A groove on the outside of a pump tube. This pump tube from the El Constante has a groove running down the outside face. Its purpose is unknown. (Photo by the author)

the tube in place when it is in position; or to allow a tool to grip the tube firmly in order to shift its position.

The use of metals in pumps, especially iron and copper, began gradually in the 16th century and increased through the 19th century. Lead was easily obtained and worked, and lead tubes or conduits were in use in water supply systems in the 16th century (Björling, 1890: 7-8). According to Usher (1957: 326) at that time the use of metals in machinery was limited because cost was more of a factor than in the production of ordnance and luxury goods. Wood was still the basic material and metals were used where strength and durability were needed. Usher refers to pumping systems on land, usually large water systems designed to supply drinking water for all or part of a city. For the average common pump, the tube was still made of wood, but other parts, such as the spear and possibly the valve boxes, might have been made of metal. Agricola (1556: 176) suggested that the valves should be made of iron, copper, or brass.

Two identical objects recovered from the Molasses Reef Wreck, an early 16th-century Spanish shipwreck in the Turks and Caicos Islands, B.W.I., may be simple piston valves (Fig. 11).¹¹ They look very much like the hubs of a wheel, which they were first suggested to be. However, they are made of lead and would not have withstood much

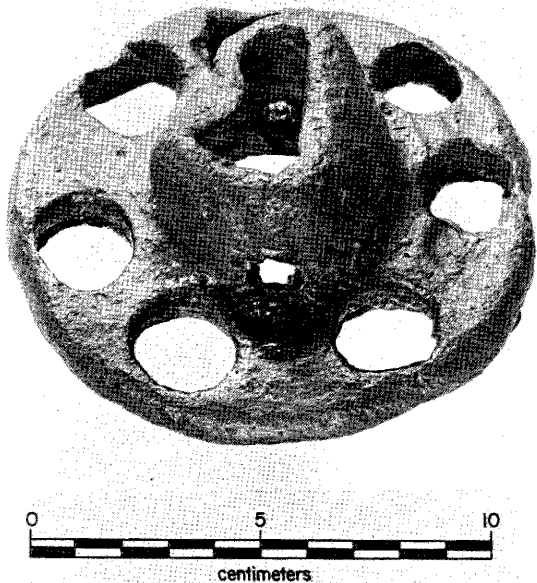


Figure 11. An upper valve from the Molasses Reef Wreck. Looking at the bottom of the valve, the spear would have entered from the opposite side. An iron pin or nail passed through the hole in the collar and fastened the valve and spear together. (MRW #598, Photo by the author)

stress. They are round discs ca. 1 cm thick with raised reinforcing collars around a central hole. A hole through each collar was for keying the rod, axle, spear, or whatever went through it. Around the central hole are seven smaller holes.

This object could easily be interpreted as being a piston valve¹⁹ and would thus represent an early form of an upper pump valve. The valve claque would have been a circular piece of leather with a hole in the center for the spear. The smaller holes would have allowed water to pass through the valve, and the leather would have closed these holes on the upstroke of the spear. The piece itself is similar to the valves described by Agricola (1556: 176):

Or else an iron disc one digit thick is used, or one of wood six digits thick, each of which is far superior to the shoe [the burr valve leather]. The disc is fixed by an iron key which penetrates through the bottom of the piston-rod, or it is screwed on to the rod; it is round, with its upper part protected by a cover, and has five or six openings, either round or oval, which taken together present a star-like appearance; the disc has the same diameter as the inside of the pipe, so that it can be just drawn up and down in it.

In 1526, Diego Rivero, the cosmographer and the instrument- and mapmaker to the Spanish Crown, invented a metal pump for use on ships bound for the Indies. He claimed his pumps were lighter than those of wood and that

they could produce many more times the amount of water that the wooden pumps could (Navarette, 1846: 360-5). There is no description of the mechanism or which metal was used to make it, so a positive identification is impossible.²⁰ However, because of the date and the use of metal, it is most likely that Rivero's pump was a suction pump.

Lead was the first metal used to form major parts of ships' pumps. The metal was easily obtained and worked and, consequently, it was a very common one. Tubes of any diameter were made by simply taking a sheet of lead, cutting its width to the desired circumference, rolling it so the edges met, and soldering the seam (Diderot, 1966: Vol. 12, 787; and Vol. 29, *plombiere*, pl. II, fig. 27). These tubes were durable, did not rust, and were not prone to splitting as wood might.

An early example of a lead pump is from the San Jose (1733) which was possibly an English-built ship purchased by the Spanish. The pump consists of a reservoir box, a dale, and a piston cylinder (Fig. 12). The reservoir box is formed by a sheet of lead welded to the top of the piston cylinder forming the bottom, and a single sheet of lead wrapped around the base forms the sides. A pipe runs off the back as a dale. A short lead tube, with a bronze gravity valve set permanently into its tapering lower end, at one time contained the piston valve. This tapering end

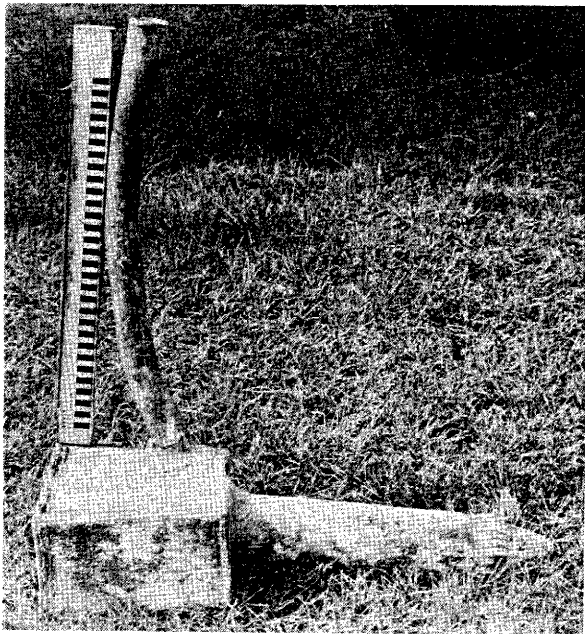


Figure 12. The lead pump from the San Jose (1733). The parts of the pump are the dale, the reservoir box, and the piston tube. A bronze valve is permanently set into the tapering end of the piston cylinder. (Courtesy of the Florida Division of Archives, History, and Records Management)

probably fit into a wooden tube. The presence of wooden lower valves on this wreck (mentioned above, p. 39) is an indication that both wood and lead pumps were present on this ship.

A pair of lead pump tubes in the Mariners Museum (#RS 2 and 3) was recovered from the York River at Yorktown, Va. (Fig. 13). Yorktown was the site of General Washington's victory over Lord Cornwallis in 1781 and the resting place of a number of ships of the British supply fleet. The pumps were salvaged during a joint project of the National Parks Service and the Mariners Museum in the 1930s (Ferguson, 1939), and they bear some similarity to the San Jose's pump. The Yorktown lead pumps also have a reservoir box on top of a piston tube, a drainage port at one side of the box, and no top on the reservoir box.

A photograph of these pipes just after their recovery shows enough lead tubing to account for at least three if not four pumps. Two bottoms and one top are shown and each with enough tubing attached to account for a separate pump (Ferguson, 1939: fig. 5).

Three sections of lead tube are in the Museum's collection. One has a reservoir box and piston cylinder. The second has a lower fitting which is an expanded section of tubing, and the third section is a length of tube that connected with the second, according to museum staff. The lengths of the sections are 15 feet for the



Figure 13. Lead pump tubes from the York River. Top: The reservoir box, valve outlet, and the upper part of the piston cylinder of one of the tubes. Bottom: The expanded lower end of one of the tubes. (Photos by the author)

first and 28 feet for the second and third sections combined. The combined sections are very close to the maximum workable height for a suction pump. The piston cylinder would have to have been within the next foot or so. It is possible that the first and third sections do not fit together, and that the lead sections represent three different pumps. The photograph in Ferguson (1939: fig. 5) shows two different lower sections, but only one is in the Museum collection.

Another pair of pumps (RS 6 and 7) (Fig. 14) was purchased in St. Thomas, B.W.I., by agents of the Museum because they looked very similar to, but were smaller than, the tubes recovered from the York River. The difference between the two sets is that the piston cylinders are made of copper. No information is available on the history of these pumps. No seams were seen on the lead tubing of these pumps.

A large diameter (18.8 cm) section of lead tubing was salvaged by an oysterman from the CSS Florida which sank in Hampton Roads in 1864 (Dick Swete, pers. com.). Its identification as part of a pump is not certain, but the large diameter suggests that it was.

Lead tubing was often used on ships for pumps, scuppers, and heads. Through time, different ways were developed to form tubes out of lead. The simplest method was to roll a narrow sheet of lead over on itself and

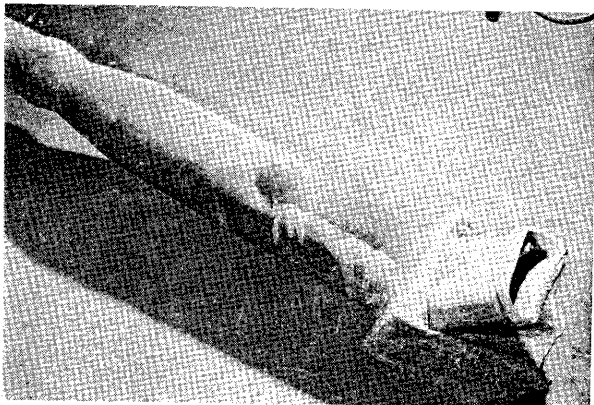


Figure 14. A lead and copper pump. One of two pumps at the Mariners Museum; the reservoir box, dale spout, and lower tubing are of lead, but the piston cylinder is of copper. (Photo by the author)

solder the edges together. A second method developed in the 18th century was to cast sections of tube in a mold, draw the finished tube out until only a few inches remained in the mold, and then pour another section that joined with the first. This process was repeated to produce tubes of any desired length that were of a consistent diameter and thickness (Diderot, 1966: Vol. 12, 784; and Vol. 29, plombiere pl. IV). Tubes made by this method thus should exhibit mold marks on opposite sides of the tube and at intervals along the tube.

