

16TH CENTURY CAST-BRONZE ORDNANCE AT THE
MUSEU DE ANGRA DO HEROÍSMO

A Thesis

by

SARA GRACE HOSKINS

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of
MASTER OF ARTS

December 2003

Major Subject: Anthropology

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ABSTRACT

16th Century Cast-Bronze Ordnance at the
Museu de Angra do Heroísmo. (December 2003)
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Within the collections of the Museu de Angra do Heroísmo (Terceira Island, Azores, Portugal) are nine cast bronze guns from the 16th century. Most were raised from the seafloor between the 1960s and 1990s, but this study comprises the first in-depth research into their design and manufacture. The importance of this kind of study lies in the fact that ordnance is commonly found on shipwrecks of this time. A greater knowledge of guns will help provide information about the ships from which they came.

Careful documentation and study of the Museu de Angra cannon will add greatly to their value as museum exhibits, by allowing museum patrons to better understand where the guns came from, how they were cast, and why they were important. This documentation adds to our knowledge of Western European gunfounding technology during the sixteenth century, as four different countries commissioned the guns: Portugal, Spain, France, and England. With detailed documentation and publication, the Museu de Angra bronze guns can be added to the bibliography of ordnance of this period, which will aid future researchers who encounter similar pieces.

The Museu de Angra bronze guns, as symbols of the military and naval power of

the countries that commissioned them, were sent aboard ships, into the field, and mounted on fortress walls. Bronze guns of this time period are particularly important, as bronze was an expensive commodity, and the demand for ordnance was increasing rapidly. Countries developed more effective ways to make use of iron for the founding of guns, and the use of bronze became more symbolic of wealth. The information that each gun contains includes both the cutting-edge military technology of the time and the artistic statement of the founder. Some of the finest metalwork of the period was displayed in cast bronze guns, and due to the founding techniques, no two are the same, making each an important piece of history.

ACKNOWLEDGEMENTS

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I want to express my great appreciation to the Tower of London (with special thanks to Bridget Clifford), Fort Nelson in Portsmouth (with special thanks to Nicholas Hall), the *Mary Rose* Museum in Portsmouth (with special thanks to Alex Hildred), the Musée de l'Armée in Paris, the Museo Naval in Madrid, the Museu da Marinha in Lisbon, and the Museu Militar, also in Lisbon for allowing me access to their collections, which made my comparative research possible.

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I wish to express my gratitude to Cristina Lima for all that she has done for me over the years. She provided me with a bed in a warm home during my stay in Angra,

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CHAPTER I

INTRODUCTION

The Museu de Angra do Heroísmo, Terceira Island, Azores possesses nine bronze guns dating to the 16th century, referred to here as MAH 1-8¹ and MAH R. 98. 14 (fig. 1). The guns were salvaged in one general location, the bays of Angra and Fanal on the southern coast of Terceira (fig. 2), but they originated from four different countries: Portugal, Spain, France, and England. It is necessary to present a general historical background in order to place these guns in their appropriate context. To better understand and interpret them, it is also necessary to review the founding processes that produced them, including any design standards, and the reasons behind the use of such standards.

During the 16th century, power struggles were commonplace and allies could quickly become enemies. European countries sought to stake their claim on newly discovered lands, as well as to acquire any other land they could. With the rise in popularity of ordnance, their circulation increased, often causing them to pass into foreign lands where they sometimes remained, be it through alliance or capture.

Technology historian Carlo Cipolla notes: “the establishment of the great national states with big armies and navies and their incessant wars, together with geographical exploration and overseas expansion, all added to the demand for cannon.”² With a greater need for guns, rulers took a personal interest in the manufacturing

This thesis follows the style and format of the *American Journal of Archaeology*.

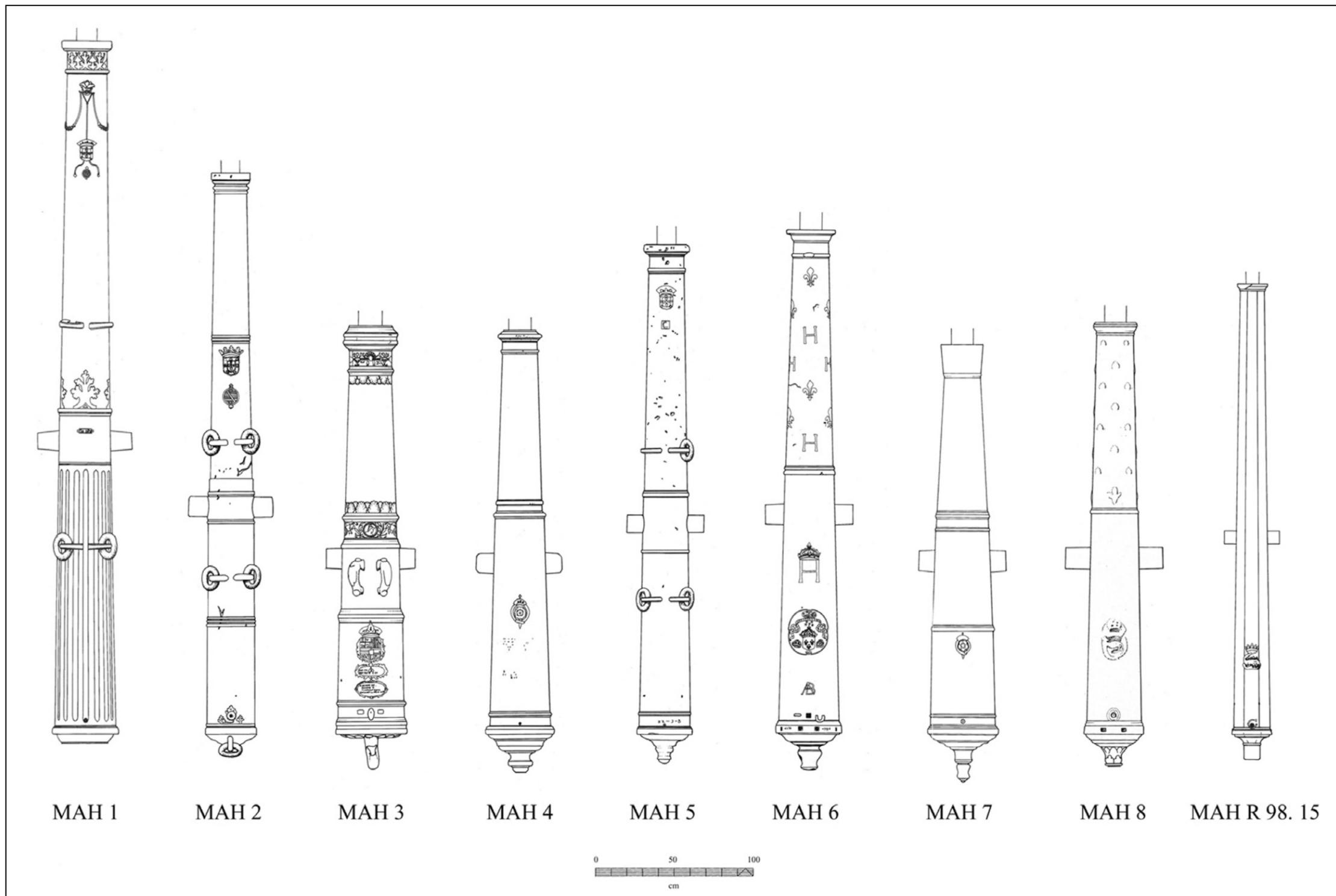


Fig. 1. The Museu de Angra do Heroísmo collection of 16th century cast-bronze guns

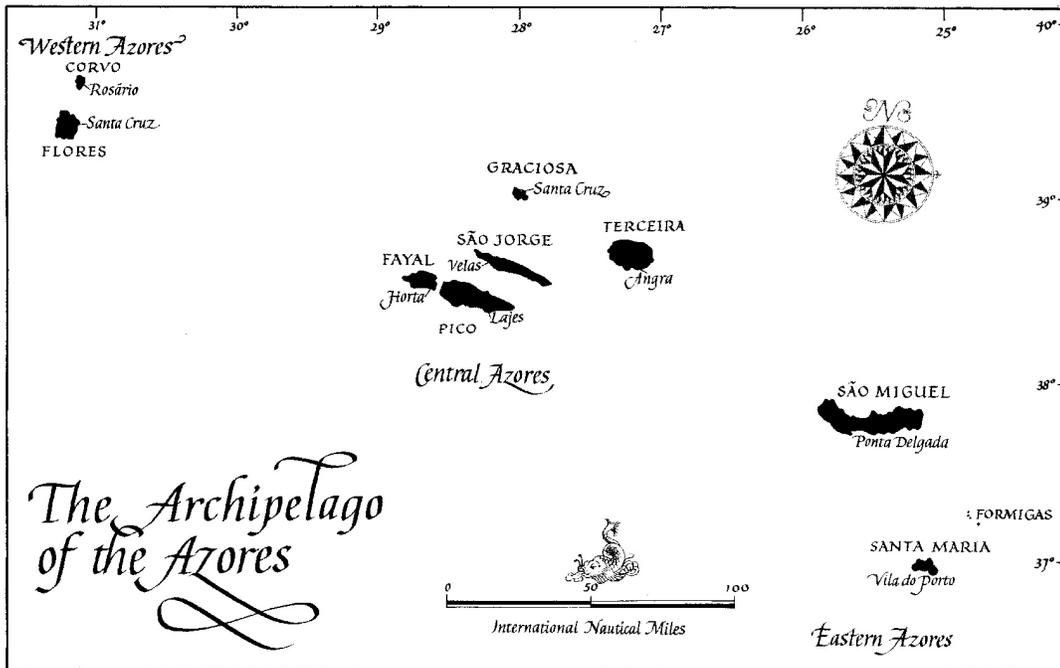


Fig. 2. Map of the Azores (from Duncan 1972, 81).

process and allocated a great deal of their resources to improving the art of gunfounding and obtaining the arsenal they desired. This provided the impetus for an evolution in gun design, leading to a form that remained relatively unaltered for at least the next century.³

Henry VIII, for one, spurred on this evolution by bringing French, Flemish, and Italian masters to England to produce guns and to teach native craftsmen the art of casting guns. It is likely that these founders in England, as well as those on the continent, became familiar with Biringuccio's *Pirothechnia*,⁴ and used it as a technical reference.⁵

It is hoped that the presentation of these guns will add to the greater knowledge of 16th century cast-bronze ordnance. Though it is not an especially large collection, the Museu de Angra guns nevertheless present an opportunity to compare gun design and founding techniques during this time period. A comparison is important because it was in the 16th century that cast guns were making their way around the world, serving as powerful new weapons of war as well as symbols the wealth and power of the countries that owned them.

Notes

¹ These eight numbers were assigned by the author in order to distinguish these guns; the number for the ninth gun was assigned by the museum.

² 1965, 26.

³ Cipolla 1965, 26; Flanagan 1988, 66.

⁴ This book, first published in 1540, describes step-by-step how to produce a cast bronze cannon.

⁵ Caruana 1992, 7.

CHAPTER II

HISTORICAL BACKGROUND¹

Throughout the 16th century European alliances were continually shifting, especially between England, France, Spain, and the Holy Roman Empire. In the early years of the reign of Henry VIII, England and France were relatively at peace, but by 1511, England was in league with the Empire and the Pope against France. This alliance led England to land an army in France in 1513 equipped with a large train of artillery. Peace was reached between France and England the following year, in part due to the marriage of Henry's sister Mary to King Louis XII of France.²

Under Louis XII's successor, Francis I, the conflict between the Empire and France continued. The two powers were at war from 1521 to 1526, and again from 1526 to 1529. Henry VIII allied with Emperor Charles V against France in the first war, making peace with France in 1525, and then switched sides for the second war.³

Following these wars, in 1536, Charles ordered an invasion of France and was aided again by England. Two years later, Pope Paul II was able to join France and the Holy Roman Empire in an alliance against England. The alliance was brought about after the annulment in 1533 of Henry's marriage to Catherine of Aragon, the aunt of Charles V. In spite of this, the Empire later allied with England, declaring war on France once again in 1543, and ordered another invasion. The tables had been turned on France, but the Empire immediately made peace with the French again, and England followed suit in 1546.⁴

With the relationship between England and France on relatively peaceful terms, both of the kings died in 1547. The new king of France, Henry II, was not keen on peace with England and the recently-crowned King Edward VI. Only two years into their reigns, the countries were at war again, but peace was quick to come in 1550. In another two years, Henry II placed France at war with the Empire (and Charles V) again, a dispute that lasted until 1559.⁵

During these years of war between France and the Empire, the House of Tudor saw yet another ruler. Mary I came to the throne of England in 1553. The following year she married Phillip II of Spain, the soon-to-be ruler of Spain and the Low Countries, thus forming an alliance between the two powers. In 1557, Henry II joined forces with the Pope against Spain. In light of the Queen's marriage, England was led to war with France once more.⁶

The crowning in England of a powerful new leader, Elizabeth I, in 1558 changed the situation yet again. Under her rule, England was not obligated to ally itself with Spain, and, two years after her accession, she was ready to "defy Spain, France, and the Pope."⁷ England, however, had come to peace with France in 1559, as did Spain. England signed two more treaties with France in the coming decades. The first ended England's part in the First French War of Religion, while the second was a promise to join forces with France against Spain.⁸

Towards the end of the 16th century, Phillip II actively sought to change the balance of power. For example, he forcefully took control of Portugal in 1580. The Azores, however were not taken easily and Dom António (Pretender to the Portuguese

throne), who was trying to reclaim Portugal from Spain, made the islands, especially Terceira, his stronghold. Spain tried to invade Terceira in 1581 but was unsuccessful. The next year, the Spanish and Portuguese (under Dom António the Pretender, and aided by French and English ships) fought “the first great sailing ship battle at the island of Terceira.”⁹ In the end, Spain was able to take the Azores, despite the fact that 800 French troops were sent there as reinforcements.¹⁰

After taking Portugal and the Azores, the king of Spain set out to conquer England. Hostilities soon broke out between the two countries, and in 1588, Phillip sent his Armada unsuccessfully to invade England. The victors of the Armada fight then joined forces with the French and the Dutch in a war against Spain in 1595, but the Spanish made peace with France in 1598, England in 1604, and the Dutch in 1609.¹¹

Brief History of Ordnance

The history and development of ordnance have been examined in many scholarly works, and for the purpose of this study it is unnecessary to present more than a brief overview. The origin of cannon lies before the first half of the 14th century, when they were first depicted. By the second half of that century they were established tools of warfare. Though the first illustrations that we have of guns depict vase-like castings of copper or bronze, throughout the 15th century most guns were small and made of forged iron staves and hoops assembled in the manner of a barrel. Between about 1460 and 1510, cannon became a crucial and decisive element in warfare. By the middle of the 16th century, forged iron guns were falling out of favor while the demand for those of

cast-bronze grew rapidly, causing the latter to become relatively abundant. At the same time, gunfounders, particularly in England, were learning to cast ordnance in iron, which was far more economical than bronze. Though iron guns were heavier and less reliable, by the 17th century they would end up dominating the market.¹²

Introduction of Ordnance on Ships

Artillery appeared on ships as early as the beginning of the 15th century, but the first sea battle in which ships used guns to fight other ships (not just batter walls or other land targets) did not occur until August of 1512, when the French engaged the English off Brest. When guns were first introduced on warships, they were simply another weapon to be used in an already-established form of warfare.¹³ Later, they provided the foundation for an entirely new type of combat at sea, and required a change in the design of the ships that would carry them. The new design allowed more guns to be mounted and used more efficiently on ships. Historian John Guilmartin observes: “It is widely accepted that European success in taking gunpowder artillery to sea was a principal mainspring behind the establishment and growth of trans-oceanic European empires.”¹⁴

Until the beginning of the 16th century, ships carried heavier guns on their upper decks, where they could fire over the bulwarks, while lighter pieces were placed in the castles. With this configuration, fighting was essentially like it was on land, the two vessels coming alongside each other and fighting more or less hand-to-hand, with guns just being another of the many weapons utilized.

With the invention of the gunport, attributed to a Frenchman named Descharges

in 1501,¹⁵ heavy guns could be moved to the lower decks. It was then that sea battles were able to take on an identity of their own, though it took more than half a century to reach the full potential. Throughout the reign of Henry VIII, even though guns were in place in gunports, sea battles continued to be shipboard versions of land battles. It was not until Elizabethan days that warships were used as fighting machines, not simply platforms for seaborne armies.¹⁶

The placement of heavy guns lower in the ship allowed for the development of the galleon, a smaller, more seaworthy vessel than those previously utilized, which were lofty with particularly high ends. The evolution of the fighting ship changed the way sea battles were fought. With a maneuverable ship and heavy guns, it was possible to disable the enemy from a distance. This was best achieved using a new tactic, the broadside, or simultaneous firing of all guns from one side of a ship.¹⁷

The Portuguese used broadsides as early as 1502 off Calicut against a Moorish fleet, as did the French and English in their battle off Brest in 1512.¹⁸ Peter Padfield speculates that, in the first half of the 16th century, only crews of weaker or outnumbered vessels would use them, not wanting to move in too close to the enemy. He notes that the first major battle fought entirely by galleons using the new technique did not occur until 1582 during the previously-mentioned struggle in the Azores. The same tactic was also used during the better-known Armada battles in 1588.¹⁹

Positioning the guns on the lower decks meant placing them in a more constricted environment, thus restricting the lengths of the guns that could be used for sea service. To properly supply ships with guns of correct length, a differentiation

existed between ordnance intended for sea service and that destined to stay on land.

