

THE HISTORY AND DEVELOPMENT OF ENGLISH ANCHORS

CA. 1550 TO 1850

A Thesis

by

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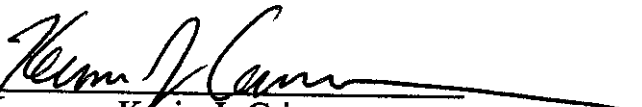
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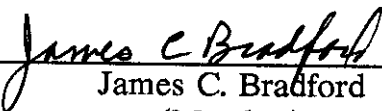
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ABSTRACT

The History and Development of English Anchors

ca. 1550 to 1850. (May 1993)

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This thesis examines the history and development of the English Admiralty pattern anchor, from ca. 1550 to 1850. The anchor is not necessarily the most essential piece of equipment onboard a vessel, but it is certainly a standard implement of extreme importance. Mariners take the anchor for granted, landlubbers seldom give it a thought, and yet the anchor has become the very symbol of the sea.

Before the beginning of the 16th century, the basic design of the anchor had been fully developed. Little or no gross modification was attained during the following two hundred years, apart from the general increase in anchor size and some minor manufacturing techniques. In the middle of the 19th century, with the increases in the knowledge of iron technology, there were radical changes in the design of anchors. These anchors were different in their design, being stockless anchors made of cast iron, instead of the earlier wrought iron anchors.

This thesis examines the small changes that the anchor underwent, in an attempt to help other researchers date and identify a specific anchor's heritage. The parts of the anchor are described, as well as the terminology involved in anchoring a vessel. The number, weight, and size of anchors for the various sizes of vessels are listed for the time periods.

DEDICATION

To my loving parents, Dick and Bettie Jobling, for their continuous encouragement and unstinting support in allowing me to follow my dreams in underwater archaeology.

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INTRODUCTION

Ever since man first took to the water in some form of primitive craft, he has found it necessary at one time or another to steady the vessel in a fixed position. This could be for any number of reasons; to avoid the river current or sea tideway, to hold the vessel in a sheltered anchorage whilst working the cargo, or to prevent the vessel from being wrecked on a lee shore.

An anchor is basically a large and heavy device that will hold the vessel in a desired locality, preventing her from drifting at the mercy of the elements. This is achieved when the anchor is lowered by its connecting cable to the bottom, where it creates sufficient frictional resistance to prevent the vessel from drifting away. From this, one can see that the anchor is obviously an implement of extreme importance to the navigator. Mariners take it for granted and landlubbers seldom give it a thought, and yet the anchor has become the very symbol of the sea.

The earliest anchors were probably large stones, or baskets and/or bags filled with stones. The term "killick", nowadays, denotes a simple stone anchor attached to a rope. It is also a slang term for any type of small anchor. As time progressed, more effective anchors were developed as the vessels became larger, and required a greater holding ability. Ancient stone anchors recovered from

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the Mediterranean were simple stone weights, pierced with a single hole for the rope. Later examples took the form of large flat stones, usually triangular in shape, with two holes for wooden stakes at the base and a rope hole at the apex. The stone provided the weight and inertia; the stakes the ability to embed and resist movement. By enclosing a stone in a wooden frame with projecting wooden teeth, additional ploughing action was achieved, which improved the overall holding power of the anchor. It was probably also discovered early on that the length of the rope was a factor in the holding power of the anchor. Experience has shown that a length of rope, three to five times the depth of water in which the craft is moored should be used in order to maximize the frictional effects of the anchor. The weight and type of anchor, used in conjunction with the length of rope, all affect the holding capacity of the anchor.

From killicks, it was a natural progression to wooden anchors with stone and later lead stocks. Another improvement was the use of metal teeth on the wooden anchor arms, which increased the ease of penetration into the sea bottom and hence the holding capacity. These metal tips (teeth, hooks or sheaths) should not be confused with flukes, a later invention.

The one-hooked (armed) anchor soon progressed into the double or two-armed anchor, as its advantages were realized. From this form, it was only a matter of time before anchors were constructed of iron. The basic design, with the long vertical stem (shank), two arms, and a cross bar (stock) set at right angles to the plane of the arms, has changed little over the centuries and is still

being used today. Within the basic design, however, anchors reflect the changes that took place in the economic, technological and social conditions of the seafaring nation that created them.

HISTORY OF EARLY ANCHORS

Historians have commented that the designer of such an important invention as the anchor always deserves note. From early times the origin of the anchor has been attributed to numerous people and the story is worthy of mention. The ancient Greeks used anchors made of stone, according to Apollonius Rhodius and Stephen of Byzantium. Stone anchors were known to Homeric Greeks as *eunai*, or beds, because of their flat shape and mode of lying on the seabed. Athenaeus states that later anchors were sometimes made of wood. With the introduction of iron hooks or teeth on the arms, the word *dentes* was used by the Greeks to describe anchors. The invention of these teeth was ascribed by Pliny the Elder (A.D. 23-79) in his *Natural History*, to the Etrurians (Rackham, 1945: 410). Pliny also reports that anchors were originally invented by Eupalamus of Sicyonia and that a second arm was added shortly thereafter by Anacharsis (ca. 590 B.C.). Pausanius (ca. 2nd century A.D.), in his *Description of Greece*, gives the credit to Midas (ca. 8th century B.C.), son of Gordius, who was king of Phrygia and built the city of Ancyra (Moll, 1927: 295). Pausanius goes on to say that the anchor, founded by Midas, was still to be seen in the Temple of Zeus during his time! Strabo (late 1st century B.C. to the early

1st century A.D.) wrote in his *Geography of Inventions* (Jones, 1924: 206-207), that Anacharsis, the Scythian philosopher, was the inventor of the grapnel and that Trynhonus (ca. 410 B.C.) invented the anchor. Ephoros (ca. 400-340 B.C.) commented on Anacharsis, calling him one of the seven wise men! Pliny also records that cork was fastened to anchor buoy ropes tied to the anchor rope to mark the anchor's position (Rackham, 1945: 410-411). This system, using a cork marker and rope, could be employed to free anchors that were stuck on the seabed, or to recover anchors after the anchor rope had broken. Herodotus (ca. 484-424 B.C.), in his *History of the World* (Godley, 1924: 246-247) makes the earliest recorded reference to iron anchors, when he states that wood and iron anchors were used simultaneously at first. One could no doubt assert that stone anchors were also in use at the same time. Athenaeus mentions them together on Hieron of Syracuse's large 5rd-century B.C. vessel, the *Siracusia*, which was equipped with eight iron anchors and four wooden ones (Gulik, 1957: 440-441).

As advances were made in the technology of working iron, so do references alluding to the use of iron chains for mooring anchors. Originally, rope was used for an anchor cable, but it does have numerous limitations. One of the earliest mentions of anchor chains is in Strabo's *Geography of the World*. He describes Alexander the Great's ships at the siege of Tyre (332 B.C.), which were anchored with iron chains as the Tyrian divers cut the ropes. Frost (1963a: 59) mentions this and goes on to say that there are a number of these misleading texts, including that written by Philo of Byzantium (ca. 30 B.C. - A.D. 45) who

states in his *Veterum Mathematicarum apex* that chains were introduced as a result of the Tyrian divers cutting the Greek vessel anchor ropes in 332 B.C. The deductions may have been logical, but these writers were working several hundred years later, and they may have been wishful thinkers!

A more persuasive argument for iron anchor chains appears in Julius Caesar's *De Bello Gallico*. Caesar (ca. 100-44 B.C.) compared the performance of Roman vessels with those of the Venetii, a tribe living in northwest France in the 1st century B.C. Caesar was not a sailor, but he does give us one definite and valuable statement on anchors: "*anchorae, pro funibus, ferreis catenis revinctae*"--the anchors fastened to iron chains, instead of ropes (Cunnington, 1884: 118). One can easily infer from this that Caesar's Roman vessels in 56 B.C. were using rope cables, and that anchor chain was a northern adaption that was new to the Romans.

The word anchor as we know it today first appeared in the 7th-century B.C. Greek language as *agkura* meaning bent, curved or hooked. The later Latin word *anchora* means bent. The Romans made more specific references to anchors. Virgil (ca. 70-19 B.C.), in his *Aeneid* (Lewis, 1953, book 1, line 169), refers to the arms and even entire anchors as "hooks".

Every ship carried several anchors, the largest of which was used only in extreme danger. Hence, it was often termed *sacra*, or sacred, from which comes the old proverb, "*sacram anchoram salvere*"--as flying to the best refuge.

There are also references to anchors in *The Bible*. The account of St. Paul's shipwreck in the Acts of the Apostles (27:28-30) indicates that the vessel carried at least six anchors. The anchor has also been a symbol of steadfastness, security, hope, and salvation to Christians through the ages. St. Paul writes, "*which hope we have as an anchor of the soul, both sure and steadfast*" (Hebrews 6:19). The first pope, Clemens Alexandrinus, was drowned by the Romans with an anchor tied to his neck. Clemens encouraged his fellow Christians to wear a ring with the engraving of the Seleucus seaman's anchor as a symbol of their faith. Clemens Alexandrinus later became the Patron Saint of the anchor smiths, who had their holiday (holy-day!) on the 23rd of November. Four other Christian saints lost their lives in the same manner.

ARCHAEOLOGICAL EVIDENCE FOR EARLY ANCHORS

Stone Anchors

Archaeological evidence has substantiated many early historical references regarding anchors that were originally taken with a grain of salt. For instance, the ancient Egyptians used stone anchors on the Nile. A bas-relief from the tomb of King Sahu-re at Abusir, ca. 3000 B.C., shows shaped stones with a hole for tying the rope (Upham, 1983: 4). An early Phoenician anchor of ca. 1900 B.C. from the Temple of Obelisks in Byblos, Lebanon, is a shaped limestone block that was dressed using a hammer and chisel (Upham, 1983: 5). This type of anchor was adapted for use on a sandy bottom, with grooves in the stone at

the top of the anchor next to the mooring rope hole. This would have prevented the rope from being abraded when the anchor was dragged across the seabed.

Stone anchors went through an evolution of their own. Refinements included: holes for wooden stakes in composite stone anchors; grooves in the anchor top for the mooring rope; and notches in the base to attach a buoy line to retrieve the anchor when it was lost or wedged between rocks (Haldane, 1990: 19). Honor Frost (1970: 55-61) used these notches, inscriptions and other details to identify stone anchors by nationality, Egyptian, Byblian, and Ugaritic.

Recently some 23 Ugaritic stone anchors were found on the Late Bronze Age shipwreck at Ulu Burun, near Kaş in Turkey. The dimensions are not known for these Ulu Burun weight anchors, as they have yet to be measured and studied (Pulak, pers. comm.). Haldane (1990: 20) has suggested that these early sailors probably used several stone anchors simultaneously to moor their ships.

Wooden Anchors

During the 7th century B.C. there was a dramatic change in anchor shape: stone anchor stocks were now being used with wooden anchors. These stone stocks would lie flat on the sea bed and force a wooden anchor arm to dig into the bottom sediment.

Kapitän (1984: 33-44) describes the evolution of these stone anchor stocks into the various types of lead anchor stocks--all fitted on wooden anchors. Four types of stocks have been identified: stone stocks (Type I), wooden stocks with

lead cores (Type II), lead stocks (Type III), and removable lead stocks (Type IV).

Haldane (1990: 22) mentions that in general, the Greeks used stone-stocked anchors (Type I), whereas the Romans used a solid lead stock (Type III). Types II and IV were transitional stocks. The Type II stock represents a shift from stone to lead stocks, and Type IV marks a more drastic evolution from wooden anchors to iron anchors. Both of these transitional types were products of historical and technological developments.

An example of an early wooden anchor with a lead stock (Type IIA) was found at Ma'agan Michael, in Israel (Rosloff, 1991: 223-226). This one-armed anchor was found lying arm down next to a small merchant vessel (ca. 400 B.C.). The anchor displays a number of interesting features that confirm the historical record. The anchor's head, shank, crown, and arm were all carved from a single crotch timber 1.89 m long and 8 cm thick. The wooden stock, 1.55 m long, 14 cm wide, and 11 cm thick, was hollowed out to hold two lead weights each weighing about 22 kg. On the tip of the wooden arm was a copper reinforcing "tooth" held in place by three iron nails. The anchor survived with the remains of a three-strand left-hand laid mooring rope and a portion of the tripping rope. The latter was looped around the crotch of the hook and tied to the crown with a simple half-hitch knot.

On a small ring seal of ca. 500 B.C., from the Phoenician colony of Tharros on Sardinia, one can see a shipwright doing the final shaping of a two-

armed wooden anchor (DeVries, 1972: 49). What is also of interest is that the depiction includes what looks like an anchor chain attached to the anchor, which also surrounds the entire scene. Another stocked two-armed wooden anchor is depicted on a Greek coin of ca. 400 B.C., attributed to Apollonia Pontica in Thrace (DeVries, 1972: 49). The anchor has both a mooring ring and a crown ring; the latter would have been used to attach a tripping rope to the anchor-buoy line.

Iron Anchors

In 1930, two Roman anchors were found in Lake Nemi, Italy (Speziale, 1931: 300-320). They date to ca. A.D. 40 and were used on two of Emperor Caligula's state barges. One is of particular interest here, as it is an iron-stocked, iron anchor with crown and shank mooring rings (Fig. 1); a length of mooring rope was still attached. The movable iron stock, also with a ring, was locked in position on the shank by a cotter pin or key. The entire anchor was sheathed in wood, which increased the load bearing surface; this would have helped prevent the anchor from sinking into the soft sediments of the lake. The dimensions of the iron anchor are as follows: shank 3.6 m; stock 3.0 m; arms 1.4 m on each side of the shank; width of shank 12 cm. The weight of the anchor (MCCIXXV) was stamped on one of the arms--1275 Roman pounds, approximately 414 kg or 912 lbs. This was an extremely large anchor for the time period. It was made up of four blooms welded together, one for the stock and one each for the shank

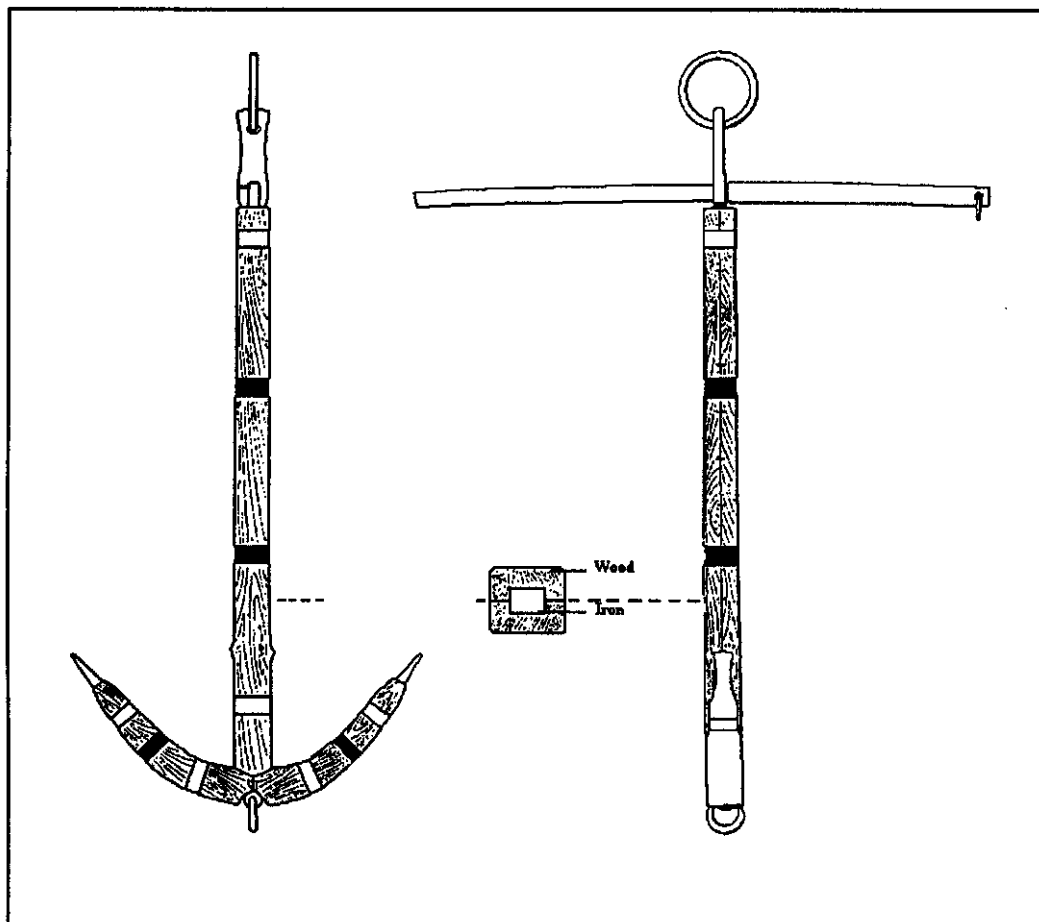


Figure 1. Nemi anchor (after Speziale, 1931: 314).

and two arms. The curved sections of the arms were well proportioned and symmetrical in shape. The second Nemi anchor was a lead-stocked wooden anchor; iron teeth were fitted to the tips of the arms to strengthen them.

The Pompeii anchor found in 1857, and dating to A.D. 79, is another iron-stocked anchor (Fig. 2) (Ucelli, 1950: 239-241). This 4½-foot-long anchor displays the partial remains of a crown ring hole and is very similar to the Nemi anchor in design. The oldest known iron anchor comes from the island of Monte Christo off Italy, and dates to the end of the 4th and the beginning of the 3rd century B.C. (Gianfrotta & Pomey, 1981: 306). All that remains of this anchor is a hollow concretion, as the iron has corroded away. Another early Roman iron-stocked anchor comes from the Roman wreck off La Ciotat (Benoît, 1958: 25), and is now in the Boreli Museum in Marseilles. Only the flukes, arms and parts of the shank with bits of the rings were preserved. A cast was made from the concretion mold, so some of its dimensions are known. This anchor, along with the Pompeii and Nemi anchors, had protruding bumps on the lower shank to prevent the wooden sheathing from slipping up and down the shank. Two other wooden-sheathed iron anchors were found in the Herault River, near the port of Agde in the south of France (Frost, 1963b: 19). These heavily concreted anchors were well preserved, and are similar in design to the iron-stocked Nemi anchor.

In 1972, three iron anchors were found on the Dramont D wreck, near Cape Dramont in the south of France (Joncheray, 1975a: 5-18). They were

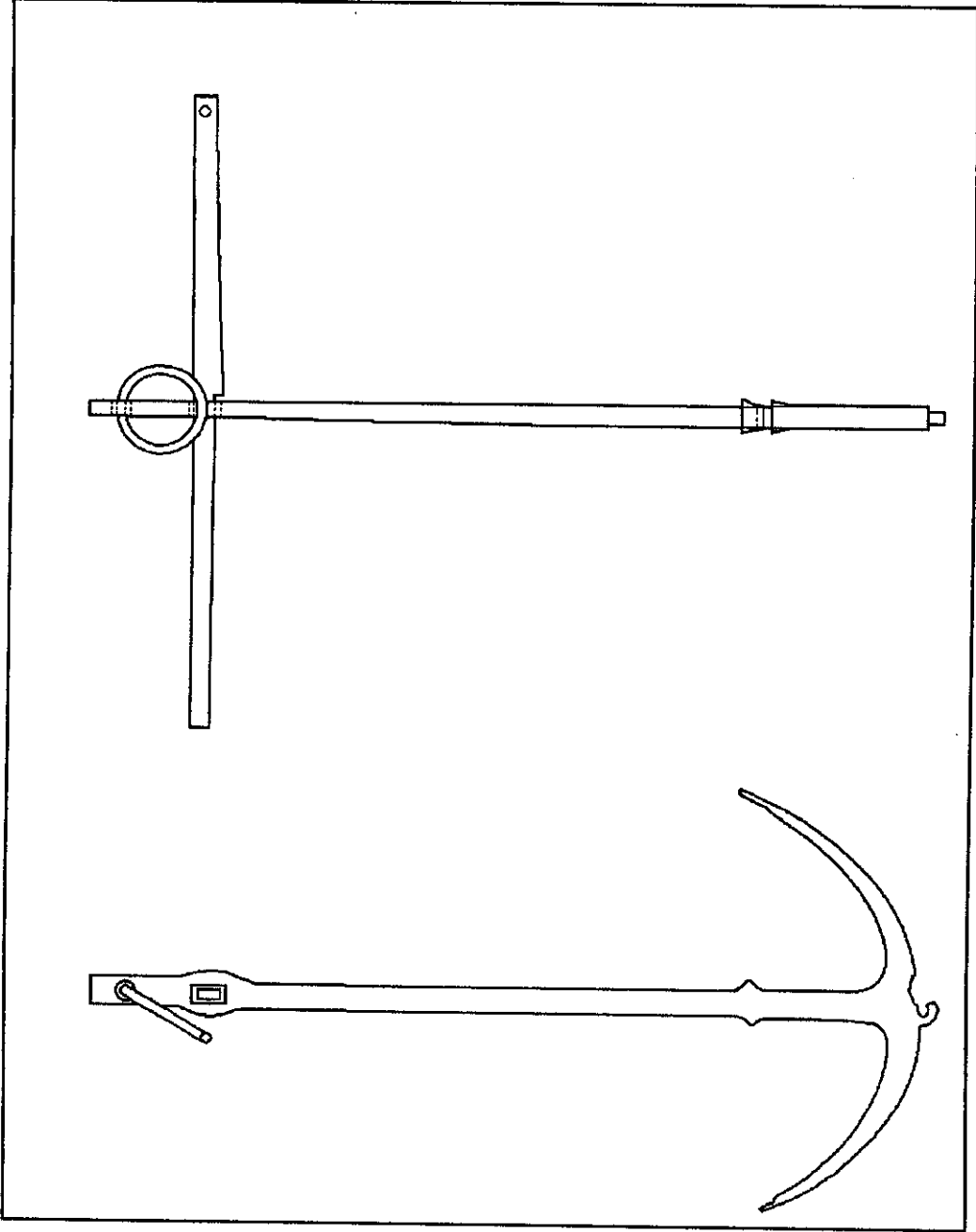


Figure 2. Pompeii anchor (after Ucelli, 1950: 239).

found complete with their rectangular-sectioned iron stocks, and range in length from 1.85 m to 2.17 m and from 1.00 m to 1.06 m in beam (width). The arms are initially set at an obtuse angle to the shank, but at their mid-point they angle sharply to run parallel with the shank. The shank extends beyond the arms, possibly to facilitate attachment of a tripping float rope. The iron is rectangular in cross-section throughout the anchors, except for the rings, which are circular in cross-section. These anchors date to the 1st century A.D.

In 1973, another four iron anchors were found on the Dramont F wreck, also near Cape Dramont (Joncheray, 1975b: 91-140). These anchors have been dated to the middle or second half of the 4th century A.D. The range in length from 1.36 m to 1.80 m and from 64 cm to 86 cm in beam. Both the shanks and the arms of the anchors are rectangular in cross-section. No stocks were found, though all four anchors have circular stock holes in the shank. The arms are all initially set perpendicular to the shank and then bend or curve to become parallel with the shank at the midpoint.

The 7th-century Byzantine vessel that sank at Yassi Ada, ca. A.D. 625 (van Doorninck, 1982: 121-143), carried eleven wrought iron anchors (Fig. 3). They averaged 2.29 m in length (2.00 m to 2.56 m), had an average beam of 1.46 m (1.29 m to 1.58 m), and varied in weight from 73.5 kg to 129 kg. These anchors were all cruciform in their basic design, with very thin round shanks. The square-sectioned arms were perpendicular to the shank in 8 of the 11 anchors; all had poorly developed flukes. The rings showed no sign of chain

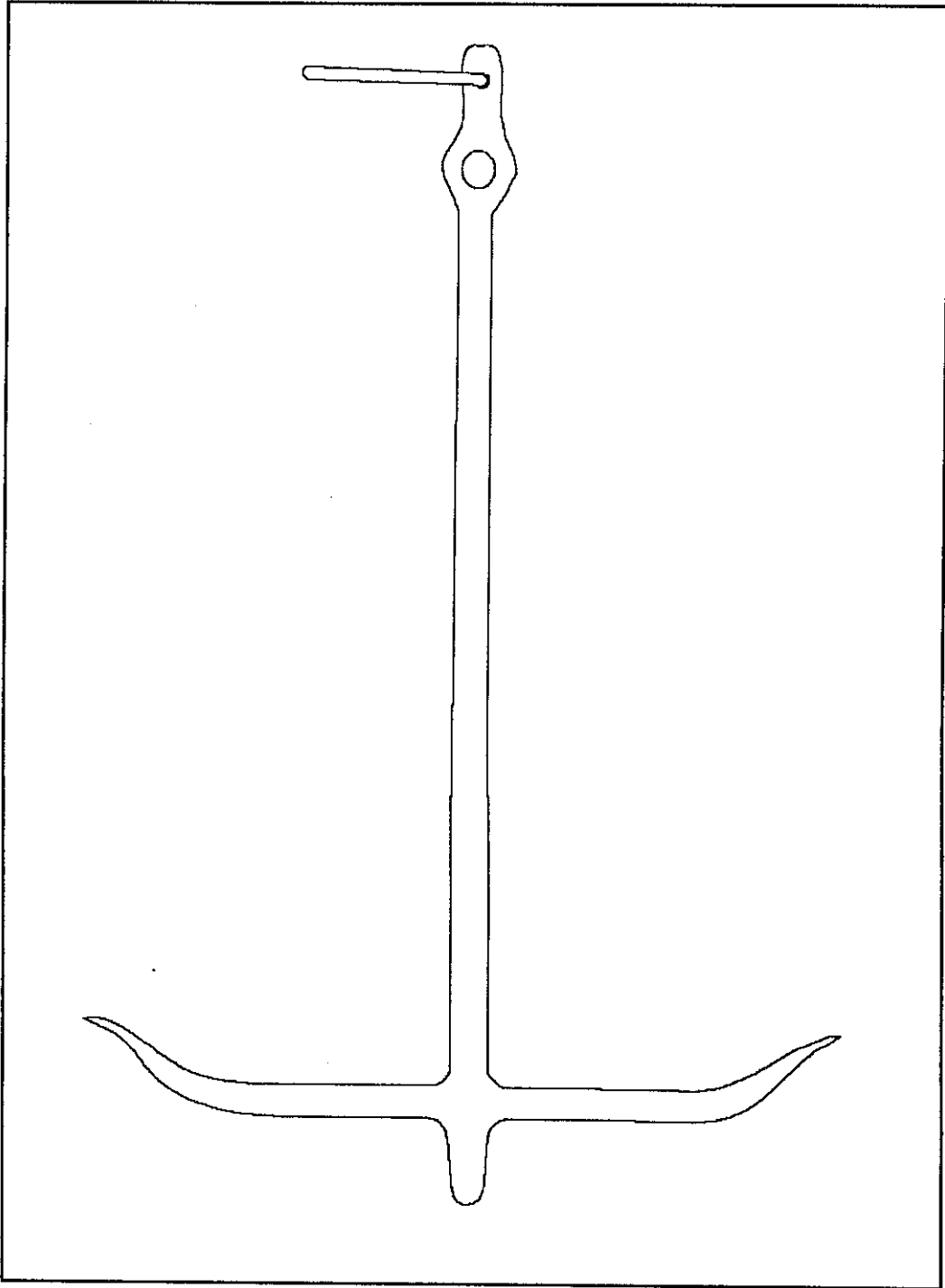


Figure 3. 7th-century, Yassi Ada anchor (after van Doorninck, 1982: 130).

wear suggesting that fiber cables had been used. One of the anchors, weighing approximately 79 kg, was made of eighteen pieces of iron welded together, with an average bloom weight of 4.4 kg. None of these anchors had a crown ring, but all the shanks extended well beyond the crown so as to provide a good purchase for a buoy rope. All the shanks did have well defined stock apertures, and two iron anchor stocks and the broken remains of a third were also recovered.

There were no holes in the iron stocks for the cotter pins/keys to fit through, suggesting that the iron stocks originally may have been sheathed in wood. Van Doorninck (1982: 136) has suggested that the other anchors may have had solid wooden stocks. The anchor complement on this vessel may have ranged from smallest to largest in increments of 50 Roman pounds (van Doorninck, 1982: 134).

The Serçe Limani vessel, dated to ca. A.D. 1023, was carrying 8 iron anchors (Fig. 4), 3 bowers, and 5 spare anchors when it came to grief (van Doorninck, 1988). The bower anchors, two to port and one to starboard, were mounted on the bulwarks and were ready for use. Another anchor of similar size and design was found a short distance from the wreck, with a broken shank that could have caused the vessel to sink! The anchors all have holes in the shank for removable stocks--possibly wooden, as no iron stocks were found. The straight arms form obtuse angles with the shank, with spade-shaped teeth set at right angles to the arms. One of the anchors weighed 67 kg and was made from 14 pieces of iron--an average bloom weight of between 4 kg and 5 kg.