A third method was detailed in 1801 in a U.S. patent by Burroughs Titus for drawing lead tubes from the molten state (Jones, 1831: 136-7). An English patent also was issued for a machine to produce the same results, but by a different construction. Thus, drawn lead pipes probably appeared in the very late 18th century. A pipe made in this manner should exhibit characteristic striations down the length of the tube.

As the ability to work copper and bronze increased, these metals, although expensive, were sometimes used in ships' pumps. In the 18th century, while other European navies were using the chain pump aboard their warships, the French depended exclusively on the suction pump as the main pump on their naval vessels. Their pumps followed a distinct form that was called the Royal Pump, because it was used on the king's warships. This pump was made up of

two wooden tubes and one cast bronze section set between them. The upper tube was 4.59 m long and 16.3 cm in bore diameter, and the lower tube was 4.98 m long and 12.2 cm in bore diameter. Five iron straps were applied to each section to prevent the splitting and cracking of the wood.

The bronze tube, called the corps de fonte or the cast body, was the place where the piston operated (Fig. 15). The wooden tubes were fastened to each end of the cast body by four holes in each flange. The length of the cast body varied depending on the location of the shipyard for which it was made. At Brest and Toulon it was 97.5 cm, and at Rochefort it was 86.7 cm (Boudriot, 1974: 145, 148, and fig. 185).

Examples from shipwrecks on opposite sides of the Atlantic show that there was indeed variation in the length. A cast body from a mid-18th-century wreck at Fort Louisberg, Nova Scotia, is 95.5 cm long. Another from L'Impatiente (1796), wrecked in Ireland, is 84 cm long (Alan Roddie, pers. com.). A small degree of variation existed in the other measurements (Table 1, p. 60). The difference in length could very well indicate Brest or Toulon as ports of origin for the Louisberg wreck. Such a clue might be valuable to archival researchers.

An upper valve, made of bronze and weighing over 20 lbs, was found with the cast body from the Louisberg wreck (Fig. 16). It is identical to one depicted in Howard

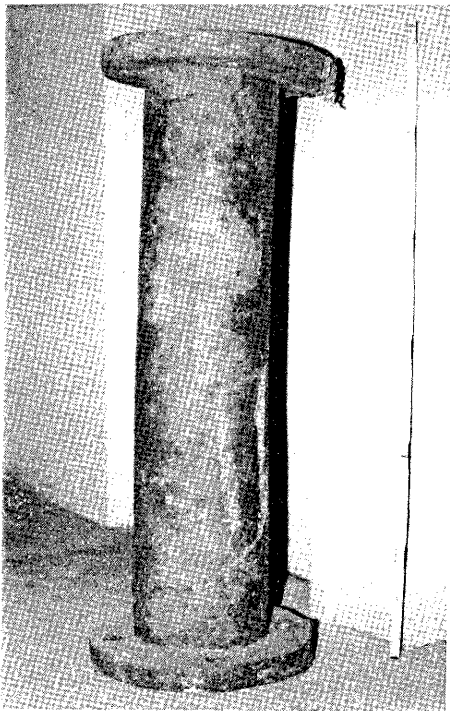


Figure 15. A corps de fonte from a French Royal Pump. The cast bronze section was fastened between two wooden tubes. A bronze piston valve worked within it. (Photo by the author)

Table 1.

The dimensions of French corps de fontes

	Boudriot (1974: 145)	L'Impatiente (1796)	Louisberg wreck mid-18th century
length	Brest and Toulon 97.5 cm Rochefort 86.7 cm	84 cm	95.5 cm
inner diameter	16.3 cm	17 cm	16.5 cm
wall thickness	1.4 cm	-----	2.4 cm
flange diameter	33.9 cm	38 cm	35.0 cm
weight	135 kg (300 lbs)	125 kg (275 lbs)	>113 kg (>250 lbs)

(1979: 193, fig. 295), except that it has three bolts securing it to the spear instead of two. Howard also shows a metal valve guide positioned at the bottom of the spear which was missing from the archaeological example. Boudriot (1974: 146) mentions only wooden valves. The figure in Howard shows the bronze upper valve and a wooden lower valve.

As has been shown, wood and lead were the common materials for pumps in the 18th century. In the late 18th and early 19th centuries, copper and bronze were used more and more often (Henderson, 1980: 240). The lead and copper pumps (RS 6 and 7) in the Mariners Museum are

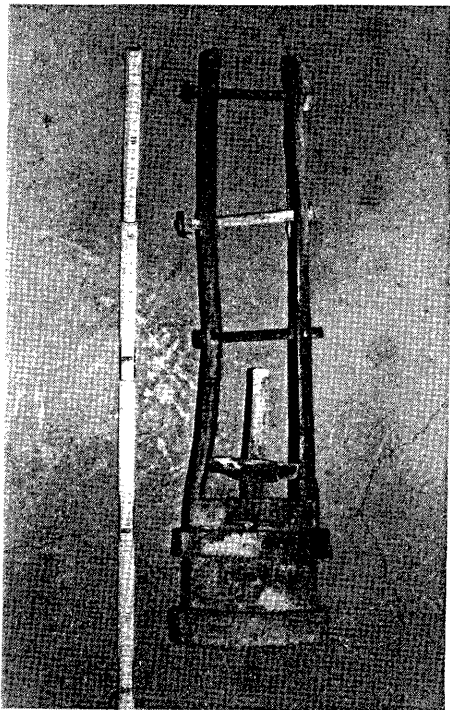


Figure 16. The bronze upper valve from a French Royal Pump. (Photo by the author)

probably early examples of the use of copper because of the use of lead for the reservoir boxes and the lower tubes. These pumps were probably made in the very last years of the 18th century and denote a transitional phase between the two metals. A copper piston cylinder retrieved from the Rapid (1811), an American East Indiaman, still has a lead nozzle connected to its bottom (Henderson, pers. com.). A section of copper cylinder from the HMS Pandora (1791) and another from the Rapid (1811) show that both warships and merchant ships were beginning to use this type.²¹ The bore diameters of these pumps are much larger than those of wooden pumps--perhaps twice as large. If the distance of the piston stroke were the same, the bronze pumps would have had a greater output than the wooden pumps.²² In the first half of the 19th century, these bronze and copper pumps were also replacing chain pumps on the smaller rate warships.

From the 15th to 18th centuries, despite the great expansion of the iron industry and the great increases in the skills of working and shaping metals, the use of metals in the construction of machinery proceeded very slowly. Here cost was more important than it was in making luxury goods or armaments, so that wood remained a basic material for machine construction. Metals were used only for such parts of machines as required strength and durability (Usher, 1957: 326).

At the beginning of the 18th century, wooden pump tubes were still in general use. Iron pump tubes were used in important works, but were still of small diameter. The only tools available for boring them were those already in use for making cannon (Wolf, 1952: 583).

The introduction of the Newcomen steam engine (1712), the first practical steam engine, created new and difficult problems for the ironmasters. The piston and cylinder of a steam engine required a high degree of exactness in their fit. At first these cylinders, 30-60 ins in diameter, were ground and filed at considerable cost (Usher, 1954: 371). Such a cylinder was, of course, far larger and was made with greater precision than any shipboard pump needed to be made. The structural and mechanical improvements needed to develop the Newcomen steam engine further could be brought about only as the tools and processes for accurately finishing the precisely fitting parts were improved and as materials such as iron both increased in strength and became more readily available (Kerker, 1961: 385).

The first notable improvement in a boring machine was the patent by John Wilkinson of January 27, 1774, for a method of boring cannon from solid castings. By 1776, Wilkinson was producing cylinders with a higher degree of accuracy than anyone had achieved (Usher, 1954: 371-2).

It is difficult to determine how the development of these machines affected the making of metal pumps. The accuracy needed for steam engine cylinders was not necessary for water pumps, especially those operating on as small a scale as on ships. However, water pumps probably did improve as a result of the advances made in steam engine construction.

Many variations in the design of the common pump are documented. However, not all were successful, nor were all successful designs adapted for shipboard use.²³ One which was successful and was used on ships was Dodgeson's pump. Invented in 1799, it was a variation in the arrangement of the common pump. Two piston cylinders were connected by a T to one tube that went to the bottom of the vessel (Fig. 17). A double action brake was used with this model, which resulted in a continuous flow up the tube that branched to one or the other cylinders. Two of these assemblies were mounted together, giving four cylinders.