This happened in England around 1560. It was not until the 17th century that the same thing occurred in Spain, and it happened even later in Portugal. The ordnance for the rest of Europe, however, was already differentiated by 1571 and the Battle of Lepanto.²⁰

Notes

- ¹ A list of the principle 16th century European rulers may be found in appendix A.
- ² O'Neil 1960, 43-4; Williams 1980, 221.
- ³ Williams 1980, 205, 221; O'Neil 1960, 45-6.
- ⁴ Norris 2000, 48-9; Williams 1980, 222-3; O'Neil 1960, 46-8, 63; Koenigsberger and Mosse 1968, 185.
- ⁵ O'Neil 1960, 65; Williams 1980, 206.
- ⁶ O'Neil 1960, 66; Williams 1980, 206, 299, 348.
- ⁷ O'Neil 1960, 67.
- ⁸ O'Neil 1960, 67, 72; Williams 1980, 206; Koenigsberger and Mosse 1968, 245.
- ⁹ Raudzens 1999, 69.
- ¹⁰ Williams 1980, 353; Martin and Parker 1988, 26, 96; Haws and Hurst 1985, 252.
- ¹¹ O'Neil 1960, 73; Williams 1980, 354-5; Koenigsberger and Mosse 1968, 266-7.
- ¹² Blackmore 1976, 1-2; Caruana 1992, 3; Cipolla 1965, 21-2, 25-6; O'Neil 1960, 43; Hodgkinson, 2000, 34-5; Guilmartin 1982, 133.
- ¹³ Guilmartin 1974, 158; Haws and Hurst 1985, 190; Konstam 1988, 21-2.
- ¹⁴ 1988, 47.
- ¹⁵ Anderson 1926, 127; Cipolla 1965, 82; Robertson 1921, 7.
- ¹⁶ Robertson 1921, 6-7, 72; Fuller 1945, 90.
- ¹⁷ Robertson 1921, 7; Anderson 1926, 129; Padfield 1974, 35; Caruana 1994, xii.
- ¹⁸ Stanley 1869, 366-71; Haws and Hurst 1985, 190.
- ¹⁹ Padfield 1974, 33, 45.

²⁰ Caruana 1994, 32; Santos 1986, 43.

CHAPTER III

STANDARDIZATION

Early 16th century gunfounders experimented with different bore sizes, barrel thicknesses, powder charges, projectile weights, and gun designs in general. The result was a lack of standards in artillery, a problem remarked upon by Biringuccio in his *Pirothechnia*.¹ This was significant because, without any regulation of calibers, it was difficult to supply guns with proper munitions.² By the middle of the century, however, European leaders were recognizing this problem and began making efforts to establish rules for the design and production of ordnance.

“Despite the almost limitless variety of forms 16th century ordnance might take,” Colin Martin and Geoffrey Parker note, “gunners usually applied quite specific names to particular types of gun. These names do not, however, imply any absolute precision of definition, for no such definition existed.”³ When cast-bronze guns were first introduced, they were often given names of fierce animals or birds of prey. In time, these names began to encompass guns of a variety of bore sizes, gun weights, and overall dimensions. The reason behind this was that guns, on the whole, were constantly changing sizes, but keeping the same class names, causing a great variety to exist within a class.⁴

Remigy de Halut, the Founder Royal of Spain, began a process to establish order among the ordnance of his country sometime after 1534. He set guidelines for caliber, barrel length, wall thickness, and total gun weight. In the 1530s or 1540s Henry VIII

implemented standards in England by issuing Artillery Charters. Charles V (Charles I of Spain) followed suit in his Empire in 1544. The latter ruler established seven standard models, while it appears the English had only five. In 1552, Henry II ordered that only six designs of ordnance should be made for France.⁵

Whether or not these rules solved the problem of standardization is questionable. Apparently, by the end of the 16th century, these standards produced 50 gun types of around 20 different calibers in Spain alone. Though an improvement, the gunners were still left with the problem of supplying all of these varieties with their correct size of shot and amount of powder. This problem was better solved in the 17th century with the practice of naming a gun based on the weight of the shot it fired, instead of by names such as culverin, cannon, and minion, which tended to have loose definitions.⁶

By the time of the Spanish Armada, there was still a great variety present among the guns, making life difficult for the gunners.⁷ Partially to blame was the long life span of cast-bronze guns, which could be upwards of 150 years.⁸ In addition, even though standards were in place in several countries, they were likely not always followed, and moreover, they did not agree with each other. This caused problems for fleets of ships armed with available guns, which likely included those captured on land, taken from foreign vessels, or purchased from foreign foundries.⁹

*Gun Types*¹⁰

By the end of the 16th century, ordnance could generally be divided into at least three distinct gun types: cannon, culverin, and perriers or stone-throwers (we will not be

concerned with the latter type here). These classes were based on function. Cannon were considered short-range battering pieces, while culverins were used to shoot objects at greater distances. Each of these broad categories was then broken down into more exclusive groups based on gun dimensions, all of which could come in a bastard version (a gun that did not meet the standard specifications of a type, usually being shorter than normal).¹¹

Different countries had their own standards, when there were any to be followed, resulting in various rules for calculating proper gun dimensions.¹² Appendix B lists those standards that I have encountered. For the sake of simplicity I have, like Michael Lewis, chosen to only deal with the broad categories of cannon, demi-cannon, culverin, demi-culverin, and minion.¹³

The appendix of types is intended merely to show general trends. It is not all-encompassing, and shows the wide varieties that were present within categories, especially in regard to gun lengths. More importantly, however, it shows that the greater variety exists between categories, particularly when it comes to bore diameter. The fact that so many of the lists of types either do not provide a length, or give a variety of lengths for one bore diameter, leads me to believe that bore diameter was the deciding dimension when it came to labeling a gun. Tucker argues the same case, but says that this occurred only in the latter part of the 16th century.¹⁴ Before that, one bore size could be found in more than one class of gun, and guns were more likely to be classified based on their length as it related to the bore diameter (caliber).

Cannon

Cannon were comparatively light and short, and were meant to shoot a heavy projectile over a relatively short distance.¹⁵ They came in lengths from 7 to 13 feet (213 to 396 cm), with bores ranging from 7 to 8 inches (17.78 to 20.32 cm) in diameter. Their lengths are often described as being 18 calibers, though Biringuccio said that, in his time, the length was roughly 22 times the diameter of the shot.¹⁶ Demi-cannon were smaller; averaging around 11 feet (335 cm) in length, with bore diameters typically only from 5.75 to 6.75 inches (14.61 to 17.15 cm).

Culverin

Culverins were long guns with thick walls. Their purpose was to accurately fire a smaller projectile at long range. They were also said to have had a relatively rapid rate of fire, being easily loaded and moved.¹⁷ Their lengths could be anywhere from 7.5 to 17.2 feet (229 to 524 cm), but were typically closer to 12 feet (366 cm), and had bores with diameters from 5 to 5.5 inches (12.70 to 13.97 cm). Caruana argues that, by Armada times, typical lengths for culverins were only 8 or 8.5 feet (244 or 259 cm).¹⁸ Demi-culverins averaged about 11.5 feet (351 cm) in length, with bores from 4 to 4.75 inches (10.16 to 12.07 cm) in diameter. Minions were significantly smaller, with bores typically of only 3.25 inches (8.26 cm) in diameter, and lengths of about 8 feet (244 cm). There are more guns in this class, such as sakers, falcons, falconets, but they are not represented in the Museu de Angra collection, and so will not be discussed.

Notes

¹ 1966, 223-4.

² Norris 2000, 54; Ffoulkes 1969, 94.

³ Martin and Parker 1988, 215.

⁴ Cordeiro 1895, 86; Robertson 1921, 74.

⁵ Flanagan 1988, 66, 70; Norris 2000, 55; Caruana 1992, 7-8.

⁶ Norris 2000, 55; Flanagan 1988, 66; Brown 1997, 104.

⁷ Martin and Parker 1988, 205.

⁸ Cast-bronze guns were used until they could no longer be of use, which makes perfect economic sense, seeing as these guns were not cheap. It was not uncommon to find 50-year old guns on ships (Caruana, 1994, xvii, 8; Roth 1996, 31). The Swedish Royal Ship *Kronan*, which sank in 1676, had one gun on board that was cast in 1514 (Einarsson 1990, 279, 294).

⁹ The *Mauritius*, *La Trinidad Valencera*, and *Kronan* all carried guns of various nationalities (Brown 1997, 104; Martin 1988, 58; Einarsson 1990, 294).

¹⁰ See appendix B for a more inclusive list of references. The guns in this collection range in length from 252 to 432.5 cm (8.27 to 14.19 ft), with bores from 8 to 15 cm (3.14 to 6 in), and I will only focus on the types within these ranges.

¹¹ Valle 1962, 382; Tucker 1976, 60; Moretii 1683, 18-9, 34-5; Cordeiro 1895, 89-90.

¹² Biringuccio 1966, 225-6; Norton 1628, 44; Collado 1592.

¹³ 1961, 17.

¹⁴ 1976, 63.

¹⁵ Norris 2000, 63; Moretii 1683, 19, 32; Caruana 1992, 6.

¹⁶ 1966, 225.

¹⁷ Norris 2000, 62; Moretii 1683, 18; Caruana 1992, 6; Biringuccio 1966, 226.

¹⁸ 1994, 37.

CHAPTER IV

GUNPOWDER AND GUN DESIGN

In the beginning of the period under discussion, guns used slow-burning serpentine powder, which was a mixture of finely ground saltpeter, sulfur (or brimstone), and charcoal. When ignited, the powder produced gasses that propelled the ball down the gun's barrel. In order for serpentine powder to reach its maximum velocity, it was necessary for the gun in which it was used to be relatively long. This may have led to the belief that longer guns provided greater range, because, in fact, if a gun did not provide an adequate length for the complete combustion of the powder, the result would be a decreased range. There was, however, a point after which lengthening the gun any more would do little to increase the range.¹ This is a concept that 16th century founders like Biringuccio appear to have grasped. He explained that the length of an intended gun was determined by considering the amount of gunpowder required to propel the desired size of ball. The length was to be such that all of the powder would have ignited just as the ball exited the gun, so that it shot with the maximum possible force.²

This concept became more complicated with the development of the faster-burning corned powder, which was made of the same elements as serpentine powder. In corned powder, however, the saltpeter was dissolved into the charcoal, binding the elements together into grains (which could be made in a variety of sizes), creating a faster-burning, more potent powder (two parts corned powder produced the same amount of propellant gasses as three parts serpentine powder).³

When lit, smaller grains of corned powder propagated energy faster than larger ones, and thus required a shorter barrel length. The larger the grain, the more length was required for the projectile to reach its maximum possible speed and range. In addition, the longer the gun, the safer it was, because the building energy and pressure behind the projectile could be distributed over a greater distance, causing less strain to the walls of the gun.⁴

Corned powder was actually known in the mid-15th century, but it took founders time to learn how to cast guns strong enough to withstand the pressures of this new gunpowder. Robertson argues that it was not until the mid-16th century that they were able to make large guns capable of using it.⁵ With the use of a new propellant, the design of ordnance had to change. Whereas guns designed to use serpentine powder only required a single reinforce to withstand the pressures of firing, those designed for corned powder required two, or at least a strengthened first reinforce.⁶

When founders began to design guns to use corned powder, it is likely that they made them excessively long, even when it was observed that only a certain length was necessary. The extra length could provide peace of mind to the gunner. It most likely took both gunners and founders time to accept that these new guns could be made shorter than those designed for serpentine powder, yet still have the same affect and be just as safe.⁷

Guilmartin suggests that guns were cast even longer than necessary for reasons of gunner safety. He argues that the only means available to a founder to combat any sponginess or honeycombing in the bronze, which would make the metal weak and

dangerous, was to increase the pressure on the bronze during casting. To accomplish this, since guns were cast muzzle upward, the founder simply had to make a longer gun, allowing a greater amount of pressure to bear down on the most critical part of the gun, the breech. The possibility of unsound metal towards the muzzle was still a problem, but, by making a longer gun, the founder placed the potential danger further away from the gunner.⁸

There are some who say that the reputation of long guns, culverins, for having longer ranges due to their length was erroneous. They contend that the effective ranges of both the cannon and culverin types would have been the same, and that range was not proportionate to barrel length, meaning that culverins would have been made unnecessarily long.⁹ This argument may be true if both gun types were loaded with the same powder charge and shot size. Primary sources, however, show that they were not.¹⁰ Culverins were loaded with a relatively greater amount of powder and a smaller ball, allowing them to effectively shoot farther than the cannon, which shot a heavier ball with less powder. Unfortunately, no accurate range tables were made in the 16th century that could settle this debate.¹¹

Though the reason behind the great lengths of some early cast-bronze guns remains unknown, we do know that they became shorter over time. There are several possible causes for this phenomenon. Presumably it occurred as founders gained greater experience and increased knowledge. More importantly, there was a great economic incentive for the development of shorter guns, which used less of the expensive metal.¹²

As to when the switch to shorter guns occurred, Lewis believes that it happened following the Armada fight, after which was “the real wholehearted introduction of the shortened broadside culverin.”¹³ Whereas culverins were previously made in the neighborhood of 26 to 32 calibers long, at the time of the Armada, they may have already been made as short as 18 calibers, which, incidentally, was the common length of the cannon.¹⁴ It is noteworthy to point out that the Spanish gun in the Museu de Angra collection, MAH 3, which dates to 1596, is a shortened, or bastard, demi-cannon. The two English guns, MAH 4 and 7, may be dated to after the time of the Spanish Armada based on this argument, because both are bastard, or shortened versions of culverins, being only 18 calibers or less in length but with bore diameters fitting the culverin classification.

Notes

¹ Robertson 1921, 76; Ffoulkes 1969, 86-7; Moretti 1683, 6; Guilmartin 1988, 42, 48, 50; Guilmartin 1982, 140; Martin and Parker 1988, 197.

² 1966, 224.

³ Guilmartin 1988, 48; Smith 1600, 38.

⁴ Guilmartin 1988, 50-1.

⁵ 1921, 70-1.

⁶ Guilmartin 1988, 43. Before this time, there were guns that appeared to have more than one reinforce, but these were likely just decorative (Caruana 1994, 34).

⁷ Roth 1996, 22-3.

⁸ 1982, 140.

⁹ Martin and Parker 1988, 197; Guilmartin 1974, 277.

¹⁰ Smith 1600, 65; Norton 1628, 46, 53; Nye 1670, 72-7; Love 1705, 184.

¹¹ Smith 1600, 48.

¹² Lewis 1961, 200-1; Guilmartin 1974, 172.

¹³ 1961, 31.

¹⁴ Lewis 1961, 32.

CHAPTER V

GUN USE

Placement on Board Ships

When guns were placed on ships, certain precautions had to be made. There is evidence that guns were kept loaded while onboard. In this situation, to protect the ball and powder, a wooden tampion (or tompion) was placed in the muzzle. This was tallowed to ensure the powder stayed dry. Another precaution taken to keep the powder dry was the insertion of a tallowed piece of oakum in the touchhole. Alternatively, some guns were even fitted with a vent cover, as was the case with MAH 3 and 6. Rectangular lead sheets could also be placed over the touchhole to protect the gun's contents from the elements.¹

Loading and Aiming

As guns were kept on board ready for use, the initial loading was not a concern, however, reloading was. For this precarious task, gunners had the option of either climbing out of the ship, straddling the barrel while he swabbed the bore and then reloaded the gun, or the gun could be pulled inboard. The problem with the latter option was the lack of room on the deck. Guns could be unlashd and hauled in to the point that their muzzles were just inboard, but, in order to reload a piece in this position, the gunner's arms and upper body had to protrude through the gunport.² Martin and Parker argue that the efficient method of allowing a gun to recoil inboard, being caught by its

breeching rope, did not come into use until the 17th century.³ This suggests that gunners really had no choice but to either crawl out onto the gun, or extend his upper body outside the gunport, an unenviable task at sea in rough weather with the possibility of enemy fire.