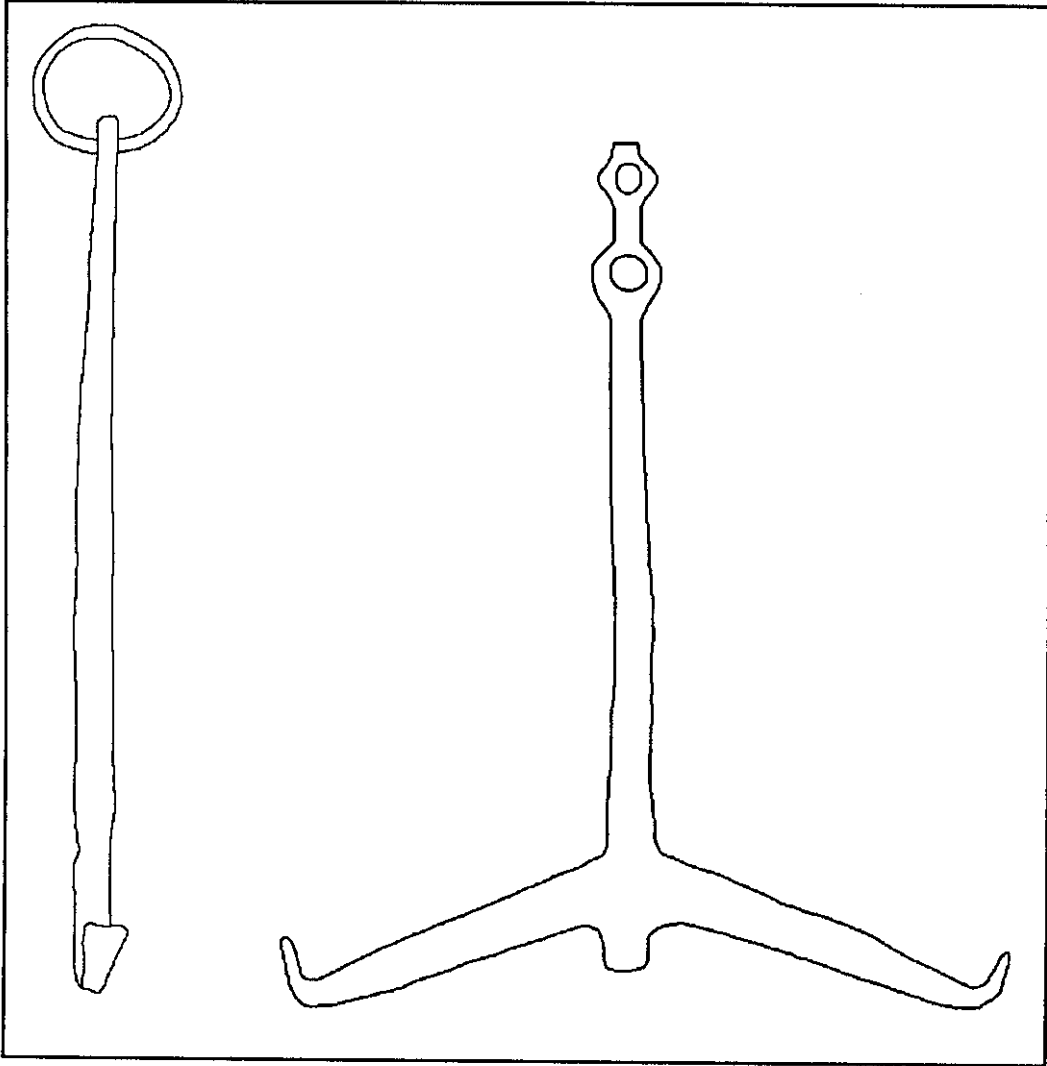


Figure 4. Serçe Limani anchor (after van Doorninck, 1988: 24).

The German nautical archaeologist, Gerhard Kapitän, has shown that the iron anchor underwent a steady evolution. Kapitän (1984: 42-43) lists five time periods: Roman Republican, Early Roman Imperial, Roman Imperial, Late Roman and Byzantine, and finally a Late Byzantine and Arab, and gives some dated examples of anchors from each period. He suggests that there were five basic types of anchor (Types A-E). Haldane (1990: 22) has suggested that the Roman Imperial Period (Type C) should be divided into an earlier and later period, and gives examples of anchors for these two periods (Fig. 5). Kapitän's earliest type (Type A), similar to the Monte Christo anchor, had straight arms set in a V-shaped position, which was derived from the two-armed wooden anchor. Subsequently, the arms took the rounded shape of a bow (Type B), similar to that of the Lake Nemi iron anchor and the Pompeii anchor. In Type C anchors, the arms are perpendicular to the shaft but the ends are inclined toward the stock end of the shaft. The difference between the earlier Type C-1 anchor, similar to those of Dramont D, and the later Type C-2 anchor, similar to the ones at Dramont F, is that the arm ends are inclined at a greater angle and this occurs somewhat nearer the shank in the earlier type. In anchor Types A, B and C the cross-sections of the shanks and arms are all rectangular. However, the stock has a round cross-section in the later Type C-2 anchors. In Type D anchors, similar to the 7th-century Yassi Ada anchors, the square cross-sectioned arms are set at right angles to the shank and the arm tips are angled more vertically and occasionally outward at the ends. The removable stock usually has

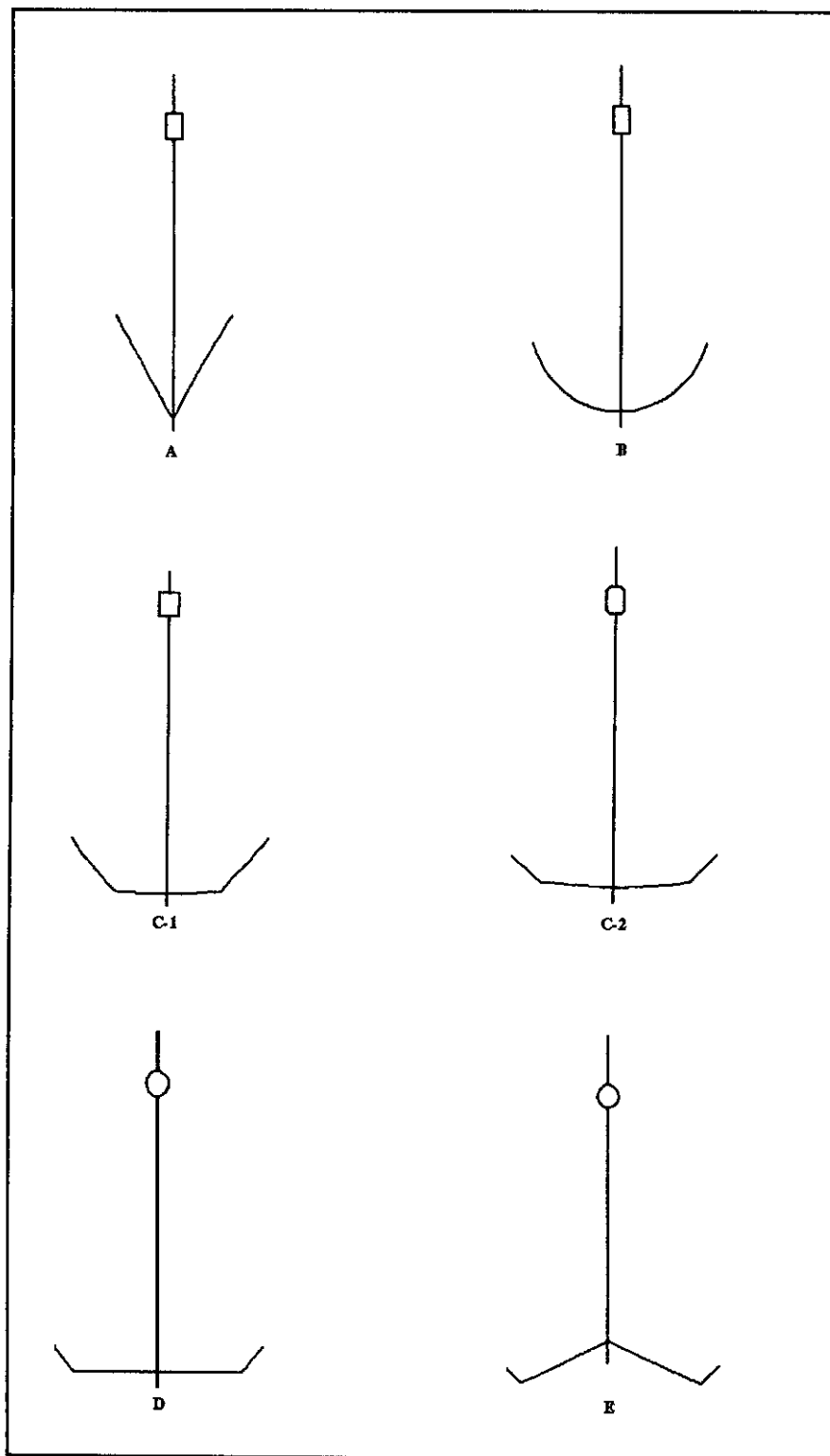


Figure 5. The early development of iron anchors (after Haldane, 1990: 22).

a round cross-section, as does the shank. The latest anchors (Type E), similar to the 11th-century Serçe Limani anchors, are characterized by a Y-shaped arrangement of slightly sloping straight arms with the tips at a right angle to the arms, pointing upwards. Kapitän (1984: 43) has suggested that there were transitional shapes linking neighbouring anchors in the typology.

Kapitän (1984: 42-43) also proposes that these Y-shaped anchors represent the last stage in the evolutionary development of ancient iron anchors in the Mediterranean. One can see that the earliest iron anchors had straight arms set at an acute angle to the stock. The arms later evolved into a more open form, ultimately becoming lunate in shape. These in turn evolved more and became perpendicular to the shank, and finally Y-shaped. One explanation of this evolution is that there was a desire to minimize the length of the shank, as the available technology could not produce a long shank strong enough to pull the arms from their embedded position on the seabed (Steffy, 1982: 143). Specifically, anchors were made from relatively small blooms that were hard hammer-welded together after being heated in a small forge. The smaller the cross-sectional dimensions, the less likely there were to be inclusions that would weaken the overall strength of the shank and welds. This limited the overall size of the anchors, and resulted in vessels carrying more anchors to cover for inevitable breakages. Both the Yassi Ada (7th-century) and Serçe Limani (11th-century) anchors were made of a soft bloomery iron (van Doorninck, 1988: 25)

that can be rendered brittle by inclusions of slag, which create weak zones that will break under excess strain.

In 1881, an iron anchor and chain were found at a Venetii hill fort, Belbury Camp, east of Bere Regis in Dorset, England (Cunnington, 1884: 115-120). The anchor is 4½ feet long, and has a beam of 27½ inches from bill to bill. Although the anchor was not found with an iron stock, there is a hole in the shank for one just below the anchor ring. The shank extends slightly beyond the arms, where there is a crown ring hole; the ring is missing. One of the other artefacts in the collection with the anchor is "a bar of iron 3 feet long, and 1 inch by ¾ in thickness" (Cunnington, 1884: 116). This could easily have been the iron stock for the anchor, as the shank varies from 2 to 3 inches in breadth and could have accommodated a stock of this size. The anchor is attached to a length of chain, the first link which is nearly 5 inches in diameter, the remaining links about 2 inches in diameter. Unfortunately, the anchor is now out of archaeological context and cannot be easily dated. One can but wonder whether this iron anchor and chain is a Venetii artefact, similar to the ones that Caesar saw, or if it is a Roman one from a later period. These artefacts are now in the Dorchester County Museum.

The archaeological record suggests that iron anchors continued to be used in Northern Europe after the decline of the Roman Empire. In his description of the Nydam Ship (ca. A.D. 350-400), Engelhardt (1866: 13) mentions "*the large iron anchor, of the same shape and construction as those now in use.*"

Unfortunately, this anchor was lost during the Danish war with Germany in 1864, hence the lack of any detailed information concerning the dimensions and construction details. Another iron anchor was found with a Viking ship burial at Oseberg (ca. A.D. 800), and can now be seen in the Bygdo Museum in Oslo, Norway. This slender, 4-foot (1.2 m) long iron anchor weighs 21½ lbs (9.8 kg) and has small strong flukes at the ends of the arms (Fig. 6). The anchor has both an iron shank ring and a crown (buoy) ring, which would have aided in retrieving the anchor.

A later iron anchor (ca. 900 A.D.) was found at Ladby, in Denmark (Sølver, 1958: 294-301). This 4½-foot (1.36 m) iron anchor was found with 30 feet (9.14 m) of chain attached to the anchor ring (Fig. 7). The chain was probably used as a "leader," or "forerunner," as the other end was attached to a fiber rope. The rope is right-hand-laid, of three strands. The open chain links (with no studs) averaged 20 cm in length and were made of wrought steel. The anchor weighs 61½ lbs (27.95 kg), nearly three times the weight of the Oseberg anchor, and was made from two large blooms: one for the shank and the other for the arms. The anchor is extremely well made, not only well proportioned and symmetrical, but also well finished and handsome to look at. Sølver (1958: 298) states that the original weight of the anchor could have been between 40 and 50 kg, as presumably a third of the weight has been lost to iron corrosion.

Nothing remains of the Ladby anchor stock, but one can presume that it would have been similar to the Oseberg and Gokstad anchor stocks. The

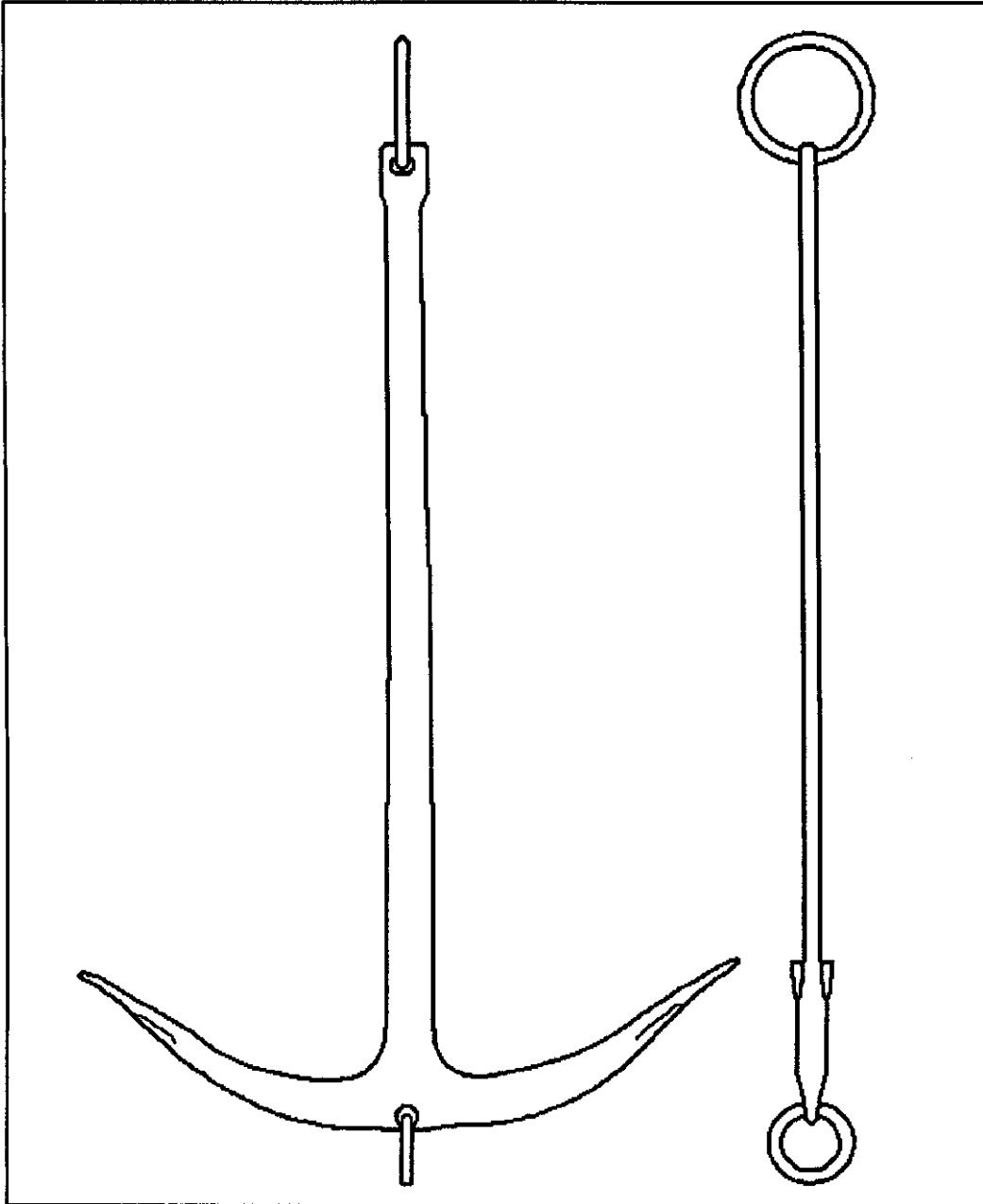


Figure 6. Oseberg anchor (after Sølver, 1958: facing page 296).

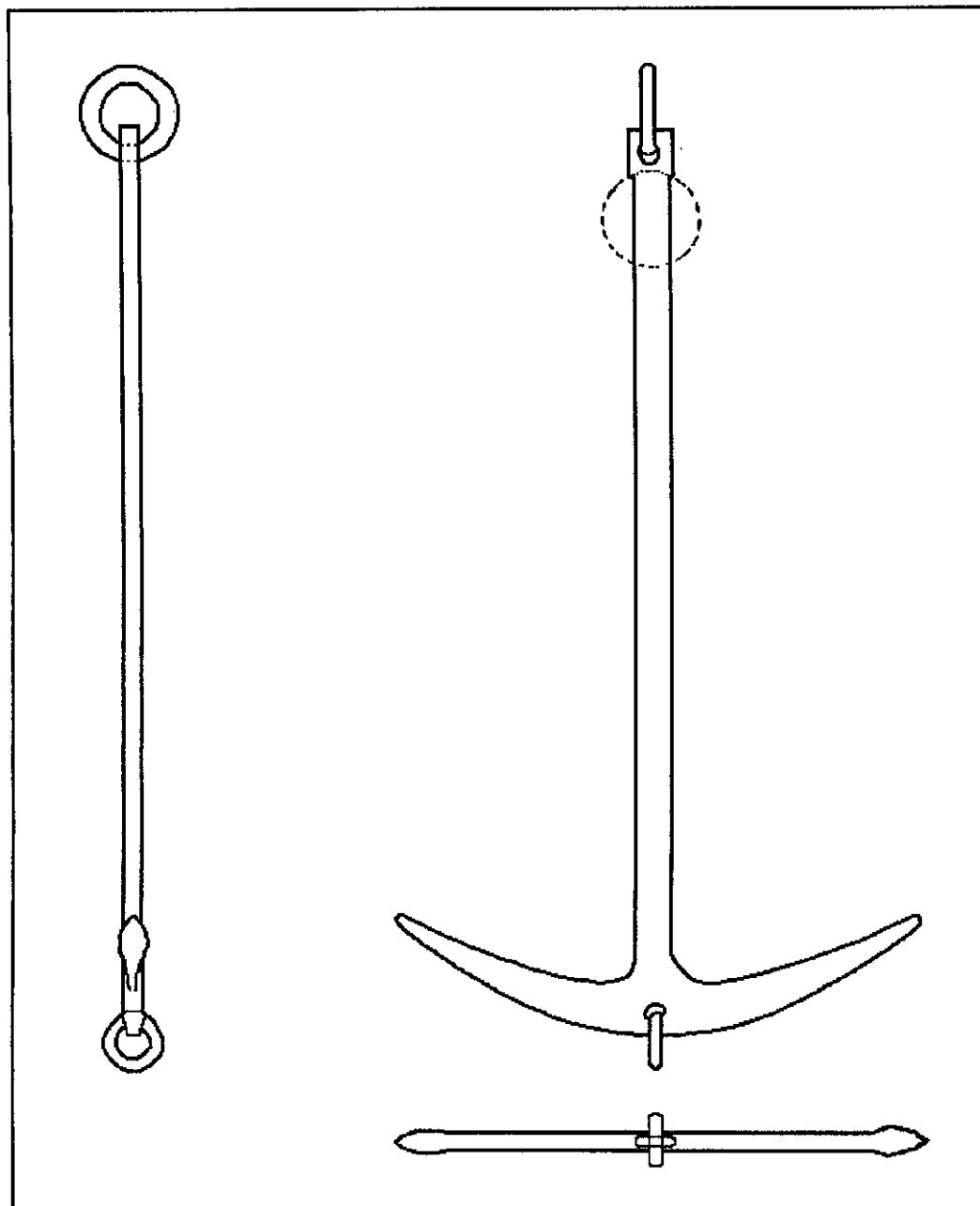


Figure 7. The Ladby anchor (after Sølver, 1958: 296).

Gokstad anchor stock is 7½ feet (2.28 m) long and 2½ inches (6 cm) thick in the middle, and round in cross section. Sølver (1958: 298) suggests that a peculiarity of Viking anchor stocks is that they were generally considerably longer than the shanks. This would make the anchor more unwieldy out of the water, but would provide for a better cant on the seabed, so that one of the arms/flukes would bite into the bottom sediment and take hold. It is unlikely that these Viking anchors were reinforced or covered with wood, as was the Nemi iron-stocked anchor. Movable stocks would have made the anchor a great deal easier to stow, as they could lie flat, and this is a convenient space saver on deck.

A length of chain in the mooring line has many practical advantages. The chain will not fray on the seabed, as a rope cable does when subjected to the action of the current and swell. The weight of the chain leader keeps the rope from lifting the anchor off the ground with every passing swell, which makes the mooring more elastic and improves the angle between the rope cable and the anchor. The use of chain also makes heavy stocks unnecessary, as the weight of the chain will help cast the anchor into its proper position.

In the eleventh century, the biographer of Abbot Ealdred of St. Albans recorded that when the holy man had stones for his new church dug from the Roman ruins of Verulamium, his men came across oak timbers smeared with pitch and with rivets in them, half-rusted anchors, and pine oars, on the river bank (Johnstone, 1974: 7). Again, were these the remains of a Venetii vessel, or an early Roman one with iron anchors?

The Bayeux Tapestry, which illustrates the conquest of England by William the Conqueror in A.D. 1066, was made by the end of the eleventh century (Bruce, 1987). The tapestry depicts 31 ships and boats, four of which exhibit anchors. They are all two-armed iron anchors with crown and shank rings. There is some discussion as to whether the stocks were of wood or of iron. They are depicted on the tapestry in a colour different from the rest of the anchor, and this could suggest that they were made from a different material--namely wood. The anchors are all attached to rope cables and there is no evidence of a chain in association with the ground tackle.

One can easily see and follow the gradual metamorphosis that the anchor underwent, from a simple stone to a wrought iron anchor, moored using a length of chain in some instances. This development was definitely a product of the available knowledge and technology of the day. One author (van Nouhuys, 1951: 17) has gone so far as to suggest that "*the efficiency of ground-tackle may, therefore, be taken as a gauge of the development of navigation.*" This may not precisely be the case, but the two, ship and anchor, are inseparable.

The development of the anchor was originally influenced by both local and regional influences. It was by slow degrees, coupled with the expansion of communication and trade, that new ideas and techniques, to improve the design, were able to spread. After the Renaissance in Europe, the dissemination of information was a great deal faster. The limiting factor was the ability to smelt and forge large quantities of iron.

IRON TECHNOLOGY

Iron is the most common of all the metals used by man. The significant importance of iron, in its many forms, is extremely obvious in our recent industrial history and in our present civilization. This was even noted and reflected upon in a medieval encyclopedia written about 1240 by Bartholomaeus Anglicus, a member of the Franciscan order of monks. He called the use of iron:

... more needful to men than the use of gold.... Without iron [he went on] the commonalty be not sure against enemies; with dread of iron the common right is not governed; with iron innocent men are defended; and foolhardiness of wicked men is chastized with dread of iron. And well-nigh no handiwork is wrought without iron: no field is eared without iron, neither tilling craft used, or building builded without iron (Schubert, 1957: 94).

Iron in the manufactured form can perform an endless variety of tasks. It can be alloyed easily with other elements that confer useful properties to the metal, while others can be detrimental and diminish its value. An example of the latter is that iron has a particular affinity to oxygen, to which it readily combines to form an iron oxide--rust. The melting point of pure iron is around 1540°C, and this temperature could not be sustained until the 19th century. However, iron can be produced at lower temperatures if it is alloyed or wrought in a reducing atmosphere. The three basic forms of iron that have been used commercially are, in order of antiquity; wrought iron, cast iron, and steel.

Wrought iron is basically a soft, ductile, fibrous product of almost pure iron that is physically mixed with a small amount of slag. Slag is the waste material that is formed during the smelting of iron, and/or the forging of wrought iron. Slag is technically a contaminant, and this was recognized by the early anchor-smiths, as it does give the iron some useful, and unusual, properties. Slag usually contains less than 0.05 to 0.08% carbon and very small traces of silicon, manganese, sulphur, and phosphorus. All of these elements must be present for the iron to be true wrought iron. This alloy is very ductile, and can easily be shaped and worked while hot by hammering or rolling. The principal value of wrought iron lies in its ability to resist corrosion and fatigue (failure under repeated loading). The metal's corrosion resistance, directly attributable to the slag fibers, is also a function of the purity of the iron base metal and the lack of segregated impurities (unwanted waste elements, e.g., phosphorus and sulphur) in the iron ore (Allen, 1969: 372).

When wrought iron is heated to 1350°C, it can easily be welded by hammering or squeezing. The process must be completed before the seam joint cools below 1050°C, as the workability of the wrought iron decreases rapidly thereafter. This technique is called fire welding, as opposed to cold working and annealing, which is done at lower temperatures around 700°C. Welding is the process whereby two separate pieces of wrought iron are joined together by heat or mechanical methods (such as hammering) without the addition of a solder. A proper weld will be as strong as the surrounding iron, but one that has been

improperly fashioned will fail under stress. Some work can be done while wrought iron is cold, however, more force will be required and the product will be questionable when put under stress. The iron silicate in the slag, left over from the manufacturing process, facilitates the welding as it acts as a flux; and it was also generally believed to inhibit the corrosion process.

Cast iron is an alloy of iron, carbon and other elements in trace quantities. This alloy, usually containing 2 to 4% carbon, is not very malleable and cannot be forged or rolled. However, it can be melted relatively easily and cast into simple or complex shapes that would be otherwise almost impossible to produce in wrought iron. Cast iron melts at a lower temperature, around 1150°C, and under a different set of conditions. A higher fuel-to-ore ratio is needed, along with an increased amount of flux and oxygen. Under these conditions, the iron absorbs so much carbon, that it forms an alloy at a resultant lower melting point.

Steel is not quite as easy to define, as it can take so many different forms, each with its own special characteristics. It is basically an alloy of iron and carbon, with other elements, such as nickel, manganese or chromium added to impart special properties. For the purpose of studying the history of anchors prior to the 1860's, it is sufficient to remember the differences between cast iron and wrought iron, as steels really only came into their own in the late 1800's.

THE WROUGHT IRON BLOOMERY

How, when, and where man first discovered how to make iron is not known, and is not the topic of this paper. There are two ways in which iron ore can be reduced in a forge to yield iron. The first process is direct, and produces wrought iron; the second is indirect, and yields cast iron that is usually treated further in a separate process before it is used. For our purposes it is sufficient to say that the direct reduction of iron was practiced from prehistoric times up until the 15th century and, incidentally, the process remained virtually unaltered during that time.

The iron smith had to devise a means of reducing the iron ore, commonly found in nature in some form of an oxide, by heating it in a furnace in contact with carbon. The carbon, in the form of charcoal or coke, was also used to provide the heat for the furnace. Under favourable conditions in the furnace, oxygen from the air and from the iron ore combine with the incandescent carbon. This has a greater affinity for oxygen than the iron does, and forms carbon dioxide and carbon monoxide, which are given off as gases into the atmosphere. Limestone is usually charged with the iron ore and fuel to act as a flux, which unites with the earthy waste material in the iron ore and the ash from the carbon to form a slag. In early furnaces there was no outlet for the slag, which collected in a cake at the bottom of the furnace below the mass of reduced iron. The Romans used a 'developed bowl' furnace in which the slag could be 'tapped' or released from the bottom through a hole in the side of the

furnace. This bowl, and the later 'shaft' furnace, assisted in maintaining the reducing atmosphere that was vital to the production of good wrought iron. Wrought iron was thus produced in a nearly solid state, by the chemical reduction of the ore to almost pure iron, at about 1200°C.

The final product from the iron furnace, or bloomery, was a pasty mass of iron, slag and pieces of unburnt charcoal/coke called a bloom, or a clod. The bloom was broken up by hammering, which separated the small pieces of iron that could then be separated from the rest of the material, as they were ductile and would flatten on hammering.

These small blooms were then reheated in a second furnace to a temperature above 1200°C, and consolidated by repeated hammering. The hammering on the bloom forced out most of the semi-fluid slag and oxides, and welded the iron particles together to form a 'bloom iron'. This second furnace, in reality a forge, was called a 'string hearth' in England. In some cases the bloom consisted of a coherent piece of iron that could be worked as a single piece. Extremely large blooms had to be cut into smaller pieces that were then individually smithed. This occurred by the early 15th century, with the application of water power, when the average bloom size increased to over 2 cwt (101.7 kg). The term 'string hearth' comes from the practice of 'stringing' the iron, which means making it tense or tight by working (hammering) the remaining slag out of the metal. Another meaning of stringing is to elongate the metal by hammering, thus forming a bar or block.