Another variation was the multiple piston pump (i.e., more than one piston valve in one cylinder). These pumps were popular in the late 18th and early 19th centuries on ships. In Taylor's pump (1780), each of the two pistons was attached to a different rod so that one piston rose as the other fell. The rod for the lower piston acted as

the guide for the valve (a disc of metal) of the upper piston. The top of each rod ended in a rack which was moved by a cog wheel. The cog could be attached to a double action pump brake or to a drum that was turned back and forth by a rope that was wrapped around the drum. Two teams of men would pull on either end of the rope in a tug-of-war fashion (Ewbank, 1842: 266-7). The result of this design was that the pump would emit a constant flow of water, producing twice the amount of water that a common pump of the same bore and piston stroke could produce.

The multiple piston pump was used by the British Navy from the 1790s to the first part of the 19th century and by the French and Dutch probably in the first half of the 19th century and beyond (Ewbank, 1842: 266-7; Bonnefoux and Paris, 1859: 550-1; Mossel, 1859: 281-4 and fig. 242).

The pistons and a rod of just such a pump were recovered by Parks Canada personnel from the wreck of HMS Tribune (1797) (Fig. 18). The rod passes through the center of the upper piston and attaches to the staple of the lower piston. A second rod would have fit into a square socket attached to the upper valve. The valves and rod are of bronze; the tube in which they operated was likely the same.²⁴

In 1825, three pistons were put into one cylinder by Jonathan Daunton of London. The three piston rods worked

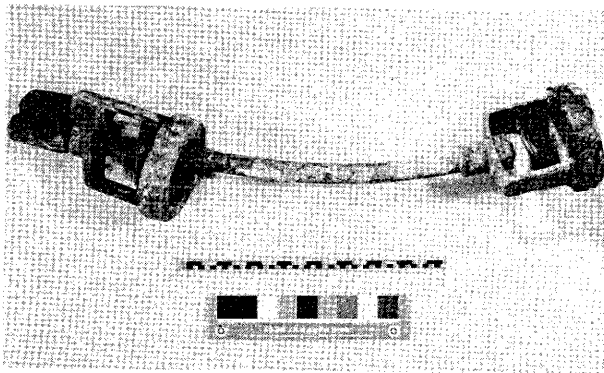


Figure 18. A double piston valve. This pump fragment was found on the wreck of HMS Tribune (1796). The upper valve (left), worked by another rod, would slide over the rod of the lower valve. (Courtesy of the Archaeological Research Division, National Historic Parks and Sites Branch, Parks Canada)

one within another, telescope fashion, and were probably connected to a cam shaft operated by a winch or crank. This pump was also used in the British Navy for many years. Another variation was made a little later by Stone and Depthford, who placed four pistons--two attached to each of two rods--in one cylinder (Björling, 1890: 35, 134). The rate of output for this pump could not have been greater than that for the double piston pump on the basis of design alone. A point in its favor was its ability to continue to work if one of the valves became clogged or needed repair. Patents for multiple piston pumps were still being issued in the second half of the 19th century, showing that these were still in use, at least on land.²⁵

Common pumps on warships of the 18th and 19th centuries had secondary functions in providing water for washing and fire fighting. Since the bilge water was usually foul, arrangements were made to bring seawater to the pumps. The two common pumps on the Victory are said to have pierced the bottom of the hull and to have provided only clean salt water (Bugler, 1966: 80).²⁶

A British plan dated 1807 (Fig. 19) shows another method of bringing seawater to the pumps. A lead pipe pierced the side of the ship below the waterline and either drains into the well or was fed directly into the pump tube. The flow of seawater through the pipes was

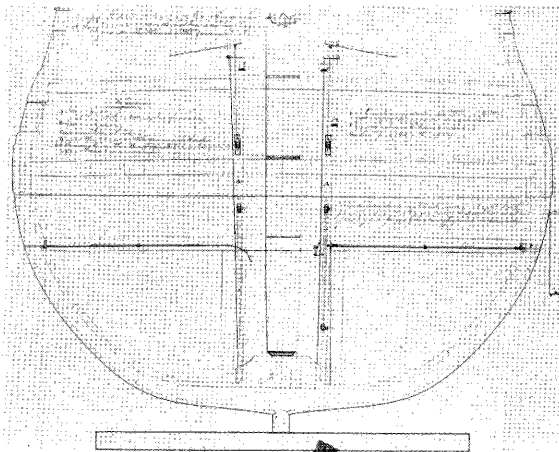


Figure 19. Common pumps as wash pumps. Sea water was fed into the well or the pumps through lead pipes. Stopcocks at the sides of the ship controlled the flow of water. A plug at the bottom of the one pump allowed it to discharge seawater without letting the water enter the bilge. (Courtesy of the National Maritime Museum from the Admiralty Collection of Plans, #7643)

controlled by stopcocks near the side of the ship." One of the pumps in this plan has a removeable plug near the bottom of the pipe. With the plug removed and the stopcock shut, the pump could be used in the normal manner. Another plan, dated 1825, shows a wooden pump set into a cistern which is filled with seawater from one of the lead pipes. The cistern was a wooden box lined with lead and was set on brackets at the side of the well up off the bottom of the ship (Fig. 20).

Howard (1979: fig. 295) states that common pumps had an advantage over chain pumps in that they could put water under some pressure so it could be used for fighting fire. However, the only pressure that a common pump could develop was the pressure of the head (the pressure attained by the weight of a column of water due to differential height). Only a force pump could put water under pressure. Force pumps were used in fire-fighting engines, which were sometimes placed on larger ships (Boudriot, 1974: 150-2; Smith, 1974: 131-2; Prijs der Zee, 1980: 8-10). The common pumps most probably supplied these engines with seawater.

The common pump first appeared in Italy in the beginning of the 15th century and by the 16th century had come into general use. In shape, the wooden upper and lower valves varied only slightly throughout the study period. The use of metals began in the early 18th

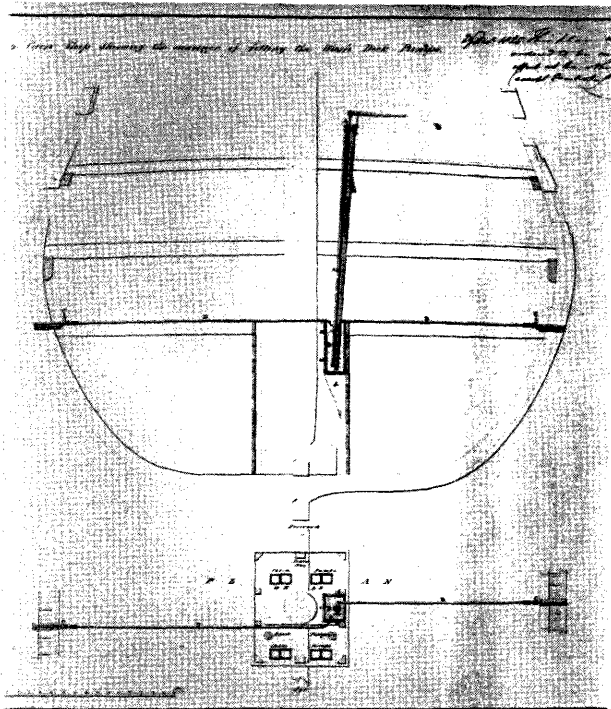


Figure 20. A wash pump set into a cistern. Seawater is brought to the cistern through a lead pipe. The cistern is mounted on brackets on the wall of the well. (Courtesy of the National Maritime Museum from the Admiralty Collection of Plans, #7605)

century. Lead was the first to be used, copper and bronze appeared later in that century, and iron came into general use only in the 19th century. The multiple piston pump was the most successful variation of the common pump. It was in use in the late 18th and first half of the 19th centuries. In conjunction with seacocks, common pumps were also used as wash pumps and to supply water for fighting fires.

CHAPTER VI

THE CHAIN PUMP

As described by Falconer (1780: 221), the chain pump (Fig. 21) was:

A long chain equipped with a sufficient number of valves, at proper distances, which passes downward through a wooden tube, and returns upward in the same manner on the other side. It is managed by a roller or winch, whereon several men may be employed at once, and thus it discharges, in a limited time, a much greater quantity of water than the common pump, and that with less fatigue and inconvenience to the labourers.

Additional parts included the winch handle that turned the drive wheel, the cistern supporting the drive wheel, and a roller or idler drum at the bottom of the round chamber (ascent tube) that helped the chain enter the tube.

The origin of this machine has been attributed to the Chinese, who used it both in agriculture for irrigation and in their ships for pumping the bilges (Ewbank, 1842: 149; Needham, 1971: 666-7). Descriptions of the Chinese chain pump by a Portuguese (1556) and a Spaniard (1585) tell of a machine made of short sections of wooden board fastened together and set in a trough. This pump was worked by turning a wheel, usually with the feet. The earliest mention of its use on European ships was by Sir

Walter Raleigh, who lists the chain pump, along with bonnets, stud'sails, and the anchor capstan, as improvements introduced into the English Navy during the last half of the 16th century (Needham, 1971: 666-7).

Chain pumps, however, did exist in Europe before the 16th century and were in use on ancient ships. The remains of machines made of rope and wood have been recovered from shipwrecks of the Roman period at Los Ullastres (Laures, 1979), Cap del Vol (Foerster, 1980: 245), Port-Vendres (Liou, 1974: 427), and Cavalière (Charlin, et al., 1979: 57), and the Byzantine-Merovingian period (Jezegou et al., n.d.: 16-7, and pls. 18-20).