Once the guns were loaded, the gunners were tasked with aiming them correctly. Biringuccio claimed that a properly made gun would shoot in a straight line.⁴ Whether or not this was the case, the gunner had several tools and methods at hand to obtain the best possible aim. He could make a sight by marking the centerline of the gun. He could place a small ball of wax at the muzzle, and a small mark at the breech, if he desired. By bringing the tips of his thumbs together in an upside-down V and looking through them, he could line up these marks with the target. To regulate the gun's elevation, and thus its range, a gunner's square was used, if available. In order to achieve the desired elevation, the gunner would have a crewmember raise and lower the gun using a handspike, then hold it in position with a wedge known as a quoin (coyne or coin).⁵

Effects of Use

Frequent firing of bronze guns had a tendency to weaken them. Bronze generates heat more readily than iron, and as a bronze gun was fired, the metal partially annealed. As these pieces were supported by trunnions toward the breech, and as many of them were long, the annealing metal towards the muzzle tended to yield to gravity, causing it to droop. In order to prevent this, supporting bars could have been used along

the gun's length, or a polygonal shape employed. This design not only strengthened the gun, but also saved metal and reduced the gun's weight, which was preferable for shipboard ordnance.⁶

In action, some guns were fired so rapidly that the metal was unable to cool properly after each shot, and the touchholes would occasionally fuse. When fusing occurred, they could be re-drilled. In the field, however, the tools for such a venture were not likely to be available, and the touchhole had to be reopened by alternative means. There are accounts of powder being lit from the muzzle of a gun in order to blow its touchhole open from the inside, a method that was apparently a success. This worked especially well for removing spikes and debris from the clogged touchhole (a gunner could drive an iron spike into the touchhole to render a gun unserviceable, at least temporarily, if it was likely to fall into enemy hands).⁷

Touchholes, however, were more likely to enlarge through successive firing. As a gun was fired, the hot gases produced by the burning powder passed out the vent as well as through the muzzle. Among these gases was sulfuric acid, which, combined with other factors, resulted in the scouring of the touchhole from the inside. The effect was the creation of a cone-shaped touchhole. This shape would weaken this area on the gun, and the enlargement would reduce the potential velocity of the shot. As these were undesirable effects, the touchholes would be repaired. There is not a great wealth of information on how this was done in the 16th century, but it can be assumed that they were drilled out and fitted with a metal bush.⁸

Notes

¹ Martin 1975, 221; Love 1705, 191; Ffoulkes 1969, 102; Puype 1990, 20.

² Konstam 1988, 19-20.

³ 1988, 202.

⁴ 1966, 420; Guilmartin disagrees with this argument, for he claims “smooth bore weapons firing a spherical projectile were – and are – inherently inaccurate. This was an unavoidable reality” (1988, 43).

⁵ Biringuccio 1966, 420; Moretti 1683, 85, 89; Nye 1625, chap. 38, 1-2; Blackmore 1976, 240.

⁶ Ffoulkes 1969, 5; Caruana 1994, 15. One of the guns in the collection, MAH R. 98. 14, is octagonal in shape.

⁷ Ffoulkes 1969, 96; Smith 1627, 68; Blackmore 1976, 244.

⁸ Caruana 1994, 13; Ffoulkes 1969, 96.

CHAPTER VI

GUNFOUNDING

Primary texts concerning the actual process of gunfounding are full of warnings to the founder. These cautions indicate the difficulties involved in the casting of bronze, as well as the complexity of casting ordnance in this metal. The artisans had to take care during every step of the process to ensure a usable outcome. Those founders who were able to master the art earned high reputations in this field that required highly skilled labor.¹

Concerning the Clay

The best clay available was to be used. Wool-cloth clippings, wool cardings, hair from tanneries, dry dung (horse, donkey, mule, or cow), chopped flax tinder, cane flowers, and finely cut straw could all be mixed in to add strength and rigidity to the clay. For a smooth surface, all elements formed from this mixture were covered with fine loam, and then dried. In every step of the process careful drying was vitally important, for any crack that formed in the clay could be detrimental.²

Making the Model

The first step in this process was to make a composite model of the intended gun. The model was made to look exactly as the gun should, with all of the ornamentations and reinforcements.³ The reinforcement rings or bands were placed along the gun in

those locations where the metal needed extra strength. One of these sets of rings was added on the outside of the model between the powder chamber and the trunnions. The purpose of the reinforcement rings at the muzzle was to prevent it from cracking when fired, which was a concern because it was this part of the gun that saw the greatest change of pressure upon firing.⁴

The foundation of the model was a tapered wooden spindle that was longer than the intended gun. The ends were placed upon trestles or model frames, and the larger end was drilled to take levers by which the model could be turned. This spindle, which may have been made of more than one piece of wood, was greased so that it could later be removed.

To achieve thickness about the spindle, rope was wound around it completely (fig. 3). On top of the rope were added layers of a mixture containing modeling clay (if available), sand, water, and a thickening agent such as dung or cloth clippings, as previously mentioned. Layers of this would be added until the desired thickness for the gun was reached. In addition, the model was made with extra room at the muzzle to form the feeding head, which would aid in the pouring of the bronze.⁵

The shape of the gun, with its moldings and rings could be easily achieved with the use of a template or strickle. This was a board with the profile of the gun cut into it. Extra clay was added at the locations of the intended rings, and the model was placed against this board and turned on its spindle leaving uniform rings and moldings (fig. 4). Formed as desired (without the trunnions or ornamentations), the model was dried.⁶

At this time, the trunnions were made. These were to be close to the diameter of

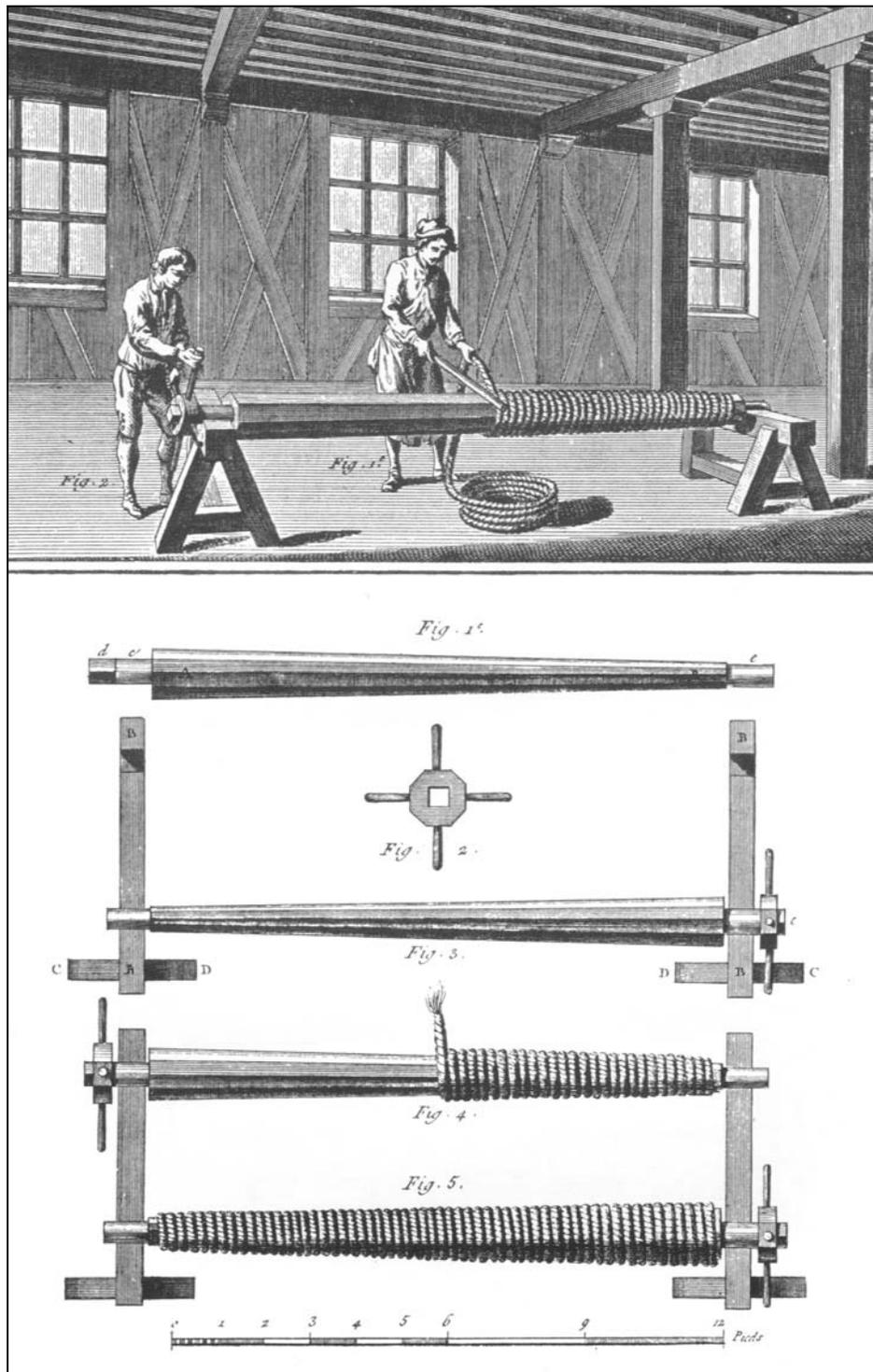


Fig. 3. Winding rope around the spindle for the model (from Diderot 1978, 1119).

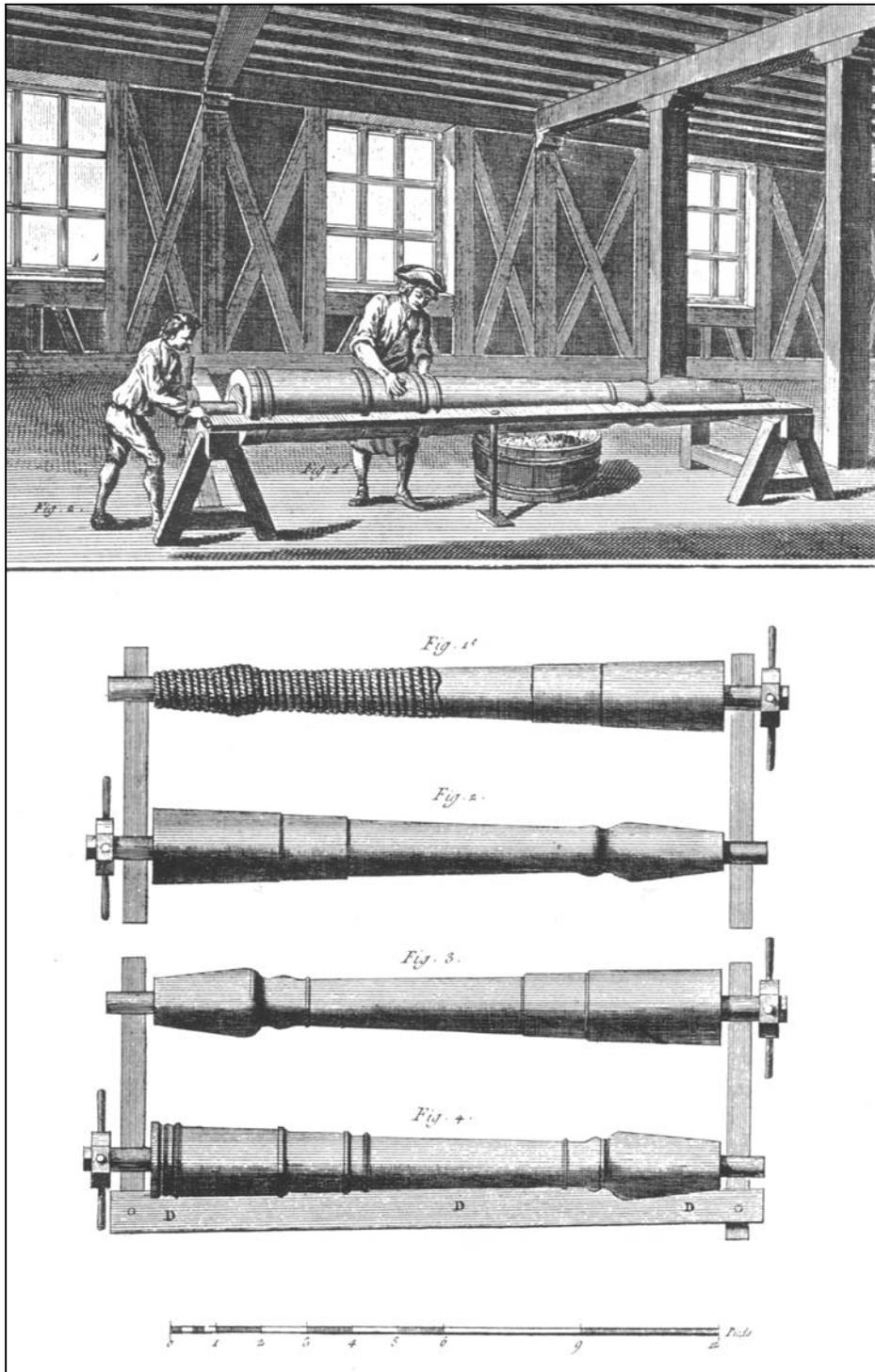


Fig. 4. Creating the reinforcement rings using a strickle board (from Diderot 1978, 1120).

the shot in thickness and length, and could taper (being larger at their base). Nails were typically used to fasten them to the model 2/5 to 3/7 either the length of the gun from the base ring, or the length of the bore from the touchhole.⁷

Caruana suggests that, ideally, their centerline should line up with that of the gun. Apparently the trunnions of older guns were set lower. The theory is that when trunnions were introduced, they were simply pieces lashed beneath the gun, and as they came, in time, to be cast with them, they moved up to the centerline of the piece.⁸

Comparato has come up with another theory concerning trunnion placement. He says that they were introduced in the 1440s and placed along the gun's centerline. Founders in the 16th and 17th centuries apparently moved this placement down so that their centers lined up with the lower edge of the bore. It was not until the 18th century that trunnions were placed back in their original position along the gun's centerline.⁹

Supporting Comparato's argument, Norton states that it was best if they were placed below the centerline so they could support more of the gun's weight.¹⁰ Moretii also suggests that they be placed so that their tops lie at or below the center of the bore. He says that placing them low allowed for them to be mounted higher on their carriage, and provided for a greater amount of elevation.¹¹ From the drawings of guns in various collections that appear in Caruana's book, it appears that the preferred placement was, in fact, for the centerline of the trunnions line up with the lower edge of the bore.¹²

After the trunnions were affixed, ornamentations were added, along with lifting rings, if there were to be any. These elements were generally made of wax, which would ease their later removal. Making them this way meant that the wax could simply melt

out when the mold was dried by fire. If they were made of clay, they would have to be removed with sticks and metal spikes, which could damage the mold.¹³

By the sixteenth century, the addition of lifting handles on heavy guns had become widespread and popular. These handles were often decorated in the forms of animals, mythical and real, the most common form being that of dolphins. In time they came to be known simply as “dolphins.”¹⁴

Making the Mold

After all of the decorative elements and lifting devices were added, the next step was to cover the model with a fatty or waxy substance (tallow, for example) and ashes. This served as a separating layer between the model and the mold. On top of this, a layer of fine loam was brushed on, and thoroughly air-dried (heat could not be applied as it would melt any wax on the model, as well as the separator). This step was then repeated one or two more times.¹⁵ It was these layers that truly dictated the appearance of the gun's surface, and any mistakes made would be apparent in the final product, therefore it was necessary to take great care.

To finish and add strength to the mold, a thick coat of clay was added. At the foot, an additional lip was attached to take the breech mold when the time came. Wire was wrapped around the entire mold; another layer of clay put on, then the mold was dried by fire. Once dry, it was reinforced with iron bars and bands, forming a cage (fig. 5). The entire mold was again dried in the heat of a fire.

Once dried, the model was removed. The first step was to withdraw the

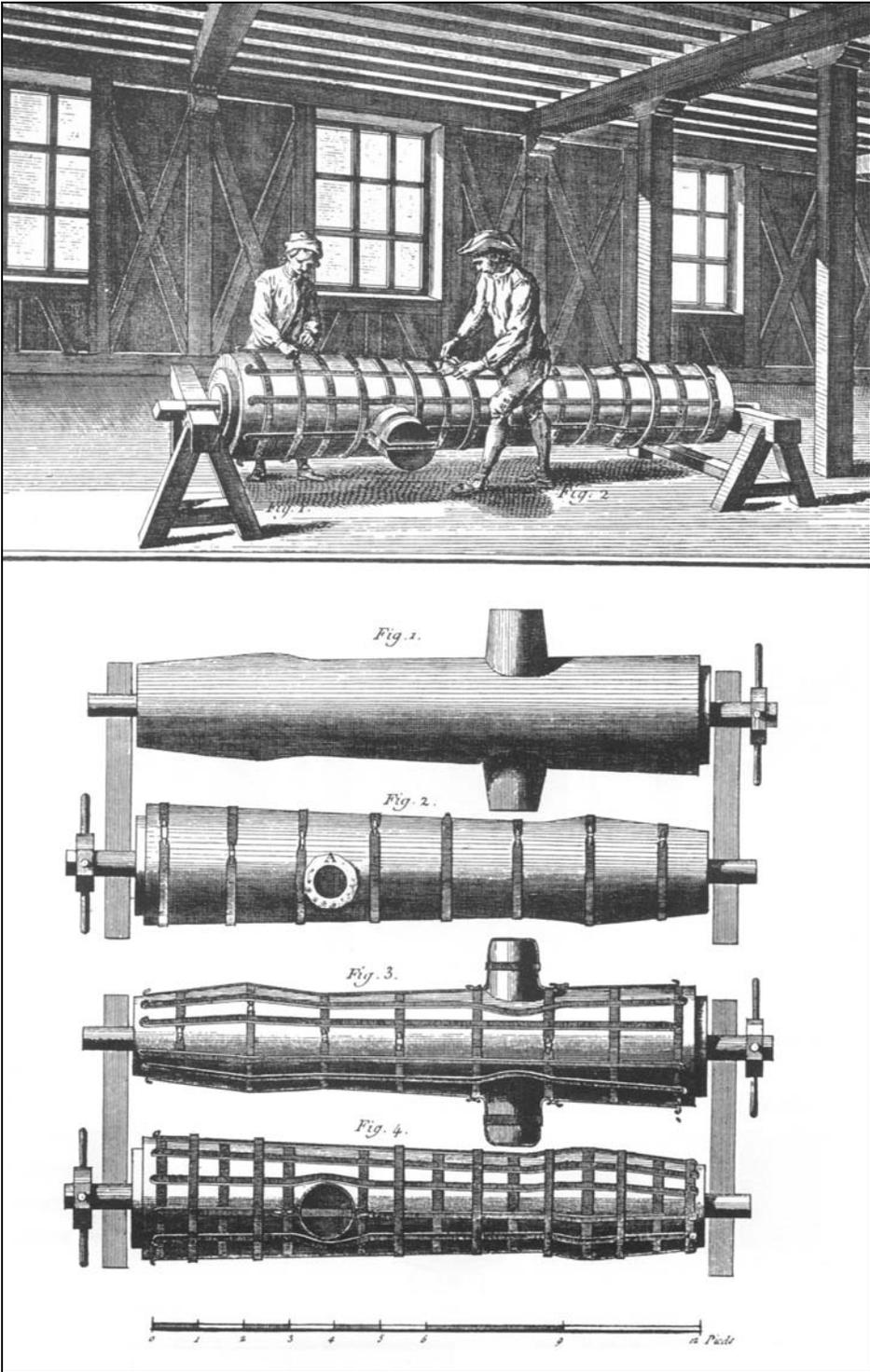


Fig. 5. Binding the mold in a cage for reinforcement (from Diderot 1778, 1122).

spindle. A blow to its muzzle end would loosen it enough so it could be pulled out through the breech. The rope and clay that remained would then fall away and could be taken out.