The last job in the stringhearth was to split the bloom, using an axe to cleave the metal deeply. This was done for two reasons. One was to test the quality of the iron and establish that the metal was indeed wrought iron. Secondly, cleaving the bloom deeply enabled it to be broken in two when cold, and thus into more manageable pieces. It was this bloom that was then sold to the blacksmith, or the anchor smith for that matter, and worked into whatever iron object that was required.

THE BLAST FURNACE

The introduction and development of the blast furnace was an important step in the history of iron technology. Cast iron was not unknown prior to the 15th century, as it had been produced unintentionally on a number of occasions even during Roman times. Once the principle had been established that water could be used to power the bellows, the way was open to produce larger blooms that in turn could be worked using water-powered hammers. Furthermore, it was this continuous operation, made viable by the use of water to power the bellows, that made the development of the blast furnace possible (Tylecote, 1976: 65).

Technically, the main difference in operation between the wrought iron bloomery and a cast iron furnace lies in the withdrawal of the liquid iron, in addition to the slag, from the bottom of the furnace. With an increased fuel-to-ore ratio, which made the atmosphere more reducing and carburize the iron, the

melting point of the cast iron was lowered to approximately 1200°C. Under these conditions the slag would be very viscous, but with the addition of a good fine flux and an increase in temperature to 1300°C, the slag was able to run freely from the furnace.

With the passage of time numerous observations were noted and improvements made in the technology. An increase in furnace height led to a longer residence period for the fuel/ore mixture, and therefore a decrease in the amount of fuel needed to maintain the working temperature and reducing atmosphere. Larger furnaces were, therefore, more economical to run. The work had to be continuous, as intermittent smelting would have been out of the question economically, with the enormous amount of fuel and ore still bound up in the furnace after the initial batch of cast iron had been tapped. Another important observation was that a constant supply of water was necessary to power the bellows, which were now needed to obtain the higher furnace temperatures. Tylecote (1976: 66) comments that once a blast furnace had been blown-in (started), the campaign would not have terminated until either the furnace had worn out, the water supply ran out, or the supply of fuel and/or ore had been exhausted.

Tylecote (1976: 81) suggests that the reason for the development of the blast furnace were purely military, as the civilian demand was for wrought iron that could be made more cheaply by the direct reduction method. Cast iron guns were a great deal cheaper, and from some points of view, better than

wrought iron 'stake' guns. Additionally, the surplus cast iron from the furnace could be converted into wrought iron. With the passage of time and improvements in the technology, cast iron produced in a blast furnace became the standard product for all iron production.

Blast furnaces were first introduced into the Sussex Weald sometime between 1490 and 1496. The first English blast furnace and forge, for which there is definite evidence, was located on the Crown property at Newbridge in Sussex by the end of 1496 (Schubert, 1957: 163). Initially, this new technology expanded fairly rapidly, but only in the Sussex Weald area. The Newbridge furnace was also where the first cast iron cannon was successfully manufactured in England, in 1509 (Schubert, 1957: 164). The output of a mid-16th century furnace seems to have been only about 4 to 5 tons of cast iron per six days (a founday). A furnace could not store such large quantities of cast iron and this limited capacity led to the early development of the double furnace, such as those at Worth in Sussex, which in 1549 were capable of producing gun castings of up to 43 cwt (~ 2200 kg) in weight from a single top (Tylecote, 1976: 82).

Despite the development of the blast furnace and the indirect process of producing cast iron in the late 15th century, the bloomery continued in use in the more remote areas of Britain. They were still being commissioned as late as 1636 (Tylecote, 1976: 86), probably because of the enormous capital required to build the far larger blast furnace that was of a more permanent nature.

THE WALLOON PROCESS

The 'Finery', from the French *affinage* (to refine or fining of metals), carried out the first stage of the conversion of cast iron to wrought iron. The aim was to reduce the carbon content of the cast iron (usually in the range of 3 to 4%), by oxidizing it with a blast of air from the bellows, to that of wrought iron (less than 0.08%). The second stage was done in the 'Chafery', from the French *échauffer* (to warm or to heat up), where the process involved the reheating and forging (hammering) of the iron. This two-hearth technique is generally known as the 'Walloon' process, and was developed so that charcoal could be conserved by using coal, or cake, in the chafery hearth. The term 'Walloon' indicates the region where the process is supposed to have originated from an area to the south-west of Liège called 'Valloon country'.

The Finery and Chafery

Originally, a single hearth process to refine the bloom had been developed in the bloomery. The cast iron pigs were melted and oxidized by air from a water-powered bellows. The aim was to reduce the carbon content to less than 0.08%. Charcoal or some other low-sulphur fuel was burned to provide the heat for the furnace. Coal was not used initially in the finery, though it was used in the chafery from the 16th century onwards (Tylecote, 1976: 87). Before the fining was finished, the 'loup' or lump of iron was forged under a water-powered hammer into a thick square half-bloom. The half-bloom was returned to the

finery for further reheating, followed by a final forging. This resulted in an odd, dumbbell-shaped bar of wrought iron, the end called the 'mockett head' being larger and the smaller end being called the 'ancony'.

The bloom was then transferred to the chafery. The ancony end was forged first, then the mockett head, was drawn down to a bar. This was accomplished in two stages with an intermediate reheating.

MECHANICAL POWER

Bellows

One of the earliest references to water power applied to an iron-smithy comes from the Domesday Book, written in 1086. There is a reference to two mills near Somerset "*II molini redd (entes) II plumbas ferri*" [two mill payments and two weights of iron], each rendering two blooms of iron as part of their customary annual rent (Schubert, 1957: 89). One could assume from this that the mills used a water wheel to drive the bellows, as water-powered corn mills were no novelty in those days, and over 5000 mills are mentioned in the Domesday Book (Crossley, 1951: 103). There is another reference, from 1346, in which the term '*Molendinum ferri*' [an iron mill] is applied to an iron mill near Liverpool (Schubert, 1957: 342). However, this evidence is not sufficient to justify a definite conclusion that water power was used as the motive power in the smithy.

The evolution of the bloomery proceeded rapidly after the Black Death of 1348, probably as a result of the consequent shortage of labour, which made the exploitation of mechanical power more desirable than ever before. The ironmakers' piece-work pay rate of 5½ d per bloom had increased to between 7½ d and 9½ d per bloom, by 1354. This increase was reflected in the price of iron that had been fairly constant at 1 s 8 d per bloom before 1334, after the plague the price in some cases rose to more than double this figure (Schubert, 1957: 144).

Generally, these bloomeries were based on a meagre capital resources, with limited technology and unskilled labour to do the heavy work. The amount of air needed to make a small bloom is easily produced by manually operating a bellows. Many of the furnaces were close to streams, but it is not clear if the water was used as a source of power. The exploitation of water power, on the other hand, required considerably more capital than was generally available at the time. This capital, usually in the hands of the church, was given to corn grinding and fulling mills, which had a greater priority at the time. There was yet another problem with this new source of mechanical power: the supply of water was uncertain because the ponds often froze in winter and dried up during the summer months.

With the substitution of hydraulic power for manual labour, the operation of a bloomery became much more economical in another sense, as it saved on labour. A smithy that worked without waterpower generally used three times as

many men as were required to operate a hearth with water-powered bellows. Not only did the bellows reduce the cost of labour, but they also permitted an increase in the overall size of the blooms.

The average size of a bloom in the 14th century was between 30 and 40 lb (13.6 to 18.2 kg). Tylecote (1976: 64) suggests that the historical evidence from England, ca. 1350, points to an average bloom weight of about 30 lb (13.6 kg) without the use of any waterpower. Schubert (1957: 139) supports this figure and gives a bloom average of 30 to 32 lb (3.6 to 14.5 kg) for the Tudeley and Northumberland forges, between 1335 and 1353, with an annual average of around three tons (305 kg) per ironworks. With the adoption of waterpower in the late 14th century, the iron production figures rose dramatically.

In 1408, the Bishop of Durham established the first documented water-powered bloomery in England (Tylecote, 1976: 65). Before this, there is no conclusive archaeological or reliable documentary evidence to support the use of waterpower for metallurgical purposes in England. With the absence of any references to hammers, one can assume here that the waterpower was made available to power the bellows. This idea is supported by the dramatic increase in the iron production figures, which could only have come from a bloomery with a water-powered draft.

Between 1408 and 1409, the Byrkeknott furnace, in Durham County, produced 278 blooms averaging 195 lb (88.5 kg) apiece (Schubert, 1957: 140). Of the 278 blooms, 254 weighing a total of 22 tons 18 cwt 65 lb (23,318 kg) were

converted into 204 blooms of forged wrought iron weighing 18 tons 8 cwt 33 lb (18,727 kg). There was a 20% loss here in the forging, which was to be expected with the technology of the day.

Hammers

Originally, all of the forge work in the iron-smithy was done with wooden-handled sledgehammers. There is no evidence to suggest that water power was used to operate a hammer in medieval times. It had been thought that the only type of mechanical hammer in use before the early 16th century in England was an 'oliver' or treadle-operated tilt hammer.

An oliver is first mentioned distinctly in a deed of 1352 relating to a bloomery in Yorkshire (Schubert, 1957: 138). However, there is also mention of a large hammer at Beaumarais Castle in North Wales, in 1335, that may have been an oliver. A distinction was made between a hand hammer (*martellum manuale*) and a large hammer (*martellum magnum*), which was apparently not operated by hand but by some mechanical means (Schubert, 1957: 139). The oliver is merely a device for transferring the power from the hand to the foot, thus freeing the hands for other purposes, and the power is also more easily applied by the foot. The oliver had one arm attached to an axle, worked with the foot by a treadle, which brought the hammer head down onto the iron anvil. When the smith removed his foot, a swing raised the hammer for the following

stoke. The smith could then hold the work with tongs in one hand, and a drift or set in the other, while the object was hit by the foot-operated hammer.

With the increase of iron production, and the increasing size of the blooms, the need for machinery to process the iron became a necessity. It was not long before the water-powered hammer made its first appearance. An early reference places a water-powered hammer at the Newbridge forge in Sussex in 1497, where wrought or bar iron was forged by the '*great water hamor*' (Schubert, 1957: 162).

The tilt, also known as the trip or tail hammer was a simple yet effective device in its earliest design. The hammer head was at the end of a wooden shaft mounted on a pivot so that the head worked over an anvil. The tail of the shaft was in contact with a number of cams (cogs) on the circumference of a drum. As the drum was turned by a waterwheel, each cam in turn struck the shaft and lifted the hammer for a moment, then released it as it moved in its circular path, allowing the hammer end to fall by gravity. A wooden spring beam (a rabbit) fixed above the hammer ensured that the hammer fell with considerable force as soon as the cam released the tail. Sometimes the tilt hammer tail struck an iron recoil block fixed in the floor, instead of coming into contact with a spring beam. Either device resulted in a rapid succession of heavy blows being struck as long as the waterwheel turned. The speed of the hammer blows was regulated by the flow of water past the waterwheel, and some waterwheels could deliver up to 200 strokes per minute with a relatively light hammer head.

The hammer that was generally used in England, from the 16th to the early 18th century, was the belly-helve or lift hammer. The shaft or helve was usually about 8 to 9 feet long with a cast-iron hammer head weighing 4 to 5 cwt (203.4 to 254.2 kg). At the other extremity of the shaft was a cast-iron hurst, or pivot collar. The cams of the waterwheel drum acted on the center of the shaft, lifting it and then allowing it to fall by gravity back onto the anvil. These hammers were also fitted with wooden spring boards to increase the velocity of the hammer blow. A variation of the belly-helve was the side belly-helve, where the wheel shaft was at right angles to the hammer shaft, and the cam box raised the hammer shaft by means of a projection on the side of the drum. The belly-helve hammers generally operated at a slower rate, 100 to 120 strokes per minute, working off four cams, but with a larger and heavier hammer.

Finally there was the nose or frontal helve hammer, the largest and heaviest of all. The cams raised the nose of the shaft, at the end opposite the pivot collar, and the hammer head was situated a short distance back from the nose. This large hammer had a solid casting and did not have a recoil device of any sort.

Rolling and Slitting Mills

Despite the obvious advantages of the water-powered hammer, there were limits to what it could do. It was not feasible to draw down (elongate) bars to less than 1 inch (2.5 cm) square, as they were too flexible when hot and cooled

quickly. For these reasons, it was necessary to have recourse to some form of rolling and slitting mill to do the work.

The development of the rolling and slitting mill marked another important stage in the history of iron technology. It not only solved an immediate problem, of reducing small iron bars, but it was also the first piece of iron working machinery to be introduced that was to become and remain a fundamental tool of the iron industry.

The rolling mill basically consisted of a pair of iron shafts, mounted horizontally above one another, in a strong frame or housing. The shaft held rolls (never called rollers in the industry) which rotated in opposite directions. As the rolls were turned by water power, an iron bar would be drawn in and compressed between the rolls, thus flattening the iron bar and extending its length. The slitting mill has cutter discs mounted on the roll, that will act like a continuous rotary shear and slice the iron into narrow strips. One can see how this process, of heating the iron and drawing it down as far as practical under the tilt hammer, then rolling and slitting the metal, made the life of the smith a great deal less arduous.

The rolling mill may have been developed from a small hand-operated mill, similar to the ones used for rolling lead '*comes*' for glass windows (Tylecote, 1976: 90). An early hand-operated rolling mill was at Robertsbridge, in Sussex, in 1565 (Schubert, 1957: 307). The wrought iron was initially cut using a large mechanical shear, and then passed through the rolls. The origin of the slitting

mill is obscure, but it is thought that they were developed near Liege, in Belgium, around 1500 (Schubert, 1957: 304). A patent was granted to Bevis Bulmer, in 1588 for a slitting mill in England. It is not known whether he actually built and operated the mill. In 1590, Godfrey Box had a slitting mill in use at Dartford, in Kent (Gale, 1967:28). During the course of the 17th century more slitting mills were built; however, the increase was very gradual. By the early 18th century, there were probably no more than twenty slitting mills operating simultaneously in England (Schubert, 1957: 311). The small number of mills in Britain at this late date is of interest, considering the advantages that the mill had over the water-powered tilt hammer.

The evolution of the mill was impeded by a number of serious handicaps. The rolls were originally set in a wooden support and framework, which was not really strong enough to allow for the more powerful machinery. This problem was eventually solved when the mounts were made from cast iron. The second problem was one of motive power. The waterwheel was adequate to drive a tilt hammer and bellows, but a rolling and slitting mill needed more than twice the power to run successfully. It was only with the advent of the steam engine in the 1780's, that the full potential of the rolling and slitting mill could be developed more efficiently. By 1785, there were sixteen rolling and slitting mills in England (Schubert, 1957: 311).

In 1755, a rolling and slitting mill in Birmingham was capable of hot rolling 3 inch (7.5 cm) wide bars with a reduction of 75%, with a resultant

increase in length from 1 foot (0.3 m) to 4 feet (1.2 m)(Tylecote, 1976: 90). A considerable amount of power was needed, as well as a strongly built mill, to facilitate such a reduction. In 1765, a mill near Kilnhurst had an 18 ft (5.5 m) diameter water wheel, generating some 20 to 30 horsepower to rotate the machinery (Tylecote, 1976: 90).

Initially, the rolling and slitting mills product would primarily have been used by 'nailors', the narrow iron bars saving them from the tedious work of cutting the nails out by hand, using a hammer and chisel. The small bars were used later in the 18th century to make up composite anchors, a large number of small bars being welded together to form the individual parts of the anchor.

Steam Power

Thomas Newcomen's 'Atmospheric Engine', built in 1712, was the first truly recognizable steam engine, having a reciprocating piston and a rocking beam (Gale, 1967: 34). Earlier engines, such as Savery's, built in 1698, were extremely limited in their application and were in effect only steam-operated devices. Initially, Newcomen's engine could only be used for pumping water, as the action provided only a reciprocating motion. It was used sparingly by the iron industry to pump water from below the waterwheel back up to the storage pond.

The invention by James Watt of the separate condenser in 1769, transformed the Newcomer engine into a much more efficient machine. Watt

entered into a partnership with Matthew Boulton in 1775, to produce his new 'patent' engine. This was a decisive step for iron technology, going from the experimental to the commercial production stage. In 1776, the second Boulton and Watt beam engine was operating at John Wilkinson's furnace at New Willey, in Shropshire (Schubert, 1957: 333). This was still a reciprocating steam engine, supplying pumped air for the furnaces. It created an interest in the iron industry, as vast amounts of water were no longer needed for the waterwheel.

Spurred on by the interest in his engine, Watt produced and patented another engine in 1781 that was capable of rotative motion (Tylecote, 1976: 106). This engine, using a sun and planet gear to obtain rotary motion, could be applied to all sorts of rotary action in the forge; bellows, hammers, and rolling and slitting mills. In 1786, John Wilkinson was again the first to harness a rolling and slitting mill to a steam engine at Broseley, in England.

By the end of the 18th century, the steam engine had revolutionized the iron industry in England. Not only did the steam engine increase the production of cast iron, by increasing the amount of available air and thus increasing the temperature, but also it speeded up the finery process of converting cast iron to wrought iron. Hammers and rolling and slitting mills became more efficient, and the end result was a wrought iron of a better quality and strength. The limiting factor was the expense involved in building a steam operated furnace and forge.

SIXTEENTH-CENTURY ANCHORS

HISTORICAL EVIDENCE

By the beginning of the 1500's, the different types of anchors were being distinguished from one another. Tinniswood (1945: 87) mentions the *Sovereign*, of 800 tons, as having eight anchors in 1495: "*Ankers called Shutte--1, Brystoll--1, Sterborde Bowers--1, Lathehorde Bowers--1, Sterborde Destrelles--1, Latheborde destrelles--1, Kaggyng Ankers--2.*" The 'Shutte' anchor was the sheet anchor, and the 'Brystoll' was a large bower anchor specially made in Bristol. Oppenheim (1894: 61) has suggested that the word 'destrelle' comes from the Catalan Spanish '*destre*', which means to bridle. The terms 'Sterborde' and 'Latheborde' are the old English terms for starboard and port, and show where the anchors were stowed. The 'kaggyng' or 'cagger' anchors are kedge anchors. The *Sovereign* also had two boat anchors, that were probably grapnels (Anderson, 1923: 315).

In 1546 the English Navy placed an order for 55 anchors with Dutch anchor-smiths in Holland, who agreed to make the anchors at a rate of one per week because they were busy with other anchors (Schubert, 1957: 313). These anchors were to be made of 'Ames' iron from the Amiens district in the North of France, as Spanish iron was hard to come by at the time. Ames iron was not of such a high quality as Spanish iron, but was still preferable to English iron. With the difficulty of procuring the required number of anchors for the English Navy,

attempts were also made to buy anchors at the German ports of Bremen, Hamburg and Lübeck (Public Record Office (PRO), Letters & Papers, XXI, 1: 166-167). Unfortunately, no further details are available regarding these orders, so nothing is known about their size, shape, weight, etc.

During the 16th century three factors led to a rapid increase in the price of iron: war, which increased the demand for cannon and iron shot; the rising population and the greater demands it placed on the iron industry; and the growing scarcity and cost of charcoal that was needed to smelt iron ore (Derry & Williams, 1960: 143). A shortage of wood during the reign of Queen Elizabeth I (1558-1603) was said to have intensified as a result of the dissolution of the monasteries, and the resulting sale of all the woodlands owned by the church. Moreover, the monasteries were no longer producing cast and wrought iron. In 1585, restrictions were placed on the amount of wood that could be used to fuel the iron smelters, as valuable old growth timber that was needed for the navy's shipbuilding program was being used to make charcoal (Abell, 1948: 92).

The publicity that was given to German metallurgy by Agricola's *De Re Metallica* in 1556, coupled with the reputation of German merchants and bankers, led various governments, including that of Queen Elizabeth I, to invite German iron workers to develop their iron industries (Tylecote, 1976: 81). Elizabeth I was somewhat apprehensive about the power of Spain and wished to be self-sufficient in the production of strategic metals. Nine groups of German workers arrived in England between 1565 and 1566, and their impact was felt

immediately by the English economy with the decrease in imported metals (Schubert, 1957: 317).

One of the earliest references to calculating the size of anchors carried by ships of war is in the State Papers of 1582. Corbett (1898: 267) mentions the rule for finding the weight of the sheet anchor and says that this was annotated "in a hand closely resembling that of Hawkyns's":

A cable of 16 inches circumference being tarred, and of the goodness of stuff and making as before specified, will require an anchor to fit the same (being made as below in the proportion of anchors) of 16 cwt., accounting the cwt. 112. This scantling and weight I account fit, and in mean proportion.

Take, therefore, the square of 16 inches circumference, which is 256, and let that number be always your divisor, and say:

If 256, the square of 16 inches circumference, give an anchor of 16 cwt., what weight of anchor shall . the square of . (such circumference of cable as you desire to know) require to have?

Multiply and divide, so shall you in the quotient find your desire.

Example

If 256 give 16 cwt., then 400 (which is the square of 20 inches circumference) shall give 25 cwt.

Again, if 256 give 16 cwt., then 144 (the square of 12 inches circumference) shall give 9 cwt (Corbett, 1898: 267).

In simpler terms, the rule was to square the circumference of the best cable in inches and divide that by 16, the result being the weight of the sheet anchor in hundredweight (cwt) of 112 lb (51 kg). The rule at the time for calculating the size of the best cable was to take one-half an inch (1.27 cm) circumference of cable for every foot (0.3 m) of the ship's beam measurement (Oppenheim, 1961: 181). Therefore, one can calculate that a ship with a 36 ft (11 m) beam would need an 18 in (0.46 m) anchor cable. From this, one can then calculate that the

sheet anchor would weigh 20 cwt and 1 qtr (1031 kg) (Table 1). A 'Quarter' (qtr) of one cwt = 28 lb.

Tinniswood (1945: 88) suggested that one could make a check against what he called '*Hawkyns's rule*', for the sake of convenience, with the size of the *Merhonour* anchors. The *Merhonour* was a 41-gun ship of 709 tons, built in 1590 (Colledge, 1987: 226). She had a 37-foot (11.3 m) beam, and 18 in (0.46 m) cables were ordered for her in 1589 (Tinniswood, 1945: 88). This would have given her a sheet anchor of between 20 cwt 1 qtr (1031 kg) and 21 cwt 1 qtr 16 lb (1089 kg), depending on which rule one uses--eighteen inch cables or a 37-foot beam. In 1590, the *Merhonour* was listed as having the following anchors: 1 of 25 cwt, 4 of 22 cwt, 3 of 20 cwt and 1 of 12 cwt (Oppenheim, 1961: 182). The sheet anchor that is listed here is larger than Hawkyns's rule allows for, but the bower anchors are well within an acceptable range for a vessel of that size. Tinniswood (1945: 90) feels that this rule (Hawkyns's) was obsolete by 1582, though this author believes that it has merit to at least the turn of the 16th century.

Fragments of English Shipwrihty (National Maritime Museum (NMM), TRN/12) gives us an idea of the dimensions of a 16th century English anchor. Mathew Baker included this description of a 15 ft (4.6 m), 20 cwt (1018 kg) anchor in 1586:

Table 1. The sizes of best cable and weight of best anchor to fit all sorts of shipping and vessels, from 44 foot in breadth of midship beam downwards (after Corbett, 1898: 267).

Ship's Beam Feet	Cable Inches	Anchor Weight		
		Cwt	Qtr	lb
44	22	30	1	0
42	21	27	2	7
40	20	25	0	0
38	19	22	2	7
36	18	20	1	0
34	17	18	0	7
32	16	16	0	0
30	15	14	0	7
28	14	12	1	0
26	13	10	2	7
24	12	9	0	0
22	11	7	2	7
20	10	6	1	0
18	9	5	0	7
16	8	4	0	0
14	7	3	0	7
12	6	2	1	0
10	5	1	2	7
8	4	1	0	0
6	3	0	2	7

The proportions of ye best sorte of Anckers by L.T.

An anchor of 20 ct weight out to be in length from ye ringe to ye crowne f. 14'9" or 15'.

The square ab about 2' from ye ringe, & must be as bigy at bb as at cc which is from 9' & whatsoever it is bigger is waste, bycause ther is ye chiefest stress from b. to c. it ought to be very nere of a bignes from c to g encreasinge by degrees, fh ye length of ye arme must be 1/3 of ye shanke & being sett of from g. ye insyde of ye arme, to h. upon ye shanke, gives ye trendinge of ye arms h.h. 1/3 also.

At halfe of d.f. yt is at e.e. ye arme at K. must be as bigy as ye shank at e.e. & ld of ye arme must be as bigy as dd of ye shanke.

the corvinge of ye arme nere a circle, but yt is toe rounde ye palm must curve as ye arm doth.

ye shanke at 9' vid. cc must be 6 1/2" or 7" thorough at ye most & soe much at bb at g. 10".

It is not known who the original author 'L.T.' was, but his terminology shows a familiarity with things nautical and he provides an early catalogue of anchor parts. There is a simple drawing of an anchor (not to scale) associated with the description, that illustrates the approximate position of the letters for the relevant dimensions (Fig. 8). It is interesting to note that the writer mentions the set of the arms, which would be at an angle of 60° to the shank.

ARCHAEOLOGICAL EVIDENCE

Unfortunately, no anchors have been recovered from 16th-century English wrecks and undergone an archaeological examination. As a result, there are no known English anchors from this period. An iron grapnel and chain were recovered from the *Mary Rose*, that sank in the Solent in 1545 (McKee, 1982: 38). John Deane salvaged the grapnel and other artefacts, using a primitive diving helmet in the 1830's. It is not known if any other anchors have been

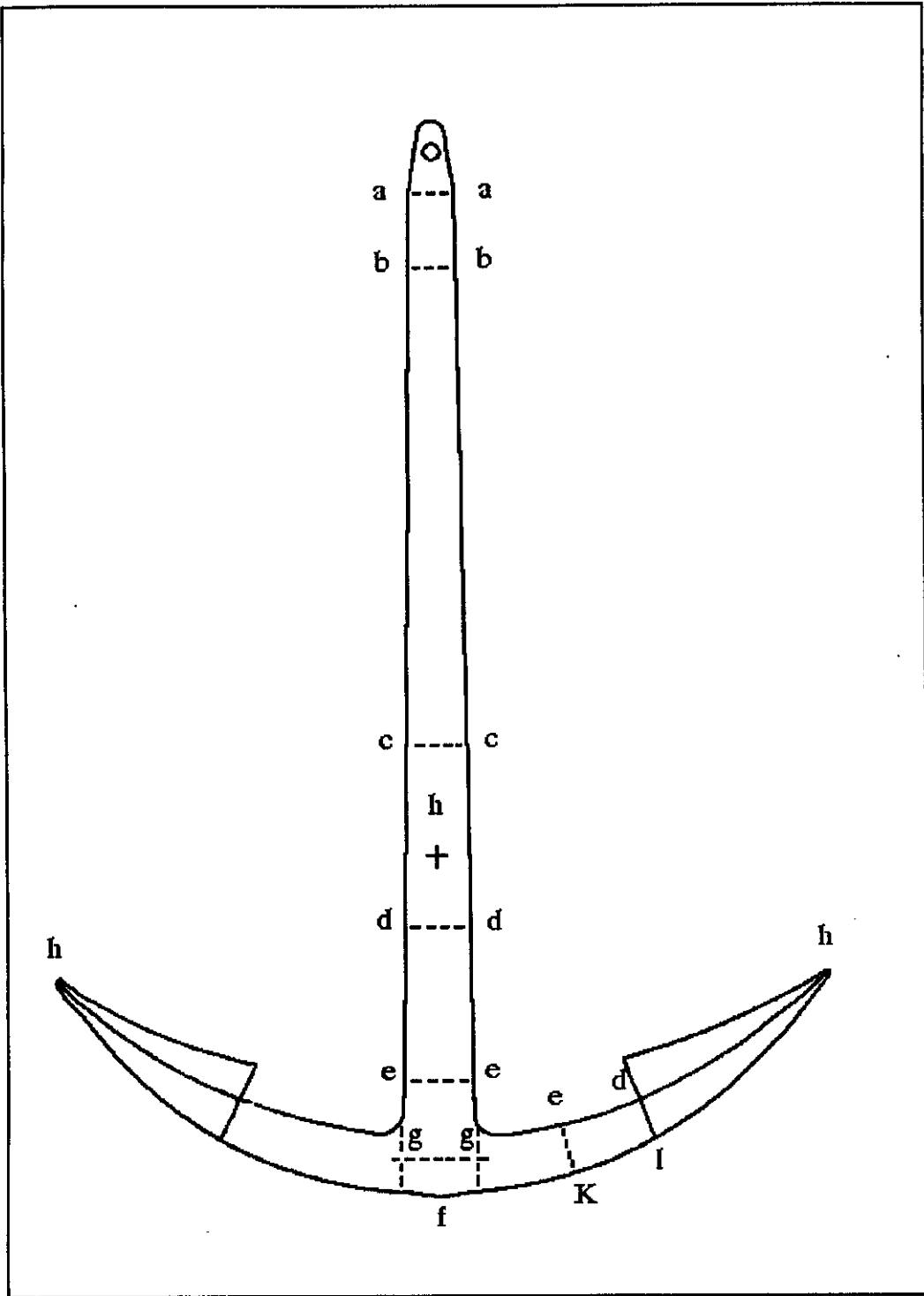


Figure 8. The Baker anchor, 1586 (after NMM, TRN/12).

recovered from the *Mary Rose*, and there are no references in the literature to the discovery of any anchors.