Sometime during the Middle Ages, the chain pump must have disappeared from use in Europe, because it was reintroduced in Italy in the early 15th century. An Italian engineer, Mariano Taccolo, recorded this machine as though it were something entirely new and different and attributed it to the Tartar peoples of Eastern Europe. It passed from them through Italian merchants to the rest of Europe where, with some adaptation, it was used extensively in mining (Prager and Scaglia, 1972: 51-2 and pl. 27). Agricola (1556: 191-7) illustrates a "pater-noster" or "rosary" pump which was a descendant of the Tartar pump (Prager and Scaglia, 1972: 52). The pater-noster pump was a crude form of a chain pump with valves made of leather bags stuffed with hair or cloth and

fastened to a rope or chain. Sixteenth-century shipboard chain pumps were described as having blocks of wood as valves to which rags were attached (Howard, 1979: 59). This description bears more resemblance to the European chain or rosary pump than to the Chinese machine.

Extensive contact with the Far East began in the 16th century, whereby Europeans were looking at different and advanced cultures for the first time. The concept of chain pumps on ships could have been brought back by early explorers, yet not necessarily the machine itself. Europeans had a perfectly good and serviceable chain pump in use in their mines and simply adapted it to use on ships. This would account for Raleigh's statement, but it is curious that no one had implemented it before.

There are no detailed descriptions of chain pumps of the late 16th and 17th centuries; dictionaries are not very specific when speaking of them. Manwayring (1644: 79) and Boteler (1634: 72) describe a chain pump as a chain full of burrs that goes around a wheel.²⁰ It was said to be the best type of pump, and it discharged the most water. Manwayring adds that it was easy to fix because spare "esses" were always carried on board. He was referring to the shape of the chain links, although standard round or oval interconnecting links were also used (Ewbank, 1842: 156; Howard, 1979: 93, fig. 294).

The burrs were valves or discs that were attached at intervals to the chain. The term burr sends us back to the burr pump, suggesting that the valves may have been made of wood as stated by Howard (1979: 59). By the late 17th and early 18th centuries, they were made of metal. "Pump chain burrs are round thin pieces of iron, very little less than the bore of the pump, which are placed between every length of chain and on each of them the leather is put for bringing up the water." (Blanckley, 1750: 125)

The drive wheel was made of a solid wooden wheel with "sprockets" driven into it around the outside. Each sprocket was shaped like a horseshoe with a tang or spike at the curved end that fastened it to the drum (Blanckley, 1750: 126). A crank shaft was fitted through the center of the drum to turn it.

A Dutch plan dated 1736 of an English chain pump for a 50-gun ship (Howard, 1979: fig. 294) is very similar to the pump described by Blanckley. Although the wheel appears to have been made of iron, the side view shows the horseshoe-shaped sprockets. The chain was made of round interconnecting links rather than S-shaped links.

Both the round and the S-shaped link chains had problems besides the difficulty in maintaining them. They tended to jerk back or slip off of the drive wheel, or they would bind and break under the weight of the water.

In the 18th century, the British Navy reviewed many "improved" chain pumps. None were satisfactory until William Cole and John Bentinck developed their new pump in 1768 (London Magazine, 1768: 499) (Fig. 21). The improved design of the chain decreased the wear put on the links and also decreased the probability that the chain would slip or jerk back when the chain was raising water. The pump could be taken apart quickly and easily for maintenance and repair and, with fewer men working it, discharged more water than did other pumps. In a test on HMS Seaford, the new pump with four men at the crank put out one ton of water in 43.5 seconds, whereas the old chain pump with the same number of men required 83 seconds to move the same amount of water (Falconer, 1780: 222-3).

The Cole/Bentinck pump had been on trial in British warships since 1770, but because the chain was prone to breaking, further installations were stopped in 1773. Problems in its design were ironed out in 1774, at which time the Navy Board ordered its use on all British warships (Gardiner, 1976: 100). In the beginning of the next century, the chain was improved by a Mr. William Collins, who replaced the cast iron links with brass links (Falconer, 1815: 360). In the British Navy, the chain pump was used throughout the first half of the 19th century.

With the exception of France, most northern European countries were also using the chain pump in their warships by the end of the 18th century.²³ It is not known why the French were the only Europeans who did not use the chain pump on board their warships. They knew of the chain pump and used it for hydraulic projects, such as emptying cofferdams and drydocks (Belidor, 1737-1753: Vol. II, pl. 1-4).

As early as 1776, the chain pump was in service in warships of the Continental Navy (Chapelle, 1949: plans 2, 3, 4, 11, and 16), but fell out of favor in the United States Navy in the first decades of the 19th century. As a result, the British sloop-of-war Cyane had her chain pumps taken out and replaced by common pumps after her capture and induction into the U.S. Navy in 1815. A reintroduction of the chain pump into larger rates occurred in the late 1830s (Ewbank, 1842: 156-7).

A description of a late model chain pump is given by Ewbank (1842: 156-7 and fig. 67). This particular pump was fitted on board the USS Independence in 1837, and two similar pumps were installed on the USS Ohio. The chain was made of copper links on the same design as the Cole/Bentinck pump. The 2 ft diameter, cast iron drive wheel was rimless, having twelve spokes spaced around the hub. A notch at the end of each spoke caught the chain as the wheel revolved. The tops of the tubes were exposed on

the deck, the cistern having been eliminated. The back case (descent tube) stood 10-12 ins above the deck to prevent water from returning to the hold. Both the back case and the round chamber were made of copper and were 22 ft long and 7 ins in diameter. The unique aspects of this pump were the length of the copper tubes and the arrangement of the drive wheel which was similar to that of early style chain pumps. Here, an old idea was reintroduced with better engineering and metal technology.

The chain pump was a great improvement over the common pump. The former could move a vast quantity of water and was easier to work than the latter. A man would work at the common pump until he made two hundred strokes, whereas a spell at the chain pump was reckoned in "glasses" (probably half-hour glasses) (Manwaring, 1644: 79). In the late 18th century, a spell at the common pump was about five minutes, and thirty minutes was still the standard shift at the crank of a chain pump (Hutchinson, 1794: 254).

However, the chain pump did have its disadvantages. A large number of men were required to operate it continuously; the many leather discs of the valves had to be replaced about every twenty days (Huntress, 1974, 69); and the efficiency of the pump itself was only about 50 per cent (Bugler, 1966: 79). For these reasons, the chain pump was not used on the smallest warships and never

became popular in merchant ships.

In the last half of the 18th century, the increasing use of metals such as lead, copper, and iron for pump tubes, valves, and pistons greatly improved the efficiency of the common pump. Although the chain pump also used copper tubes in some cases, its use began to decline in the first half of the 19th century (Ewbank, 1842: 156-7).

The only extant chain pump known to this author is on board HMS Victory (Bugler, 1966: 78-9; Longridge, 1955: pls. 10 and 24). There are other post-Medieval examples from the archaeological record. Parts of a chain pump have been recovered from the wreck of the Santo António de Tanna, a Portuguese warship sunk in Mombasa Harbor in Kenya in 1697 (Piercy, pers. com.). Two objects recovered from a Revolutionary War shipwreck in the York River, Virginia, in the 1930s were thought to be parts of a chain pump. Excavations on another wreck in the York River, the HMS Charon, a 44-gun 5th-rate British warship, have uncovered the remains of a Cole/Bentinck type pump. Recent excavations on HMS Pomone have yielded a section of chain from the pump.³⁰

The chain pump parts recovered from the Santo António de Tanna represent the only definite example found so far of an early type of chain pump.³¹ The remnants consist of lengths of the chain with parts of the leather valves in place and a few of the horseshoe-shaped sprockets, all of

which were found in a tool box. The chain links are S-shaped, and the eyes of each link are turned 90 degrees to one another (Fig. 22). Special links held the metal discs and the leathers of the valves together. A stirrup-shaped link with an expanded bottom formed one half of the valve, and an eye-bolt link (half of an S with a straight shaft at the other) formed the other half. One metal and several leather discs, forming the valve, were placed over the straight shaft of the eye-bolt link, which fit through a hole in the base of the stirrup. The end of the straight shaft was then flattened to secure the whole assembly. As the chain ascended, the stirrup link was above the leather discs.

This type of valve assembly was certainly strong, but it was also semi-permanent, as each valve assembly had to be taken apart for replacement of its leather discs, and then put back together again. Therefore, it was recommended that a second chain always be kept for each pump. While one was on the pump, the other could be repaired and/or have the leathers replaced. Two different tools might be used to do this. One was a fidd, or large marlinspike, which is a common maritime tool. The other was a "bolster," which was "a round piece of iron with a hole in the middle, and are for opening an Ess or hook when any want shifting." (Blanckley, 1750: 125) Since the chain fragments from the Santo Antonio were found stored

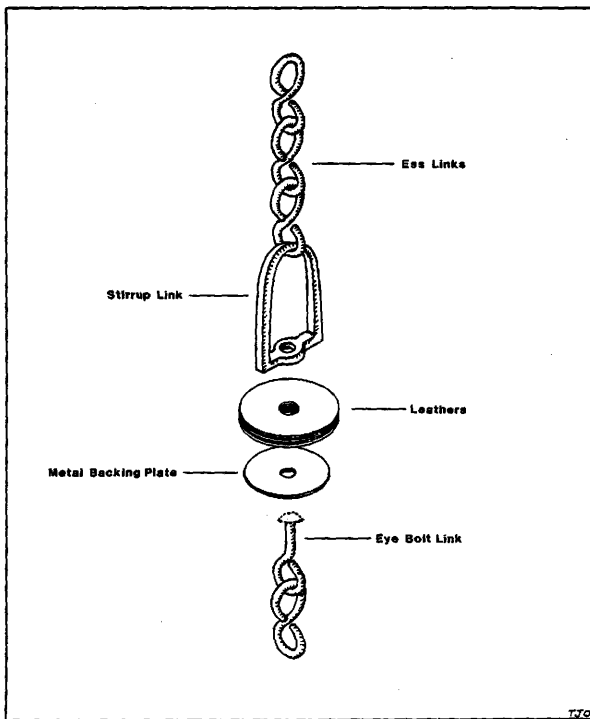


Figure 22. The chain and valve assembly of an early style chain pump. This assembly is representative of the Santo Ant3nio de Tanna's chain pump.

in a box and not loose in the pump well, they most likely represent a spare chain.