The trunnion models also had to be removed. If their ends were not covered with the mold, then they could be struck so that they fell into the mold, and could be easily extracted. The holes left in the mold at the trunnion ends were then covered with tiles that were tightly wired to the mold cage.¹⁶

At this point, it was possible to drill the gates and vents in the feeding head. The former would serve as the molten metal's entrance into the mold, while the latter would allow any trapped air or moisture to escape when the bronze was poured. These holes were drilled on opposite sides of the head. To prevent any gurgling of the metal during casting, they needed to be large, as bronze is relatively thick in its liquid form.¹⁷

The mold was cleaned of any remaining iron pieces, such as the nails used to secure the trunnions, and any clay that was left using long-handled tools. It was then baked to remove any residual wax, and then the inside was cleaned out with a sponge attached to a pole. The sponge was soaked with water or egg whites and a finely ground ash, or anything that would serve to cover any small holes created by the previous processes. This also served to keep the molten bronze from sticking to the mold during casting.¹⁸

Making the Core

It was not until the 18th century that cannon were cast solid and then bored out.

Until then, guns were cast hollow using a core to take up the space of the intended bore while the bronze was poured. To form the core, an iron bar was typically used as a foundation. The bar was longer than the intended bore so that it could pass through the feeding head and be secured. The end intended to protrude through the muzzle was in the form of a heel with a hole through it. An iron bar was passed through the hole and was bound to the metal cage to keep the core from shifting vertically or floating in the molten bronze.¹⁹

The first step in making the core was to cover the bar with ashes, which would serve as a separator between it and the outer layers. It was then wrapped with rope and covered with a layer of clay. This process was repeated until the desired bore diameter was reached. Some gunfounders reinforced the core by wrapping it with iron wires just before or just after the final application of clay, and even after the final separating layer.²⁰

After the final layer of clay was applied, a strickle board was placed against the surface. The core was turned against it to ensure that it was smooth and level all around. Once the core was in the form desired, it was dried and covered with ashes, which would serve as a separating layer to ease the core's removal after casting.²¹

The clay chosen for the core needed to be one capable of standing up to the heat of the molten bronze without cracking, yet tender and crumbly enough so that it could be removed after the metal was poured.²² If the clay cracked, molten bronze would seep into the open spaces. Excess bronze would then have to be removed by a boring machine.

If the core was not placed perfectly straight in the center of the piece, the resulting gun would be difficult (if not impossible) to aim. In addition, some portions of the gun's walls would end up thinner than others, creating a precarious situation that could lead to weak spots in the thinner areas. An extreme example of such a situation is found in a Spanish demi-culverin recovered from *El Gran Grifon*, a Spanish Armada flagship that wrecked off Scotland in 1588, whose bore was found to be extremely off-center and illustrates the necessity of securing the core in the mold while the metal is poured.²³

Collars²⁴ or Castles

In order to hold the core in place in the center of the mold at the breech, either a collar (fig. 6) or a castle (fig. 7) was used. The collar was made of wrought iron and could consist of one or several pieces. It was attached at the breech end of the mold by planting its legs into the mold. These legs could number between two and six, but were typically four, and came in various formations. The collar portion of the piece fit snugly around the core, thus keeping it in place. If a castle was used, it was placed in the breech mold. This piece consisted of a base that was fixed into the base ring or breech mold and held up the castle portion, which gripped the end of the core exactly.²⁵

According to Biringucci, the collar was to be placed approximately 30 centimeters (11.8 in) from the base ring,²⁶ but Wignall has found that it could actually be placed as far as 75 centimeters (29.5 in) from this ring.²⁷ To secure the collar, its legs were implanted into the mold, sometimes even penetrating through it entirely. As might

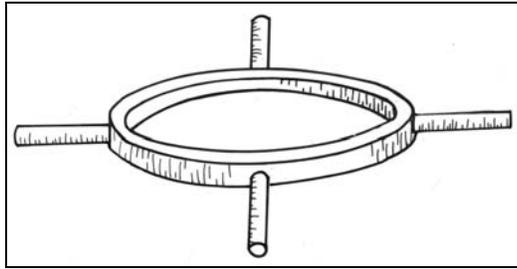


Fig. 6. An example of a collar with four circular arms (after Biringuccio 1966, fig. 31).

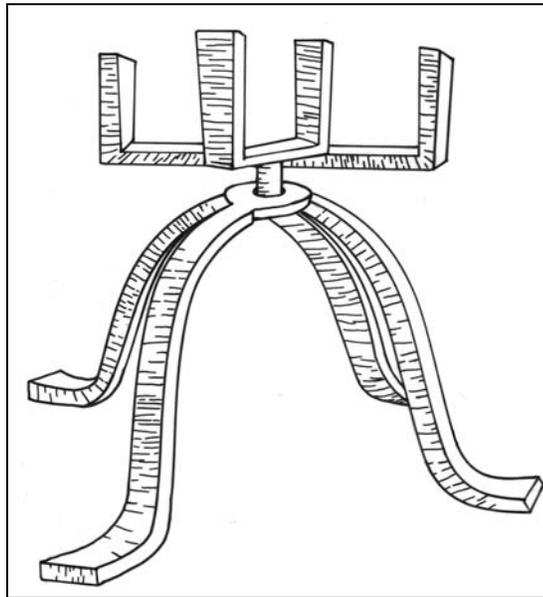


Fig. 7. An example of a castle (after Biringuccio 1966, fig. 31).

be apparent, this piece was permanently cast into the gun. Once the gun was cast and removed from its mold, any parts of the arms that protruded above the surface were sawn off or filed down. They were sometimes even chiseled below the surface, creating a cavity that could be filled with a bronze plug. The arms of an iron collar could be visible on the surface as dimples that would weep rust and corrode over time.²⁸

To hold the core in place at the muzzle, gunfounders used a clay disc or another iron collar. The clay disc (which was Biringuccio's preference) fit exactly into the top of the feeding head and had a hole for the core cut in the center of it. The collar worked like that at the breech. The advantage of the disc was that it kept dust, dirt, and other matter out of the mold while it was waiting to be cast. If these items somehow got in, they could compromise the piece, possibly causing a violent reaction of the bronze when poured, which would lead to defects (such as cracks or a spongy appearance) in the final product.²⁹

Making the Breech

The breech was made like the rest; a model of wood, clay, or wax was covered with clay to form the mold. A clay rim was added to fit into the lip made at the breech of the previous mold so that the two would join perfectly together. Once the mold was dried, the model was removed and the inner surface cleaned in the manner previously described.³⁰

At this point it could be attached to the other mold if an iron castle was used to secure the core. If an iron collar was used, the breech was usually joined to the other

mold only after the core was in place. This would make the insertion of the core easier as the founder would have access to both ends of the mold, and thus a greater ability to align the core in the collar correctly.³¹

To ensure that the mold was tightly bound and reinforced, a cage was fastened around it. When the time came to join the two molds, they were fit snugly together and secured by binding the two cages to each other with wires.³²

Pouring the mold

Before the mold was poured, it had to be thoroughly baked, leaving no moisture inside. If there were any moisture left, the piece would come out with defects and a rough surface. It was necessary for the founders to use caution, though, when baking the molds as damage could occur if they touched the fire. This was a danger because it was desired for the mold to be as near the fire as possible to ensure that it was completely dried.³³

Once the mold was ready, it was placed in a pit, breech-down, and surrounded by compacted earth. The channel leading from the tap hole to the feeding head was cleaned out, lest any debris get mixed in with the bronze, and heated. When the metal³⁴ was uniformly heated, the tap hole plug was opened, allowing the metal to flow down the channel and into the mold. In order to produce a sound gun it was necessary to allow the metal to be heated to between 1250° and 1350° C, beyond its melting point of 1090° C, a lesson learned recently when a bronze culverin from the *Mary Rose* was reproduced. During its first pouring, the metal was too cool, resulting in a highly flawed gun. The

muzzle was incomplete, and there were severe cracks on the chase of the gun.³⁵

Molten bronze needed to be poured into the mold to the point that it nearly overflowed from the gunhead, providing a reservoir of metal to make up for the contraction that occurred when the bronze in the mold cooled. This shrinkage caused the loss of around 4 to 5 inches (10.16 to 12.7 cm) for a gun 10 feet (304.8 cm) in length. If excess were not poured, flaws would appear on the gun, and in particular the muzzle could be full of holes and unsafe. Other possible problems would be cracks and depressions on the outer surface, which would occur most often near the muzzle. The most detrimental flaw would be the porosity of the metal within the gun's walls. Such a flaw would lead to dangerous weak spots, which could cause the gun to crack and later burst upon firing.³⁶

When the metal was poured to maximum capacity, the founder may have wanted to add more tin, the purpose of which was to lower the temperature at which the metal solidifies. In doing so, it was thought that the metal in the gunhead would compress the bronze below, thereby strengthening it and minimizing the risk of any cracks or porosity.³⁷

Finishing the Gun

When cooled, the gun was broken free of the mold and cleaned. Presumably, the first step was to disassemble the supporting iron cage. Once the hoops and staves were removed, the clay on the outside was broken off with a chisel, and the surface thoroughly scoured.

To extract the core, its heel was struck in order to loosen it enough to be withdrawn. With the core removed, the feeding head could be sawn off (preferably using a thin saw with small teeth). Sawing took anywhere from 10 hours to 3 days to complete, depending on the size of the gun, and usually required a large saw handled by four men. Once this task was accomplished, any unevenness left at the muzzle was smoothed down with files. The outside of the gun was typically hammered out to make the surface smooth. To clean out the inside, a long tool with a sharp point was used to carefully scrape the walls. If there were defects in the bore, a drill could be used to remove any superfluous bronze, or to smooth out any uneven surfaces.³⁸

It has been suggested that all guns cast with a bore required some amount of boring, because they never came out of the mold smooth, and an uneven or rough bore would affect the accuracy of the gun. If that was the case, bores were cast to be the diameter of the shot. The boring machine would then drill out the diameter of the windage, usually about 1/4 inch, thus reaching the desired bore diameter. This windage was used as a safety valve to keep excess pressure from building up behind the shot and straining the metal at the breech.³⁹

Boring machines in the 16th century were primitive and lacked bearings, which meant that a straight, true cut was not certain. Even before a gun reached the machine its bore could be off, the core having shifted or distorted during casting. Bores that were off-center or awry were not uncommon, as gunners' manuals often told how to determine if the bore was true, and what allowances to make if it were not.⁴⁰

Once the bore was drilled, it was checked for flaws. A visual inspection could be

achieved by passing a candle (on a long rod) into it, or, if the sun was right, a mirror. A tactile form of inspection could be accomplished with the use of a device called a searcher. This instrument consisted of a long rod with three to four perpendicular arms, which, when passed up and down the bore, would catch on any flaws. In addition, to ensure that the metal was not full of honeycombs or cracks, one could hit it with a hammer. If the metal consistently made a clear sound then it was deemed safe, but if, at any place, it made dull sound, then it was surely flawed.⁴¹

The Touchhole

After the bore passed inspection, the touchhole was drilled. This was placed at the very end of the bore. It was usually drilled vertically, but it was not unknown for it to lie at an angle. Touchholes were made using a small steel drill that was thinner than the desired touchhole. This diameter was sometimes greater than one inch at the surface, but would usually taper towards the bore. Biringuccio suggested that only a small part of the touchhole be opened up into the bore, which resulted in less kick when the gun was fired.⁴²

Proof Firing

The practice of proof firing each gun before it left the foundry was begun by Remigy de Halut around 1534. The exact method for proving a gun varied by country and through time, but the general concept remained the same, at least through the 16th century. Guns were laid with their breeches on the ground, and their muzzles slightly

lifted. They were shot three to four times with varying amounts of powder. Generally, proof charges increased at each firing, starting with the amount the gun would actually use and ending with an amount equal in weight to the gun's intended shot. If a gun was able to withstand this the pressure exerted on it from the excessive powder charges, then it proved itself to be sound and safe for use with its normal charge.⁴³

Composite Construction

Ordnance historian John Guilmartin analyzed bronze cannon from the *Sacramento*, a Portuguese galleon that sank in 1668. He used a stud finder magnet to detect traces of iron on several guns, some of which were from the 16th century, resulting in interesting and unexpected finds. Two of the guns, which he believes are English and cast before the 1580s, showed signs of an iron element along the cascabel, as well as in the trunnions, and on the lifting rings. He found that a wrought iron sleeve was placed on the inside surface of the rings. These finds imply a more complicated use of iron elements in the manufacture of bronze guns than described by Biringuccio, for example, and would suggest the existence of composite guns. This type of construction would not have been technologically inferior, a point argued by the fact that these two guns were in use on board a first class warship of the 17th century, around a century after they were cast.⁴⁴

The wreck of the Dutch East Indiaman *Batavia*, lost on the coast of Australia in the 1620s, yielded at least two composite guns. These guns are of a slightly later date than any of those in the Museu de Angra collection, but they show a remarkably

different method of construction than that previously described. They were made using a combination of iron bands, copper sheeting, and lead solder. The copper formed the skin of the guns (both outside and around the bore) while the iron provided the internal structure and mass. Any spaces between the iron bars and the copper were filled with solder.⁴⁵ This example presents an interesting deviation from what is generally regarded as the standard process of gunfounding, and provides us with the possibility that any oddities found in the guns of the Museu de Angra collection could be caused by departures from what were considered the normal practices.

These discoveries from the *Sacramento* and *Batavia* suggest (in the words of Guilmartin):

that the development of bronze ordnance was a far more complex process than has been hitherto suspected, that it may have overlapped the development of wrought iron construction and that it varied considerably from place to place, driven largely by economic considerations.⁴⁶

Another possibility is that founders in different countries simply found different solutions to the same problem. In either case, the MAH guns, coming from different countries and different points in the evolution of ordnance, display variety in construction and design.

Gunfounders

During the 16th century Flemish, Dutch, German, Italian and Swiss founders were in high demand. For example, around the turn of that century, England was importing Flemish artillery. The Flemish, along with the Germans, also provided Portugal and Spain with ordnance. Most of these continental founders were artisans that

were familiar with the process of casting in bronze, because they were bell founders and had little problems switching to casting ordnance.

In the beginning, their products were simply exported to those countries desiring them. Later, these countries preferred to have their guns cast at home, and so started importing the founders, rather than just their guns. The Portuguese even set up foundries in their possessions at Macao and Goa, in addition to those they had in Iberia, to take advantage of the local raw materials, not to mention the cheap labor.⁴⁷

Rudi Roth argues that:

the gunfounders of this period were highly individualistic in their production of guns and in demonstrating their craftsmanship in a competitive environment in the middle of the 16th century. Because he was usually paid only for his successes, founders would be reluctant to experiment lightly with the basics of design and risk costly failures.⁴⁸

It is thus likely that a founder consistently produced guns of a certain style or styles until he had a significant motivation to change.

Gunfounders distinguished themselves not only by the style of guns they produced, but by the ornamentation they put on them. Early guns, like those in the Museu de Angra collection, could be elaborately decorated, as they functioned not only as machines of war, but also stood as symbols of pride for their country and ruler. As time passed, however, and guns became more commonplace, they also became more utilitarian.⁴⁹

Though each gun was a one-of-a-kind due to the founding process, it was possible to reuse some of the design features time and time again. These were elements such as those decorating the surface in relief, as well as the lifting rings, which could be

made in wax or clay from a more permanent mold. It is these elements, in addition to overall gun design, that can serve to identify guns made in the same foundry.⁵⁰

The area around the vent, or touchhole, was apparently a place for founders to express their individuality. This was especially true when different founders used one gun design, such as seen in the guns made for Philip II and III, many of which were cast in the Spanish Netherlands, in Malines, which became Spain's royal foundry in 1520.⁵¹

Notes

¹ Biringuccio 1966, 213; Flanagan 1988, 68.

² Biringuccio 1966, 218-20.