However, a larger number of anchors have been recovered and recorded from Spanish vessels that sank during the same time period. Admittedly, these anchors are not English in origin, but the technology and designs that were used to manufacture them would have been similar. Thus, one can draw some ideas, and conclusions, as to what 16th-century English anchors may have looked like.

The 1554 Fleet Anchors

The largest group of anchors from the 16th century that have been archaeologically studied, are those from the Spanish 1554 fleet that was lost off the Texas coast. Seven anchors from the wreck of the Spanish galleon *San Esteban* (Arnold & Weddle, 1978), another complete anchor from the wreck of the *Santa Maria de Yciar* and the shank and ring from a broken anchor off the *Espiritu Santo* were recovered (Arnold, 1976). Two other anchors were also recovered from the same area, the Jetties anchor and the Raymondville anchor. The Jetties anchor possibly comes from the *Santa Maria de Yciar* site (Arnold, 1978: 188). The Raymondville anchor was snagged by a shrimper in the area of the shipwrecks. Artefacts from the 1554 wrecking event were found concreted to the anchor (Arnold, 1978: 322).

All of these Spanish anchors are very similar in their basic dimensions, with the exception of the Jetties anchor, which is somewhat more robust and

does not have the 'Gothic finial' at the top of the shank. They average 12 feet (+/- 14 inches) in length with extremely slender shank and a relatively short arm span, compared to the length of the shank. This clearly supports a nautical expression of the day "*to be as meagre as a Spanish anchor.*" Van Noughuys (1951: 44) comments that Spanish anchors were notorious for the thinness of their shanks, right up to the seventeenth century. A proportionately high percentage of the 1554 anchors are broken or damaged in some way or other. Three of the Padre Island anchors had broken shanks with their parts stored together; another with the palm missing was in storage with the ballast, while all that remained of a fifth was the ring and shank (Arnold & Weddle, 1978: 224). The perceptible double bends in some of the complete anchors indicate an inherent weakness in the shank, which could easily bend or break when being weighed. A buoy and rope attached to the crown of the anchor was a common fixture, according to Mainwayring (1622: 3), and was used to facilitate handling the anchor from a small boat. This would have also enabled the distal end of a broken anchor to be recovered. The nuts or stock keys on the square are parallel to the arms, which is a classic diagnostic feature of early Spanish anchors.

The 'Gothic finial' is another classic feature of Spanish anchors, and is the result of their manufacturing technique. The top end of the shank was forged and drawn down (narrowed), then bent around a mandrel to form an eye and welded back onto the shank. There were advantages to this method, as the

forging and drawing down toughens the iron, which would then be more resistant to wear. This method produces a stronger anchor than the English method of squaring off the end of the shank and punching a hole for the eye with a drift. Some other construction methods used on the large Padre Island anchors were apparent on two of the badly corroded specimens. On one of the anchors (No. 157-1) it looks as though the two arms were made from one bloom or bar, and then joined by a single simple lap-scarph weld to the shank. The second anchor (No. 161-1) was made somewhat differently, as each arm was fashioned separately and then joined to the shank with separate simple lap-scarph welds. The arms of the anchors generally formed the arc of a circle, with the average angle between the shank, the crown, and the fluke being 57°. Another interesting aspect relating to the construction of these anchors is the remains of rope wrapped around the ring of one of the anchors (No. 310) (Arnold & Weddle, 1978: 230). Such ropes were intended to prevent the iron anchor ring from chafing the anchor cable, and are called puddenings. Mainwayring (Perrin, 1931: 78) mentions 'puddings', "*the Sarving of the Ring of the Anchor, which [are] roapes, to fave the clinch of the cabell from galling aginft the iron.*" Two of the anchors, No. 310 from the *Santa Maria de Yciar* and the Jetties anchor, have maker's marks that have yet to be identified. It is interesting to note that one of the marks is on the crown, while the other is on the Gothic finial.

The Molasses Reef Anchors

Other anchors from this period exhibit similar characteristics. Two associated anchors were recovered from the Molasses Reef vessel that sank in the second quarter of the 16th century (Keith, pers. comm.). A four-meter-long sheet anchor was found on top of the ballast pile, suggesting that the anchor was stowed in the hold when the vessel sank. This wrought iron anchor exhibits all the distinctive features of the classic Spanish anchor. It was fabricated from several different 'assemblies' and the scarp weld between one of the arms and the crown is clearly visible (Keith, pers. comm.). The second, smaller, boat anchor is of more interest, as this anchor has similar proportions and design to the sheet anchor yet it has two holes in the top of the shank. The first hole is obviously for the ring and the second would be for a movable iron stock, which was supposedly only reintroduced toward the end of the 18th century. Neither the ring nor the iron stock for this anchor was recovered from the wreck site. It is quite plausible that this boat anchor was made in the 16th century, as the metal corrosion is similar to that of the larger sheet anchor, and is not intrusive to the wreck. However, iron-stocked anchors were not supposed to have been re-invention until the late 18th century.

The Highborn Cay Anchors

Mendel Peterson (1974) reported finding three anchors on an early 16th-century Spanish wrecksite in the lee of Highborn Cay, in the Bahamas. Two

anchors lay 100 to 150 meters off the bow of the wreck, the larger sheet anchor and one bower anchor, suggesting that the vessel was at anchor when she sank. A third anchor lay on top of one end of the ballast pile, leading to the conclusion that it had been stowed in the hold. These anchors all exhibit features similar to those of the 1554 anchors: very long slender shanks, stock nuts in the same plane as the arms, and the gothic finial at the top of the square. The palms are in the shape of an isosceles triangle and are equal to half the arm length in diameter. The ring on the 9 ft 10 in (3 m) long ballast pile bower anchor was extremely large, nearly $\frac{3}{4}$ of the arm in length. Keith (pers. comm.) has commented that a fourth anchor was later found on this site and now resides somewhere in Florida along with the first three. Ordinarily, the sheet anchor was only used when there was a question as to whether the bower anchor would hold the vessel. That the sheet anchor had been deployed, led Peterson (1974: 235) to conclude that the vessel had been in danger prior to anchoring in the lee of the island.

The Bahia Mujeres Anchors

Two anchors recovered from a 16th-century wrecksite off Bahia Mujeres, Mexico, by divers in 1960, are now in the Playa Adventura Museum. These anchors were never conserved and have not survived the years well. One is broken in the middle of the shank, while the other has a broken ring hole and damaged flukes (Fig. 9). The better-preserved anchor has the following

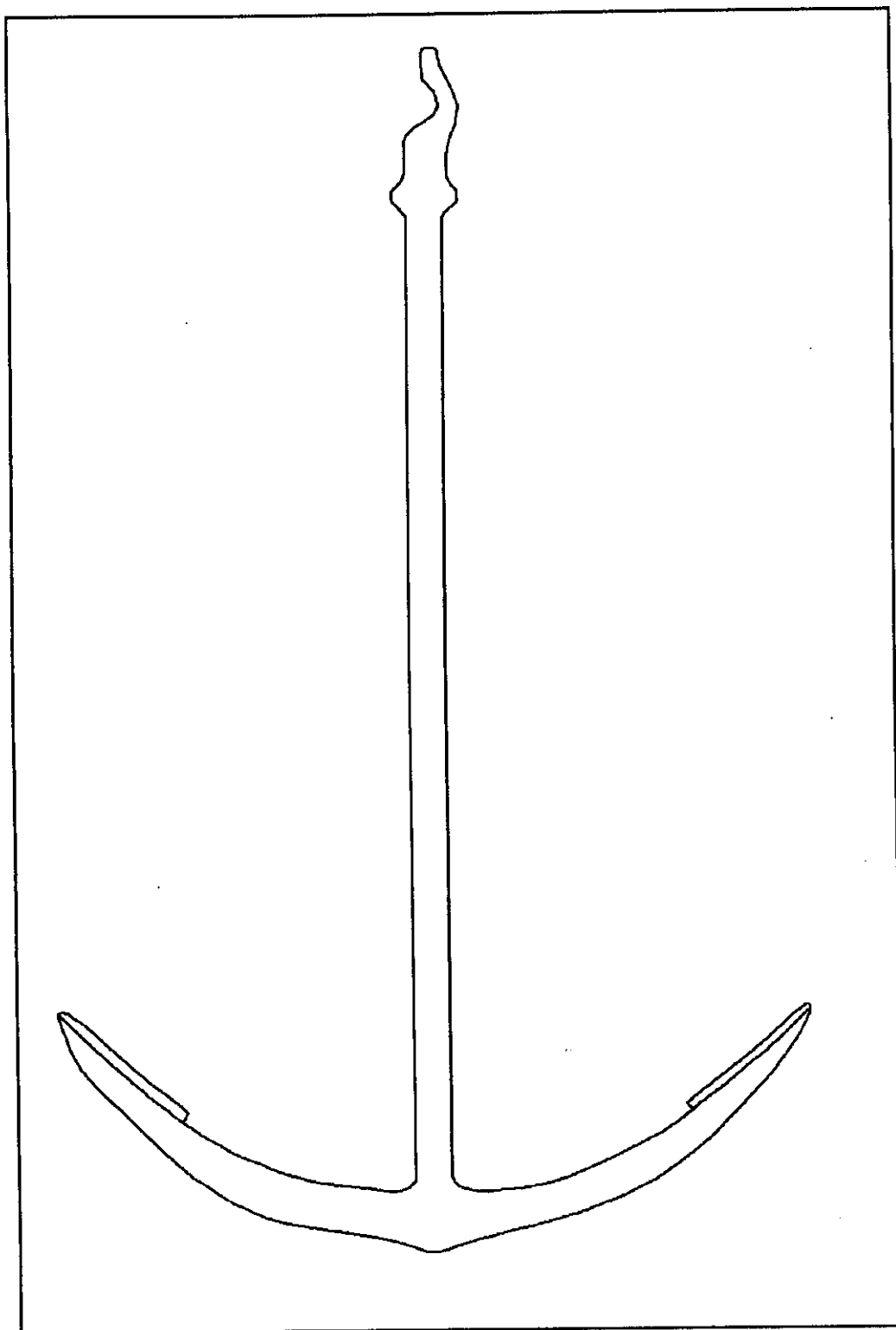


Figure 9. The Bahia Mujeres anchor (after Keith, 1986).

dimensions: length 7 ft 8 in (2.4 m), beam 4 ft 8½ in (1.45 m), length of arm 33 in (0.84 m), length of palm 17 in (0.43 m). The angle between the shank and the arm is approximately 58 degrees. There is no doubt that they are 16th-century Spanish-style anchors, but, only gross diagnostic features can be alluded to: the stock nuts are in the same plane as the arms, the gothic finial is present, and the anchors exhibit a generally long slender shape coupled with relatively short arms.

The Red Bay Anchor

The Red Bay anchor (Light, 1990: 307-316) was recovered near the remains of the *San Juan*, a Basque shipwreck at Red Bay, in Labrador, Canada, believed to date to 1565. It is not clear whether the anchor belonged to the *San Juan* or not, but it can still be dated from the archaeological provenience to the years 1540 to 1600 (Light, 1990: 307). This anchor has undergone a detailed study that has yet to be equalled.

The anchor proportions were recorded in the same format as those from the 1554 fleet, so comparisons can easily be made. The shank is 3.5 m long, with the arms being of unequal length and angles (between shank, crown and fluke). The flukes are less than half the arm in length, and the ring diameter is greater than the fluke length. These measurements are all well within the 'classic' Spanish-anchor dimensions.

The anchor was probably forged in the chafery as water-driven tilt hammers were necessary for forging an anchor of this size, although the work could have been done entirely with hand sledges. Light (1990: 307) states that the master smith was probably working from a mental template, that was handed down within the oral tradition, which was constrained and shaped by the technology of the day. The proportions of an anchor could easily vary, resulting from the fact that the bloom produced in the finery was smaller, or larger, than usual. The lengths and diameters of the various parts were also judged by eye, and not with a gag (pattern).

The anchor was basically forged from three large bars of iron from the chafery. The bars were approximately $3\frac{1}{2}$ in (9 cm) square and $6\frac{1}{2}$ ft (2 m) long. One bar was drawn down (elongated and narrowed) at either end to form the shape of the arms, and the flukes added. The bar was then bent in the shape of a half moon to form the curve of the arms. Another bar was scarfed at one end and lipped at the other. The third bar was drawn down and scarfed at one end, then bent around a mandrel to form the eye and welded back onto itself. The stock nuts were then welded on below the eye. The other end of the third bar was lipped, and then welded onto the lipped end of the second bar to form the shank of the anchor. The shank was then welded onto the middle of the bar forming the arms, the center positioning being done by eye. One can see how easily one arm could end up being longer than the other. The scarf had to be welded quickly, while the metal was still at a sufficiently high temperature,

and there was little time for exact measuring. The final job was to make and weld the ring into the eye of the shank. The anchor had a maker's mark, as well as the weight of the anchor (possibly in quintals of 47 to 48 kg) marked on the gothic finial at the top of the shank. Unfortunately, the origins of the mark have yet to be traced to a specific smith or forge.

The Spanish Armada Anchors

A number of anchors have been recovered from Spanish Armada vessels that sank off the Irish coastline, in 1588. Sidney Wignall (1982) describes a number of anchors that were recovered from the *Santa Maria de la Rosa* wrecksite in Blasket Sound, on the Kerry coast. The 15 ft 6 in (4.72 m) long sheet anchor had lost an arm, while a second, possibly a bower anchor, had broken in the shank and a third anchor had lost the ring. Some of the classic Spanish-anchor features are still present: the gothic finial, and the shank length being $3\frac{1}{2}$ times the length of the arm--which was fairly standard for these long slender anchors.

Two wrought iron anchors were recovered from the *La Trinidad Valencera* wrecksite (Martin, 1979: 31-32). This 1100 ton Venetian merchantman, requisitioned by the Spanish, sank off Donegal in northern Ireland. The two bower anchors were 15 ft (4.57 m) and 15 ft 9 in (4.80 m) long. The smaller anchor had a gothic finial, while the larger was finished-off square at the head of the anchor.

All of these anchors are similar, and reminiscent of the other known Spanish Armada anchors the *Girona* (Sténuit, 1972), the *San Juan de Sicilia* (Martin, 1979: 31), and the *El Gran Grifón* (Martin, 1979: 31). The arms are more angled than curved, with the arm angle becoming more acute at the base of the fluke. The flukes are still isosceles in shape, and equal to half the arm in length. The shanks are all rectangular in section, and the nuts are still in the same plane as the arms. The nuts are perpendicular to the arms in 17th-century anchors, and it is not known when this change took place.

Looking at the known examples of Spanish anchors from the 16th century, it is not difficult to prove that they were of a poor quality. The majority of the anchors display some form of damage or breakage, be it the loss of a fluke or an entire arm, a broken ring, or ring hole. With the long-slender shank working as a lever, it is not difficult to displace a fluke, or fracture an arm, of an anchor that is well set into the seabed. There are even examples of the central shank being snapped in half.

Two aspects of Spanish anchors will continue to be discussed at length, their proverbial weakness and their proportions, and one should realize that they were being made using the best available techniques and material of the day. The problems were inherent not only in the manufacturing process, but also in the design.

SEVENTEENTH-CENTURY ANCHORS

HISTORICAL EVIDENCE

Tinniswood (1945) in his *Anchors and Accessories, 1340-1640*, attempts to list the proportions of an anchor of about 1600. He uses Mainwayring (1622) as his guide, and adds information gleaned from pictorial evidence. The shank length of the anchor is equal to three times the fluke length plus half the beam, or $4\frac{3}{4}$ flukes in length. The lengths of the flukes equal half the length of the arm, which is set at an angle of 60° to the shank. The stock of the anchor is the same length as the shank (it could safely be made a little longer) and is 1 in (2.5 cm) thick in the center for every foot (0.3 m) of length, with the ends measuring half of that. Tinniswood (1945: 86) goes on to say that the shank could have been shorter in earlier times, twice the length of an arm, with shorter flukes and an arm-to-shank angle of between 45 and 50 degrees. He does not give any evidence to support his ideas.

Tinniswood (1945: 90) adopted a formula for estimating the size of an anchor for a given weight. The formula also works for the reverse, estimating the weight for a given size (length of shank). The formula is:

$$S = \sqrt[3]{W \times C}$$

where S is the length of the shank in feet, W the weight of the anchor in tons, and C being a constant, with a value of 2000. This formula could be used for

anchors for the period 1550 to 1640. However, if one was to test this theory with the anchors from the 1554 fleet, it quickly becomes obvious that the formula does not work. The weights and lengths are known for seven anchors, and when they are applied to the formula the constant will vary from 3665 to 7888 in value. It is clearly obvious that one cannot standardize a length/weight ratio, and formulae such as Tinniswood's should be avoided at all costs.

During the reign of King James I (1603-1625) there were two Jacobean Commissions of Enquiry into the affairs of the state (McGowan, 1971). In the papers relating to the second Enquiry, there is a collection of information pertinent to the Navy. There is little or no useful information regarding anchors, save for a table that lists the number, type and weight of anchors for three sizes of ships: 650, 450, and 350 tons (Table 2). The table also lists the value of the anchors and their cost in shillings per hundredweight.

Mainwayring's rule, in his *Seaman's Dictionary* of 1622, for the proportions of an anchor was that "*the shank is thrice as long as one of the flukes, and half the beam*" (Manwaring & Perrin, 1922: 88). The beam is the perpendicular distance across the shank from one arm tip to the other. Mainwayring lists the various parts of the anchor, mentioning that the fluke is also termed the palm, and makes a few minor technical mistakes and omissions. He describes the fluke being set on the arm or beam, whereas it should read that the fluke is set on the arm, and he calls the shank the beam in another passage (Manwaring & Perrin,

TABLE 2. The weight and value of anchors in 1618 (after McGowan, 1971: 293).

SHIP Tons	ANCHORS			VALUE			
	No.	Type	Cwt	s/Cwt ¹	£	s	d
650	2	Bower	26	35	91	0	0
	2	Bower	25	35	87	10	0
	2	Bower	22	35	77	0	0
	1	Stream	10	30	15	0	0
	1	Kedge	3	30	4	10	0
	1	Boat	0.63	30	0	18	9
	1	Boat	0.44	30	0	13	4
450	2	Bower	17	33	56	2	0
	2	Bower	15	33	49	10	0
	2	Bower	14	33	46	4	0
	1	Stream	8	30	12	0	0
	1	Kedge	2.5	30	3	15	0
	1	Boat	0.5	30	0	15	0
	1	Boat	0.34	30	0	10	4
350	1	Bower	15	33	24	15	0
	2	Bower	13	33	42	18	0
	2	Bower	12	33	39	12	0
	1	Stream	6	30	9	0	0
	1	Kedge	2.5	30	3	15	0
	1	Boat	0.5	30	0	15	0
	1	Boat	0.25	30	0	7	6

1. Shillings per Hundredweight.

1922: 89). Mainwaring does give us a few useful hints, when he states that a ship of 500 tons would have a sheet anchor of 18 cwt (915 kg) (Manwaring & Perrin, 1922: 88). This weight is a little more than the Jacobean Commission of Enquiry gave in 1618, but Mainwaring was writing a few years later. He goes on to say that the largest ship in England had an anchor of about 31 cwt 1 qtr (approximately 1600 kg).

Mainwaring does mention a few changes in the terminology and lists the following anchors: first, second, third, and kedger. Before this, the bower anchors had been referred to as the port and starboard anchors--or rather by their old English equivalents '*Latheborde*' and '*Sterborde*'. The kedger (kedge) anchor was the smallest anchor carried by a vessel, and could easily be handled from a small boat. Mainwaring (1622: 4) also mentioned that the stock was the same length as the shank of the anchor. The use of tallow on the flukes and arms of the anchor is described, as enabling the anchor to go through the softer sediments and bite deeper into the harder sediments lying below (Manwaring & Perrin, 1922: 89).

There is a careful differentiation in the 17th-century texts between port and starboard. The veering effects of storms in the northern latitudes was recognized, and seamanship skills advanced enough, to know that it was wise to keep the best ground tackle on the starboard side. If a second anchor was needed, the port bower was then let go, and the cables would not cross as the storm moved the vessel counter-clockwise.

Early forms of the word 'sheet' as applied to the largest anchor are often spelled differently--'shot', 'shotte', and 'shutte'. Numerous historians have attempted to come to conclusions as to the origins of the terms, but have achieved no real certainty. Tinniswood (1945: 87) offers the most plausible answer when he gives references to the 'shutyng' or 'shuttyng' of anchors. The largest anchor on a ship had to be built up from smaller bars of iron, and the term 'shut' is an old English word for welding iron. As the size of ships, and hence anchors grew, more and more anchors would have had to be 'shut', so the term would be most appropriate for the largest anchor.

David Pietersz de Vries in his *Korte Historiae* (van Nouhuys, 1928: 89) mentions that on the 20 May, 1622, an iron-stocked anchor fished up by him on the road [stead] off Tampan, at the mouth of the Rhône, was: "*een heel dun Ancker ghelyck een Spaens-Ancker, en had een Yseren-stock*" [a very thin anchor like a Spanish anchor, that had an iron stock]. De Vries considering this iron stock very curious, tried to get information about this type of construction from the local fishermen ashore, who informed him: "*datmen in gheen vyf of ses-hondert Jaren sulcke Anckers ghebruyckt hadden daer de Stocken van Yser waren*" [that men had used such anchors five or six hundred years ago having stocks that were of iron]. From this reference in the narrative, which was originally printed in 1655, it seems that anchors with iron stocks did exist long before the beginning of the 17th century, but were unknown to the Dutch sailors of the time. This could tie in well with the earlier archaeological evidence from

northern Europe. The Romans, and possibly the Venetii, used iron-stocked anchors, and de Vries may have unknowingly found one. On the other hand, if the small iron-stocked anchor found on the Molasses Reef Wreck dating to the second quarter of the 16th century was Spanish, it may indicate that the iron stock continued to be used up to the 1500s. One is making the assumption here that the small anchor belongs to the Molasses Reef wreck assemblage, and is not a later intrusion.

Captain John Smith (1627) included a small section on anchors in his *Sea Grammar*. The information is correlative to that given by Mainwayring (1622), with similar errors and omissions. He states (Smith, 1627: 36) that the "*flooke* [fluke] *is but the third part of the shank in length*", when he really means that the arm is $\frac{1}{3}$ of the shank in length. These anchors did not differ in shape, only weight: from two hundred to between three and four thousand weight (Smith, 1627: 37).

Confusion of terminology is a common problem with some historical writers. Boteler, in his *Dialogues* of 1634, mixes up the terms 'shank' and 'beam' stating that the stock and arms are attached to the beam which is the longest part of the anchor. What he really means is that the stock and arms are attached to the shank. No doubt he was quoting verbatim from Mainwayring (1622) and did not pick up the original errors. Botelar goes on to mention two types of grapnels (Perrin 1931: 188). Grapnels with four flukes were used on galleys and boats by boarding parties, and were often fastened to chain, which

could not be cut readily. Three-fluked grapnels were used to sweep (search) the seabed for lost cables and anchors. Neither the three- nor four-fluked grapnels had stocks.

Laird-Clowes (1931) lists the numbers, types and weights of anchors for various ships in the Royal Navy. The information comes from a small treatise entitled *The lengths of Masts and Yards, etc., 1640*, but the original author is unknown. The number of guns and the tonnage of each vessel has been added to the original information to compile Table 3. Some of the information in Table 3 is confirmed by Henry Bond (1642), in his book *The Boate Swaines Art*. Bond lists a vessel of 300 tons, having a length of 75 ft (23 m) and a beam of 29½ ft (9 m). This vessel would have carried a main cable of 15 in (6 cm) and, therefore, a sheet anchor of 15 cwt (765 kg). This is the same weight of sheet anchor as allowed for in a 24-gun, 300 ton vessel listed in Table 3.

The sheet and bower anchors were by far the largest iron objects carried by a ship, and correspondingly would have been expensive to produce in terms of both materials and labour. During the Commonwealth, 1649-1660, Samuel Pepys, with his usual business acumen, suggested the idea of standing contracts for the supply of stores to the Navy. Under this new system, competitive tenders were invited for the supply of the necessary stores or services that were required by the Navy over a fixed period of time. These contracts often continued indefinitely, or until either party gave the stipulated warning notice to terminate the contract for a particular item. Anchor contracts were generally awarded out

in parcels, for a fixed number of anchors of stipulated sizes. By this time, Pepys was writing of 'Best' and 'Small' bower anchors, as though the anchors were descending in order of size and weight (Tinniswood, 1945: 87).

These new contracts between 1661 and 1670 were generally for services like anchor making/repairing, which would require the tender to have a workshop near or inside the particular naval dockyard. The contracts were often simple in form, setting out the bare essentials on a single sheet of paper (Pool, 1966: 33). Anchors were to be made of "*good quality Spanish iron*", and to be "*well substantially and workmanlike wrought*". Spanish iron was "*particularly chosen for Anchor Smiths, because it abides the Heat better than other Iron, and when it is well wrought it is toughest*" (Moxon, 1677: 53). To prevent fraud, the anchors were to be well marked with the '*Broad Arrow*' which was the mark of His Majesty the King, and the maker's name. Once the contract was made, the dockyard would order supplies from the contractor when the need arose. The contractor was expected to maintain a reasonable stock, so that the requirements could be met without any delay.

These standing arrangements were convenient and made things easy for the Navy. They were not without their problems, though, as an Admiralty Letter dated 28th January, 1664, (PRO, ADM 106/2507 #31) states:

These are to pray and require you henceforth to receive no new anchors into H.M. Stores under your charge unless by special warrant from this Board but what are marked both at the Nutt and Cross with the letters of the Anchor Smiths same by whom they are made, and also when soever you issue any Anchor or anchors unto any ship to

enter down in your book the letters upon the Anchor or anchors issued unto each ship and signify the same also unto the Clerk of the Survey directing him from us to do the like that so in case of any damage happening to any of H.M. Ships through the defects of her anchors we may know where to charge to same upon, hereof you may not fail.

This letter basically reiterates an earlier Navy Board Letter, dated 26th February, 1661, that had presented the new ruling concerning the marking of anchors.

In 1677, there were at least eight anchor smiths working in the vicinity of London who were producing anchors for the local merchant fleets (Schubert, 1957: 313). At the other large English ports of Liverpool and Newcastle-on-Tyne, the manufacture of anchors was extensive in order to keep up with the local demands.

The contracting anchor smith's were loath to be held liable for any failing in their anchors, and this problem was to continue for a number of years.

Another Admiralty Letter, dated 4 December 1682, ordered that the Broad Arrow and the maker's marks be inscribed more deeply into the iron (PRO, ADM 106/2507 #61):

Whereas this Board have received complaints of the marks of H.M. Anchors wearing out, so as that after some years service they cannot be known from Merchants anchors a particular instance whereof we have lately received from Deal of an anchor taken up in the Downes which is believed by good circumstances to be the Constant Warwick's Anchor lost some months ago about the place where this was found but is disputed by the person that look it up whether it be the King's Anchor or not, by reason H.M. mark doth not appear thereon. These are therefore to direct and require you to take particular care that as well the Anchors now remaining on shore as such as shall be hereafter made for H.M. Service by H.M. Anchor Smiths have the Broad Arrow

together with the Mark of the Anchor Smith marked so much deeper upon them than hath been hitherto usual, as that the said mark may probably continue many years without wearing out.

By the end of the century, the weight of the anchor was also being inscribed on the shank of the anchor--in hundredweight (cwt=112 lb), quarters (qtr=28 lb) and pounds (lb).

King James II (1685-1688) ordered an investigation into the affairs of the Navy, when he ascended the throne in 1685. One of the results of this commission was a lengthy document (NMM, AND/33) entitled: *A distinct proportion for Eight and Twelve Months-Sea Stores for every of his Majesty's Ships, Yachts, Ketches, Sloops and other Vessels now in Being, 1686*. Some of the information on the number and weight of anchors carried by the various vessels has been extracted and compiled in Table 4. The number of guns and tonnage has been added to clarify the sizes of the various rates of vessels.

There were a number of Dutchmen who were writing nautical treatises at the end of the 17th century: Witzen (1690), van Yk (1697) and van Dam (1701). There was a great deal of interaction between the English and Dutch involving both war and trade, and the information in these books is also applicable, in some instances, to English anchors of the period.

Witzen (1690: 143), in his *Architectura Navalis et Regimen Nauticum*, states that the length of the shank of an anchor will equal twice the thickness of the shank measured in Amsterdam inches (A. inches) (2.59 cm), expressed in Amsterdam feet (A. feet) (0.724 m) plus the product in inches. Therefore, for a

TABLE 4. The number and weight of anchors in 1686 (after NMM, AND/33).