The two ends of the horseshoe sprockets are flared outward to catch the chain as it came up the tube (Fig. 23). If the sprockets caught the valves themselves or just the chain is not known.

No evidence was found for a chain pump seating anywhere in the bottom of the Santo Antônio. Two holes within the well for the seating of the suction pumps were the only openings in the ceiling planking.

Two wrought iron objects were recovered from the Revolutionary War wrecks in the York River during the 1930s. One was made of two four-spoked, rimless wheels. The four ends of one wheel were bent, threaded, and bolted through holes in the ends of the other four spokes. The other item looked like a bar link, with a hole at each end (John Sands, pers. com.).

The identification of these objects as chain pump parts is open to question. Their proveniences are unknown, and they cannot be associated with any one wreck. As we have seen, chain pumps were used almost exclusively on warships. They are not part of the Charon's pump, and the only other warship left on the bottom of the river is the Fowey, a 24-gun 6th-rate built in 1749 (College, 1969: 219). Because she was an old ship, she would have had an early style chain pump. Recent archaeological work on the

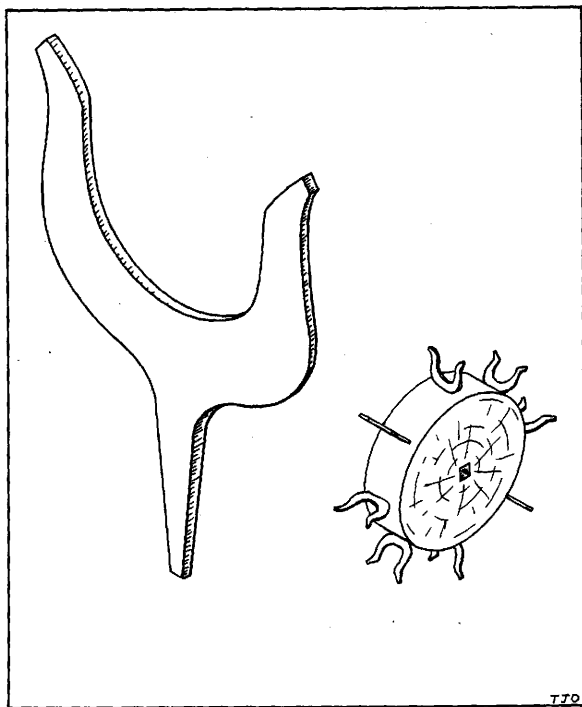


Figure 23. The sprocket and drive wheel of an early style chain pump. The Santo Antônio's chain pump was similarly constructed. The sprockets were of iron and the wheel was of wood.

Cornwallis Fleet by the State of Virginia has not produced any similar artifacts, nor any items identifiable as chain pump parts other than those from the Charon.

The Cole/Bentinck chain pump became the standard equipment on British warships of the late 18th century. The remains of a pump of this type were recently discovered during the excavation of HMS Charon. The Charon was the flagship of General Cornwallis' supply fleet and was sunk during the siege of Yorktown, Virginia in 1781.²²

The Charon's chain pumps were contained within the well, which also held the main mast step and the suction pumps. Two shot lockers, one afore and one abaft the well, shared common walls with it. The arrangement of shot lockers, mast step, and pumps was one of the features that aided in the identification of the wreck as the Charon (Steffy et al., 1982: 139).

The seating was a hole cut out of the sides of two adjacent frames. Planks placed at the fore and aft faces of this hole supported the round chamber (ascent tube), the back case (descent tube), and the cast iron roller or idler drum that guided the chain up the round chamber (Fig. 24). The lower support structure of the Charon's pump was set into the fabric of the hull, thereby strengthening the pumps and allowing them to remove more water since the ends of the tubes were lower. Falconer

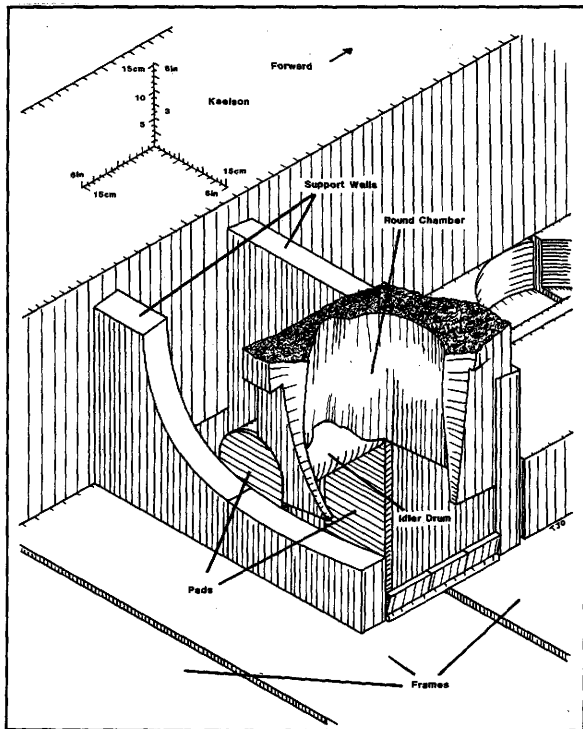


Figure 24. The seating of HMS Charon's chain pump. Boards fit into a hole cut into the frames and formed the support for the back case, round chamber, and idler drum. (Oertling, 1982: fig. 4)

(1780: pl. VIII) shows the entire lower assembly above the tops of the frames.

According to Davis (1929: 100-1), the chain loop passed over two drive wheels on the gun deck and, at the bottom of the ship, passed through a space between the keelson and the keel. A plan of the Raleigh (1776) shows a single drive wheel on the centerline of the ship (Chapelle, 1949; plan 3). The chain may have passed under the keelson in this vessel as described by Davis; however, paired pumps, one on either side of the keelson, were the standard arrangement.

The bottom 12ins of the round chamber, the outboard ascent tube, from the Charon's pump were preserved. Its inner diameter was ca. 7ins, and its base was cut to fit the supporting walls of the lower structure. Figure 21 shows that the round chamber was a bored tube that did not extend up to the cistern. The intervening section was made of plank. A division in the ascent tube on the Charon's plan must represent this (Ferguson, 1939: plan ff. fig. 13). Remnants of the back case show that it was a box made of vertical planks similar to that of the Victory's pumps (Longridge, 1955: pl. 10).

The basic design of the chain is the same as that illustrated in Figure 21, a single center link alternating with paired or double links, joined at each end by copper coated iron pins (Fig. 25). Cotter keys cut from a sheet

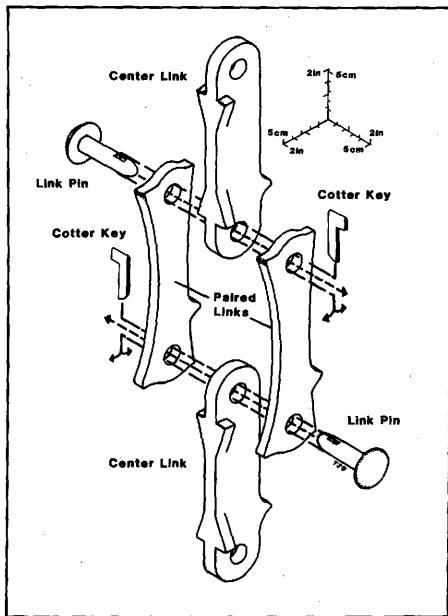


Figure 25. The chain assembly of HMS Charon's chain pump. Note the nipples on the inner edge of the links and the unusual triangular shapes on the outside of the center links. (Oertling, 1982: fig. 7)

of copper were inserted through slots in the end of each pin to secure the links. The pattern of the keys was that of a squat-T which was folded at the center to give an L-shape.

The construction of the chain was such that there was a definite inside and outside of the loop. A nipple extended out on the inside of each link near one end to engage the bars of the drive wheel and to prevent the chain from slipping, which is in keeping with the Cole/Bentinck design. On the Pomone's and the Victory's pumps, hooks replaced the nipples (Bugler, 1966: 79).

A feature of the Charon's chain which is not mentioned in any contemporary source was the arrangement of triangular extensions on the back edge of the center links and the corresponding projecting ends of the paired links. The bases of the triangles face the ends of each link and would have made contact with the projecting ends of the two outside links. Therefore, the chain could not bend inward as it came off of the drive wheel nor scrape and damage the inside of the tube or the valve leathers. Since the chain could bend only in one direction, it could not collapse down the tube, thus aiding in its recovery if it broke.