³ See appendix C for an illustration of gun parts.

⁴ Biringuccio 1966, 234, 237; Norton 1628, 72; Caruana 1994, 10.

⁵ Biringuccio 1966, 256; Ffoulkes 1969, 16; Kennard 1986, 10; Wignall 1973, 88.

⁶ Biringuccio 1966, 237; Kennard 1986, 11; Wignall 1973, 88.

⁷ Biringuccio 1966, 235-6; Caruana 1994, 10; Norton 1628, 72; Moretii 1683, 27; Smith 1600, 72.

⁸ 1994, 5.

⁹ 1965, 7.

¹⁰ 1628, 73.

¹¹ 1683, 27.

¹² 1994.

¹³ Kennard 1986, 11; Biringuccio 1966, 238.

¹⁴ Carman 1955, 41.

¹⁵ Biringuccio 1966, 236; Kennard 1986, 11.

¹⁶ Biringuccio 1966, 236, 254; Kennard 1986, 12.

¹⁷ Biringuccio 1966, 248-9; Kennard 1986, 12, Norton, 1628, 73.

¹⁸ Biringuccio 1966, 239; Kennard 1986, 12.

¹⁹ Guilmartin 1982, 133; Biringuccio 1966, 254; Kennard 1986, 13; Norton 1628, 72.

²⁰ Biringuccio 1966, 240-1, 252; Kennard 1986, 13; evidence for the latter case was found in the bore of MAH 4.

²¹ Biringuccio 1966, 241; Kennard 1986, 13.

²² Biringuccio 1966, 240.

²³ Collado 1592, tractado secundo, folio 9; Wignall 1973, 93, pl. 10, pl. 11; Martin and Parker 1988, 205.

²⁴ Also referred to as core-iron, crown-iron, chaplet, *cruzeta*, or crown piece.

²⁵ Biringuccio 1966, 246-8; Guilmartin 1982, 133.

²⁶ 1966, 246; MAH 1, 3, 4, and 7 follow this guideline, but MAH 2, 5, 8, and R. 98. 14 are placed closer to 20 cm from the base ring.

²⁷ 1973, 89.

²⁸ Wignall 1973, 88-9; Kennard 1986, 14; Guilmartin 1982, 135.

²⁹ Biringuccio 1966, 245-6.

³⁰ Biringuccio 1966, 244; Norton 1628, 72; Kennard 1986, 13.

³¹ Biringuccio 1966, 248.

³² Biringuccio 1966, 245; Kennard 1986, 13.

³³ Biringuccio 1966, 250-1.

³⁴ Gunmetal was around 2 to 3 parts tin and 25 parts copper; or around 100 parts copper combined with 8 to 20 parts latten, and 5 to 10 parts tin (Ffoulkes 1969, 25; Moretii 1683, 5; Smith 1600, 33).

³⁵ Biringuccio 1966, 254-5; Hall 2001, 111-2.

³⁶ Biringuccio 1966, 259-60; Barker 1983, 71; Caruana 1994, 10.

³⁷ Biringuccio 1966, 297; Barker 1983, 71; Caruana 1994, 10.

³⁸ Biringuccio 1966, 307-8; Kennard 1986, 16. According to Collado, this practice had a tendency to cause unseen weaknesses in the cannon walls (1592, tractado secundo, folio 9).

³⁹ Kennard 1986, 13, 16-7; Love 1705, 184; W. T. 1672, 3; Nye 1624, 71-6; Caruana 1992, 13.

⁴⁰ Kennard 1986, 17-8; Norton 1628 80; Smith 1600, 60; Nye 1670, 67.

⁴¹ T. W. 1672, 8; Kennard 1986, 16; Nye 1670, 47-49; Love 1705, 171; Smith 1627, 65.

⁴² Kennard 1986, 18; Biringuccio 1966, 308; Ffoulkes 1969, 27-8.

⁴³ Flanagan 1988, 70; Biringuccio 1966, 312; Smith 1600, 82; Kennard 1986, 19; Ffoulkes 1969, 95.

⁴⁴ Guilmartin 1982, 134-9.

⁴⁵ Green 1980, 48-50.

⁴⁶ 1982, 134.

⁴⁷ Cipolla 1965, 23, 25, 31, 34; Brown 1997, 106; Caruana 1992, 4; Ffoulkes 1969, 29; Allen 1978, 12.

⁴⁸ 1996, 27.

⁴⁹ Brown 1997, 104.

⁵⁰ Hall 2001, 108.

⁵¹ Roth 1996, 26-7; Kennard 1986, 86.

CHAPTER VII
THE MUSEU DE ANGRA DO HEROÍSMO 16TH CENTURY CAST-BRONZE GUN
PROJECT

During the 16th century artillery was brought to Terceira to arm its fortifications. These came mainly from Lisbon, but guns from England and France came as well. An inventory taken in 1583 described more than 300 pieces of artillery present on the island of Terceira, of all different styles, calibers, and periods.¹ Since the 17th century, most of these guns have been taken back to the mainland either for display in museums, to decorate fortresses, or to melt down and recycle the bronze. Guns tossed into the water by shipwrecks or by seismic events that dislodged them from their places on fortress walls escaped shipment back to the continent. Sydney Wignall (a British maritime archaeologist) and M. C. Baptista de Lima (the former Director of the Museu de Angra do Heroísmo) believed that all of the bronze guns in the Museu de Angra collection (MAH R. 98. 14 had not been recovered) fell into the sea due to seismic disturbances. They remained on the seafloor in the bays of Angra and Fanal, on the southern coast of Terceira island, until raised and put on display in the museum.²

The Portuguese Navy, in collaboration with the Comando da Zona Aérea of the Azores, the US Air Force stationed on Terciera, and the city of Angra do Heroísmo, recovered five of the Museu de Angra guns in expeditions between 1961 and 1965. MAH 2, 3, 4, 5, and 6 were salvaged at this time near the Fortresses of Zimbreiro and São Diogo, and given to the Museu de Angra.³

MAH 1 was recovered and presented to the Museu de Angra in 1972 by Sydney Wignall's Marine Archaeological Expedition. Wignall located the gun off Monte Brazil, near the fortress of Santo António, in 30 meters (98.4 ft) of water in Angra Bay, and dubbed it the "Monte Brazil gun."⁴ In 2002, MAH 1, 2, 3, 4, 5, 6, 7, and 8, were on display outside of the Museu de Angra do Heroísmo. All were covered with a black and turquoise patina, which indicates that they were suffering from bronze disease, or ongoing corrosion of the metal.

MAH R. 98. 14 was recovered from off the steep southern cliffs of Monte Brazil in July of 1996 by the Grupo Arqueologia Subaquática. It was found in 36 meters (118 ft) of water near the fortress of Quebrada. The concretion that had built up on the gun's surface during its time underwater was cleaned off and it underwent conservation, which consisted of soaking in sequential baths of sodium sesquicarbonate (to remove the chlorides that leached into the bronze from the salt water), deionized water (to remove the sodium sesquicarbonate), and a 3% solution of Benzotriazol (BTA) (to help prevent bronze disease). After these baths, another 3% BTA solution was brushed over its surface and allowed to air dry. To seal and protect the bronze from the elements, the gun was covered with Paraloid, an acrylic resin. It was put on display inside the Museu de Angra and was in a stable condition.⁵

No information pertaining to the backgrounds of MAH 7 and 8 have been kept by the Museu de Angra. We therefore have no information in regards to the locations from which they were recovered or their subsequent treatment. However, due to their conditions (namely their worn surfaces), it is obvious that they were recovered from the

sea, but when and where this salvage occurred is unknown.

Sydney Wignall has studied not only the gun that he raised (MAH 1), but four other guns in the Museu de Angra collection (MAH 2, 3, 4, and 6). The main focus of his research was to discover information pertaining to the use of collars (or crown pieces) in the production and development of ordnance. His findings on MAH 2 and 3 agree with those of the author, but those on MAH 1, 4, and 6 do not. These discrepancies will be discussed in chapter VIII. In addition to investigating the collars, Wignall attempted to research the origin of MAH 4, which he refers to as the “unidentified Tudor Rose gun.” This search only resulted in proving that the gun arrived on Terceira after 1583, because the inventory taken in this year listed no English guns.⁶

Dr. M. C. Baptista de Lima, former Director of the Museu de Angra do Heroísmo, also published a study on one of the guns in the Museu de Angra collection, MAH 1. In his research, he attempted to discover when the gun arrived on the island and where it was stationed throughout its career. He found that it was likely transferred to the fortress of Santo António on Mont Brazil from the fortress of Nossa Senhora da Luz at Praia da Vitória (on the eastern coast of the island) after 1583, and may have originally been sent to the fortress of Nossa Senhora da Luz between 1561 and 1571 when defenses were being built there.⁷

In addition to these studies, the Museu de Angra do Heroísmo published a booklet in 1976 that includes information concerning MAH 1, 2, 3, 4, 5, and 6.⁸ This booklet lists each gun’s total length, bore diameter, and country of origin. The decorative features on each gun’s surface are also described, as well as the general

locations from which the guns were recovered, and the rulers under which the guns were cast.

In the summer of 2001, the author was given permission to undertake a new study of the cast-bronze guns in the Museu de Angra collection. In order to properly record this collection, it was necessary to establish a systematic method of documentation, as well as to visit other similar collections to gain a basis of comparison. By visiting collections in England, France, Spain, and Portugal, I was able to gain an appreciation for the varieties in gun design and form, but I was also able to see similarities in guns from the same country.

I visited the Museu de Angra do Heroísmo in the summer of 2002 in order to take the proper measurements and photographs of the guns to be able to produce an accurate scale drawing of each. To ensure that I took all of the necessary measurements from each gun, I prepared data recording sheets for each one prior to my visit to the museum.⁹

Before I arrived in Angra, however, I visited other museums and studied the 16th century cast bronze ordnance in their collections. I was given permission to take measurements and photographs of the guns in the Tower of London, Fort Nelson in Portsmouth, the *Mary Rose* Museum in Portsmouth, the Musée de l'Armée in Paris, the Museo Naval in Madrid, the Museu da Marinha in Lisbon, and the Museu Militar, also in Lisbon. The information gathered from these guns was later used as a reference for understanding and interpreting the guns in the Museu de Angra collection.

At the Museu de Angra, I used the prepared forms along with a specialized tool

kit to collect all of the appropriate measurements. I began by making two overall sketches of each gun, one from the top, and the other from a side. The side that I chose to draw was based on the gun's condition and ornamentation, and I selected the one with the most amount of information. In addition, a sketch was made of both the muzzle and the cascabel, and yet another that focused on the order and configuration of the reinforcement rings. The maximum diameters of each ring set, taken with a set of large calipers, were recorded on this last sketch.

Once these drawings were complete, the remaining measurements were taken. All of the diameters were taken with calipers, while the remaining dimensions were determined using a cloth tape measure. The overall length of a gun was taken by drawing the tape measure from the muzzle face to the end of the cascabel. For the length of the gun, which is the used portion, it was only necessary to bring the tape measure to the breech end of the base ring. To establish the length of the bore, when the bore was unobstructed, I used a retractable metal tape measure that was extended into the bore until it reached the end of the bore.

Each of the ornamental features for the guns was carefully sketched and measured so that they could be properly placed in the final drawings. In addition, each of the reinforcement rings was recorded using a profile gauge. Any additional measurements, such as muzzle droops or breech swells, not listed on the sheets, were simply added when encountered. Once the data sheets were filled in, an extensive set of photographs was taken for each gun. Shots were taken in both digital and slide format.

In addition to the measurements listed on the data sheet, I located the collar or

castle arms for each gun. When holes were not visible on the surface, I used a stud-finder magnet to detect the iron of the arms.¹⁰ This was accomplished by simply running the magnet over the gun's surface until it reacted. When all of the arms were located, their distances from the base ring were recorded, as well as their relative placement on the gun's circumference, and the diameter of the gun at that location.

After all of the measurements and photographs were taken, it was possible to use this information to discover details about each gun and to produce a scale drawing of each of the guns. The data collected allowed for conclusions to be reached. In some instances, the details on the gun revealed its founder, in others they uncovered errors in the founding process, and in all cases, they exposed the nationality of the gun.

Notes

¹ This was an inventory taken by the Auditor Geral da Armada de Don Alvaro de Baçan discussed by Baptista de Lima (n.d., 523).

² Baptista de Lima n.d., 523-5; Wignall 1973, 92.

³ Wignall 1973, 89, pl. 2, pl. 3, 92.

⁴ Wignall 1973, 93, pl. 12; Museu de Angra do Heroísmo 1976.

⁵ Monteiro 1996, 6; Museu de Angra do Heroísmo 1998.

⁶ Wignall 1973, 89, pl. 2, pl. 3, pl. 6, 92, 94.

⁷ Baptista de Lima n.d., 530-1.

⁸ Museu de Angra do Heroísmo 1976.

⁹ See appendix E for an example of a recording sheet.

¹⁰ Guilmartin (1982, 136) used this tool to detect iron within the barrels of several guns.

CHAPTER VIII
MUSEU DE ANGRA GUNS¹

MAH 1

The elaborate design of this Portuguese culverin² (fig. 8) was unusual for 16th century guns of this country. When compared to those of other continental countries, such as Germany, the design and decoration of most Portuguese guns was quite modest.³ This gun, however, was embellished from its neck all the way to its breech.

The neck bears a trilobate acanthus leaf border (fig. 9), a design repeated, with a slight change, above the second reinforce (fig. 10). On the chase, near the muzzle are three masks (fig. 11) that surround this part of the gun and are connected to each other with floral clasps (fig. 12). The top mask is interlaced to the Arms of Portugal below, under which is found an armillary sphere (fig. 13). Below the right mask is a plaque with the date, 1545, in relief, and below the left is a military trophy (fig. 14). On the second reinforce there is a cartouche bearing the mark of the founder, *IO DIZ* (fig. 15), which stands for João Diaz, a Portuguese founder who cast guns under João III and Sebastian.⁴ The first reinforce of this gun takes the form of a Doric column, and the touchhole is seated in the terminus of the top flute. The cascabel is flat, and, in the center, bears the profile of a warrior's head bearing a renaissance style helmet.⁵ As is typical of Portuguese guns of this century, it has a set of four lifting loops,⁶ a pair on the chase, and the others on the first reinforce.

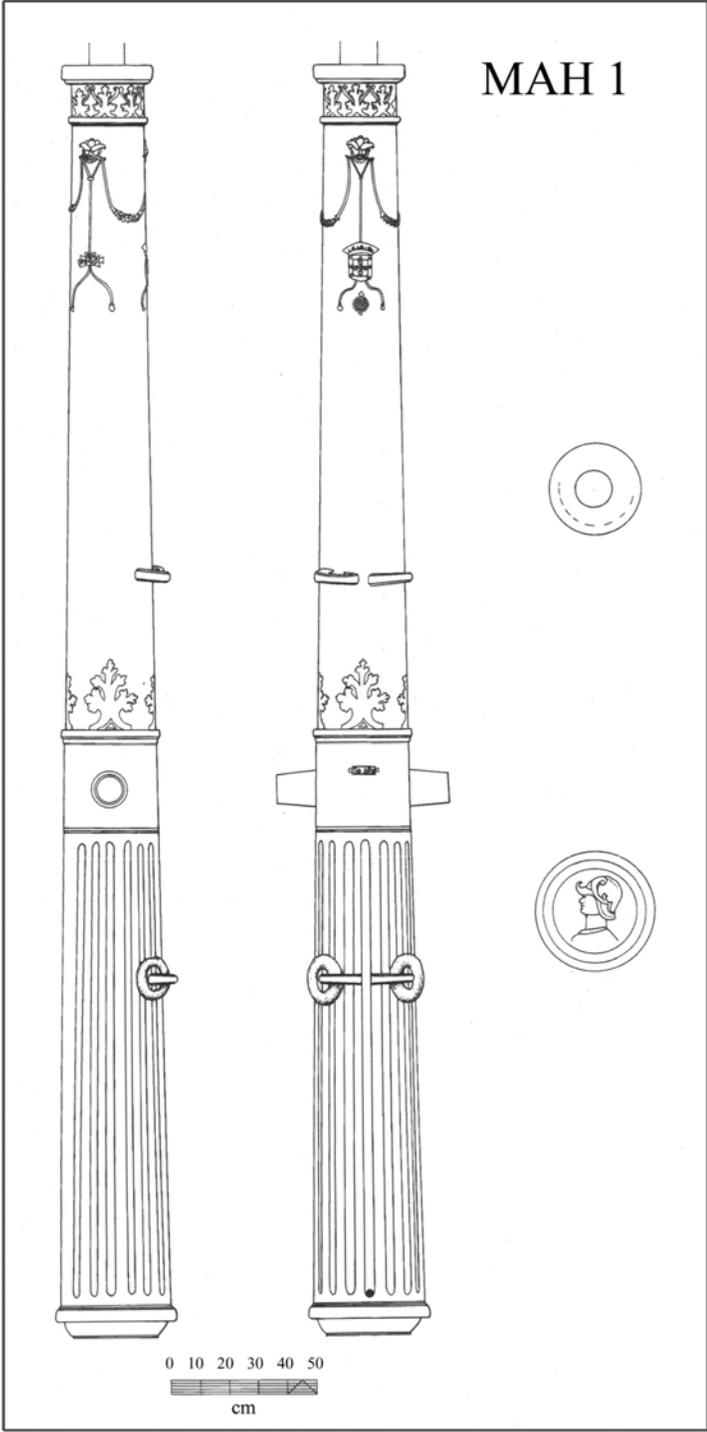


Fig. 8. The Portuguese culverin MAH 1.