Rate	Ship		Sheet Anchors			Bower Anchors			Stream Anchors			Kedge Anchors		
	Guns	Tons	No.	Cwt	Qtr	No.	Cwt	Qtr	No.	Cwt	Qtr	No.	Cwt	Qtr
1	100	1500	1	69	2	3	62	0	1	19	1	1	7	2
						1	58	0				1	4	0
1	96	1225	1	56	0	3	53	0	1	16	2	1	6	2
						1	49	0				1	3	3
2	84	1150	1	47	0	3	45	0	1	14	0	1	6	0
						1	42	0				1	3	2
3	68	900	1	40	2	2	38	2	1	11	2	1	3	2
						1	36	0						
3	60	750	1	34	2	2	33	0	1	9	2	1	3	1
						1	31	0						
4	50	600	1	27	0	2	25	2	1	8	0	1	3	0
						1	24	0						
4	46	425	1	22	2	2	20	2	1	6	2	1	2	2
						1	18	2						
5	32	250	1	15	0	2	14	0	1	5	0	1	2	0
						1	13	0						
6	16	180	1	10	2	2	9	2	1	3	0	0	-	-
						1	9	0						
Ketch	12	90	1	7	2	1	6	2	1	2	0	0	-	-
						1	6	0						

thickness of 6 A. inches: $2 \times 6 = 12$ feet + 12 inches = 13 feet and 1 inch (11 A. inches = 1 A. feet). Witzen goes on to say that for anchors weighing less than 500 Amsterdam pounds (A. pounds of 0.495 kg) (about 250 kg), three times the thickness of the shank in A. inches will give the length in A. feet. Furthermore, three times the thickness of the shank in A. inches plus two zeros will give the weight of the anchor in A. pounds. Witzen gives a table (1690: 143) that lists the lengths of the anchor shanks, their thickness, and weights. Sadly, this table is full of inconsistencies and does not agree with the proportions given by his numerous rules. These rules should be avoided as they are not consistent with the increasing proportions of the vessels and their respective anchor weights. The reader also has to decide as to whether the weights of the anchors for the various vessels are valid.

Witzen (1690: 143) does give us the dimensions for a 10 cwt (545 kg) anchor. The shank is $11\frac{1}{2}$ ft long, with the wooden stock being the length of the stock and the ring--13 ft. For every foot of stock-length, the stock is 1 inch wide, being 13 inches square in the middle and tapering on the bottom and sides to either end, where it is $6\frac{1}{2}$ inches square. The top of the stock is always left flat. The square at the top of the shank is $4\frac{1}{2}$ inches square and 1 ft 9 in in length. The arms are 5 ft long, with the flukes being half of that in length, and $\frac{2}{5}$ the arm length is equal to the width of the fluke. The eye is $2\frac{1}{2}$ inches in diameter, and the 2 in thick ring is 16 inches in diameter. These dimensions are useful, as one can now see the overall shape of the anchor. The length of the arm-to-

shank ratio has been reduced considerably, from that of Spanish anchors, while the flukes are still $\frac{1}{2}$ the arm in length. This anchor is still very light for its length, though not as slender as the earlier Spanish anchors.

Van Yk (1697: 219), in his *De Nederlandsche Scheeps-bauw-konst Open Gestelt*, states that the weight of an anchor can be calculated by taking the cube of the shank in A. feet to give the weight in A. pounds. This is not a very accurate rule and van Yk (1697: 219) notes that anchors having the same length can vary in weight between 3000 and 5000 lb (1485 and 2475 kg). He mentions another rule saying that the length of the anchor will equal $\frac{4}{10}$'s of the vessel's beam, at the mid-ship-line (van Yk, 1697: 216), which is a fair measurement for the time. As far as anchor dimensions are concerned, van Yk allows 7 ft along the curve of the arms, for every 8 ft of anchor length. A good angle for the arms is 60° , with a smaller angle decreasing the holding power and a greater one having less ability to bite into the seabed. The palms are equal to half the arms length, with their width $\frac{1}{6}$ narrower than their length--to give the shape of an isosceles triangle. The diameter of the ring is equal to 2 inches for every foot of shank length, the ring thickness is 1 foot circumference (round) for every 3 inches in ring diameter. Therefore, for an anchor of 12 feet in length, the ring will be 24 inches in diameter and 8 inches in circumference (3.2 in diameter of thickness). One can clearly see that the ring described by van Yk is considerably larger than that of Witzen's, which is definitely on the small side. The stock is the same length as the anchor and the ring, having a width of 1 inch in the

middle for every foot in length. The width is half of that at either end. Van Yk (1697: 217) states that the stock width is always more than the thickness, but fails to inform the reader of the difference.

Van Dam (1701), in his *Beschrijvinge van de Oostindische Compagnie*, gives the specifications for anchors for three classes of Dutch East India Company (V.O.C.) ships, for the year 1697. A 160 foot-long ship carried nine anchors, the heaviest being 3600 A. pounds (1782 kg), a 140 foot long vessel carried eight anchors, the heaviest being 3000 A. pounds (1485 kg), while a 130 foot long vessel carried only seven anchors, the largest being 2200 A. pounds (1089 kg) (van Dam 1701: table 3). It should be noted that the V.O.C. ships were carrying anchors a great deal heavier than Witzen's rules would have allowed for, and the heavier weights are actually more feasible for the time period.

ARCHAEOLOGICAL EVIDENCE

There are only two known English wrecks, from the 17th century, that were found to have anchors on the wrecksite. Sadly, neither of these vessels had their anchors recorded in any detail, so little can be gleaned from the measurements. Three Dutch East India Company wrecks have been included, to add to the scant archaeological record.

The *Trial* Anchors

At the same time that Mainwayring was writing, in 1622, an English East India Company (E.E.I.C.) ship, the *Trial*, became the earliest known shipwreck on the Australian coast (Green, 1977). The vessel was lost on the northwest coast on a reef subsequently named 'Trial Rocks'. Eight anchors were recorded on the site in 1971, and two others were possibly recorded by earlier expeditions. All were badly eroded, some even badly broken, and only rough measurements were taken. The sheet anchor is approximately 5.5 m long (18 ft) and weighed an estimated 32 cwt (1625 kg). Two of the bower anchors were about 16.5 ft long (5.0 m) and weighed an estimated 30 cwt (1525 kg) and 24 cwt (1220 kg) respectively. The anchors all appear very slim for their size, but very large for the time period (Green, 1977: 50). No other dimensions are given, nor is any comment made as to which plane the anchor stock nuts are in, parallel or perpendicular to the arms.

There is no documentary evidence to indicate the size of the *Trial*; she was, however, carrying at least seven cannon (perhaps one or two more), which would indicate a vessel of about 100 feet in length and 100 tons in displacement. However, Green (1977: 50) suggested that the number and size of the anchors on the wrecksite tend to suggest a much larger vessel, although it is also possible that the *Trial* was carrying spare anchors for other E.E.I.C. ships in the Indies. However, there is no documentary evidence to support this theory.

The *Batavia* Anchors

The *Batavia* was a 160 ft V.O.C. ship that wrecked on the Wallabi Group of the Hautman Abrolhos, Western Australia, in 1629 (Green, 1975: 43-63). Nine wrought iron anchors were recorded on the wrecksite, their lengths are as follows: a 4.5 m sheet anchor, a 4.25 m bower, two 3.5 m bower anchors and a 3.25 m stream anchor. There was also a collection of four bower anchors in the center of the wrecksite, all 4.25 m in length. Green (1977: 51) has suggested that from the way the *Batavia* appears to have fallen over on her starboard side, one could conclude that these anchors were stored upright in the hold, unstocked with their crown down. Unfortunately, no other dimensions are available for these anchors.

The *Vergulde Draeck* Anchors

The *Vergulde Draeck*, the 'Gilded Dragon', was a V.O.C. yacht that sank on the shore of Western Australia, in 1656 (Green, 1973: 267-289). Five anchors were recovered from this wrecksite: three bower anchors, a stream anchor, and a kedge anchor. No dimensions were given, for the size and weight of the anchors.

The *Kennemerland* Anchors

The *Kennemerland*, an outward bound V.O.C. vessel on the way to Batavia in the East Indies, was wrecked in 1664 on the Shetland Islands (Forster

& Higgs, 1973: 291-300). Five anchors were found on the wrecksite, though it is known that some anchors were salvaged shortly after the vessel's loss. The anchors were all badly corroded, so only simple measurements were recorded. Anchor #1 was 2.55 m long with a beam of 2.5 m, Anchor #2 was 2.94 m long with a beam of 2.74 m, Anchor #3 was 3.0 m long with a beam of 2.6 m, Anchor #4 was 3.6 m long with a beam of 2.3 m, while Anchor #5 was 1.2 m long with a beam of 1.48 m. These measurements are of little use, as they include the mass of iron concretion surrounding the iron anchor. There is also the problem of how the measurements were taken. If one looks at Anchor #1, the beam and shank measurements are almost the same. This could be the case, only if the beam measurement was taken along the curve of the arms, otherwise the arm-to-shank length ratio would have been ridiculously low. Dutch anchors do have a smaller arm-to-shank ratio, but these measurement are way out and possibly include the concretion around the metal. The recorders do mention that the top of the anchor shanks were square in section, which indicates the use of wooden stocks.

The *Dartmouth* Anchors

H.M.S. Dartmouth, a 5th Rate 32-gun frigate of 260 tons, was wrecked off Mull, Scotland, in 1690 (Adams, 1974: 269-274). Three anchors were found on the wrecksite and only their shank lengths were recorded. The sheet anchor was 12 ft (3.6 m) long, and the two bower anchors, found together, were 8 ft (2.4 m)

in length. From the site plan of the wrecksite, it looks as though one arm on one of the bower anchors was broken off and missing.

The 1686 Establishment (Table 4) stipulates of 15 cwt. (763 kg) sheet anchor for a 5th Rate, 32-gun vessel of 250 tons. A 15 cwt anchor is about 12 ft in length, which corresponds to the large anchor found on the wrecksite. If one were to test Witzens's rule on this anchor, one would find that it does not work very well. Witzens's 11½-foot long anchor only weights 10 cwt, which is far too light. Van Yk's rule of allowing 4/10's of the vessel's beam for the length of the sheet anchor, gives a better result. The *Dartmouth* had a beam of 25 ft (7.6 m) which would allow for a 12½ ft (3.8 m) long anchor. This is within an acceptable range. Sutherland (1717b: 22) lists a 12 ft 2 in long sheet anchor, weighing over 18 cwt (915 kg), for a 5th Rate vessel of 364 tons. Sutherland's anchor is a great deal more robust than the *Dartmouth's* sheet anchor, and was for a larger vessel.

EIGHTEENTH-CENTURY ANCHORS

HISTORICAL EVIDENCE

General contracts continued to be the accepted method for supplying the Navy with anchors in the early 18th century. Such a contract had been made with a Mr. Loader, at Chatham Dockyard, for supplying the Navy with anchors at the time of the New Commission in 1686 (Merriman, 1961: 156). This contract was still in effect in 1704, after being renewed twice during King William III's reign (1688-1702).

William Sutherland (1717a: 144) made some general observations on a copy of a contract, dated 3rd of December, 1698, that was entered for a 'Master Anchor Smith'. He listed the costs for making new anchors (Table 5), and goes on to list the cost of repairs to anchors and parts thereof (Table 6). The anchor-smith was paid 24 shillings a week, the eleven hammermen at a rate of 12 shillings a week with an added daily allowance of a gallon of beer a day while they were making anchors (Sutherland, 1717a: 144).

The greatest stress that is exerted on an anchor, occurs mainly in three places: near the middle of the shank above the trend, at the middle of the arm at the base of the fluke, and at the throat where the arm joins the shank in the crown. When an anchor is weighed, the shank acts as a lever and forces the arm out of the bottom sediments. If there is any weakness in the crown weld, the arm will part from the shank. Sometimes the fluke-to-arm weld fails, and the

TABLE 5. The cost for making new anchors (after Sutherland, 1717a: 141).

Weight of Anchor in Hundred-weights Cwt	Cost/Cwt ¹			Total Cost ²		
	£	s	d	£	s	d
up to 10	1	14	6	17	5	0
from 10 to 20	1	17	6	37	1	0
from 20 to 30	1	19	6	58	1	0
from 30 to 35	2	4	6	77	17	6
from 35 to 40	2	6	6	93	0	0
from 40 to 45	2	8	6	105	2	6
from 45 to 50	2	12	6	135	5	0
from 50 to 55	2	17	6	157	2	6
from 55 to 60	3	5	6	196	10	0
from 60 to 65	3	12	6	235	12	6
from 65 to 70	4	2	6	292	15	0

1. Cost per cwt according to weight.
2. The value of the material and workmanship, or the charge of the anchor delivered from the forge for the largest size.

Table 6. The cost of repairing anchors (after Sutherland, 1717a: 141).

Type of Repairment	Value ¹		
	£	s	d
For streightening and refitting an Anchor in all its Parts ²	0	1	6
For cutting of an Anchor in the Shank, and shutting on a new Piece of Shank	0	1	6
For Weilding or new shutting on an old or a new Ring to an Anchor, and taking out the old Ring	0	0	8
For new pointing an Anchor when the Bills are broke off	0	0	9
For weilding a Palm of an anchor old or new	0	1	6
For cutting off a Palm of an Anchor, and making it a mooring Anchor	0	1	0

1. For every Hundred Weight any Anchor doth weigh, that is to be repaired accordingly.
2. And for every Pound of Iron that shall be added to an old Anchor, for making good the same, he was to be allowed the Price per Hundred as for Anchors of the like Bigness (Table 5) over and above the said Rates for repairing Anchors.

arm twists free to leave the fluke behind, or the arm simply breaks at the base of the fluke. If the anchor is a slender model, there is the possibility that the shank is not strong enough to force the arm from the sediment, and shank will bend and ultimately break. These stress points were known to the anchor smiths, who took care in fabricating these sections, often reinforcing them with extra metal.

Sutherland (1717a: 145) discusses the liability of anchors failing while in use, and expounds on the idea that there should be an 'engine' for testing the anchors with some form of "strength and strain" before their use. The anchor contract should also mention the '*Price of the Tryal*', the '*Nature of the Engine*' and also the '*Manner of the Tryal*'. However, if the owner does not stipulate an anchor test and the anchor fails while in use, then the owner is the one who is liable for the loss of the vessel and not the anchor-smith (Sutherland, 1717b: 110). Such a test would have been beneficial to all, putting a check on the smith as well as on the poor management of putting inadequate anchors on vessels that would only end up as casualties: "*...such an Undertaking may be very easily comply'd with, and not very chargeable; provided it was made general, and every one help'd to pay for the Engine*" (Sutherland, 1717b: 110). There was no real test for an anchor at the time, occasionally a trial test was attempted where the anchor was raised up and dropped, allowing it to fall on its crown. If no defects were found after this 'test', the anchor was said to be 'sound'.

The limiting technology of the day was also one of the prime factors governing the anchor failure rate. Techniques were still not yet available for

successfully forging and handling large masses of iron. The *Nassau*, a 3rd Rate of 80-guns (Colledge, 1987: 238), lost her Best Bower and Spare anchor off the coast of Holland in May, 1700. Both anchors, weighing about 40 cwt each, broke in the shank which was supposed to be the strongest part, as "*they were so very ill wrought that the bars were whole and entire, and only cased over with a thin shell of iron*" (Merriman, 1950: 159). The Navy Board explained away this defect by arguing that it,

...may have arisen from Mr. Loader's having undertaken so great a work as the making of anchors for the whole Navy; for that, in the great quantity of iron which he must necessarily deal for, 'tis very probable he cannot help being imposed upon as to some thereof; and that due care has not or, it is likely, cannot be taken that all his workmen perform their labour as they ought to do (Merriman, 1961: 156).

The real reason was that it was extremely difficult to successfully forge weld a large mass of iron (made up from a number of smaller iron bars bundled together into a faggot) that was over 16 feet long and 10 inches thick in places. In a letter from the Navy Board to the Admiralty, dated 15th June, 1704, the idea was put forward that anchors weighing less than 30 cwt "*would be best made solid*" (Merriman, 1961: 157). It is not known if this recommendation was accepted, but finding a large enough bloom to make the shank for a 30 cwt anchor would have been a task in itself. Anchors weighing less than 10 cwt (510 kg) were generally made solid, whereby each piece of the anchor was made from one wrought iron bar or bloom.

The Navy did try to solve the problem by having the anchors made by the contracted anchor smiths working permanently within the naval dockyards. It was also suggested that the Navy should make the larger anchors, with the smaller anchors continuing to be made under contract at private forges. The respective dockyards played an important role in the contract machine. The 'Officers of the Yards' or some other experienced people were supposed to oversee the anchor-making operations and ensure the "*goodness of the materials and workmanship*" (Merriman, 1961: 158). They were also responsible as to whether any goods were rejected or not.

Such contract work was not always profitable, as the Navy Board drove a hard bargain. In the early 1700's Sir Ambrose Crowley, one of the leading ironmasters, complained that he was left, upon the termination of his contract to provide anchors, with several that were too large for any but naval use (Pool, 1966: 101). The Navy Board declined to take them off his hands unless he would accept unfavourable long-term payment. It was well known that better prices could be had from merchants than from the Navy. In 1703, three ironmasters, Davis, Smith, and Bradfield, declined to accept orders from the Navy Board on the grounds that "*they had better prices of the merchants than are now given by the Navy*" (Merrimen, 1951: 163).

The weakness of the ground tackle, on which the ship's safety depended, was tragically demonstrated by the heavy losses along the South and East coasts of England in 'the great storm' of November 1703. With the intent of finding

out what proportion of the anchors had failed, as many anchors as possible were salvaged from the Downs and elsewhere along the coast. Of the twenty-two anchors that were recovered and examined, all but two were classified, rather surprisingly, as serviceable. However, one of them was so hollow that over two quarts of water could be poured into the spaces between the bars in the center of the shank. In another survey of eleven anchors, eight were found to be '*defective in iron or workmanship*'. Mr. Loader's mark (J.L.) was found on five of the anchors, which he denied ever having made (Merriman, 1961: 157).

Clearly, this all-important article had been causing anxiety for a number of years. The growing size of ships only emphasized the fact that anchors produced by the methods of the day were unreliable. The process consisted of welding a number of iron bars together to form the component parts. With the difficulty of evenly applying heat over a large surface area, this often resulted in the pieces being imperfectly welded together. Internal flaws were almost impossible to detect, being hidden under a thin skin of the outer welded material. This problem, and the use of low quality iron, were the main contributors to the ongoing problem. During the war of the Spanish Succession, 1701 to 1713, it was difficult to manufacture anchors with a minimum of two-thirds Spanish iron in England. That stipulation was dispensed with and the "*best Swede or such other iron as shall be most proper for the same*" was used (Merriman, 1961: 158). Attempts were made to test the anchors, but there was no certainty that the anchor would not break at a later date. Suggestions for

improving the manufacturing techniques were constantly being examined--some of them good ideas, and some bad.

Allard (1716), in his *Algemeene en Verbeterde Hollantsche Scheepsbouw*, illustrates an anchor having a round-sectioned shank and curved arms in the shape of gentle arc. The ring appears to be of a similar size to the flukes, which are isosceles in shape and half the arm in length. The stock is held together using eight treenails per side, and does not have iron stock hoops. Allard (1716: 44) gives a table showing the various widths of the ship's beam, the length of the anchor, the anchor weight, and the diameter of the cable that is copied directly from van Yk (1697: 219-220). Unfortunately, this practice was a common one and researchers should watch that they are not using out-of-date information. This table of van Yk's was fairly popular, as the Frenchman Nicolas Aubin (1722) also used it in his *Dictionnaire de Marine*. He does, however, say that the table is from the Flemish writer van Yk. The old rule for calculating the length of the anchor, as being $\frac{4}{10}$'s of the vessel's beam, was still in use in the second quarter of the 18th century.

One of the best early descriptions for the dimensions of an anchor, is in William Sutherland's *Britain's Glory: or, Ship-Building Unvail'd*. Sutherland (1717b: 22) makes the general observation that the length of an anchor is equal to $\frac{2}{5}$'s of the vessel's extreme breadth (beam). He lists the sheet anchor dimensions for six classes of vessels (Table 7), and goes on to accurately explain the various measurements and how they are taken.

TABLE 7. Shape and dimensions of anchors (after Sutherland, 1717b: 22).

Tonnage of the Six Sizes	1677 Tuns		1488 Tuns		969 Tuns		625 Tuns		364 Tuns		225 Tuns	
	feet	inch	feet	inch	feet	inch	feet	inch	feet	inch	feet	inch
Weight of the biggest Anchor	C. qr. 1. 71: 2: 0		C. qr. 1. 64: 0: 0		C. qr. 1. 45: 0: 0		C. qr. 1. 30: 0: 0		C. qr. 1. 18: 3: 6		C. qr. 1. 11: 2: 1	
Cube Root of the Weight	4.15		4.00		3.55		3.10		2.65		2.26	
Length of the Shank as aforesaid	18	6	18	2	16	1	14	2	12	2	10	8
Bigness of the great End of ditto	0	11.5	0	11.1	0	10.1	0	8.8	0	7.55	0	6.7
Ditto at the small end	0	8.65	0	8.5	0	7.5	0	6.6	0	5.65	0	4.7
Length of the Square	2	11	2	10.4	2	6.4	2	3	1	11	1	8
Length to the Nut	1	11	1	10.6	1	8.8	1	5.6	1	3.1	1	1.4
Bigness of the Nut Square	0	2.3	0	2.26	0	2	0	1.76	0	1.51	0	1.44
Diameter of the Rings inside clear	2	1.5	2	1	1	10	1	7.6	1	3	1	2
Bigness of the Ring	0	4	0	3.94	0	3.48	0	3.06	0	3	0	2.72
Diameter of the Hole for the Ring	0	4.6	0	4.5	0	3.98	0	3.5	0	3	0	2.66
Length of the Crown	1	2	1	1.7	0	11.1	0	9.75	0	8.35	0	7.7

Length of the Shank, A-b
 Bigness of the great end, c-d
 Ditto of the small end, e-f
 Length of the Square, g-h
 Ditto to the Nut, G-h
 Bigness of the Nut Square, G
 Bigness of the Ring, 1-2
 Diameter of the Ring's Hole, 1-3
 Length of the Crown, m-b
 Length of the Arm, c-x or d-r
 Length of Flook R-4
 Thickness of Flook 4-5
 Square of the Arm at the Flook, R
 Length of the Bill, 5-r
 Clutching of the Arm, e-m
 Inside meeting, Z-x-c
 Outside meeting, x-L-y
 Middle meeting, x-y-c (after Sutherland, 1717b: 22)

This description is illustrated with a drawing of an early 18th-century anchor (Fig. 10). This is one of the earliest drawings of what was later referred to as an 'Old-Plan Long-Shank Anchor'.

Sutherland (1717b: 22) discusses the options of setting the arms of the anchor at the different settings. The length of the arm is from c to x (Fig. 10), if the arm is set (angled) to the point Z that is the 'inside meeting'. The 'outside meeting' is set to point L, and the 'middle meeting' is to point y. The angle to any of these three points, is such that the three sides form an equilateral triangle. One can see that there is a difference between the inside and outside meetings, as the bill will be closer to the shank in the outside meeting. The greater the angle between the arm and shank, the greater the strain on the arm-shank weld in the crown. This can be allowed for by making the crown more robust and

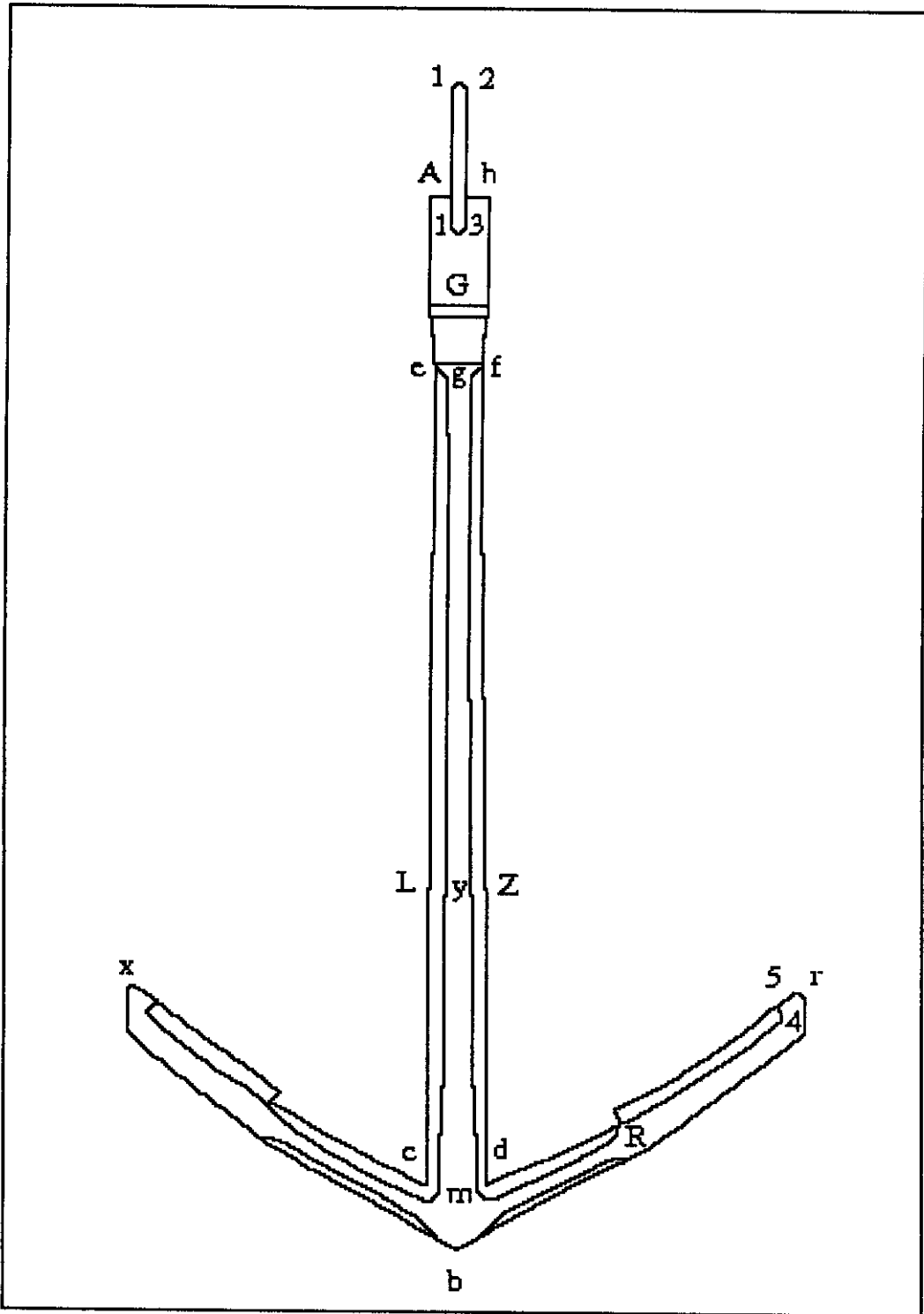


Figure 10. An early 18-century English anchor (after Sutherland, 1717b: 23).

strengthening the weld. Too shallow an angle, and the anchor will not hold as well. The ideal is an angle of 60° , set at the middle meeting.

Reaumur, in his *Fabrique des Ancres* (1764), gives an excellent account of the anchors used in the French Navy. The treatise explains the methods used to fabricate an anchor, their sizes and dimensions and the number and weights of anchors carried by the various classes of ships. A drawing of a French anchor, ca. 1723, has been included to illustrate the differences from the English Old-Plan Long-Shank anchor of the time (Fig. 11). French anchors of the 18th century had curved arms, as opposed to the straight arms on the large English anchors. The angle of the arms was still much the same, being an average 60° to the shank. The stocks on French anchors were curved (not shown), the top of the wooden stock having a gradual upwards curve that was mirrored by the underside. The 'spade' shaped flukes were curved to fit the arms, extending right up to the extremity of the bill where they were squared off.