Another unique feature of the Charon's pump was the valves. Falconer (1780: 222) describes chain pump valves as ". . . two circular plates of iron with a piece of

leather between them . . ." which is similar to the Victory's (Longridge, 1955: pl. 10), the Pomone's, and the Santo Antônio's pumps (Bruce Thompson, pers. com.). The valves found on the Charon were short cylinders made of a cast metal, with a hole through the center (Fig. 26). A lip projected out from the bottom of the disc, and a band of stains could be seen on the outside face. A piece of leather would have been fastened here with its bottom resting on the lip.

The reason for the change of the valve assembly is unknown. Perhaps this design was an experiment to reduce the wear on the leather and to decrease the frequency of replacement. At any rate, it does not appear to have been successful, since this type of valve is not known from any other context. The spacing of the valves on the chain could not be determined in this example nor on the Santo Antônio's chain, but the valves on the Victory's chain were three feet apart (Bugler, 1966: 79).

According to Figure 21, the valve assembly sat upon a support ledge on the center link and was secured with a cotter key inserted through the link. On the Charon's pump, a center link (without a triangular extension at one end) passed through the hole in the valve cylinder. To secure the valve in place, two small bars covered the opening of the hole on either side of the link and provided a place on which a cotter key could bear (Fig.

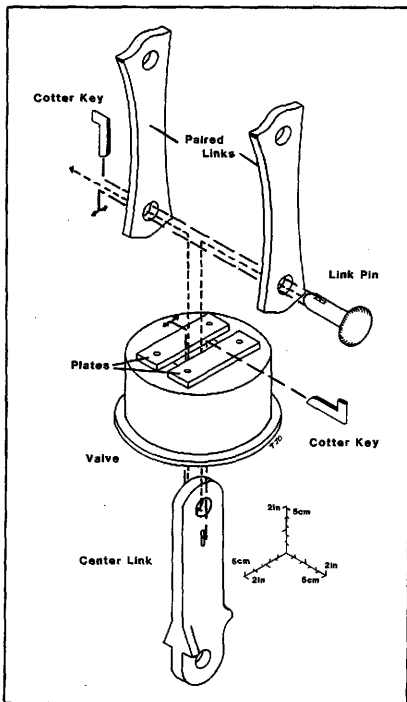


Figure 26. The valve assembly of HMS Charon's chain pump. This valve assembly is a marked departure from the standard valve design. A piece of leather was fastened around the outside of the valve body with the lower edge resting on the lip. (Oertling, 1982: fig. 12)

26).

Other artifacts which may have belonged to the pump were found in the well area. A curved piece of cast iron with a threaded hole in one side may have been part of the drive wheel. The remains of more copper-covered pins of different diameters and of longer lengths than those required for the link pins were found. These pins may have been used in the back case to hold the sides together and to hold the tube in place at its base. The panels of the back case were removable to facilitate clearing and repairing the pump.

The Cole/Bentinck pump became standard equipment in 1774 (Gardiner, 1976: 100), but by the time the Charon was launched, there were noticeable developments in the design of the chain. Wood at this time was still a very important material in the tubes and the lower structures. No evidence for metal sleeves in the tubes was found.

One of the most important features of the Cole/Bentinck chain pump was the ease and speed with which it could be repaired. The chain links were cast to the same size and were therefore interchangeable. Link pins were made to a standard length, since the widths of the links were constant. The valve cylinders or discs could be prepared ahead of time and kept ready. Cotter keys could be cut from a sheet of copper. Wooden parts could be fabricated by the ship's carpenter, and all these

stores would have been kept on board.

The Victory's and the Pomone's pump chains were the same type as the Charon's, but were different in shape (Fig. 27). The links were thinner and the nipples on the inside edge developed into hooks to catch the bars of the drive wheel. There were no projections on the sides or ends of the links. The Pomone's (built 1805) chain is made of bronze, which concurs with Falconer (1815: 360) who states that a Mr. Collins made that improvement to the pump. In addition, the pins joining the chain links were riveted, except for the ones joining the links holding the valves, which had the standard cotter key (Bingeman, pers. com.). The valves look like those described in Falconer--leather between metal discs. On the Victory, the round chamber was made up of short metal sections bolted together. The lower structure around the roller was also of metal, and the back case was made of boards (Longridge, 1955: pl. 10).

Chain pumps were in use in European ships for about 250 years. In that time significant changes occurred in design and materials. The Santo António's and the Cole/Bentinck type pump reveal two stages in the development of a carefully engineered and constructed machine, reflecting the technology of each period.

A variety of tools was used for repairing the pump: tongs, hooked poles, and counterweights (Oertling, 1982:

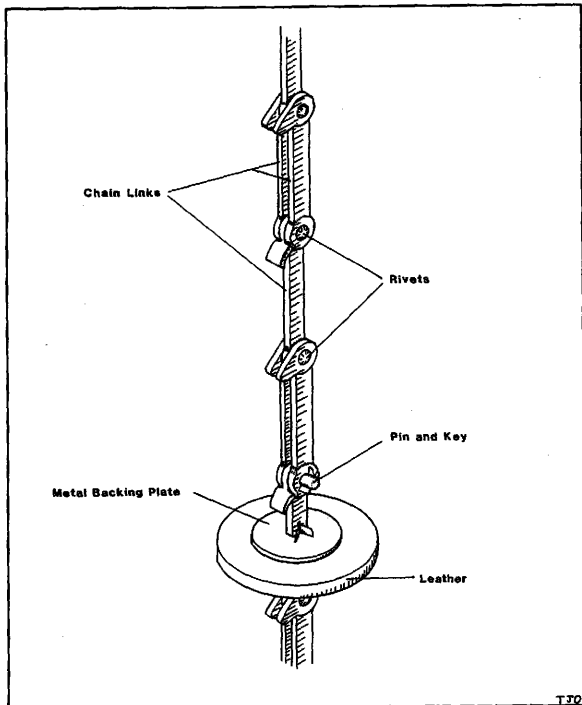


Figure 27. The chain and valve assembly of the Victory's and the Pomone's pumps. This is a generalization of the type of chain and valves used in the late 18th and 19th centuries. The links were of bronze.

fig 1). Directions for remounting the chain and maintenance of the pump are given in Falconer (1815: 360-1):

First, try if it [the chain] can be hooked in the pump; if it cannot, turn the chain gently back until it will go no farther; then you may be sure the end of it is down at the bottom of the pump. Ease off the back-case, by taking out the iron pins, haul out the chain, and put it aside; apply a hook-rod with the hooks toward you, and hook the end of the chain at the bottom of the pump: when you have it fast, let the men above put back the chain gently, to enable you to haul it up to the wheel, where the broken link is to be taken out and a new one put in. Observe always to put the stops or hooks of the new link in the same direction as those on the chain you join them to, overhaul the pump, examine the fore-locks, make all safe, put on the back-case, and the pump is ready to work.

It is strongly recommended to all persons who may have charge of a chain pump, to practise the method of recovering the end of the chain until they are expert in the performance of that operation, and putting in a new link.

In case the chain draws to one side of the wheel in working, raise the rhoding [bushing] on that side until you find it keeps an equal distance from the sides. To prove what water the pump loses in working, turn the winches with a velocity that will keep the water to the top of the pump, but without flowing over; observe how many revolutions per minute are required to do this, for so many are lost in that time.

The ironwork was to be covered with tar or varnish or, if those materials were not available, with tallow. By protecting the iron from corrosion in this way, its strength was preserved for a longer period (Falconer,

1815: 360).

The chain pump is an old machine which was used on ships by the ancients. Completely forgotten in the Middle Ages, the device was reintroduced from eastern Europe through Italy in the 15th century. The idea of using it on ships may have been brought from the Far East. By the last quarter of the 16th century, the English had it on their warships, and from that time it was used by most European navies except the French. The early type of the machine exemplified by the pump of the Santo António de Tanna, with its horseshoe-shaped sprockets and S-shaped chain links, was always subject to failure. Not until the late 18th century were chain pumps built with an adequate chain. The Cole/Bentinck pump, after some years of testing and development, became the standard pump for most British warships. Even after the Cole/Bentinck pump was accepted by the Admiralty, changes were made in the chain and valve assemblies, as shown by the Charon's pump, in apparent experiments to improve them. The chain pumps of the Victory and Pomone are most likely the final form of the pump.

CHAPTER VII

CONCLUSIONS

As ships sink, the rate of flow of water into the hull decreases. If at some point the rate of pumping and bailing will equal the water coming in, the ship will not sink. The rate of inflow of water varies proportionately with the depth of the leak below water and the its location fore or aft of midships. The location of a leak can be generalized by the differential amount of water a ship takes in between different tacks and between sailing and heaving to. Leaks could be found by listening for the vibrations of the water entering the ship through the planks. Once found, leaks were plugged with a variety of caulking media, up to and including raw beef and bags of oatmeal and rice.

Given effective leadership, the response of passengers and crew was often heroic, and many of the lives of those on board were saved. However, there were many cases where the stress created by a ship sinking reduced all on board to a state of panic. Pumps were important to ships, not only because they maintained the buoyancy of the hull, but also because they were often the last hope of preserving the lives of the passengers and crew.

Between the early 15th and mid-19th centuries, the machines used to rid water from ships changed in type and developed through improvements in design and materials.

Wooden tubes for all pumps were made by boring holes through the centers of solid logs. The logs, carefully chosen for straight grain, were fastened securely to a frame or platform and a small pilot hole was made, after which successively larger bits were used to widen the bore to the proper diameter. Wooden pump tubes continued to be made in this way well into the present century.