Fig. 9. The acanthus leaf border on the neck of MAH 1.



Fig. 10. The acanthus leaf border on the chalice of MAH 1.



Fig. 11. One of the masks from the chase of MAH 1.

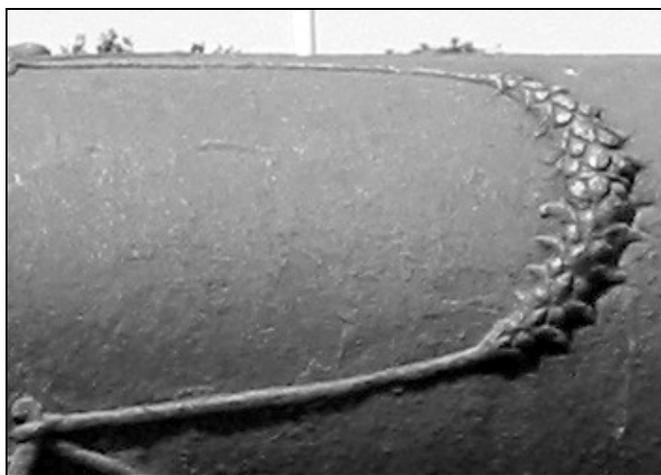


Fig. 12. A floral clasp joining the masks on the chase of MAH 1.



Fig. 13. The Arms of Portugal and armillary sphere on MAH 1.

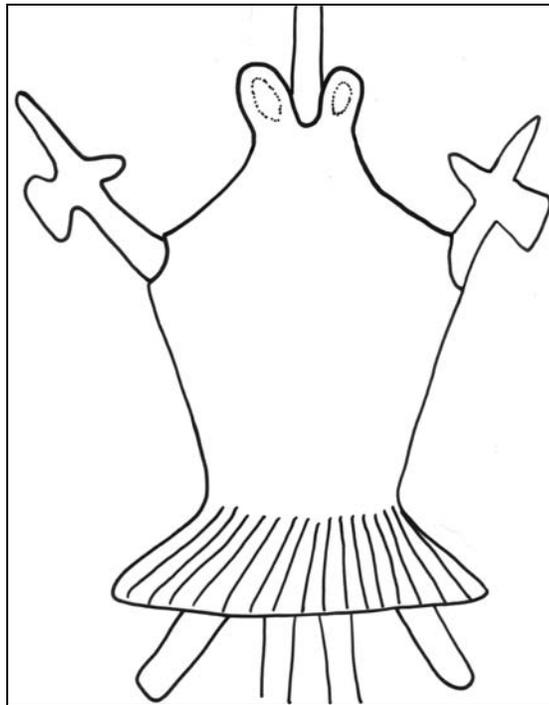


Fig. 14. The military trophy on MAH 1.



Fig. 15. The mark of the founder João Dias on MAH 1.

Sydney Wignall, who raised and studied this gun, remarks that:

it represents the transitional period when land artillery was being developed for shipboard use. Too long and too weighty for use on a galleon, the Monte Brazil gun [MAH 4] was a fortification defensive weapon, designed to outdistance the 50-lb. shot Whole Cannon which were generally used as battering pieces, and knock them out of action before they could be transported within range of a castle.

However beautiful and elaborate the design of this gun is, its casting was flawed.

Along the fluted reinforce, just in front of the iron collar, is a swell in the bronze. The flaw was most likely caused during use, not in the actual founding process, but poor casting is nonetheless partly to blame for it. The walls of the gun at this point were likely made too weak (either too thin or simply unsound) to withstand the pressure of firing.

Fortunately for the gunner who was operating this culverin, under excessive pressure a bronze gun will crack and bulge before it bursts, as opposed to guns of iron, which burst without any warning. Such a flaw may not have been caused entirely by poor founding, however. Overcharging a gun would cause the metal at the breech to be under excessive stress. In addition, if a gun was rammed too hard, the metal at the breech would be strained upon firing, because it would take longer for the powder to properly ignite and expel the shot, all the while building up pressure in the breech. A buildup of pressure was also likely to arise due to two other inherent flaws in the gun that would impede the ejection of the ball from the bore. First, the body of the gun droops slightly in the center, and second, the gun bows slightly to the left along the chase, when viewed from the breech.⁷

Two other guns by this founder are located in the Museu Militar in Lisbon. The Portuguese bastard culverin labeled D-4 appears to be a sister gun to MAH 1, but was made in 1575. It bears the same founder's mark, also on the second reinforce, but here, it was incised into the gun after founding instead of being cast in relief. The first reinforce of D-4 is also in the form of a Doric column, and the same mask and trophy motif are found on the chase, which is also lined at the rear with a band of acanthus leaves. This pattern is missing at the neck, and the armillary sphere is in a different location, but the design of the Arms of Portugal is the same as that found on MAH 1. Though also beautifully designed, casting flaws are present on D-4 as well, namely sponginess towards the muzzle.

The demi-culverin labeled D-5 at the Museu Militar is less ornate than those previously mentioned, though made by the same founder. Like D-4, it bears an incised IO DiZ mark on the second reinforce, and the Portuguese shield and the armillary sphere found on the chase are virtually identical to those on MAH 1.

The same trilobate acanthus leaf pattern as that of MAH 1 is found around the touchhole of a Portuguese perrier (6970) in the Museo Naval in Madrid from the Spanish nao *San Diego*, lost in the Philippine Islands in 1600. In this instance, it is assumed to be the founder's mark.⁸ As the leaves match those on MAH 1 and D-4 at the Museu Militar, and the Arms of Portugal are similar in style to those from the Diaz guns, it is likely that 6970 was made in the same foundry.

MAH 2

This Portuguese reinforced demi-culverin⁹ (fig. 16) bears the Arms of Portugal above the armillary sphere on the third reinforce (fig. 17), and a three-leaf pattern around its sunken touchhole, which was likely a symbol of the founder. It is reinforced with simple astragal bands, and has a set of four lifting rings on the reinforces, and one lifting ring at the cascabel. Unlike any of the other guns in this collection, on the muzzle side of the trunnions, there is a place on the gun where the diameter changes abruptly; what I call a step-down band (fig. 18).

Several flaws are apparent upon inspection of MAH 2. There are depressions in the muzzle, evidence of the use of insufficient metal in casting. Other flaws include cracks under the first set of reinforcement rings, and cracks and holes behind the muzzle set of lifting loops. The fact that these cracks exist under the rings makes it likely that they occurred when the model was being made. The plain model (without any embellishments or reinforces) may have been improperly dried, allowing the cracks to form. The founder may have not seen them as he applied the extra clay and used the strickle board to produce the reinforcement rings. Or, it may be that he chose this location to apply the rings because of the cracks in the clay. The rings were cast with the gun, and were not later additions designed to strengthen a weak spot on the tube.

Overheating brought about by an excessively rapid rate of fire probably caused another problem with this gun. Its muzzle droops slightly, starting 49 centimeters (1.6 ft) from the face of the muzzle. As was discussed earlier, when bronze generates too much heat, it anneals. As the muzzle is the least supported and fortified part of the gun,

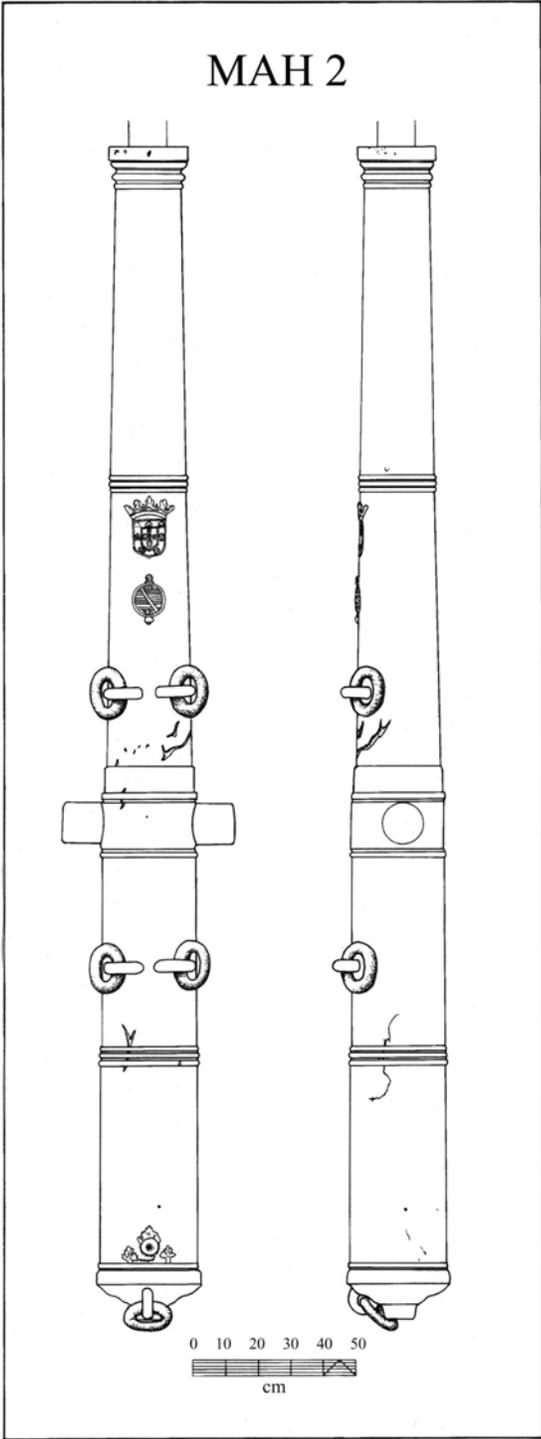


Fig. 16. The Portuguese reinforced demi-culverin MAH 2.



Fig. 17. The Arms of Portugal and armillary sphere on MAH 2.

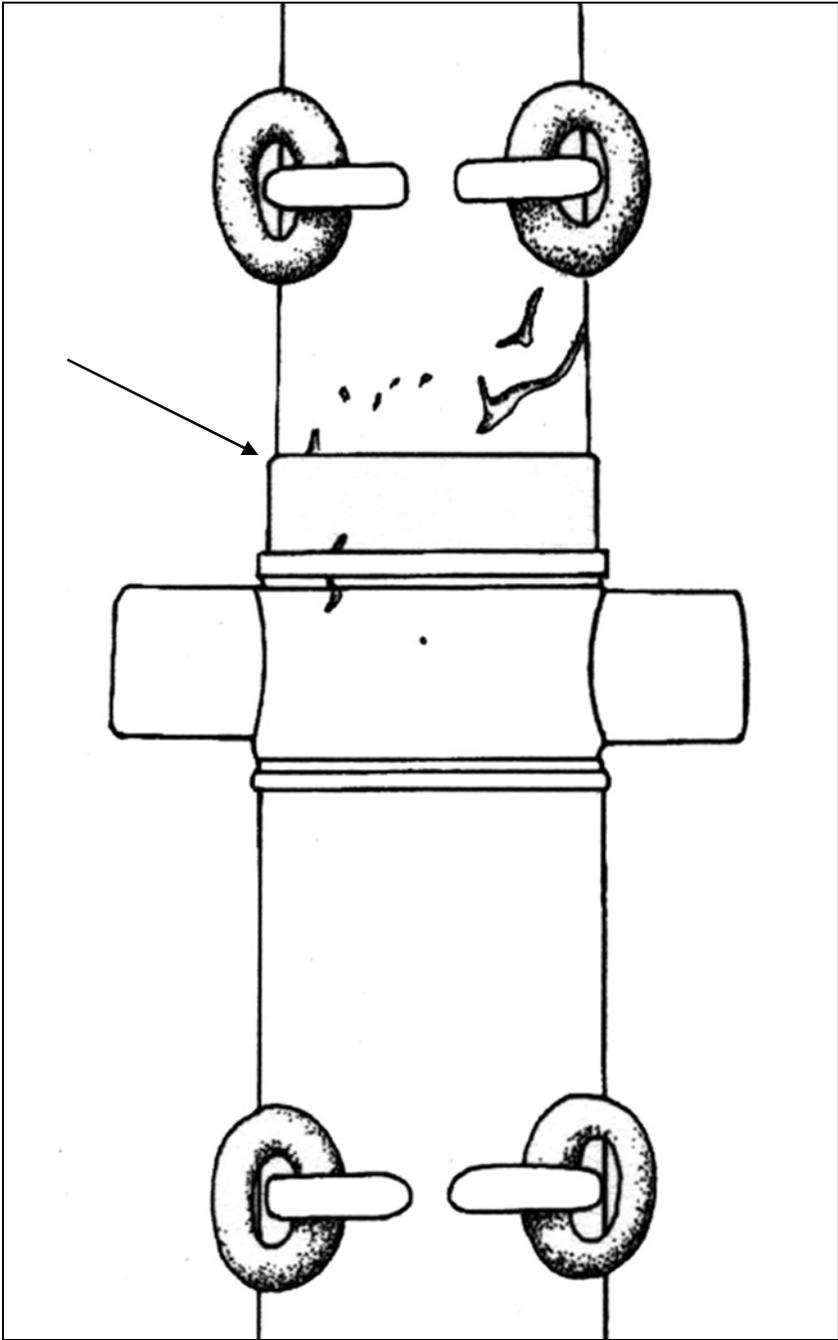


Fig. 18. The step-down reinforcement ring on MAH 2.

it is here that gravity takes affect and draws the metal down, as was the case on MAH 2.

In the Museu Militar in Lisbon, the gun labeled R-16, dated to the first half of the 16th century, bears a resemblance to MAH 2. The types of reinforcement rings, simple astragals as well as a step-down, are the same, and these are a type that I rarely saw. The base ring and muzzle also bear a striking resemblance, including the same depressions in the muzzle face. The arms of Portugal (fig. 19) and the armillary sphere on this gun are all but identical to those on MAH 2. In addition, there is a similar 3-leaf pattern found on one side of the reinforcement rings, as well as along the base ring, that is similar to that around the touchhole of MAH 2.

The step-down reinforcement band is a feature shared by a Portuguese bastard double culverin (C-4), a Portuguese eagle (C-5/A), and a Portuguese stone-thrower (C-6) at the Museu Militar, all dating to the first half of the 16th century. The first gun also bears a three-leaf pattern around its sunken touchhole, similar to that of MAH 2. The last gun (C-6) has the same simple astragal reinforcement rings as MAH 2, as does a Portuguese *camelo* (C-7), which, again, dates to the first half of the 16th century. C-7 also has the remains of a lifting ring at the breech, similar to MAH 2.

Based on comparative evidence, MAH 2 appears to date to the first half of the 16th century, which agrees with the Museu de Angra booklet that dates it to the reign of Manuel I.¹⁰ Important characteristics to note of the guns from the reign of Manuel are the relatively flat cascabels, with or without rings, as well as the presence of an armillary sphere.¹¹



Fig. 19. The Arms of Portugal on R-16 at the Museu Militar in Lisbon.

MAH 3

This Spanish/Portuguese reinforced bastard demi-cannon¹² (fig. 20) has the same general appearance as most guns produced for Philip I and II of Spain: a triple-molded base and muzzle ring, two reinforces, a chase girdle, a vent field, a neck, and a pair of dolphins for lifting. This gun also has a matching dolphin at the breech, and a touchhole that is drilled out of a raised oval. On either side of the touchhole are the remains of the rectangular bases for the touchhole cover lugs, which, along with the cover itself, are now missing.

The cannon's decoration has been described as Renaissance in character.¹³ The neck is elaborately decorated with a border design that appears to have an Aztec-style headdress as its centerpiece (fig. 21). The chase girdle carries another elaborate border design, which is mostly floral in nature, but centered on the top is the profile of what appears to be a Spanish conquistador wearing a renaissance-style helmet (fig. 22). These two contrasting motifs are separated by a chase that is lined with borders of acanthus leaves.

The design on the neck appears to be a repeating pattern. It seems that the patterns mold was filled three separate times (once on top, and once each for the bottom left and right) and fixed onto the model of the gun. This is obvious from the seams present (fig. 23), which are found at the same point on the pattern each time it repeats. There are similar seams on the chase girdle (fig. 24), although in this case the pattern on top was slightly different from the one used on the bottom.