Bouguer (1746: 95-103), in his *Traite du Naviere*, states that there is an easy way to calculate the weight of an anchor. If the length of an anchor, in inches, is cubed and then divided by 1160, the result will be the weight of the anchor in pounds. Clearly, this is yet another bad rule, as anchors of the same length can vary considerably in weight. Bouguer gives a second rule for calculating the anchor's weight, saying that the anchor will weigh half of the weight of its cable. This rule does allow for very 'light' anchors though. He also gives some useful information in the text, stating that small vessels generally

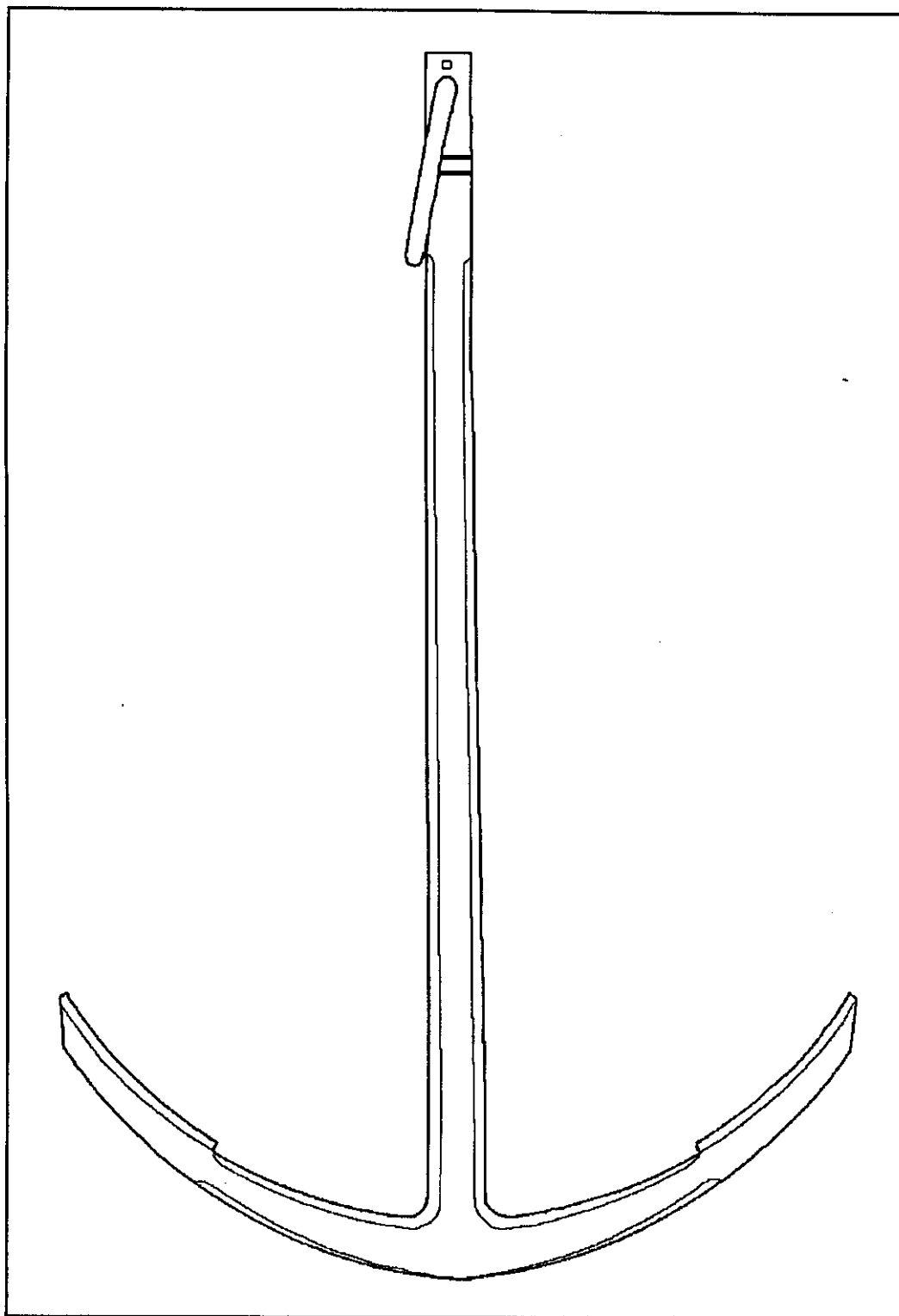


Figure 11. A French anchor of 1723 (after Reaumur, 1764: Plate 1).

carry five or six anchors, while larger ships had eight anchors. The sheet anchor was now usually only $\frac{3}{8}$'s of the vessel's beam in length, which is a slight reduction from the early 18th century.

The Deptford dockyard predominated in anchor production in the early 1700's. By 1748, there was a master anchor smith, 12 foreman smiths and 88 hammermen. This was the largest single group of skilled workers in the yard, except for the shipwrights. Because making an anchor required a great deal of skill and strength and was very laborious, the anchor-smiths and hammermen were paid extra wages and given an extra beer allowance, while they were working, as further encouragement in their endeavours. In a letter (PRO, ADM 106/2507 #272) dated 20 January 1728, the Navy Board stipulated that anchor-smiths making new anchors between 10 and 40 cwt were to receive 1 quart of 'Strong Beer', and 3 pints of 'Strong Beer' for anchors over 40 cwt. For repairs to all anchors over 10 cwt they were to receive 1 quart of 'Strong Beer', in addition to their usual daily allowance of a gallon of 'Small Beer'. A young boy was even employed to help the anchor-smiths, whose main duty was to replenish the beer supply whenever necessary (Bugler, 1966: 68).

Deptford could not keep up with the demand for anchors that was created by the large-scale ship building programme of the time, and anchor forges at the other Navy dockyards of Chatham, Woolwich, Portsmouth, Plymouth, and Sheerness, were greatly expanded in the second half of the century. There was also a shortage of skilled workers, as a letter from

Commissioner Richard Hughes to the Navy Board on 11 July 1744, remarks: "... and smith's, particularly to breed up good hammermen, which are scarce too; especially those employed in making anchors and on large work" (Baugh, 1977: 309).

The Naval Expositor, the first really adequate English maritime dictionary with illustrations, was written by Thomas Blanckley in 1750. Blanckley (1750: 1-2) states that:

The Anchors on board a Man of War are the Sheat, Spare, Best and Small Bower, which by the Establishment, are all of one Weight, the Stream one Fourth, the Kedge one Eighth, of the large ones; and the First and Second Rates are allowed a small warping one, one half the Weight of the Kedge.

Blanckley goes on to briefly describe the various parts of the anchor, using the common terms of the day. Unfortunately, he does not give any dimensions or proportions to the anchors, nor does he give any lists to indicate the sizes of anchors carried by the different classes of warships. The Establishment that Blanckley (1750: 2) was writing about, was the Establishment of 1744. Part of this document stipulates the number, type, and weight of anchors carried by the various 'Classes of Ships' (Table 8).

Mungo Murray, in his *Supplement to the Treatise on Ship-Building*, makes an interesting observation in a statement about anchors: "*The anchors in France, England, and Holland are of forged iron; but in Spain they may be seen of copper, and likewise, in several parts of the South Sea*" (Murray, 1765: 18). There are a

TABLE 8. The number, type, and weight of anchors for a ship of each class in 1745 (after NMM, RUSI 42).

Vessel		Anchors				
Rate	Guns	No.	Type	Cwt	Qtr	lbs
1	100	5	Bower	77	3	0
		1	Stream	20	0	0
		1	Kedge	10	0	0
2	90	5	Bower	71	3	0
		1	Stream	17	0	0
		1	Kedge	9	2	0
3	80	4	Bower	65	3	0
		1	Stream	16	0	0
		1	Kedge	8	2	0
3	70	4	Bower	56	2	0
		1	Stream	14	0	0
		1	Kedge	7	2	0
4	60	4	Bower	51	2	0
		1	Stream	12	0	0
		1	Kedge	6	2	0
4	50	4	Bower	46	2	0
		1	Stream	11	2	0
		1	Kedge	6	0	0
5	40	4	Bower	37	3	0
		1	Stream	9	2	0
		1	Kedge	5	0	0
6	24	4	Bower	29	1	0
		1	Stream	6	2	0
		1	Kedge	3	0	0
Sloop	--	3	Bower	15	0	0
		1	Stream	7	0	0
		1	Kedge	3	2	0

few known examples of 'copper' anchors (Jobling, 1989: 67), the term bronze should be used here, so there must be some truth to his comment. There is a particularly fine bronze anchor on display at the Old Custom House in Monterey, California. The use of bronze anchors was not the norm for the time period, and this anchor was probably used by the Spanish in the South Sea (Pacific Ocean). If no iron anchors were available, it may have been simpler to cast a bronze anchor in the East Indies than forge an iron anchor.

Murray goes on to describe an anchor, saying that the arms were generally in the form of an arc of a circle, making an angle of 120° (Murray, 1765: 18). The arm length was equal to $\frac{3}{8}$'s of the length of the shank, and the flukes were $\frac{1}{2}$ the arm in length. An English anchor of the period (1760's) had straight arms, so Murray's comment on curved arms is unusual. There is a possibility that he was copying from Bougier's (1746) *Traite du Naviere*, as he does refer to Bougier's rule for finding the weight of an anchor, and French anchors did have curved arms. Murray's (1765) other anchor dimensions are all similar to Bougier's (1746), so one should realize that this information could be twenty or so years old.

H.M.S. Victory, a 1st Rate of 100-guns, was being built at Chatham, England, in the mid-1760's. The Navy Board arranged that several dockyards would assist in fabricating her anchors, as they were particularly large. A letter of instruction to the Chatham dockyard reads as follows:

Having directed the Officers of Deptford yard to cause an anchor of 85 to 88 cwt. to be made for the 'Victory', the Officers of Woolwich to make one for her of the like weight; and the Officers of Portsmouth yard to send an anchor of 87 cwt. to your yard. These are to direct and require you, to cause two anchors of 85 to 88 cwt. to be made by the smiths of your yard for the said ship, this shall be your warrant dated at the Navy Office 1st March 1764 (Bugler, 1966: 8).

By the end of June 1764, one of the *Victory's* anchors, weighing 87 cwt 1 qtr and 14 lb (4440 kg) had arrived from the Deptford dockyard. Initially, the *Victory* was issued with one sheet and four bower anchors, one stream anchor of 21 cwt (1068 kg), and two kedge anchors of 10½ cwt (534 kg) and 5 cwt (254 kg) respectively. The extra, small, kedge anchor was still issued to 1st and 2nd rates for use as a small warping anchor.

The large wrought iron sheet anchor was 21 ft 2 in (6.45 m) long, with a wooden stock 22 ft 4 in (6.81 m) in length. The rest of the anchor's dimensions were as follows: the square and trend were both 11 in by 11 in (0.28m x 0.28 m); the small round being 9 in by 9 in (0.23m x 0.23 m); the beam width 13 ft 9 in (4.19 m); the arm length was 8 ft 4 in (2.54 m); the outside diameter of the ring 3 ft 4 in (1.01 m); the ring thickness 5 in (12.7 cm); the middle of the stock was 1 ft 10 in (0.56 m) square; and the ends of the stock being 11 in (0.28 m) square. The trend of the arms was approximately 59°, with a 7° increase in the arm angle at the base of the fluke. The length of the fluke was 3 ft 3 in (1.0 m), being slightly less than ½ the length of the arm, and nearly the same as the outside diameter of the ring.

These bower anchors were a great deal larger than those normally issued to a 1st Rate vessel of the time. According to Sutherland (1766: 139), a 1st Rate of 100-guns was listed as having five bower anchors of 77 cwt and 3 qtr (3950 kg). However, the stream and kedge anchors he lists are of a comparable size (Table 9).

The weights of bower anchors given by Sutherland (1766: 139), in his *Shipbuilder's Assistant*, seem to be consistently short. This becomes more evident, when the weights are cross-checked against the weights of anchors listed for a particular man of war. The *H.M.S. Bellona*, a 3rd Rate of 74-guns and 1615 tons, built in 1760, was issued with the following anchors (Lavery, 1985: 15):

<i>Best Bower</i>	69 cwt.	0 qtr.	0 lb.
<i>Small Bower</i>	57	0	0
<i>Spare Bower</i>	65	3	5
<i>Sheet Anchor</i>	68	3	0
<i>Stream Anchor</i>	16	3	2
<i>Kedge Anchor</i>	9	2	0

One should take note of the fact that the best bower is larger than the sheet anchor. The sheet anchor was not necessarily the largest anchor, and the captain of the vessel had the right to choose which anchors he would use as bowers, etc. In this case, the sheet anchor may have been a better fabricated anchor, than the larger bower, and was kept in reserve. This reference also informs the reader that the kedge anchor was iron-stocked in 1775.

TABLE 9. The number, type, and weight of anchors for a ship of each class in 1766 (after Sutherland, 1766: 139).

Vessel		Anchors				
Rate	Guns	No.	Type	Cwt	Qtr	lbs
1	100	5	Bower	77	3	0
		1	Stream	20	0	0
		1	Kedge	10	0	0
2	90	5	Bower	71	3	0
		1	Stream	17	0	0
		1	Kedge	9	0	0
3	80	4	Bower	65	3	0
		1	Stream	16	0	0
		1	Kedge	8	2	0
3	70	4	Bower	56	0	0
		1	Stream	14	0	0
		1	Kedge	7	2	0
4	60	4	Bower	51	2	0
		1	Stream	12	0	0
		1	Kedge	6	0	0
4	50	4	Bower	46	2	0
		1	Stream	11	2	0
		1	Kedge	6	0	0
5	40	4	Bower	37	3	0
		1	Stream	9	2	0
		1	Kedge	5	0	0
6	24	4	Bower	29	1	0
		1	Stream	6	2	0
		1	Kedge	3	0	0
Sloop	--	3	Bower	15	0	0
		1	Stream	7	0	0
		1	Kedge	3	2	0

If these anchor weights are to be compared with Sutherland's (1766: 139), one will find that he lists four bowers of 56 cwt (2850 kg), which is less than that for the spare bower of the *Bellona*. The stream and kedge anchors are also on the small side. If one was to look at the weight of anchors for a larger rate of vessel, and substitute them for the rate below, the figures would be in closer agreement. There is a possibility that Sutherland was using the 1744 Establishment, as a basis for the number and weight of anchors he lists in 1766. With the gradual trend towards larger size anchors, this would allow for his anchors being 'light' as the figures were twenty years out of date.

Occasionally letters to and from the Navy Board, record the weights of anchors carried by specific vessels. One such letter, dated 7 May 1779, was from the master of *H.M.S. Bedford*, a 3rd Rate of 74-guns and 1600 tons, at Plymouth. Commander Thomas Graves, Esq., wrote that his vessel had the following anchors (NMM, RUSI/86):

<i>Best Bower</i>	69 cwt.	0 qtr.	0 lb.
<i>Small Bower</i>	57	0	0
<i>Spare Bower</i>	65	3	5
<i>Sheet Anchor</i>	68	3	0
<i>Stream Anchor</i>	16	3	2
<i>Kedge Anchor</i>	9	2	6

The anchors listed weigh the same as those listed by Lavery (1985: 15) for the *Bellona*, and he may have used the *Bedford's* anchor weights for the *Bellona*. The information contained in these letters can be used in the same way as anchors recovered from an archaeological site. They give the specific weights of anchors

for a particular date, which can then be used to cross-check the anchor weights stipulated by a particular Establishment.

According to the 1786 Establishment a few years later, the *Victory's* four bower anchors should weigh about 81 cwt (4120 kg) apiece (NMM, RUSI/57). The official reduction in the number of bower anchors carried by 1st and 2nd Rates came in 1779. In a letter dated 14 September 1779, the Navy Board sent an order to the Portsmouth dockyard stating:

These are to direct and require you to supply the 'Senwich' [H.M.S. Sandwich, a 2nd Rate of 98-guns] with only 4 anchors instead of 5 anchors and 8 cables instead of 9 cables and in future to supply no more to any 1st and 2nd Rates that may be fitted at your Port and as the ships of those Classes now in Commission come in because of being refitted You are to receive into store one of the five anchors and one of 9 cables they have now (PRO, ADM 106/2508 #879).

In 1761, the 32-gun frigate *Alarm* was the first Royal Navy vessel to be experimentally sheathed in copper. After numerous trials and failures, the electrolytic problem was solved and the fleet was ordered to be 'copper bottomed'. The program began in earnest in May 1779, and more than half the fleet had been coppered by 1781 (NMM, MID/9/1). Copper is a fairly soft and malleable metal that is easily damaged. It was quickly noted that handling an anchor in heavy weather was detrimental to the copper sheathing, as the square ends of the wooden stocks could easily gouge the metal. In a letter dated 16 May 1780, the Admiralty Board informed the various naval dockyards that:

It appearing that the Copper of the Bottom of His Majesties ships has of late been found to be injured by the ends of the Anchor stocks being left square; these are to direct and require you to round the ends of the Stocks in future in Stocking all Anchors of H.M. Ships of every rate (PRO, ADM 106/2508 #975).

This gives the researcher a good *terminus post quem* for wooden stocked anchors with their ends rounded off. Anchor stocks had a relatively short lifespan, and it was not uncommon for a vessel to carry one spare stock for every anchor on board (NMM, AND/34).

In a letter dated 3 November 1784, the Admiralty noted that "*the true establishment of anchors not being known at some of the yards*" (PRO, ADM 106/2509 #347). A new list was prepared and the 1786 Establishment (Table 10) was sent to the Yards to be used for fitting out vessels in the future. According to the new Establishment, the four bower anchors, inclusive of the sheet anchor, were to be identical in size. However, in practise, there was always some variation in the weights of the bower anchors.

The naval dockyards usually stored the anchors and their stocks separately. A Navy Board Letter (PRO, ADM 106/2509 #422), dated 10 January 1786, instructed the dockyards "*to keep some stocked anchors in store for ships of each class under guardships.*" This would speed up the rate of re-supply, and save the crew from having to stock the anchor before putting it into use. The very large anchors were left unstocked, as they were easier to handle on

TABLE 10. The number, weight, and value of anchors for ships of each class in 1786 (after NMM, RUSI/57 and PRO, ADM 106/2509 #347).

Ship		Bower Anchors					Stream Anchors					Kedge Anchors				
Guns	Tons	No.	Weight		Value		No.	Weight		Value		No.	Weight		Value	
			Cwt	Qtr	£	s		Cwt	Qtr	£	s		Cwt	Qtr	£	s
100	2164	4	81	0	299	14	1	21	0	40	19	1	10	2	19	19
90	1931	4	73	0	248	4	1	18	0	34	4	1	9	0	17	2
80 3 decks	1615	4	69	0	216	4	1	17	0	32	6	1	8	2	16	3
80 2 decks	1991	4	73	0	248	4	1	81	0	34	4	1	9	0	17	2
74 1 class	1799	4	71	0	241	8	1	17	2	33	5	1	8	2	16	3
74 2 class	1620	4	67	0	209	18	1	16	0	30	8	1	8	0	15	4
70	1426	4	59	0	162	5	1	25	0	28	10	1	7	2	14	5
64	1369	4	57	0	156	15	1	15	0	28	10	1	7	2	14	5
60	1285	4	53	0	137	16	1	12	0	22	16	1	6	0	11	8
50	1044	4	49	0	120	1	1	11	0	20	18	1	5	2	10	9

Table 10. Continued.

Ship		Bower Anchors				Stream Anchors				Kedge Anchors						
Guns	Tons	No.	Weight		Value		No.	Weight		Value		No.	Weight		Value	
			Cwt	Qtr	£	s		Cwt	Qtr	£	s		Cwt	Qtr	£	s
44	939	4	40	0	92	0	1	10	0	19	0	1	5	0	9	10
38	879	4	40	0	92	0	1	10	0	19	0	1	5	0	9	10
36 (large)	879	4	40	0	92	0	1	10	0	19	0	1	5	0	9	10
36 (small)	849	4	36	0	77	8	1	9	0	17	2	1	4	2	8	11
32	678	4	33	0	66	16	1	8	1	15	13	1	4	0	7	12
28	594	4	31	0	62	15	1	8	0	15	4	1	4	0	7	12
24	511	4	29	2	57	10	1	7	2	14	5	1	3	2	6	13
20	429	4	25	0	48	15	1	7	2	14	5	1	3	2	6	13
Sloop	300	3	20	0	39	0	1	7	0	13	6	1	3	2	6	13
Sloop	200	3	15	0	28	10	1	6	0	11	8	1	3	0	5	14
Sloop	140	3	12	0	22	16	1	5	0	9	10	1	3	0	5	14

land when they did not have their stocks attached. Guardships, during the 18th century, were generally 3rd Rate, 74-gun vessels.

Small modifications were continually being made to anchors, to improve the design and rectify problems as they evolved. One modification was recorded in an Admiralty Letter, dated 24 August 1786,

Having considered the reports from several Yards in answer to our directions respecting the propriety of forming the hole in the shank of anchors for the Ring to move and finding the majority of their opinions are as well as our own in favour of making the hole to round agreeable to the Circumference of the inscribed circle of the ring; These are to direct and require you to make the hole for the ring in the Shank of all anchors in future to round agreeable to the circumference of the inscribed circle accordingly (PRO, ADM 106/2509 #450).

Even though this change was a small one, the alteration in the design can be used as a date marker for the researcher and archaeologist.

Thomas Pennant, a naval officer, inspected the Portsmouth Dockyard in the late 1780's. He commented on the anchor smiths: "*seventy or eighty brawny fellows were amidst the fires busied in fabricating those securities to our shipping*" (Singer et al., 1958: 580). He also saw the faultless anchor that had been recovered from the unfortunate *H.M.S. Royal George*, a 1st Rate of 100-guns, that foundered at Spithead in 1782. The motto on the anchor read: "*Fear not; I will hold you fast*" (Singer, 1958: 580).

The *H.M.S. Bounty*, ex *Bethia*, an armed-transport of 215 tons, was the well-known vessel on which the mutiny against Capt. William Bligh took place.

For the extended voyage to the East-Indies, in 1787, the Deptford yard specified the anchors they proposed to be purchased with the vessel (McKay, 1989: 10):

<i>Anchor of</i>	<i>13 cwt.</i>	<i>3 qtr.</i>	<i>0 lb.</i>
	<i>13</i>	<i>3</i>	<i>8</i>
<i>Iron-stocked</i>	<i>5</i>	<i>1</i>	<i>0</i>
	<i>2</i>	<i>1</i>	<i>20</i>
	<i>1</i>	<i>3</i>	<i>10</i>

The two 13 cwt (661 kg) anchors were wooden-stocked bower anchors, while the stream and kedge anchors were all iron-stocked anchors. All these anchors were smaller than the 1786 Establishment called for in a vessel of 200 tons. The Establishment stipulated three bower anchors of 15 cwt (763 kg), one stream anchor of 6 cwt (305 kg), and a kedge anchor of 3 cwt (152.5 kg). Why the *Bounty* only sailed with two bower anchors on such a long voyage we will never know.

Captain Bligh made a note in the *Bounty's* log, on 4 April 1789, concerning the best bower anchor:

In stowing the best bower anchor the stock broke in the nut and fell overboard, being destroyed by worms. My sheet [stream] anchor had an iron stock for the convenience of carrying it in the chains, and I used it therefore as a small bower; I saved the anchor stock. Ships that come here should have iron stocks (McKay, 1989: 10).

The *Bounty* was obviously carrying a spare anchor stock, as a note in the log three days later reads, "*New stocked the best b[owe]r anchor.*" It is interesting to

note the use of iron stocks, for the stream and kedge anchors, and Capt. Bligh's comment that the larger anchors should also have iron stocks.

When leaving Tahiti for the last time, Fletcher Christian cut the *Bounty's* anchor cable and 'ran'. This anchor was subsequently recovered by *H.M.S. Pandora*, the frigate sent out to capture the mutineers. The *Pandora* ended up being wrecked on Australia's Great Barrier Reef in 1791 and it is believed that the bower anchor lies with her remains (McKay, 1989: 10). The *Bounty's* other bower anchor was recovered from Bounty Bay, at Pitcairn Island, where it now resides. This anchor is 11 ft 7 in (3.53 m) long, and has a beam of 8 ft (2.44 m).

Steel (1794: 76), in his *Elements and Practice of Rigging and Seamanship*, mentions the different types of anchors in use: "*the sheet, best bower, and small bower; these do not vary in form or weight from each other, in the Navy. Stream and kedge anchors are smaller, and grapnels are for boats only.*" He does not specifically mention the spare bower, which was still carried, being similar in weight and size to the other bower anchors.

There is one piece of information in the text that is particularly interesting. "*Kedges, or small anchors, are made in proportion to the large anchors; their stocks were formerly of iron but are now mostly of wood*" (Steel, 1794: 80). The general consensus of opinion, today, is that the iron-stocked anchor was being reintroduced at the end of the 18th century. Is this really the case, or are we incorrect and the iron-stocked anchor was in use all the while. An Admiralty Letter (PRO, ADM/2508 #1054) dated the 24th January, 1781, reads,

Understanding that in the receipt of anchors with iron stocks at some of the Yards the weight of the stock is included so that an anchor of 12 cwt. will be little more than 10 cwt--without the stock. These are to direct and require you in future not to include the weight of the stock in the anchor but to require the anchor to be of the weight ordered exclusive of the stock, you are nevertheless to pay for the stocks at the same rate as for the anchors and give the Contractors notice hereof.

From this it is possible that all kedge anchors, including those on 1st Rates weighing $10\frac{1}{2}$ cwt, could have been iron-stocked. There is insufficient information in the literature to make a positive statement, as to whether or not iron-stocked anchors were a re-invention.

Steel (1794: 76) lists the various parts of an anchor: the shank, two arms and flukes (or palms), a ring and the stock. These parts were all forged separately and then welded together, with the exception of the large wooden stock which was fastened to the shank using bolts, treenails, and hoops driven onto the stock.

Steel (1794: 77-82) states that several parts of the anchor are governed by the length of the shank, and the size of the trend. The length of the square is $\frac{1}{6}$ that of the shank, and ends at the small round. The small round is the narrowest part of the shank, which is equal in size to $\frac{1}{6}$ less than the size of the trend. The square and the trend of the anchor have the same dimensions. The thickness of the anchor ring is half the diameter of the small round, the diameter of the ring being such that the ring will rest in the curve of the small round below the square. The arm of the anchor is set at an angle of 60 degrees,

between the bill and the trend on the shank. Steel (1794: 81) then lists the dimensions for anchors of various weights and lengths (Table 11). He also lists the number, weight, and value of anchors for each class of vessel in the navy (Steel, 1794: 81) (Table 12). These figures are the same as those for the 1786 Establishment, and that is probably where Steel originally found the information. Steel (1794: facing pages 77 & 78) illustrates his treatise with two good drawings of anchors. The first is one of an Old-Plan Long-Shank bower anchor (Fig. 12), while the second is of an iron-stocked kedge anchor (Fig. 13).