The burr pump was in general use in the early 16th century, but had fallen out of use by 1625. In this period the burr pump consisted of the tube, a large separate foot valve forming the base, and the rod and burr. With the pump tube set on top of the foot valve, the pump must have been difficult to repair. The existence of the burr pump was noted on three 16th-century wrecks and was denoted by the large hole for the foot valve in the mast step section of the keelson. Because of its simplicity of construction, the burr pump never completely disappeared. Examples have been found on ships of the 1860s. However, the pump was modified in that the separate foot valve was replaced in favor of a lower valve as in the common pump.

As the burr pump declined in popularity, the common pump was developing. With its first appearance in Italy

in the early 15th century, the common pump gradually became one of the more important hydraulic machines in Europe. When it was first used on ships is not known, but certainly by the last half of the 16th century common pumps were in general use. In one form or another they were used in all merchant ships into the 19th century and beyond.

As long as the upper and lower valves were made of wood, each kept its own basic shape. With the improvement of metallurgy in the 18th century, lead, copper, and bronze began to appear in ships' pumps. The use of iron did not generally occur until the 19th century. Between 1810 and 1830 the common pump had so improved that it had displaced the chain pump on smaller naval vessels and on some larger warships.

Many variations of the common pump were invented, but not all were successful nor were all of these used on ships. The more popular variations were Dodgeson's pump and different designs of multiple piston pumps. In conjunction with seacocks, common pumps could also supply seawater for washing decks and fighting fires.

Archaeological evidence shows that the chain pump was used on ships of the Romans and Byzantines. It disappeared in the Middle Ages and was reintroduced from eastern Europe. Possibly, the idea for using chain pumps on ships was brought from the Far East by early explorers.

The English were using the chain pump by in the last quarter of the 16th century. By the 18th century, all European countries, except France, were using chain pumps on their warships. In the last half of the 18th century, the English considerably improved this machine by redesigning the chain and drive wheel. Even after this time, modifications were made to the pumps in attempts to improve their performance. In the first decades of the 19th century, the chain pump was replaced in some warships by the common pump. Most likely, improvements in metallurgy had so increased the efficiency of the common pump that it was preferred over the chain pump. However, the chain pump was still being used in the mid-19th century.

By the nature of their construction, all wooden ships leaked to some extent. Therefore, a pump was a required piece of equipment on any vessel. Pumps are important because they reflect the economic and technological status of the time. Moreover, the fate of the ship and the lives of the passengers and crew often depended on these machines.

NOTES

1. Sails, rudder, and anchor would do little good if the ship is sinking for want of working bilge pumps. The case of HMS Centaur (1782) (Huntress, 1974: 66-77) and the Vrouw Maria (1771) (Ahlström, 1978: 66-7) serve to illustrate the point. In the former, the ship's carpenter was preoccupied with keeping all the pumps working, leaving no time to make repairs to the rigging and the rudder. The ship's fate was sealed when debris in the hold smashed the well and displaced the pumps. In the latter, the ship's anchor held, but the ship sank because the pumps failed to keep up with the rising water.

N.B. Unless otherwise stated, the date in parentheses after a ship's name refers to the year in which the ship sank.

2. With the help of many people I have collected information on a number of examples from excavations, salvage projects, and museum and state collections. These range from the burr pump on the Basque whaler San Juan at Parks Canada, Ottawa, to the bronze pump tubes of the USS Cumberland (launched 1842, sunk 1862) and USS Hartford (the tubes are dated 1858) at the Mariners Museum, Newport News, Va.

3. It was disappointing to learn that in 1836 the U.S. Patent Office in Washington, D.C., burned to the ground with the loss of all of the country's patents. A program was instituted at that time to collect copies from the patentees, but only a fraction of the original number was turned in.

An index of the original holdings of the U.S. Patent Office before the fire listed four patents for ships' pumps, dated 1779, 1801, 1811, and 1829 (Legget, 1874). The Franklin Institute in Philadelphia houses many patents from the 18th and 19th centuries, but had none on ships' pumps.

4. For example, assuming that there are holes of equal size in the hull of a ship, the proportional rate of flow of water is equal to the square root of the depth of the hole below the waterline. That is, a hole 16 feet below the waterline leaks water four times faster than a hole one foot below the waterline. Once the water within the hull covers the hole, the rate of flow equals the square root of the distance between the water inside the hull and the waterline.

5. On the São Thomé (1589), the crew plugged a severe leak with sacks of rice and placed a chest on top

of them to weight the patch against the force of the water (Boxer, 1959: 55-6). Apparently, raw beef was not an unusual caulking medium, since it was used thus on an early voyage to the American colonies (Wright, 1964: 9). After several weeks or months in the cask, the properties of salt beef were most likely more conducive to filling planking seams than men's stomachs.

6. Lead strips were found on the ships of the 1554 Fleet, Padre Island, Tx. Lead strips were in place on the keel section of one of the ships. The lead was a form of caulking, having been nailed over a caulked seam and having a layer of cloth beneath it (Arnold and Weddle, 1978: 223, 261).

7. Elm water mains were uncovered in London in the 1930s. They were still in good condition although they had lain buried for over 300 years. In 1770, pine tubes were used for a water scheme for London (Edlin, 1949: 56, 126). The pump tube from the privateer Defence, sunk near Castine, Me. in 1779, is believed to be made of pine (Steve Brookes, pers. com.).

8. See Horsley (1978: 225-6) for methods of marking out and shaping masts and spars. These were probably the same methods used by pumpmakers to give ships' tubes an octagonal cross section. Land pumps in the Mercer Museum, Doylestown, Pa., and in the Pump Museum, Saco, Me., have square sections. The bottoms of the two pumps from the El Constante (1766) are the only examples known to the author of asymmetrical cross sections (Pearson, 1981, 20-1 and fig. 10). Their shape is most likely a product of the way in which they were seated.

9. Accounts for the building of the Frigate Essex (built 1798-9) show that copper dogs were specially made for the boring of the ship's pumps (Smith, 1974: 211-212). One of the problems encountered in my research was the inability to determine whether the term "copper" actually meant bronze. The dogs for the Essex would have been much stronger had they been made of bronze rather than copper.

10. In shipwrecks which do have some portion of the fabric of the ship preserved, it is normally the very bottom of the hull which remains. The upper part of the ship, along with most of the pump tube, brake handle, and pump rod, is lost through natural decay processes. Examples of where only the bottom of the tubes were left include: HMS Charon, the El Constante, and the Defence.

11. AUS; RG45, AF Box #62: Com. John Rodgers, letter to James Strong, Sept. 1834.

12. The spear of a small burr pump in the collection at Parks Canada was in use until recently. It has a short staff, about three feet long, with a piece of leather wrapped around it to form a cone at one end and a dowel put through a hole in the other as a handle. A story was also related to me of a pump made from a piece of PVC tube and a trimmed mop which is similar in concept to the San Juan's pump (Zacharchuk, pers. com.).

13. Part of a pump tube was found on Find V, a 16 m long boat of ca. 1500, in the harbor of Kalmar, Sweden. It was reconstructed as a force pump requiring a base containing the valves and a second tube that acted as an effluent tube (Akerlund, 1951: 153 and pl. 16d). This shows that the ancient force pump was still in use in this time and the common pump had probably not yet appeared in this region.

14. A pump needs to be primed when there is no column of water in the tube. Water is poured down the pump to cover the lower valve, thus sealing it to air. As the piston works, the air is slowly drawn out from below the lower valve, and the water is raised because of the differential pressure inside and outside of the tube.

15. Comparison of the pump valves from the Machault (1760); Defence (1779); San Jose (1733); the Pump Museum, Saco, Me.; and the Mercer Museum, Doylestown, Pa., show them to be identical in form to those illustrated in O'Sullivan (1969: figs. 7-12).

16. An example of this type of valve from the Machault is in the Parks Canada collection, artifact #2M2 B2-14.

17. Coastal Environments, Inc., artifact #16CM 112-1186.

18. The two objects were recovered at different times. The first was found by Caribbean Ventures, Inc.; the second was discovered by the Institute of Nautical Archaeology (MRW #598).

19. Photographs of this object were shown to Ivor Noël Hume and William Kelso, who both substantiated the author's opinion that it was a pump valve.

20. This is possibly the pump Fernández Duro (1895: 327) refers to when he says that the Spanish invented copper pumps in the first half of the 16th century.

21. This section of the Pandora's pump is thought to

have been the lower end of the tube (Henderson, pers. com.). However, compared to the Hartford's and the Cumberland's pumps, it must have been the piston cylinder. Also, the increasing use of copper cylinders was pointed out by Henderson (1980: 240).

22. The diameters of the bronze valves will vary from pump to pump. The Cumberland's valve was 22.1 cm; the inner diameter of the Pandora's tube was 17 cm. These valves are all much larger than the 9-12 cm diameter wooden valves.

Two bronze valves were recovered by Seaborne Ventures, Inc., of Miami from a wreck somewhere near the island of Dominica (Voynick, 1980: 69). Since the article was written, the company has either disbanded or moved its operations. Letters sent to the company's Miami address were returned by the postal service. Therefore, no further information on the date or nationality of the wreck could be obtained.

23. One of the problems with relying on patents is that a bad invention can be issued a patent as easily as a good one. Also, many of the pumps patented under a normal "pump" classification could be adapted for maritime use.