The first reinforce bears the Arms of Spain and Portugal, bordered by the Golden

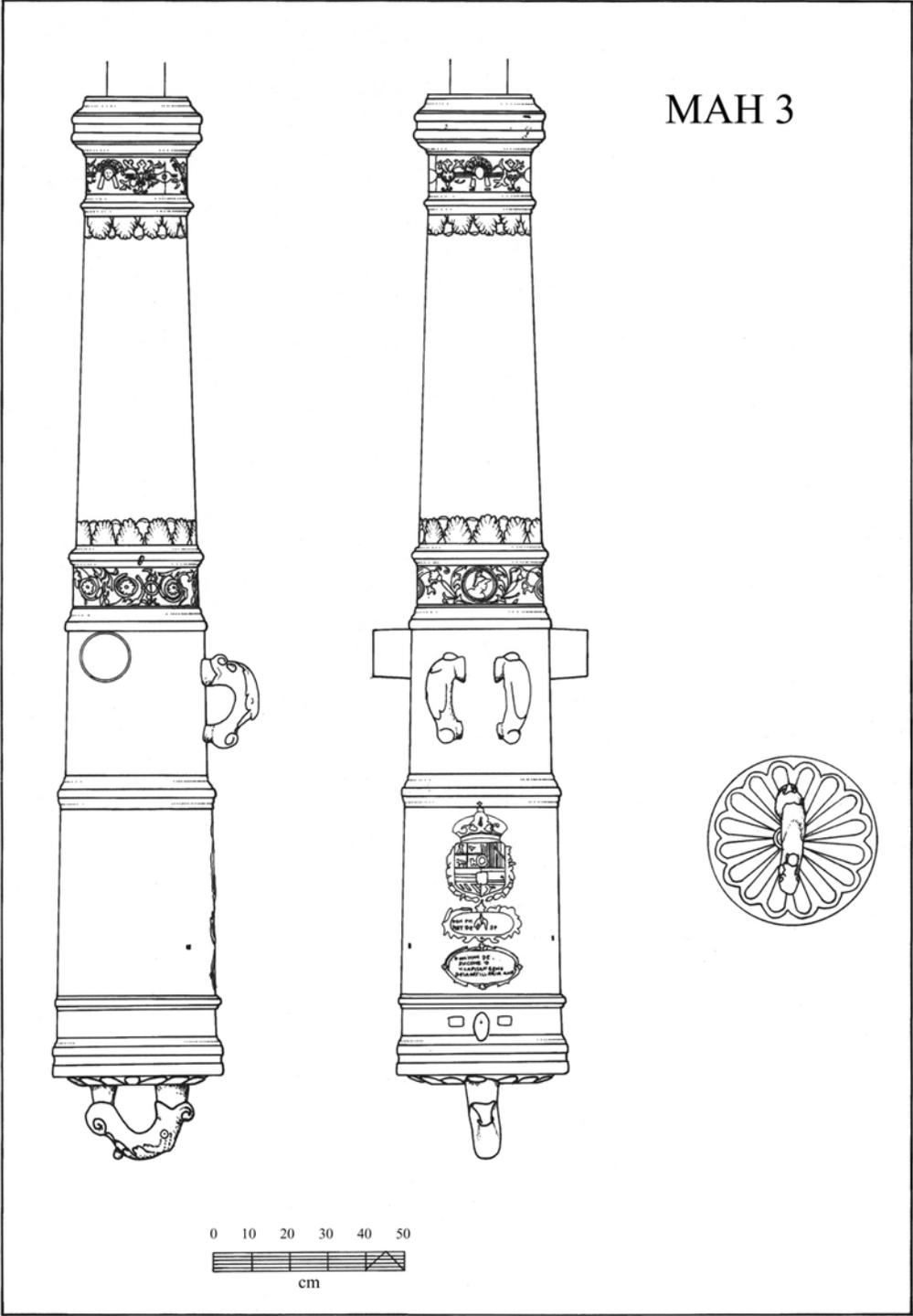


Fig. 20. The Spanish/Portuguese bastard demi-cannon MAH 3.



Fig. 21. The Aztec headdress adorning the neck of MAH 3.



Fig. 22. The conquistador on the chase girdle of MAH 3.

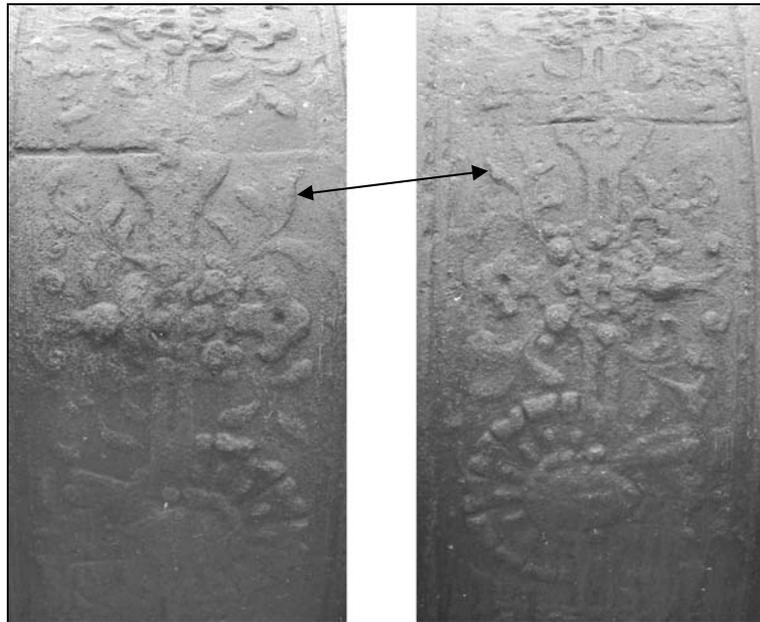


Fig. 23. The seams in the pattern on the sides of the neck of MAH 3.

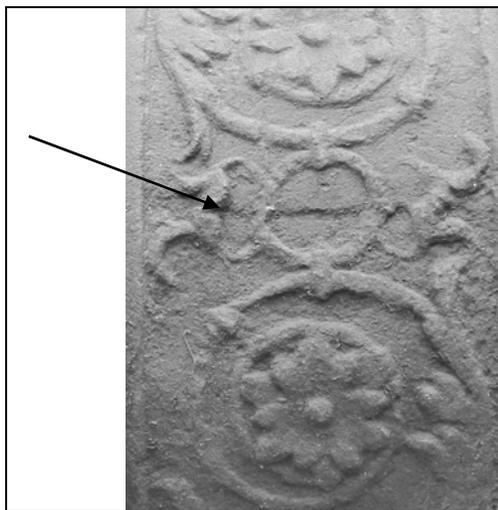


Fig. 24. One of the seams in the pattern around the chase girdle of MAH 3.

Fleece, and topped with a crown. Below this are two plaques, which, like the rest of the gun's surface, have been worn down with time. The top one once read "DON PHELIPE II REI DE SPANA" around the emblem of the Golden Fleece. The bottom plaque read "DON IVAN DE ACANUS V. CONSELO DE GUERA V. CAPITAIN GENERAL DE LA ARTILLERIA AÑO 1596."

The Arms of Spain and Portugal found on a Spanish short culverin (E-5) cast in Lisbon in 1604 and a Spanish gun (E-8) from 1635, both at the Museu Militar, are almost identical to that found on MAH 3. The plaques on E-5 are very similar in style, and the bottom one read the same. This might indicate that the same man, Fernando Ballesteros, who was a Spanish founder working in Lisbon, as indicated by the inscriptions on the gun, made MAH 3. It is interesting to note that this gun has only three legs attached to its collar, like MAH 3, as opposed to the normal four.

The Armada ship *La Trinidad Valencera*, which wrecked off the coast of Ireland in 1588, yielded three *cañones de batir* that were produced under Phillip II while Juan Marcus de Lara was the Captain General of Artillery, and were ordered aboard the ship under the new Captain General of Artillery Juan de Acuña Vela, the same man under whose order MAH 3 was made. These were made by the Flemish founder Remigy de Halut of Malines, and had a similar overall appearance to MAH 3. They are in the typical Spanish style, and have dolphins at the breech, acanthus leaf borders on the chase, as well as an elaborate decoration on the neck. Though these guns bear a great resemblance to MAH 3, Remigy died in 1568 and therefore could not have made this gun. It is possible, however, that it was cast by an apprentice of his.¹⁴

The guns from *La Trinidad Valencera* had their weights incised on their first reinforcement rings. They also bear the inscription of the maker and year on the middle ring of the triple-molded base ring. The maker's name and other markings were also engraved in the same location on D1, D3, D8, E2, and E3 at the Museu Militar. This could have been the case on MAH 3, but the surface is worn, and if any inscriptions were originally present, they have been obliterated by the effects of time.

MAH 4

The simple style of this bastard culverin¹⁵ (fig. 25) is common amongst Tudor guns.¹⁶ It has only one reinforce, a vent field, a chase girdle, and a neck, only one of which contains any embellishment. Time has worn the entire surface of this gun so that its features are no longer crisp. In addition, the muzzle is spongy in appearance, a sign that an inadequate amount of metal was poured into its mold.

The only decoration on this gun, on the first reinforce, is a Tudor Rose surrounded with a garter and surmounted by a crown, the standard emblem on Tudor-era guns. Wignall states that the garter surrounding the Rose would have read "Honi Soit Qui Mal y Pense," which means "Shame on He Who Thinks Evil of It" or "Evil to Him Who Thinks Evil," and is the motto of the Order of the Garter.¹⁷ Beneath the rose there was once an inscription, which likely mentioned the ruler, the date, and the founder, but this is now worn to the point that it is no longer legible.

The shape of its cascabel is unusual for a bronze gun. It is more stout than is typical, and would be much more at home at the breech an iron cannon, such as those

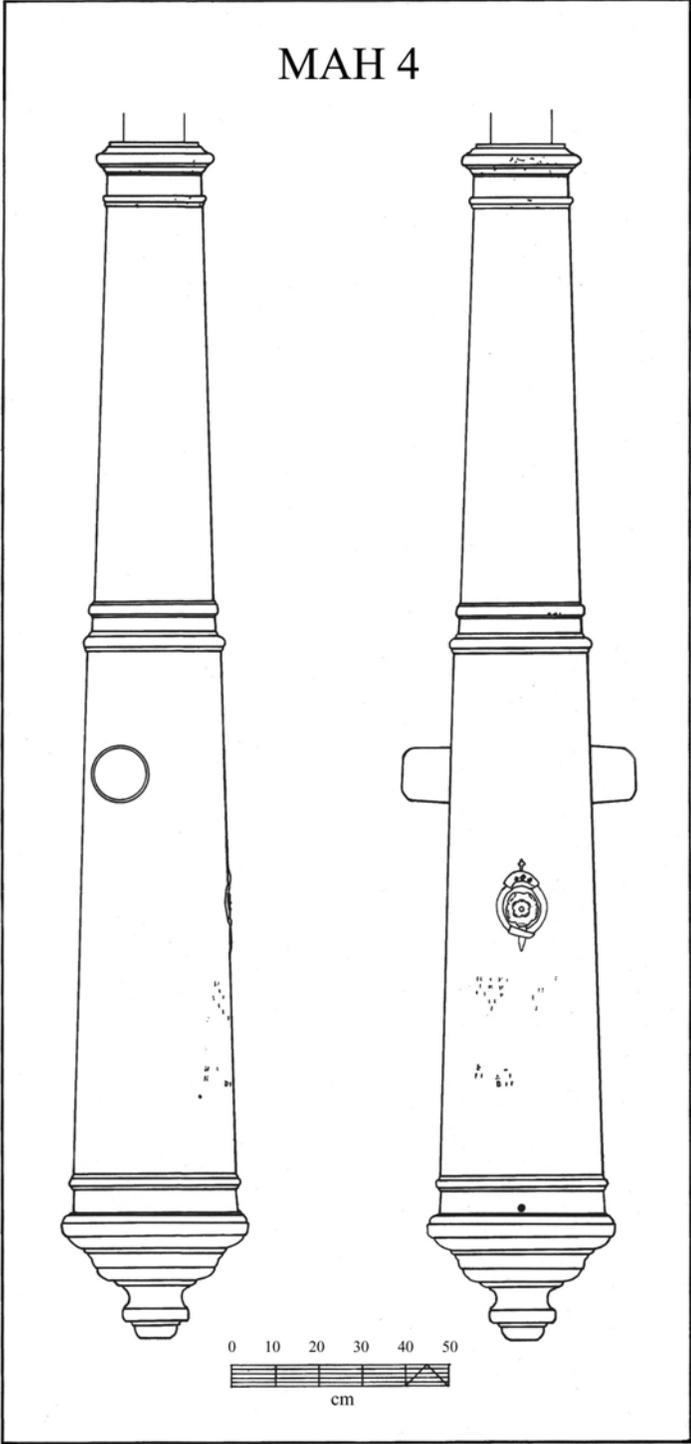


Fig. 25. The English bastard culverin MAH 4.

from the *Mauritius*, which sank in 1609,¹⁸ and the Elizabethan iron guns illustrated in Caruana's book.¹⁹ This suggests that it was manufactured during a time when cast-iron guns were becoming popular, which was in the latter half of the 16th century.²⁰

Its simplicity in design is very typical of English guns, especially those from the reign of Elizabeth. Wignall says "that its [MAH 4's] origin would be contemporary with the failure of the Spanish Armada in 1588."²¹ He describes it as a shortened culverin; shortened for use on ships, which Lewis notes as typical with the Armada guns (both English and Spanish).²² Whether or not it was cast after the Armada battle, all of the evidence indicates that it was at least made during the reign of Elizabeth I, the last Tudor monarch.²³

Wignall proposes that this gun came from the English royal galleon *Revenge*, which sank off Terceira in 1591, and was salvaged between 1591 and 1592. If this is true, then it likely only returned to the seafloor after the seismic disturbance in the late 19th century.²⁴

MAH 5

This Portuguese reinforced demi-culverin²⁵ (fig. 26) has a set of four lifting rings, an unadorned neck, two reinforces, and a vent field. It bears the Arms of Portugal on the chase near the muzzle, with a square cartouche below containing the letter C. Conspicuously absent is an armillary sphere, typically found on Portuguese guns of the 16th century.

Serious flaws are obvious on the surface of this gun. Angular pits visible along

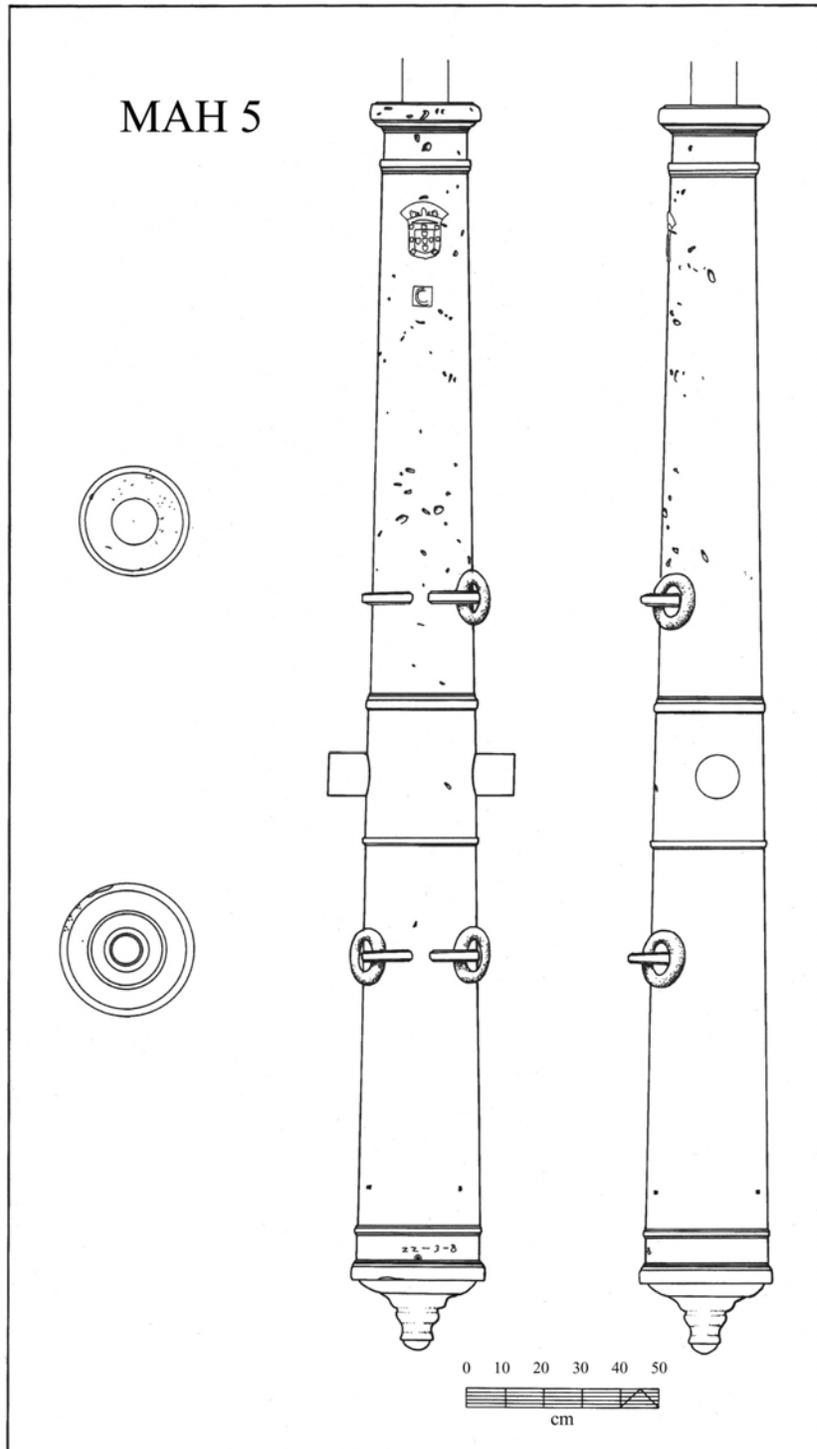


Fig. 26. The Portuguese reinforced demi-culverin MAH 5.

the chase and on the muzzle, as well as in the bore, are evidence that problems occurred during the casting process. When the bronze reached the chase and muzzle, it either did not settle properly because it was no longer molten enough, or because it had a violent reaction to a portion of the mold that was not properly dried, leaving cavities on the surface of the final product.