By the end of the 18th century, the *Bellona* was carrying four bower anchors of 71 cwt (3610 kg) that were 18 ft 5 in (5.62 m) long, the stream anchor was 17½ cwt (890 kg) and 12 ft 6 in (3.81 m) long, while the single iron-stocked kedge anchor weighed 8½ cwt (432 kg), and had a length of 9 ft 6 in (2.90 m) (NMM SPB/15). One can see that there was a gradual trend to the increasing anchor weight. Not only were the vessels becoming larger, hence the anchor size increasing, but also larger anchors were being carried by vessels of the same weight. This change may have been based on a hope that the stronger anchors would not break when under strain, as the smaller anchors were prone to do. There was a second trend during the course of the 18th century, in the decreasing size of the stream anchor. The stream anchor was originally ⅓ the weight of the bower, but decreased to ¼ the weight of the bower by the end of the century. The kedge anchor was about ⅓ the size of the stream anchor in

TABLE 11. Anchor dimensions (after Steel, 1794: 81)

Weight	Length of the Shank		Length of the Arms		Breadth of the Palms		Thickness of the Palms		Size of the Tread		Size of the small Round		Outer Diameter of the Ring		Thickness of the Ring	
	Ft	In	Ft	In	Ft	In	Ft	In	Ft	In	Ft	In	Ft	In	Ft	In
1	5	8	1	10	0	9	0	0 $\frac{3}{4}$	0	2 $\frac{1}{2}$	0	2	0	9	0	1
5	8	0	2	8	1	2	0	1	0	3 $\frac{1}{2}$	0	3	1	2	0	1 $\frac{1}{2}$
10	10	4	3	5	1	7	0	1 $\frac{1}{8}$	0	4 $\frac{1}{2}$	0	4	1	7	0	2
15	12	0	4	0	1	9	0	1 $\frac{3}{8}$	0	5	0	4 $\frac{1}{2}$	1	9	0	2 $\frac{1}{4}$
20	13	0	4	4 $\frac{1}{2}$	1	9 $\frac{1}{4}$	0	1 $\frac{1}{2}$	0	5 $\frac{5}{8}$	0	5 $\frac{1}{8}$	1	9 $\frac{1}{4}$	0	2 $\frac{1}{2}$
25	13	10	4	7	1	11	0	1 $\frac{5}{8}$	0	6 $\frac{1}{2}$	0	5 $\frac{1}{4}$	1	11	0	2 $\frac{7}{8}$
30	14	7 $\frac{1}{2}$	4	10 $\frac{1}{2}$	2	0 $\frac{1}{2}$	0	1 $\frac{1}{4}$	0	6 $\frac{1}{4}$	0	6	2	0 $\frac{1}{2}$	0	3
35	15	2	5	0 $\frac{5}{8}$	2	2 $\frac{1}{2}$	0	2	0	7 $\frac{3}{8}$	0	6 $\frac{5}{8}$	2	2 $\frac{1}{2}$	0	3 $\frac{1}{4}$
40	15	10	5	3 $\frac{1}{2}$	2	4	0	2 $\frac{3}{8}$	0	7 $\frac{1}{4}$	0	7	2	4	0	3 $\frac{1}{2}$
45	16	4	5	5 $\frac{1}{4}$	2	5 $\frac{1}{2}$	0	2 $\frac{1}{2}$	0	8	0	7 $\frac{1}{4}$	2	5 $\frac{1}{2}$	0	3 $\frac{5}{8}$
50	16	9	5	6 $\frac{1}{4}$	2	7	0	2 $\frac{5}{8}$	0	8 $\frac{1}{4}$	0	7 $\frac{1}{2}$	2	7	0	3 $\frac{3}{4}$
55	17	2	5	8 $\frac{1}{4}$	2	9	0	2 $\frac{3}{4}$	0	8 $\frac{1}{2}$	0	7 $\frac{3}{4}$	2	9	0	3 $\frac{7}{8}$
60	17	7	5	10 $\frac{1}{4}$	2	10 $\frac{1}{2}$	0	2 $\frac{7}{8}$	0	8 $\frac{3}{4}$	0	7 $\frac{7}{8}$	2	10 $\frac{1}{2}$	0	3 $\frac{7}{8}$
65	18	0	6	0	3	0	0	3 $\frac{1}{8}$	0	9	0	8	3	0	0	4
70	18	4	6	1 $\frac{1}{4}$	3	1	0	3 $\frac{1}{4}$	0	9 $\frac{1}{4}$	0	8 $\frac{1}{4}$	3	1	0	4
75	18	11	6	3 $\frac{1}{4}$	3	1 $\frac{1}{2}$	0	3 $\frac{3}{8}$	0	9 $\frac{5}{8}$	0	8 $\frac{1}{8}$	3	1 $\frac{1}{2}$	0	4
80	19	6	6	6	3	2	0	3 $\frac{1}{2}$	0	9 $\frac{3}{4}$	0	8 $\frac{1}{4}$	3	2	0	4 $\frac{1}{8}$

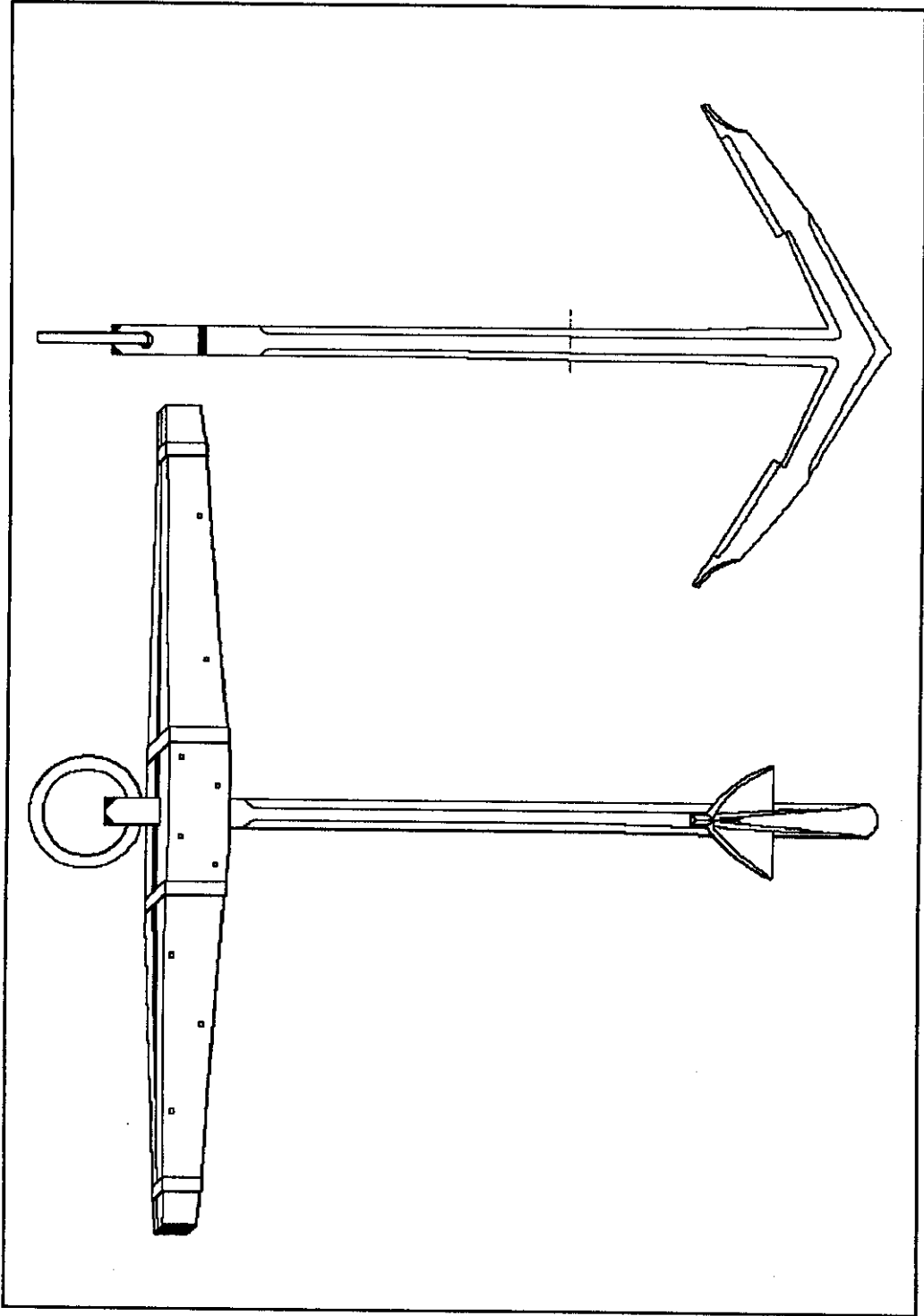


Figure 12. . Old-Plan Long-Shank anchor of ca. 1790 (after Steel, 1794: facing page 77).

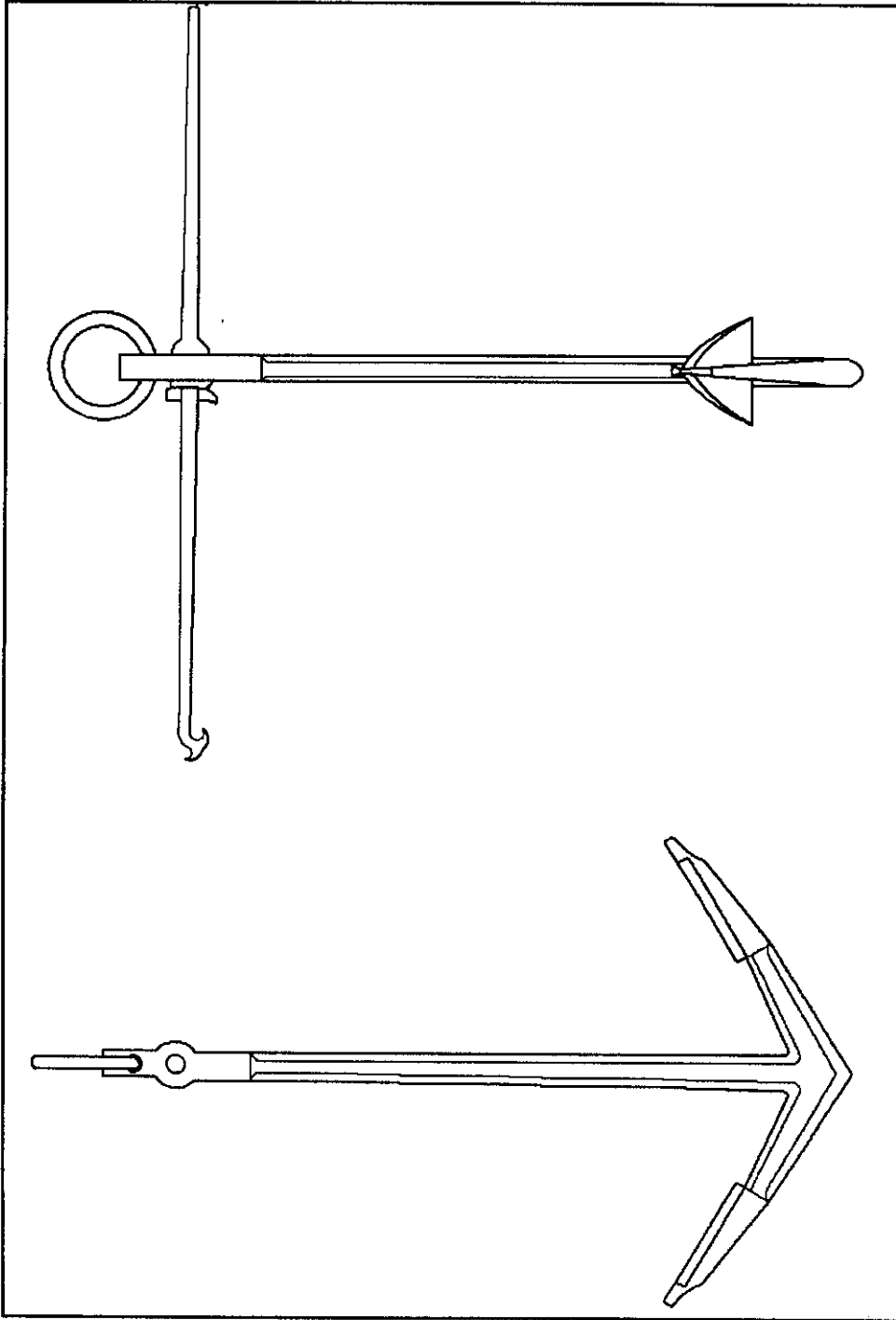


Figure 13. An iron-stocked kedge anchor. ca. 1790 (after Steel, 1794: facing page 78).

1686, and increased to weigh about $\frac{1}{2}$ the stream anchor in 1709 (Lavery, 1987: 35).

ARCHAEOLOGICAL EVIDENCE

As with the preceding centuries, there are few references in the archaeological literature to anchors being recovered and recorded on 18th-century English wrecksites. There are two of note, the *Association* and the *Endeavour*. The anchors from a Dutch vessel the *Hollandia*, have been included to supplement the information lacking from the mid-18th century.

The *Association* Anchor

The *Association* was a 2nd Rate, 90-gun vessel of 1459 tons, that sank off Scilly, England, in 1707 (Colledge, 1987: 40). One of her bower anchors was recovered and the dimensions recorded (Morris, 1967: 49). The 18 ft 4 in (5.6 m) anchor had a beam of 10½ (26.7 cm), the square being 9 inches (22.9 cm) in cross-section, the small round was 8 inches (20.3 cm) in diameter, and the 3 inch (7.6 cm) thick equilateral flukes were approximately 3 ft (0.9 m) long by 3 ft (0.9 m) wide. The original salvors had suggested a weight of 4 tons for the anchor, which would have included the weight of the iron concretion on the anchor.

The dimensions of this anchor (length, beam, etc.) compare favourably with those stated by Sutherland (1717b: 22) for a vessel of 1488 tons (Table 7).

However, the weight given by Sutherland for his 18 ft 2 in long anchor is 64 cwt, which is probably nearer to the true weight of the anchor.

The *Hollandia* Anchors

The Dutch East Indiaman *Hollandia* was also wrecked off Scilly, England, in 1743 (Cowan et al., 1975: 267-300). She was in the 150 foot class of V.O.C. vessels, weighing about 750 tons. Six anchors were recorded on the wrecksite, along with the partial remains of another two anchors. Three anchors were found in close proximity, their lengths being 4.7 m, 3.7 m and 3.3 m. It has been suggested that the sheet and two bower anchors were stored in the hold when the vessel sank. One bower (3.3 m long) and the kedge anchor (2.0 m in length) were found fairly close to one another, while the stream anchor (2.3 m long) was some distance off from the others. These lost three anchors were probably the ready-use anchors that were stowed on the bows of the vessel when she was lost. No other dimensions are given for any of the anchors.

The *Endeavour* Anchor

In June 1770, during Lieutenant James Cook's first voyage around the world, *H.M.B. Endeavour* (H.M.B.--His Majesties Bark) ran aground on a coral reef (now known as Endeavour Reef) off the coast of Queensland, Australia. During the efforts to pull the vessel off the reef, the small bower anchor was

cut free and abandoned. This anchor was recovered in 1971, and is the subject of Knuckey's (1988) treatise, *An Anchor from H.M.B. Endeavour*.

The information contained in the book covers the history of the anchor's loss, the recovery and conservation of the artefact, the anchor's design and manufacturing sequence, as well as a detailed section on the anchor's dimensions (Knuckey, 1988). This bower anchor is a standard Old-Plan Long-Shank Anchor from the late 18th century.

The original weight of this 12¾ ft (3.9 m) anchor was 17 cwt 3 qtr and 14 lb (908 kg). The weight was stamped into the bottom of the shank and into the underside of the arm of the anchor, along with the 'Broad Arrow' mark to signify that the anchor belonged to the Royal Navy. Each segment of each inscribed figure was started and finished with a deep punch mark. The numerals were 50 mm high. A third Broad Arrow was found inscribed below the square of the anchor.

The anchor lost over 100 kg of metal weight due to the corrosion processes over the 200 years that it was submerged in the sea. This is equivalent to a loss of ⅛ of an inch (3.2 mm) of metal over the whole surface, assuming a uniform loss of metal. Clearly, one can see that this does not affect the overall dimensions of the anchor.

The dimensions of the anchor compare closely to those of the Establishment of 1786 (Table 10) and to the information contained in Tables 11 and 12.

The *Dictator* Anchor

In 1959, a navy hard hat diver working in the Patuxent River, near Point Patience in Maryland, found and recovered an 'Old-Plan Long-Shank Anchor' (Schwartz & Green, 1962: 367-370). Upon investigation, the anchor was found to have a number of marks inscribed in the metal, the 'Broad Arrow', 'Rec Chat 6x3x24' and the number '6625'. The Broad Arrow is well known, as the mark of the Royal Navy. 'Rec Chat 6x3x24' (cwt, qtr, lb) meant that the 780 lb (355 kg) anchor was received at Chatham and had been made by a contractor, and the '6625' was the anchor's inventory number. The name 'Dictator' was marked on the underside of the wooden anchor stock. This 8 ft 7in (2.62 m) long kedge anchor was lost by *H.M.S. Dictator*, a 3rd Rate of 64 guns, sometime during the summer of 1814 when she was stationed there as a troopship during the War of 1812 (Schwartz and Green, 1962: 367-370). The anchor ring still had the well preserved remains of the puddening, indicating that a rope cable was used to moor the vessel. The 1786 Anchor Weight Establishment (the *Dictator* was launched in 1783) lists a 3rd Rate, 64-gun vessel as having a kedge anchor weighing 7 cwt 2 qtr (380 kg). Steel's (1794: 81) list of anchor weights for a 64-gun vessel are the same as those in the 1786 Establishment. The ends of the 9 ft 4 in (2.85 m) wooden stock were squared, and not rounded as the Admiralty Letter (ADM 106/2508 #975) dated 16th of May, 1780, explicitly instructs. This kedge anchor was obviously an 'Old-Plan Long-Shank' anchor that had seen many years of service, and whose stock had not been modified to 'round the

ends'. Clearly, anchors could have a long life, and were often used until they were either lost or broken.

CONCLUSIONS

This study analyzes the history and development of the English anchor over a three hundred year period. During this period, the wrought iron anchor underwent few gross changes, if any, while gradually increasing in size and weight. Few changes were made in the anchors, as the technology of forging iron remained fairly constant. Until machine power replaced manpower, the amount of wrought iron that could be handled was very limited. A second limiting factor was the strength of the welds, connecting the component parts of the anchor together. This was directly related to the size and power of the available hammer. As the knowledge and skills in the technology for forging iron developed, the size and weight of the anchors increased.

Another controlling factor was the design of the anchor itself. The design reflected the technological advance of the manufacturers, who did not yet have the knowledge or ability to design a stronger anchor. When an anchor is weighed, the shank of the anchor acts as a lever to force the arm from its hold in the sediment. Elementary laws of physics dictate that the larger the lever, the greater the force on the arm and the arm weld, thereby placing a limit on the size of anchors. The anchor had to be small enough, that the pressure exerted in weighing it did not break the welds attaching the arms to the shank. In very large anchors, the arms were likely to fail, as the welds did not have the necessary holding strength when put under a severe strain.

The anchor is one of the most important piece of equipment onboard a ship, and is certainly essential for the safety of the vessel. The two are mutually inseparable from one another, and an early 19th-century writer once commented,

There is nothing in a ship of more anxious consequence than anchors. Many thousands of brave men have lost their lives, and numbers of ships wrecked, from the insufficiency. All anchors for the navy should be made of the very best iron that can be procured; manufactured with the utmost care, and upon such a principle as, on trial, proves to be the best; and their sufficiency in point of strength should be proved before being delivered to the ships (Blackburn, 1817: 183).

The examination of contemporary documents, treatises on shipbuilding, and the archaeological record from the relevant period, have all yielded contributions to the chronology in the development of the anchor. A brief summary of the anchor's history follows, with the few developments mentioned during the various time periods.

By the beginning of the 16th century, the different types of anchors were being distinguished from one another. Large vessels generally carried seven anchors--one sheet, four bowers, one stream and a kedging anchor. There were a number of rules for calculating the weight of the sheet anchor towards the end of the 1500's, but these should be treated with caution. Hawkyns' rule, for calculating the weight of a sheet anchor, suggests values that are within an acceptable range for bower anchors, but the weights are too small for a sheet anchor. Baker's dimensions suggest that the English anchor was definitely more robust than the long slender 'classic' Spanish anchor of the period. His

statement that "*ye length of ye arme must be 1/3 of ye shanke*", was probably accurate, and his angle of 60° for the arm was a good measurement. Spanish anchors from the period generally reflect a length that is three times the length of the arm and ½ the beam, and reflect a similar angle to the arm. This arm angle of 60° continued to be used through the mid-19th century.

Similarly, Mainwayring's rule from 1622 would be more accurate if the shank was three times the length of the arm (instead of the fluke) and ½ the beam. Anchors were increasing in size, as the size of the vessels grew, and the weight of an individual anchor also increased. Formulae that include length/weight ratios should be avoided if at all possible. One cannot apply them with any certainty, as anchors of similar lengths can easily have a wide range of weights.

By the middle of the 17th century, 1st and 2nd Rate vessels still had five main anchors, a stream and kedge anchor, as well as a small warping anchor. The 3rd and 4th Rate vessels usually only had four main anchors, along with their stream and kedge anchors. The small 6th Rates, and other unrated vessels, only carried three anchors. These anchors all had curved arms, but with the increasing size and weight the straight-armed anchor was introduced into the Navy during the latter half of the 17th century. By this time, the dimensions and weights of the anchors had been standardized, so there was some uniformity amongst the different classes of vessels.

Royal Navy anchors were also supposed to be marked with their weight, the Broad Arrow and the maker's initials. This rule was stipulated in the contracts, though in practice the smiths were loath to put their name to their work. The reason for this was obvious, as the skills in iron technology had not advanced far enough to successfully forge a large anchor that would not break when put under a severe strain. The smiths realized the problem, but had yet to find a solution and did not wish to be held liable for the loss when the anchor failed.

The preferred use of 'Spanish Iron' was easily explained, "*because it abides the Heat better than other Iron*" (Moxon, 1677: 53). The reason behind this is that iron smelted in England was prone to having a relatively high phosphorus content, which made the metal 'red- or hot-short'. The iron would crumble while it was worked at a red hot temperature, as the phosphorous made the metal brittle and difficult to work. Spanish iron ores were relatively free from phosphorus, as was Swedish iron. English iron also suffered from sulphur contamination, that made the metal 'cold short'. This resulted in the iron crumbling while being worked at too low a temperature. The sulphur contamination came about from using coal or coke as a smelting fuel, during the 17th and early 18th century. Spanish and Swedish iron was smelted using charcoal, that was free from sulphur contaminants.

During the 17th century, the information contained in the various original anchor Establishments is accurate, and reflects the correct weight of anchors for

the various sizes of vessels. Some Establishment lists include the names of particular vessels in each of the rate categories, with the number and weight of the anchors listed alongside. Later authors copied these lists and, unfortunately, did not give the date or source of the original reference. This can lead to problems when the secondary source is used, as the anchors will appear to be 'light' for the given time period.

The technique used to manufacture anchors had been causing anxiety for a long time. By the beginning of the 16th century, the growing size of vessels only emphasized the fact that anchors produced by the methods of the day were unreliable. With the increasing use of coke to fuel iron smelters, and the resulting usage of low quality iron, anchors continued to break with frightening regularity. The straight-armed anchor was strengthened in the crown to prevent the shank-arm weld from failing, but the power necessary to weld a large anchor successfully was still unavailable.

During the latter half of the 18th century, there were a number of changes regarding anchors that were recorded historically. An example of this was the official date for the reduction in the number of bower anchors, carried by a large vessel, that took place in 1779. However, as early as 1760, 74-gun ships were only carrying four bower anchors of similar weight, along with their stream and kedge anchors. With the general introduction of copper sheathing into the fleet in 1779, the ends of the wooden anchor stocks were ordered to be rounded, to prevent them from damaging the copper plates. In 1786, the eye, or

ring hole, of the anchor was rounded to conform with the arc of the ring. These date markers can all be used by the modern researcher to narrow down the possible date of the manufacture of an anchor.

The possibility of calculating the size of a vessel from the number and weight of anchors can be problematic. As the late Keith Muckelroy so correctly commented:

The possibility of deducing the size of ships involved from the size of anchors recorded has been suggested, on the basis of standard relationships laid down by various authorities (e.g. Witsen 1671 [1690], 142-63, on seventeenth-century Dutch ships), but there is considerable doubt as to the extent to which these were generally adhered to (Muckelroy, 1978: 149).

The lack of typological variations in the design of the Old-Plan Long-Shank Anchor severely limits the accuracy of the chronology. However, if information from the history of iron technology is applied to the chronology, the date ranges can be reduced further. Construction changes often came about as a result of changes in the technology. Other changes in the technology can sometimes only be seen when looking at the microstructure of the iron itself. The introduction and use of coal/coke brought about an increase in the amount of sulphur in the iron. With the success of Henry Cort's early experiments in puddling and rolling cast iron in 1784, anchors were again made exclusively of English iron (Jump, 1928: 6). Cort's work enabled the detrimental contaminants of sulphur and phosphorus to be eliminated from the iron in the smelting process. Therefore, if an anchor has a high level of sulphur or phosphorus in

the iron, this points to a pre-1780's date. Similarly, the 'terminus post quem' for sulphur and phosphorus is also known.

A successful chronology of known dated anchors could easily be assembled and recorded, and used to illustrate the variation in anchor typology during the relevant periods. Sadly, the depredation of non-archaeological salvage and the lack of accurate and standardized record keeping by archaeologists have restricted the number of anchors that could be included in this typology.

REFERENCES

- Abell, W. Sir, 1948, *The Shipwright's Trade*. University Press, Cambridge.
- Adams, J. R., 1974, *The Dartmouth*, a British frigate wrecked off Mull, 1690. *The International Journal of Nautical Archaeology and Underwater Exploration*, 3.2: 269-274.
- Allard, C., 1716, *Algemeene en Verbeterde Hollantsche Scheepsbouw*. Johannes Oostewyk, Amsterdam.
- Allen, D. K., 1969, *Metallurgy, Theory and Practice*. American Technical Society, Chicago.
- Anderson, R. C., 1923, Sheet anchors. *Mariner's Mirror*, 9.4: 315.
- Arnold, J. B. III, 1976, *An Underwater Archaeological Magnetometer Survey and Site Test Excavation Project off Padre Island, Texas*. Publication No. 3, Texas Antiquities Committee, Austin, Texas.
- Arnold, J. B. III & Weddle, R. S., 1978, *The Nautical Archaeology of Padre Island*. Academic Press, New York.
- Aubin, N., 1722, *Dictionnaire de Marine Contenant les Termes de la Navigation et de l'Architecture Navale*. Jean Covens & Cameille Mortier, Amsterdam.
- Baugh, D. A., 1977, *Naval Administration 1715-1750*. *Navy Records Society*. Vol. 120, London.
- Benoît, F., 1958, Nouvelles epaves de provence. *Gallia*, 16.1: 5-39.
- Blackburn, I., 1817, *A Treatise on the Science of Shipbuilding*. Joyce Gold, London.
- Blanckley, T. R., 1750, *The Naval Expositor*. E. Owen, London.
- Bond, H., 1642, *The Boate Swaines Art: or, the Compleat Boate Swaine*. Richard Cotes, London.
- Bouguer, M., 1746, *Traite du Navire*. n.p., Paris.
- Bruce, J. C., 1987, *The Bayeux Tapestry*. Dorset Press, New York.

- Bugler, A., 1966, *H.M.S. Victory: Building, Restoration and Repair*. H. M. Stationery Office, London.
- Colledge, J. J., 1987, *Ships of the Royal Navy. Vol. 1*. Naval Institute Press, Annapolis, Maryland.
- Corbett, J. S., (Editor), 1898, Papers relating to the Navy during the Spanish War, 1585-1587. *Navy Records Society. Vol. 11*. London.
- Cowan, R., Cowan, Z., & Marsden, P., 1975, The Dutch East Indiaman *Hollandia* wrecked on the Isles of Scilly in 1743. *The International Journal of Nautical Archaeology and Underwater Exploration*, 4.2: 267-300.
- Crossley, F. H., 1951, *Timber Building in England*. n.p., London.
- Cunnington, E., 1884, On a hoard of bronze, iron, and other objects found in Belbury Camp, Dorset. *Archaeologia*, 48: 115-120.
- Derry, T.K. & Williams, T.I., 1960, *A Short History of Technology*. Oxford University Press, London.
- DeVries, K., 1972, Greek, Etruscan and Phoenician ships and shipping. In Bass, G.F. (Ed), *A History of Seafaring*. Thames & Hudson, London.
- Engelhardt, C., 1886, *Denmark in The Early Iron Age*. Williams & Norgate, London.
- Forster, W.A. & Higgs, K.B., 1973, The *Kennemerland*, 1971. An interim report. *The International Journal of Nautical Archaeology and Underwater Exploration*, 2.2: 291-300.
- Frost, H., 1963a, *Under the Mediterranean*. Prentice-Hall Inc., Englewood Cliffs, New Jersey.
- Frost, H., 1963b, From rope to chain: on the development of anchors in the Mediterranean. *Mariner's Mirror*, 49.1: 1-20.
- Frost, H., 1970, Stone anchors as indications of early trade routes. In *Sociétés et Compagnies de Commerce en Orient et dans l'Océan Indien*, 55-61. Bibliothèque générale de l'école paractique des hautes études, Paris.
- Gale, W. K. V., 1967, *The British Iron and Steel Industry*. Augustus M. Kelley, New York.

- Gianfrotta, P. A., & Pomey, P., 1981, *Archeologia Subacquea*. Arnoldo Mondadori, Milan.
- Godley, A. M. (Trans), 1924, *Herodotus. Vol. IV. Books VIII-IX*. Heinemann and Putnam's Sons, London.
- Green, J. N., 1973, The wreck of the Dutch East Indiaman the *Vergulde Draeck*, 1656. *The International Journal of Nautical Archaeology and Underwater Exploration*, 2.2: 267-290.
- Green, J. N., 1975, The VOC ship *Batavia* wrecked in 1629 on the Houtman Abrolhos, Western Australia. *The International Journal of Nautical Archaeology and Underwater Exploration*, 4.1: 43-64.
- Green, J.N., 1977, Australia's oldest wreck: the loss of the *Trial*, 1622. *British Archaeological Reports, Supplementary Series*, 27.
- Gulik, C. B. (Trans), 1957, *Athenaeus, The Deipnosophists. Vol. II. Books III-V*. Heineman, London.
- Haldane, D., 1990, Anchors in antiquity. *Biblical Archaeology*, 53.1: 19-24.
- Jobling, J., 1989, Bronze anchors. *International Journal of Nautical Archaeology and Underwater Exploration*, 18.1: 67.
- Johnstone, P., 1974, *The Archaeology of Ships*. The Brodley Head, London.
- Joncheray, J. -P., 1975a, Étude de l'Épave Dramont D: les objets métalliques. *Cahiers d'Archeologie Subaquatique*, 4: 5-18.
- Joncheray, J. -P., 1975b, Une Épave du bas Empire: Dramont F. *Cahiers d'Archeologie Subaquatique*, 4: 91-140.
- Jones, H. L. (Trans), 1924, *The Geography of Strabo. Vol. III. Books VI-VII*. Heinemann, London.
- Jump, P., 1928, Chains through the ages. *The Staffordshire Iron and Steel Industry*, 44: 4-10.
- Kapitän, G., 1984, Ancient anchors--technology and classification. *The International Journal of Nautical Archaeology and Underwater Exploration*, 13.1: 33-44.