24. It should be noted that the Tribune, a 36-gun 5th-rate, was originally a French ship captured by the British in 1796 and taken into the British Navy. She was wrecked on Thrum Shoals, Halifax, in 1797 (College, 1969: 569). Although she was probably refitted by the English, it cannot be certain that this pump is English rather than French, since no markings were found anywhere on the object.

25. A modification of the Stone/Depthford pump was patented by Blundell and Holmes in 1876. It provided easier access to the valves for maintenance (Björling, 1890: 137).

26. Bugler does not seem very certain of this statement. Such an arrangement would have involved making a hole through more than of foot of oak frame and planking and piercing the copper sheathing without permitting leaks. Although this was done with stopcocks at the sides of ships, the water pressure against the bottom of the hull at this spot would have been considerable, and leaks would have been likely to develop here.

27. The loss of HMS Royal George (1782) occurred while repair crews were fixing such a stopcock (Barnaby, 1968: 1-2). The French also used stopcocks to let seawater into ships (Boudriot, 1974: 152).

28. Manwayring uses the word "barres" instead of burrs as Boteler does, but they are referring to the same thing.

29. See Howard (1979) for a selection of warship plans of the 18th century. It can be noted that the Swedish warship Vasa (1628) did not carry a chain pump (Ohrelius, 1962).

30. The Pomone was built in 1805 and wrecked on the Needles, Isle of Wight, in 1811 (John Bingeman, pers. com.). There are other British warships for which excavations are underway or being planned which may produce parts of chain pumps. These are: HMS Pandora, a 24-gun 6th-rate, built 1779, wrecked 1791 on the Great Barrier Reef; and a British warship wrecked on Goodwin Sands, Kent, England, in 1703. This latter wreck could be any of three 3rd-rate 70-gun ships: HMS Stirling Castle, HMS Northumberland, or HMS Restoration.

31. Information on this pump and the permission to use it in this thesis were kindly provided by Robin Piercy. Alison Darroch, Manuela Lloyd, and Bruce Thompson brought the information from Africa and provided additional descriptions of the artifacts.

32. The ships that were sunk in the York River during the siege have been the subject of continuing research by the state of Virginia (Broadwater, 1980). In the summer of 1980, Texas A&M University, in conjunction with the Virginia Research Center for Archaeology, conducted an underwater project on the wreck designated G1-136, which was identified through this work as the Charon (Steffy et al., 1982). The Charon's chain pump was described in detail in an article by the author (Oertling, 1982: 113-24).

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APPENDIX A

PUMPS AND PUMP PARTS IN MUSEUMS AND COLLECTIONS

Coastal Environments, Inc., Baton Rouge, La.
El Constante (1766)
 lower end of pump tube with sieve 16CM112-129
 " " " " " " 16CM112-1367
 extra lead sieve 16CM112-1186

Division of Archives, History, and Records Management,
 Tallahassee, Fla.
San Jose (1733)
 lead pump with bronze valve L3893
 wooden lower valves L3900 and
 two others

Maine State Museum, Augusta, Me.
Defence (1779)
 lower valve fragment HR178-1-76
 lower end of pump tube HR178-1-229

Mariners Museum, Newport News, Va.
 USS Cumberland (1862)*
 bronze valve with claque NA
 bronze tube with lower valve body NA

Yorktown Wreck (1781)
 three sections of lead pump tubes RS 2 and 3

from St. Thomas, B.W.I.
 two lead pumps with copper piston
 cylinders RS 6 and 7

The Mercer Museum, Doylestown, Pa.
 numerous sets of auger bits
 several auger shafts
 iron dogs
 several pumps from the 19th c.

*Since the time the author viewed the pump tube from the Cumberland, all of the artifacts recovered from this wreck, as well as from the CSS Virginia and the CSS Florida have been turned over to the Portsmouth Naval Museum, Portsmouth, Va.

Parks Canada, Ottawa, Ontario

The Louisberg Wreck (mid-18th c.)

bronze corps des fonte

74-2776-1B

bronze piston valve

76-1459-1b

HMS Tribune (1797)

bronze double piston assembly

NA

Machault (1760)

wooden lower valve

2M2 A3-8

" " "

2M99 A5-227

" " "

2M2 B2-14

" upper "

2M2 C2-4

" " "

2M5 C1-83

" " "

2M3 B3-55

lead sieve, box-like

2M9 A5-10

" " sheet

2M99 A1-31

three wooden pump tubes

NA

The Saco Pump Museum, Saco, Me.

auger bits, auger shafts,

several pumps from the

18th and 19th centuries

wood and iron pump valves

Virginia Research Center for Archaeology

HMS Charon (1781)

numerous elements of the chain pump

including chain, copper pins, cotter

keys, the lower part of the back

case, valves, parts of the

idler drum, and the lower

part of a common pump tube

APPENDIX B

LETTERS OF PERMISSION



FLORIDA DEPARTMENT OF STATE

George Firestone
Secretary of StateDIVISION OF ARCHIVES,
HISTORY AND RECORDS MANAGEMENT
The Capitol, Tallahassee, Florida 32301
(904) 488-1480

February 10, 1983

Mr. Thomas J. Certling
P.O. Box 1426
College Station, TX 77841

Dear Mr. Certling:

There will be no problems for you using the photos of the pump. They will have to be credited to the Florida Department of State, Division of Archives, History and Records Management.

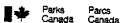
Secondly, we have no knowledge of the files you mentioned concerning J.J. Bezrier Jr. dated 1-21-71. If you know that Roger Smith got the files from us, then they can be credited the same way as the photos.

Sorry I couldn't be of more help.

Sincerely,

James Levy
Assistant Historic Conservator

JL/mrl



Tom Oertling,
P.O. Box 1426,
College Station,
Texas, U.S.A.
77841

Dear Tom:

1600 Liverpool Court,
OTTAWA, Ontario K1A 1G2
December 30, 1982

Your file: 1000-100000

Our file: 1000-100000


-- As requested I am sending you photos of the double piston from the Tribune (we have not located the artifact).

As for the photos of the Basque artifacts I have not had a reply from Mr. Robert Grenier as yet, however, if he is in agreement I will forward them to you. The screen or sieve # is 2M19A5-10. There is no problem in publishing the photos as long as the Department and Parks Canada get credit.

I am glad to hear that your trip was successful and research material bountiful it is too bad about the money.

Best wishes of the season.

Yours sincerely,


Walter Zacharchuk,
Head, Underwater Liaison,
Archaeological Research Division,
National Historic Parks
and Sites Branch,
Parks Canada.

Encl.

NATIONAL MARITIME MUSEUM

- NMM 22

APPLICATION TO REPRODUCE PHOTOGRAPHS

INSTRUCTIONS

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- If the application is approved, authorisation will be completed on both copies, of which one will be returned to the applicant with an invoice, the second being retained in the Museum for record purposes.
- No receipt will be sent unless requested.
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Permission is requested by: Thomas J. Oertling(Address) P.O. Box 1426, College Station, Texas USA 77841Tel. No. (713) 845-6398 Ext. _____to reproduce the undermentioned photographs in the publication/television programme entitled The History and Development of Ships' Bilge Pumps, 1500-1840. (A thesis for a Master of Arts Degree.)

Artist or Reference	Subject	Monochrome (M) or Colour (C)
All from Ships Plans Collections: Ships Fittings: List 3.		
6562	Bentinck and Coles Chain Pump ca 1800	M
7605	Wash deck pump for a 74 1825	M
7612	Dodgeason's patent ship's pump 1800	M
7643	Lead piping and pumps for a 74 gun ship 1807	M
SPECIAL ATTENTION IS DRAWN TO THE CONDITIONS OF NMM.A. IN PARTICULAR PARAS 11 & 13.		
ACKNOWLEDGEMENTS: SEE OVERLEAF		
The photograph entitled _____ is to be used on the cover and/or dust jacket.		

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Signed <u>J. Moore</u>	Date <u>7.1.83</u>
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Charge: <u>NO FEE</u>	Manuscript Number
<u>Sluiter Thesis</u>	

VITA

Thomas J. Oertling was born in New Orleans, La. to Sewall J. and Lillian Trolicht Oertling on December 2, 1954. He enrolled at Tulane University in New Orleans in the spring of 1975 and graduated in May, 1977 with a Bachelor of Science degree in Anthropology. In 1978 he worked consecutively for the Institute for New World Research and for New World Research, Inc. as a laboratory technician and field crewman. In the spring of 1979, he entered Texas A&M University as a Master's degree candidate in Anthropology, specializing in Nautical Archaeology. His special interest is in ship construction of the post medieval period.

Fall, 1983. Diver/Archaeologist for the State of Virginia on the Yorktown Shipwreck Project, the excavation of the shipwreck site YO-88. Virginia Research Center for Archaeology, Yorktown, Virginia.

July 2-Aug 14, 1983. Visitor on the fourth season of the Red Bay Archaeological Project--the excavation of the Basque Whaler San Juan. Parks Canada, Red Bay, Labrador.

April-May, 1982. Archaeologist on Molasses Reef Shipwreck Excavation, 1st phase. Institute of Nautical Archaeology, Turks and Caicos Islands, B.W.I.

July-August, 1981. Member of TAMU graduate fieldschool in Port Royal, Jamaica.

July-August, 1980. Member of TAMU graduate field school at Yorktown, Va. HMS Charon Project.

July-August, 1979. Volunteer on the Yorktown shipwreck project. Virginia Research Center for Archaeology, Yorktown, Va.

Permanent address: 5722 Danneel St., New Orleans, La. 70115.