- Keith, D. H., 1986, *Anchors*. Unpublished notes from part of the Hunter 'Cannons and Anchors' Symposium during the Conference on Underwater Archaeology in Sacramento, California, January, 1986. (Private Collection, H. J. W. Jobling).
- Keith, D.H., 1987, Personal Communication.
- Knuckey, P. J., 1988, *An Anchor from H.M.B. Endeavour: Restoration and other Aspects*. Materials Research Laboratory, Melbourne.
- Laird-Clowes, G. S., 1931, The length of Masts & Yards, etc., 1640. *Society of Naval Research*, Occasional Publication No. 3, London.
- Lavery, B., 1985, *The 74-gun Ship Bellona*. Naval Institute Press, Annapolis.
- Lavery, B., 1987, *The Arming and Fitting and English Ships of War, 1600-1815*. Naval Institute Press, Annapolis.
- Lewis, C. D. (Trans), 1953, *Virgil, Aeneid*. Doubleday, Garden City, New York.
- Light, J. D., 1990, The 16th century anchor from Red Bay, Labrador: its method of manufacture. *The International Journal of Nautical Archaeology and Underwater Exploration*, 19.4: 307-316.
- Mainwaring, G. E. & W. G. Perrin, (Eds.), 1922, The life and works of Sir Henry Mainwaring. *Navy Records Society*. Vol. 56. London.
- Mainwayring, H., Sir, 1622, *The Seaman's Dictionary*. n.p., London.
- Martin, C. J. M., 1979, *La Trinidad Valencera*: an Armada invasion transport lost off Donegal. Interim site report, 1971-76. *The International Journal of Nautical Archaeology*, 8.1: 13-38.
- McGowan, A. P., 1971, The Jacobean Commissions of Enquiry, 1608 and 1618. *Navy Records Society*. Vol. 116. London.
- McKay, J., 1989, *The Armed Transport Bounty*. Naval Institute Press, Annapolis.
- McKee, A., 1982, *How we found the Mary Rose*. Souvenir Press, London.
- Merriman, Commander R. D., 1950, The Sergison Papers. *Navy Records Society*. Vol. 89. London

- Merriman, Commander R. D., 1961, Queen Anne's Navy, 1702-1714. *Navy Records Society. Vol. 103.* London.
- Moll, F., 1927, The history of the anchor. *Mariner's Mirror*, 13.4: 293-327.
- Morris, R., 1967, *Island Treasure.* Hutchinson, London.
- Moxon, J., 1677, Anchors, *Mechanick Exercises*, III: 53.
- Muckelroy, K., 1978, *Maritime Archaeology.* Cambridge University Press, London.
- Murray, M., 1765, *Supplement to the Treatise on Shipbuilding.* A. Miller, London.
- National Maritime Museum (NMM) *Manuscripts*, 1586, TRN/12. Greenwich, London.
- NMM *Manuscripts*, 1686, AND/33. Greenwich, London.
- NMM *Manuscripts*, 1689, AND/34. Greenwich, London.
- NMM *Manuscripts*, 1745, RUSI/42. Greenwich, London.
- NMM *Manuscripts*, 1775, RUSI/86. Greenwich, London.
- NMM *Manuscripts*, 1781, MID/9/1. Greenwich, London.
- NMM *Manuscripts*, 1786, RUSI/57. Greenwich, London.
- NMM *Manuscripts*, 1800, SPB/15. Greenwich, London.
- Oppenheim, M., 1894, Naval accounts and inventories in the reign of Henry VII. *Navy Records Society. Vol 8.* London.
- Oppenheim, M., 1961, *A History of the Administration of the Royal Navy and of Merchant Shipping in Relation to the Navy.* The Bodley Head, London.
- Perrin, W. G. (Ed), 1931, Boteler's Dialogues, 1634. *Navy Records Society. Vol. 65.* London.
- Peterson, M., 1974, Exploration of a 16th-century Bahamian Shipwreck. Reprinted from *National Geographic Society research reports, 1967 Projects.* National Geographic Society, Washington, D.C.

- Pool, B., 1966, *Navy Board Contracts, 1660-1832*. William Clowes & Sons, London.
- Public Record Office (PRO) *Admiralty Board Letters*, 1664, ADM 106/2507, #31. Kew, London.
- PRO *Admiralty Board Letters*, 1682, ADM 106/2507, #61. Kew, London.
- PRO *Admiralty Board Letters*, 1728, ADM 106/2507, #272. Kew, London.
- PRO *Admiralty Board Letters*, 1779, ADM 106/2508, #879. Kew, London.
- PRO *Admiralty Board Letters*, 1780, ADM 106/2508, #975. Kew, London.
- PRO *Admiralty Board Letters*, 1781, ADM 106/2508, #1054. Kew, London.
- PRO *Admiralty Board Letters*, 1784, ADM 106/2509, #347. Kew, London.
- PRO *Admiralty Board Letters*, 1786, ADM 106/2509, #422. Kew, London.
- PRO *Admiralty Board Letters*, 1786, ADM 106/2509, #450. Kew, London.
- PRO *Letters & Papers, Foreign and Domestic*, n.d., Henry VIII, Vol. XXI, Part 1. Kew, London.
- Pulak, C., 1992, Personal Communication.
- Rackham, H., (Trans.) 1945, *Pliny, Natural History. Vol. VI. Books XII-XVI*. Heinemann, London.
- Reaumur, R. A. F. de, 1764, *Fabrique des Ancres, lue l'academie en Juillet 1723, Avec des Notes e des additions de M. Duhamel*. Academie des Sciences, Paris.
- Rosloff, J. P., 1991, A one-armed anchor of c.400 B.C.E. from the Ma'agan Michael Vessel, Israel: a preliminary report. *The International Journal of Nautical Archaeology*, 20.3: 223-226.
- Schubert, H .R., 1957, *History of the British Iron and Steel Industry from c. 450 B.C. to A.D. 1775*. Rowledge & Kegan Paul, London.
- Schwartz, F. J., & Green, J., 1962, Found: one anchor from *H.M.S. Dictator*. *Maryland Historical Magazine*, 57.4: 367-370.

- Singer, C., Holmyard, E.J., Hall, A.R. & Williams, T.I., 1958, *A History of Technology, Vol. IV*. Oxford University Press, London.
- Smith, Capt. J., 1627, *A Sea Grammar*. n.p., London.
- Sølver, C. V., 1958, The Ladby Ship anchor. *Mariner's Mirror*, 44: 294-301.
- Speziale, G. C., 1931, The Roman anchors found at Nemi. *Mariner's Mirror*, 17: 300-320.
- Steel, D., 1794, *The Elements and Practise of Rigging and Seamanship. Vol. 1*. Little Tower Hill, London.
- Steffy, J. R., 1982, Anchor design. In Bass, G.F. & van Doorninck, F.H. (Eds), *Yassi Ada, Volume I: A Seventh-Century Byzantine Shipwreck*. Texas A&M University Press, College Station, Texas.
- Stenuit, R., 1972, *Treasures of the Armada*. Newton Abbot, London.
- Sutherland, W., 1717a, *The Prices of the Labour in Ship-Building Adjusted: or, the Mystery of Ship-Building Unveiled*. D.L., London.
- Sutherland, W., 1717b, *Britain's Glory or Shipbuilding Unvail'd*. John Clark, London.
- Sutherland, W., 1766, *The Shipbuilder's Assistant, or Marine Architecture*, Revised and Improved. Mount and Davidson, London.
- Tinniswood, J. T., 1945, Anchors and accessories 1340-1640. *Mariner's Mirror*, 31.2: 84-105.
- Tylecote, R. F., 1976, *A History of Metallurgy*. The Metals Society, London.
- Ucelli, G., 1950, *Le Navie di Nemi*. n.p., Rome.
- Upham, N. E., 1983, *Anchors*. Shire Publications, London.
- van Dam, P., 1701, *Beschrijvinge van de Oostindische Campagnie*. Martinus Nijhoff, 's-Gravenhage.
- van Doorninck, F. H., 1982, The Anchors. In Bass, G.F. & van Doorninck, F.H. (Eds), *Yassi Ada, Volume I: A Seventh-Century Byzantine Shipwreck*. Texas A&M University Press, College Station, Texas.

- van Doorninck, F.H., 1988, The anchors: a limited technology, a sophisticated design. *INA Newsletter*, 15.3: 24-25.
- van Nouhuys, J. W., 1928, Iron-stocked anchors. *Mariner's Mirror*, 14.1: 89.
- van Nouhuys, J. W., 1951, The anchor. *Mariner's Mirror*, 37.1: 17-47.
- van Yk, C., 1697, *De Nederlandsche Scheeps-bauw-konst Open Gestelt*. Andries Voorstad, Amsterdam.
- Wignall, S., 1982, *In Search of Spanish Treasure: a diver's story*. David & Charles, London.
- Witzen, N., 1690, *Architectura Navalis et Regimen Nauticum*. Pieter en Joan Blaeu, Amsterdam.

APPENDIX I

ANCHOR PARTS

- ANCHOR** - a large, heavy iron object that is dropped from a vessel, in order to hold the vessel in a desired position regardless of the wind, tide or current.
- ARM** - the armed cross-pieces at the bottom of the anchor that dig into and hold the anchor in the sediment.
- BALANCING BAND** - an iron band placed on later iron-stocked anchors, near the center of gravity on the shank, so as to allow for easier handling.
- BEAM** - the perpendicular distance across the shank from one arm extremity to the other.
- BENDING SHACKLE** - a term used to describe the shackle, connecting the chain cable to the anchor.
- BILL** - the outer extremity of the arm.
- BLADE** - the part of the arm on which the fluke is fitted, which was originally square in section on the Old Plan Anchor.
- CABLE** - a large, strong, three strand hemp rope that is used to attached the ship to her anchor(s). The usual length of a cable was 120 fathoms (220 m).
- CHAIN** - Iron chain was officially re-introduced into the navy in 1809, as an experiment to replace hemp cables that rotted and frayed with the passage of time and frequent use. Early chains were of the open-link variety, as stud-link chains were a later invention (mid-1800's).
- CROSS** - an old term for the crown of an anchor.
- CROWN** - the part of the anchor at the bottom of the shank, in the form of an arc, where the arms are attached.
- CRUTCH** - or throat, the curved inner part of the arms where they join the shank.

EYE - the hole in the top of the square of the anchor, that holds the ring or shackle.

FLOOK - also 'flooche', an old English term for fluke.

FLUKE - or palm, the broad, flat, triangular plate attached to the inner, upper surface of the arm to provide greater holding power to the anchor.

GRAVITY BAND - another term for a balancing band.

HAND - an old term for the fluke.

HEAD - the part of the anchor formed by the crown and the joining of the two arms.

HOOPS - or bands, the straps of iron that are driven onto the stock to hold it together.

JEW'S HARP - the shackle used to attach the anchor chain to the eye of the anchor.

KEY - an L-shaped cotter pin used to secure a metal folding stock in position on the shank.

KNOBS - a slang term for the nuts or stock keys.

NUTS - also ridges or stock keys, the two small projections on the square of the shank that hold the stock in position.

PALM - an old term for the fluke.

PEA - also peak or pee, an old term for the bill, the outer extremity of the arm.

PICK - an old naval slang term, for an anchor. Also, the bill of the anchor.

PIN - another term for the key, the pin for securing a metal stock in position on the shank.

POINT - another term for the anchor bill.

PUDDENING - the serving of rope around the anchor ring, to prevent the iron anchor from galling (wearing) the anchor cable.

RIDGES - the nuts on the square of the anchor.

- RING** - a circle of iron attached through the eye of the anchor, to which the anchor cable is bent (fastened).
- RODE** - an old term for an anchor cable.
- SCARF** - the joint where two pieces of the anchor are welded together, ie. the arm to the shank.
- SHACKLE** - an iron loop attached by a pin through the anchor eye, used in place of the ring when attaching chain to the anchor.
- SHAFT** - an old term for the shank, the largest part of the anchor.
- SHANK** - the largest part of the anchor, the main stem to which the arms are attached at one end and the stock at the other.
- SHOE** - triangular boards of wood attached to the fluke, to increase its size and thus holding power in soft sediments. Also, a block of wood attached to the bill to prevent it from damaging the ship's side while being handled.
- SMALL ROUND** - the diameter of the shank where it is least, just below the square of the shank.
- SNAPE** - the outer, lower extremity of the arm, where it decreases in size by a half--resembling the bill of a duck on the Old Plan Anchor.
- SQUARE** - the upper part of the shank that is square in cross-section, holding the stock and ring.
- STOCK** - originally made from two pieces of wood tapering from the middle, and fastened together with treenails and iron hoops. This was fixed to the square of the anchor, at right angles to the arms, so as to cant (turn) the arms so that they dug into the sediment. Later anchors had iron stocks.
- THROAT** - the inner curved part of the arms, where they join the shank.
- TREENAIL** - wooden pegs or dowels used to fasten the two halves of the stock together.
- TREND** - the place on the shank where the anchor size is taken, one arm length up the shank from the crown. Also, this is from where the trend or angle of the arm is set.

APPENDIX II

TYPES OF ANCHORS

BEST BOWER - originally, the larger of the two bower anchors, usually carried on the starboard side. Nowadays, the bower anchors are of equal size.

BOWER ANCHOR - one carried at the ship's bow.

BREAST ANCHOR - an anchor located and stored at right angles to the fore and aft line, at either end of the vessel. This anchor is usually a stockless anchor from a later period--late 19th century.

CREEPER - a small four armed anchor, with no flukes or stock. This was used to sweep (search) the bottom for any items that were lost overboard, or to recover a lost anchor cable and anchor.

EBB ANCHOR - one used to hold a ship against an ebbing tide, when moored in a tideway.

FIRE GRAPNEL - similar to a grapnel and weighing about 20 lb., with strong barbed hooks and attached with a chain to the ring. They were used on fire-ships and sometimes by boarding parties.

FIRST ANCHOR - another name for the best bower.

FLOATING ANCHOR - another name for a sea anchor.

FLOOD ANCHOR - one used to hold a ship during a flood tide, when moored in a tideway.

FOLDING ANCHOR - one that can be folded or collapsed to facilitate storage, ie. a folding stock anchor.

GRAPNEL - a small anchor having four or five arms with flukes, or claws, and no stock, used as an anchor in small boats.

GRAPPLING IRON - an old term for a grapnel. Also, a grapnel with barbed hooks (flukes) attached to chain, used to hook onto a vessel in order to board her.

ICE ANCHOR - a special type of anchor with a single fluke, designed to bite into ice. Also, a screw type anchor that could be screwed into solid ice.

JURY ANCHOR - a makeshift or temporary anchor.

KEDGE ANCHOR - a light anchor used to move a ship from one berth to another in a harbour. This operation is called kedging--the action of taking the anchor out in a small boat and dropping it then heaving the ship up on the cable. A kedge anchor often weighed one eighth that of a bower anchor. Note, if the operation is to change a vessel's heading by heaving here stern around, the term is warping. If a ship runs aground, she may be pulled off by kedging and this operation may require several large anchors.

KILLICK - a slang term for any small anchor.

LEE ANCHOR - the anchor on the lee bow away from the wind which has not been dropped. Or, if the ship is riding from two anchors, the anchor on the lee side of the wind.

MOORING ANCHOR - a heavy weight or special anchor positioned where needed in a harbour or roadstead bottom, as a more or less permanent mooring with an attached buoy. Specifically, it could also be an Old Plan Anchor with only one arm, commonly called a one-armed anchor.

MUSHROOM ANCHOR - a type of mooring anchor having a saucer shaped head on a central shank--resembling a mushroom.

PATENT ANCHOR - usually an anchor that has been granted a patent. But, more commonly, a double-fluked, stockless anchor.

SEA ANCHOR - also a drift, driving, drogue, fly or water anchor--usually in the form of a canvas funnel bag, which when bridled to a cable, will keep a vessel's head into the wind while riding out a storm in open seas. Also, a sea anchor is one that lies to the sea-ward side of the vessel.

SECOND ANCHOR - another name for the small bower.

SHEET ANCHOR - the largest and best anchor carried on the ship, held in reserve to be used in an emergency. This anchor was often stowed upright in the forward part of the hold.

SHORE ANCHOR - an anchor that lies between the ship and the shore.

SMALL BOWER - originally, the smaller of the two bower anchors, usually carried on the port side and used as a second anchor. Later, this anchor was of the same weight as the best bower.

SPARE ANCHOR - a third anchor of similar size to the bower anchors, which was kept as a spare. Sometimes referred to as a third bower.

STERN ANCHOR - another name for the stream anchor carried in the stern of a vessel.

STOCKLESS ANCHOR - one without a stock, post 1850's.

STREAM ANCHOR - a small anchor one fourth of the weight of a bower anchor, used for warping purposes, or when necessary in a stream (tideway) or restricted place.

THIRD BOWER - another name for the spare anchor.

UPSTREAM ANCHOR - another term for an ebb anchor.

WAIST ANCHOR - another name for the sheet anchor stowed in the waist.

WEATHER ANCHOR - the anchor on the windward side, by which the ship in riding.

APPENDIX III

ANCHORING TERMINOLOGY

A-STAY - the condition of an anchor cable when it is in line with the fore stay--dead ahead.

ANCHOR BALL - a black, spherical-shaped signal hoisted forward of the mast, to indicate the vessel is riding at anchor. This signal is used during daylight hours.

ANCHOR BED - a support or platform fitted on the side of the forecastle where a stocked anchor is stowed and secured while at sea.

ANCHOR BELL - a warning bell that is hung near the bow of a vessel, that is rung during foggy conditions by the crew of a ship riding at anchor. The bell is also used to indicate the number of cable shackles (shots) still out, while heaving the anchor cable in.

ANCHOR BITES - said of an anchor when one of the flukes is firmly embedded in the bottom.

ANCHOR BRACKET - a heavy iron bracket fitted at the forward end of the billboard recess, which supports the shank's upper end and secures it with a hinged iron strap.

ANCHOR BUOY - a small buoy attached to a rope bent to the crown of an anchor, used to mark the position of the anchor when it was on the bottom. It was also used as a guide marker to a lost anchor, after the anchor cable had parted.

ANCHOR CHOCK - an angular, iron sheathed timber aft of the cathead on which the anchor's fluke was hung, when secured by a shank-pointer. Also, when used on deck, another name for an anchor bed on which the anchor was stowed.

ANCHOR DECK - or bed, sometimes called the 'monkey-forecastle', a very short top-gallant forecastle deck used to stow the bower anchors on old ships.

ANCHOR GROUND - ground that is suitable to anchor in, neither too deep nor too shallow, and not too rocky. Also, another term for an anchorage.

ANCHOR HOY - a small vessel or derrick-lighter used to convey anchors and chain about the harbour, also called an anchor- or chain-boat.

ANCHOR KNOT - a fisherman's bend. The knot used to fasten the cable to an anchor.

ANCHOR LIGHT - another name for riding lights, the white lights used at night, or in bad weather, to signify that a vessel is riding at anchor.

ANCHOR LINING - a sheathing of planks or iron plates fastened to a vessel's bow, to prevent injury to the hull by the anchor.

ANCHOR POCKET - a later term used to describe the recess at the lower end of a hawse pipe, into which the flukes of a stockless anchor are hoisted in stowing.

ANCHOR RODE - an old term for cable, the line attached to an anchor of a boat, or some other small vessel.

ANCHOR STOCK TACKLE - a small purchase (block and tackle) once used to cant an anchor stock when securing the bower anchor for storage.

ANCHOR WARP - the name given to a rope or hawser when it is attached to an anchor and used as a temporary cable.

ANCHOR WARP LEADER - a small fitting having a sheave to take the warp on an open boat's bow, so that the occupants can raise or lower the anchor without going forward to do so.

ANCHOR WATCH - a group of seamen led by an officer, who are ready to watch and work the anchor cable if the anchor starts to drag in bad weather.

ANCHORAGE - an area off the coast where the seabed is suitable for ships to lie at anchor, having a good secure holding ability. Also, the royal duty levied on vessels coming into port or a roadstead for shelter.

ANCHOR'S APEAK (A-PEEK) - said of an anchor when the cable has been heaved vertically, so that the ship is directly over the anchor which has yet to break out.

ANCHOR'S A-TRIP - said of an anchor when it has just broken out of the ground and is hanging by the cable.

- ANCHOR'S AWEIGH** - another term for a-trip, the call indicating that the anchor is free and the vessel has 'way'.
- AT ANCHOR** - fastened to or held by an anchor. In the legal sense, when a vessel is attached to the seabed by anchor and cable, or by being moored to a dock or mooring buoy.
- ATHWART-HAWSE** - said of a vessel riding with one anchor that rides across its own cable. This condition is caused by changing wind and tides.
- BACK AN ANCHOR** - to lay out a small anchor, such as a kedge anchor, ahead of the larger lower anchor by which the ship rides, the cable of the kedge anchor being bent to the crown of the bower, so as to provide a greater holding power and preventing the bower from breaking out and coming home.
- BECUEING** - a method of securing the cable to the anchor when anchoring in foul ground. The cable is bent to the anchor's crown, then led and made fast to the ring with a light seizing. If the anchor should become fouled, a sharp tug would break the seizing and the anchor could be raised by the crown.
- BILLBOARD** - an iron plate fitted near the cathead to receive the flukes of a stockless anchor, when it is hoisted aboard and stowed secure.
- BREAK GROUND** - to weigh the anchor and lift it out of the ground.
- BREAK OUT AN ANCHOR** - to pull the anchor out of the ground, then it is said to 'break ground'.
- BREAK SHEER** - said of a vessel at anchor when she swings across her own anchor and cable. This condition is caused by changing current or tides.
- BRING HOME AN ANCHOR** - to heave the ship up to the anchor.
- BROUGHT TO ANCHOR** - said of a vessel having just anchored.
- BUOY ROPE** - a light rope bent to the anchor on the sea bed and connected to a small buoy on the surface, to mark the anchor's position.
- CABLE PARTY** - the hands (seamen) detailed to work a cable.
- CANT AN ANCHOR** - to turn an anchor so that one of the arms will bite into the bottom sediments.

CARRY OUT AN ANCHOR - to carry an anchor some distance away in a small boat before dropping it, as done in kedging.

CAST ANCHOR - to drop or let go an anchor onto the bottom.

CAT AN ANCHOR - to hoist an anchor up to the cat-head and secure it by the ring to the cat-head.

CATBACK - a small line fastened to the back of the cathook-block, used to guide the hook in the anchor ring or balancing hand in order to cat the anchor--hoist it aboard.

CATBLOCK - a heavy, three-sheaved block fitted to the cat davit used to cat the anchor--hoist it aboard.

CATDAVIT - another term used to describe a cat head, a davit (a beam or crane) used to hoist the anchor from the waterline up to the billboard.

CATFALL - the rope forming the tackle with which the anchor is hoisted up from the waterline to the billboard in the bow.

CATHEAD - a davit (a beam or crane) used to hoist the anchor from the waterline up to the billboard.

CATHEAD STOPPER - a small, short length of chain or rope used to secure the stock of the anchor after it has been hoisted up to the billboard.

CLEAR HAWSE - to disentangle the anchor cables, that become crossed when an anchored ship has swung around with the tide--thus creating a temporary condition of 'foul hawse' before being cleared. Also, the condition where a ship riding on two anchors has both cables clear of one-another.

CLEAR HAWSE SLIP - a special cable which temporarily secures the end of a foul cable while it is being cleared.

COCKBILL AN ANCHOR - to have an anchor hanging from its ring at the cat-head, ready to drop at a moment's notice.

COME TO ANCHOR - to safely bring the ship to a desired location and to drop the anchor there and then ride by it. Also, to make fast to a mooring buoy or dock.

- COMES HOME** - said of an anchor when it breaks free of the bottom by action of the wind, waves, or current, and drags towards the ship.
- CROSS ANCHOR** - a condition caused when a vessel riding to two anchors swings through 180°, so that the cables become crossed.
- CUT AND RUN** - to cut through the anchor cables, so that the vessel can get underway in an emergency without having to raise the anchor.
- DAVIT** - a small beam derrick, or crane, used to hoist the anchor and or anchor flukes to the top of the bow, a cat davit or fish davit. Also used occasionally in a large longboat to weigh or handle an anchor.
- DRAG ANCHOR** - a term said when the anchor drags over the bottom after breaking free.
- DRAG FOR AN ANCHOR** - to sweep for an anchor, to search for a lost anchor.
- DROP ANCHOR** - to cast anchor, to let it go for mooring purposes.
- ELBOW** - the twist formed in the cables of a vessel riding to two anchors, when the vessel swings through 360°. Each of the cables, after crossing the other in front of the vessel, is directed outwards on the same bow from which they were issued.
- END FOR END** - when the anchor cable is let out to the point where the end is lost through the hawse-hole.
- FISH AN ANCHOR** - to pull the anchor, after it has been catted, up to the gunwale for securing and stowage.
- FISH DAVIT** - a davit used with cat davit to hoist the flukes of an anchor up to the billboard.
- FLAMMING TACKLE** - the tackle used to haul the anchor to the vessel's side when it is stowed vertically. This tackle is worked through a special port in the side of the vessel.
- FOUL ANCHOR** - an anchor which has become entangled in its own cable, or fouled on some underwater obstruction.
- FOUL HAWSE** - the term used to describe a condition when a vessel has swung around and crossed her cables.

GIMLET AN ANCHOR - to turn an anchor around while it is hanging from the cat-head.

GIRT - a situation whereby a ship is held so tightly by her two anchors that she cannot move to the wind or the tide.

GROUND TACKLE - a general term used for all the equipment (anchors, cables, etc.) employed in mooring a vessel.

GROW - a term used to describe the direction of the anchor cable, as it leads away from the vessel towards the anchor.

HAWSE - the condition of the vessel's cable(s) in front of her bows and the anchor(s) to which she is riding.

HAWSE HOLE - or hawse pipe, the holes in the bow of a vessel through which the anchor cable passes.

HEAVE - the work the bars or handspikes that operate a windlass or capstan, thus hauling in the anchor cable.

HEAVING AHEAD - hauling in the cable secured to an anchor some distance ahead, thus moving the ship forward.

HEAVING SHORT - heaving the cable ahead, so that the ship is almost vertically above the anchor at a short stay.

HOUSE AN ANCHOR - to heave a stockless anchor into the hawse pipe and secure it.

KECKLING THE CABLE - another term for securing the cable, the wrap the cable with old rope to preserve the cable from galling (abraiding) against the hawse-hole or anchor ring.

LAY AT ANCHOR - an incorrect term for lying at anchor.

LIE AT ANCHOR - to ride secured to an anchor.

LONG STAY - a term said of an anchor cable when the anchor is a long way from the vessel's bow, the length of cable being more than four times the depth of water.

OPEN HAWSE - the same as clear hawse, the term used to describe a ship riding at anchor with her cables clear of one another.

OPEN HAWSE TO THE GALE - the condition when a ship is moored open hawse, with the wind coming from dead ahead.

PART FROM AN ANCHOR - said of an anchor when it breaks its cable and is carried away by the wind, tide, or current.

PROVED - a term used to describe anchors and cables that have been tested for strength and quality of an approved standard.

RANGING CABLE - the operation of laying out the anchor cable and examining it for wear. Also, the operation of laying the cable out on deck before coming into a difficult or deep anchorage, so that the cable will run out quickly.

RIDING AT ANCHOR - the state of a vessel, or vessels, on the surface of the water when at anchor.

RING UP AN ANCHOR - to heave the anchor up, or cat the anchor, with the ring close up to the cathead.

ROUSE-IN - the command given to take up the slack in the anchor cable, to prevent the anchor from fouling the cable.

RUNNING MOOR - to moor the ship while still underway, dropping one anchor then moving ahead to drop a second anchor--so there will be an equal strain on each of the anchor cables.

SCOPE - the length of cable that is run out when a vessel rides at anchor.

SERVE THE CABLE - to wrap the cable with old rope to prevent it from galling (abraiding) against the hawse-hole or anchor ring.

SHANK PAINTER - a short length of rope or chain used to secure the shank of an anchor to the billboard when stowed.

SHEER - the angle between the vessel and her single anchor cable. Also, the position maintained by a vessel when at single anchor.

SHEER THE SHIP TO HER ANCHOR - to steer the ship in the heading towards where her anchor lies, while heaving up the anchor cable.

SHOE AN ANCHOR - to bolt planks of wood to the flukes, to enlarge their surface area, thus increasing the holding power in very soft sediments.

SHORT STAY - the condition of an anchor cable when it is fairly taut and the scope is less than one and a half times the depth of water.

SHORTEN IN - to decrease the amount of anchor cable between the vessel and her anchor, thus shortening the scope.

SLIP STOPPER - a short length of chain used with a slip or hook to hold the anchor onto the billboard. By releasing the slip, the anchor falls free to hang from the cable.

SPRING - a rope run from the stern of a vessel at anchor to the anchor cable, so as to turn the vessel's bow in a particular direction.

START - to ease the anchor out of the bottom.

SWALLOW THE ANCHOR - naval slang meaning to retire from a sea career, to go ashore and stay ashore.

SWEEP FOR AN ANCHOR - to search for a lost anchor, using a creeper or a sweeping line between two boats.

SWING - the movement of a vessel from side to side while at anchor, due to the wind and or tide.

TEND - an old term said of a ship at anchor, that swings to the tidal current.

TIDE RODE - the condition of a vessel when swung to her anchor by the tidal current, having her bow pointing into the tide.

TREND - means the same as shear, the angle between the fore and aft line of the vessel and the anchor cable by which she is riding.

TRIP AN ANCHOR - to break an anchor out of the ground by using a previously attached tripping line or anchor buoy line, bent to the anchor crown. Also, to free an anchor when it is fouled.

TRIPPING LINE - similar to an anchor buoy line, a line which is bent to the crown of an anchor, so that the anchor can be tripped if it becomes fouled.

UNDERFOOT - the condition when an anchor is under a vessel's bowsprit and the cable is nearly up and down.

UP AND DOWN - a term used to describe an anchor cable when it is vertical and the anchor is directly under the bow of the vessel.

VEER THE CABLE - to slacken or let out cable so that it may run out and thus increase the scope.

WEIGH ANCHOR - to heave the anchors in, to raise them, in preparation for getting under way.

WEIGHT ANCHOR BY A BOAT - when an anchor cannot be broken out, a tripping line is brought over the ship's boat stern and secured, while the men fill the stern-sheets to keep the stern down--following which the men go forward (lifting the stern) thus 'jumping out the anchor' from the ground.

WIND RODE - a term used to describe an anchored vessel swung by the wing, so that the vessel's bow points into the wind.

VITA

Harold James Williamson Jobling (Jim) was born in Messina, South Africa, to Dick and Bettie Jobling on September 25, 1957. After serving two years in the army, he enrolled at the University of Cape Town, South Africa, in February 1979. He graduated in December, 1982, with a Bachelor of Arts Degree in Archaeology. He continued his studies at the University of Cape Town, and graduated with an Honours degree in Archaeology in May, 1984. In the summer of 1984, he enrolled at Texas A&M University, as a Master's degree candidate in Anthropology, specializing in Nautical Archaeology. His interests are in conservation, and the exploration and expansion of trade into the New World. He has participated extensively in both land and underwater surveys and excavations in South Africa, Jamaica, Texas, and Louisiana.

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