Surrounding the touchhole is an arc of recessed metal. Above the touchhole, in the vent field, is inscribed ZZ-3-8, offset to the right (when looking towards the muzzle), and in the Portuguese style of weight markings. The inscription indicates that the gun weighed 22 quintal, 3 arroba, and 8 arratel (1340.24 kg).²⁶ A similar touchhole and markings were found on a Portuguese stone-thrower (B-5) at the Museu Militar that dates to the mid-16th century.

Another Portuguese stone-thrower (6970) at the Museo Naval in Madrid that was recovered from the Spanish nao *San Diego* of 1600 bears an overall resemblance to MAH 5 and has the same style numbers incised above the touchhole, again, offset to the right. Its morphology is the same as that of MAH 5, and the plaque accompanying the gun states that it was made during the reign of Sebastian (1557-1578). As previously mentioned, it is possible that João Diaz or one of his apprentices made this gun.

Two of the oldest guns found on the Portuguese galleon *Sacramento* of 1668 are culverins, one of which is 308 centimeters (10.1 ft) long (MAH 5 is 307) while the other has a length of 313 centimeters (10.3 ft). Both have the same morphology as that mentioned above, and the longer one even has the same recessed arc around the touchhole as MAH 5.²⁷

This morphology is again found in a Portuguese demi-culverin (D-5) at the Museu Militar in Lisbon, made by João Diaz during the reign of Sebastian. D-5 also shares the same style cascabel and Arms of Portugal with MAH 5. Consequently, the only guns with similar Arms of Portugal are those by Diaz (D4, D5, and MAH 1).

Based on the design of the Arms, it is likely that MAH 5 was cast in the foundry of João Diaz, because this is an element that likely would have been made from a permanent mold. A founder named Cosme Diaz was known to be working in Lisbon by 1576. It is possible that he was the son of João, and continued to use his father's designs, marking his guns with the monogram from his first name.²⁸ Whether or not this gun was actually made in the Diaz foundry, which seems likely, it was almost certainly made during the reign of Sebastian.

On the outer ring of the cascabel, three sets of three indented dots are visible on the upper left. There is an additional dot on the next ring on the cascabel below the top set of three (fig. 27). The meaning of these markings is uncertain, but they could have indicated the size of shot or amount of powder that the gun used. This would prevent the gunner from continually having to take measurements and make calculations (as prescribed in the gunner's manuals) to determine this. It is also possible that the marks could indicate the gun's inventory number, its place onboard, or even the gun's length.²⁹

MAH 6

This French culverin³⁰ (fig. 28) is elaborately decorated for King Henry III, though its overall form is simple. It has only a single reinforce and an unadorned neck.



Fig. 27. The marking on the cascabel of MAH 5.

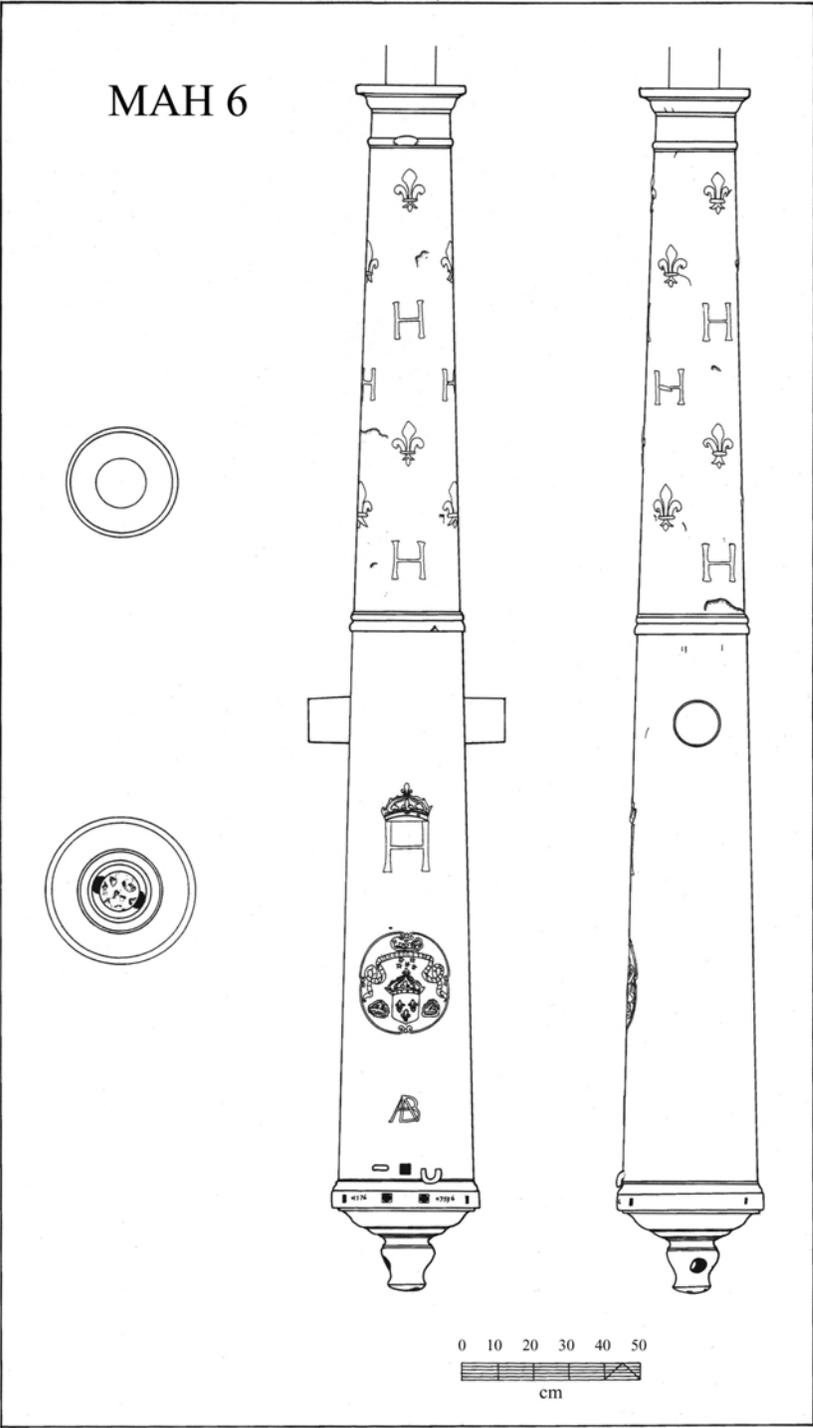


Fig. 28. The French culverin MAH 6.

The chase is lined with alternating paired bands of Hs and fleur-de-lys, a pattern also found on a bastard demi-culverin (S.2) at the Museu Militar. On the first reinforce, there is a crowned H, and the coat of arms of France (fig. 29). The mark of the founder, an overlapping AB, is located above the touchhole, and the date, 1576, is engraved on the base ring.

The details on this gun are exquisitely preserved. Tool marks that were left by the founder when he shaved down the surface of the model to get it to look exactly as he wanted are still visible on the surface. Even though this gun is beautifully decorated, founding flaws do exist on its surface. On the chase, there are places where there are sharp indentations (fig. 30) that appear to have been caused when the model was made.

Like MAH 3, this gun was originally fit with a touchhole cover. The cover itself is now missing, but its lugs lie on either side of the touchhole. The one on the right has been flattened to the barrel, but it is the one that would have hinged the cover to the gun and allowed it to open to the right. As for the touchhole, as will be discussed later, it was originally drilled out of a square iron bush that was cast with the gun, and has now been corroded away through the reaction of the metal with seawater.

On the top of the base ring, there are two square holes. Inside each of these holes there is a double hexagonal lip less than a centimeter below the surface (fig. 31).

Wignall argues that these were part of a six-legged collar.³¹ Upon closer examination, it becomes clear that a castle, not a collar, was cast into this gun, and these holes are distinctly different than those left by the arms of the castle. There is distinct iron staining around these holes, leading to the conclusion that iron objects were once locked



Fig. 29. The coat of arms of France on the first reinforce of MAH 6.



Fig. 30. The flaws on the surface of MAH 6.

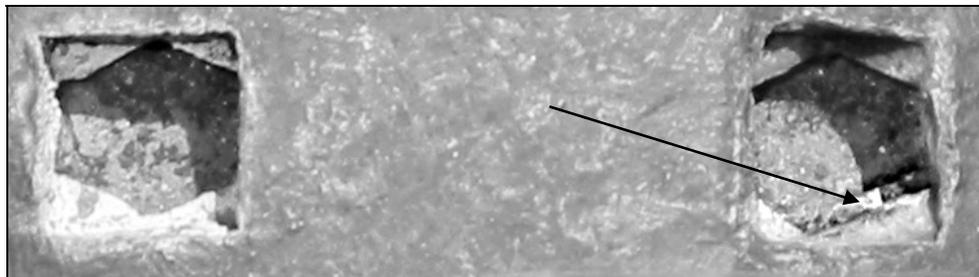


Fig. 31. The holes in the base ring of MAH 6 with a double hexagonal lip; the arrow indicates the lower lip.

(by way of the lip) into these holes, but for what purpose, I do not know for certain.

It is possible that they were part of some sort of sight for the gun, or, they could have been part of the touchhole cover system.³²

A French cannon (77) at the Musee de l'Armee in Paris also has these squares, but they still contain iron. This gun also has bands of fleur-de-lys lining the chase, but as it was made for Francis I, they alternate with bands of Fs not Hs. In this case, the touchhole was drilled out of a circular iron bushing.

To the left of the square base ring holes on MAH 6, the date is etched, and on the right, the number 3536, which might indicate the gun's weight, or its identification or inventory number. To the left of each of these numbers is an incised square. Similar markings were found on a bastard demi-culverin (S.2) whose left mark reads 2479, a French stone-thrower (S.8) dating to 1568, both at the Museu Militar,³³ an octagonal French minion at Fort Nelson (XIX.168) dating to 1551, and an octagonal culverin (92) at the Musee de l'Armee whose left mark reads 1457. This latter gun, dating to 1548, also bears a crowned H (for Henri II) and has fleur-de-lys running the length of the chase, as well as a touchhole that is filled with a circular iron bushing.

MAH 7

The lines on this bastard reinforced English culverin³⁴ (fig. 32) are simple, like MAH 4. This gun has two reinforces, a chase girdle, a vent field, and a muzzle unlike any of the other guns in this collection. In this case, instead of having bands to reinforce the muzzle, the muzzle itself swells or flares. Muzzle swells appeared on English naval

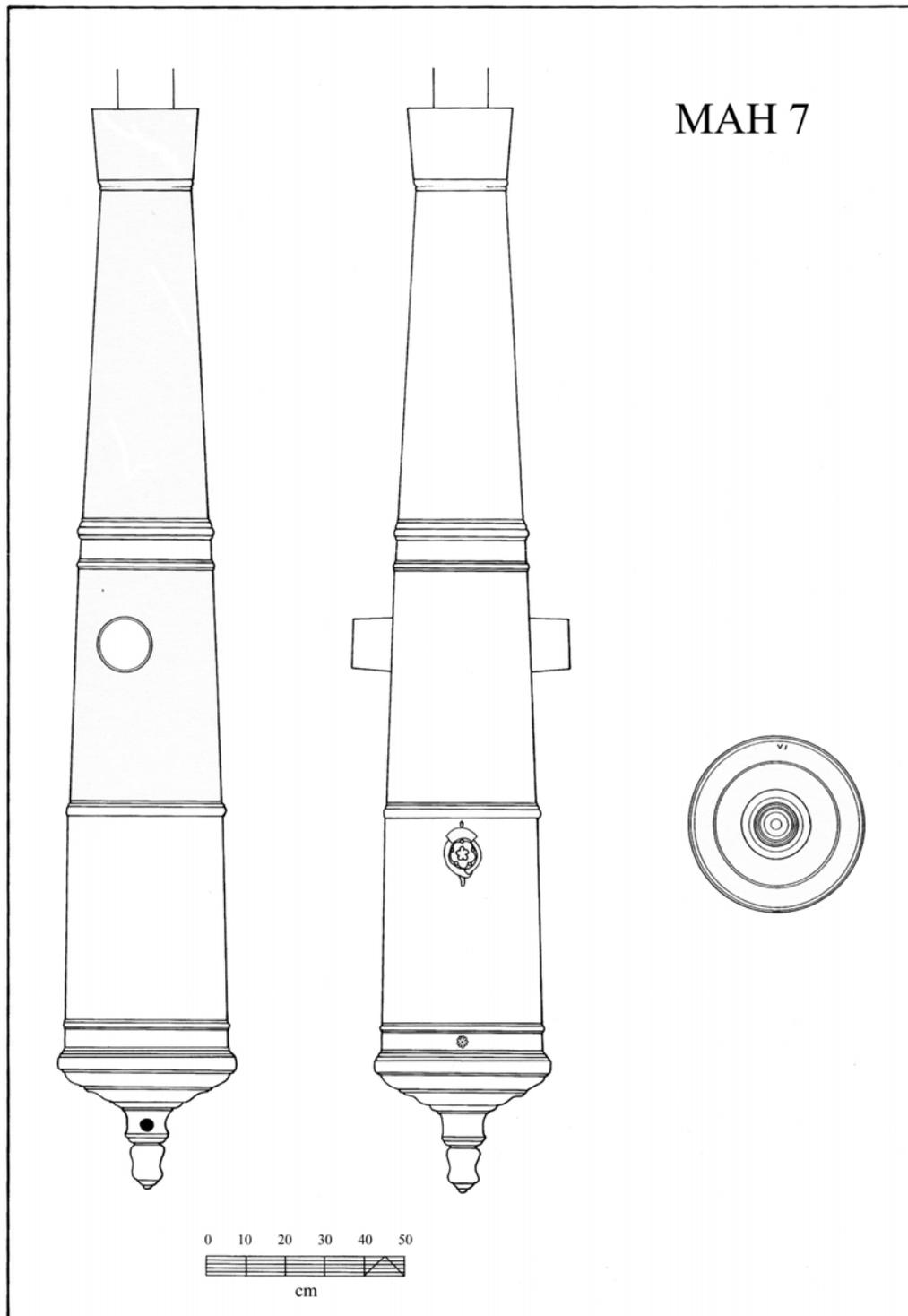


Fig. 32. The bastard reinforced English culverin MAH 7.

guns around 1560, when naval ordnance became differentiated from land guns.³⁵

On the first reinforce is a Tudor Rose (fig. 33), that is crowned and surrounded by a garter. It is possible that there was once writing engraved on the surface below the Tudor Rose mentioning the ruler, the date, and the founder. The surface of the piece, however, is worn to the point that any writing that may have once been engraved on it is no longer detectible.

Surrounding the touchhole is a depressed floral design; a feature that also appears to be present on a bastard reinforced English demi-culverin (3211) at the Museo Naval in Madrid. Though this demi-culverin bears no Tudor rose, it does have an inscription, giving its date of 1592, and the founder, Henri Pitt. A saker (XIX.302), cast by the Owen brothers for King Edward in 1548-9, now at Fort Nelson, also appears to have a similar feature around the touchhole. In addition, it bears a general resemblance to MAH 7, especially in the style of reinforcement rings and cascabel, though it does not have the flared muzzle or an extra reinforce. Another gun by the same founders, a quarter-cannon (S.7) at the Museu Militar³⁶ is of a more complicated design (the reinforce and muzzle spiral), but it has a flared muzzle, and the reinforcement bands, as well as a cascabel of the same style as MAH 7, and it may also have the same floral indentation around the touchhole, possibly indicating the same founder.

The surface of the gun is covered with small circular depressions or indentations that look like they were caused by corrosion of the metal while it was immersed in salt water, or extensive hammering to the surface of the gun (fig. 34). These indentations may also have been the result of the post-founding process of hammering the metal to



Fig. 33. The Tudor Rose on the first reinforce of MAH 7.



Fig. 34. The dents on the top surface of MAH 7.



Fig. 35. The markings on the cascabel of MAH 7.

smooth and strengthen it, or hammering by gunners to test the soundness of the metal.

On the second outermost ring of the cascabel, the Roman numeral VI was etched just off-center to the right (fig. 35). Like the markings on the cascabel of MAH 6, the meaning of these is uncertain. It is not likely that they indicated the size of the shot this gun threw because MAH 8 has the same size bore, and would throw the same size shot, but has a different number marked on its cascabel. These markings might, however, indicate the weight of the powder that the gun used, or, as mentioned previously, the gun's location on board, or its inventory number.³⁷

Based on the presence of the muzzle swell and the Tudor rose, it is safe to assume that this gun was made during the reign of Elizabeth I. She became the Queen of England in 1558, two years before muzzle swells began to appear on English naval ordnance, and was the last ruler in the House of Tudor. Based on arguments previously made concerning shortened guns, this gun most certainly was founded near the end of her reign.

MAH 8

The upper surface of this French cannon³⁸ (fig. 36) has been worn down significantly and the features are difficult to discern, likely as a result of the gun lying in a high-energy zone where sand or surf constantly moved over its surface. The rows of fleur-de-lys that line the chase are in excellent condition, however, on the right and under sides. The remains of a crowned salamander of Francis I are present on the first reinforce, dating the gun between 1515 and 1547.

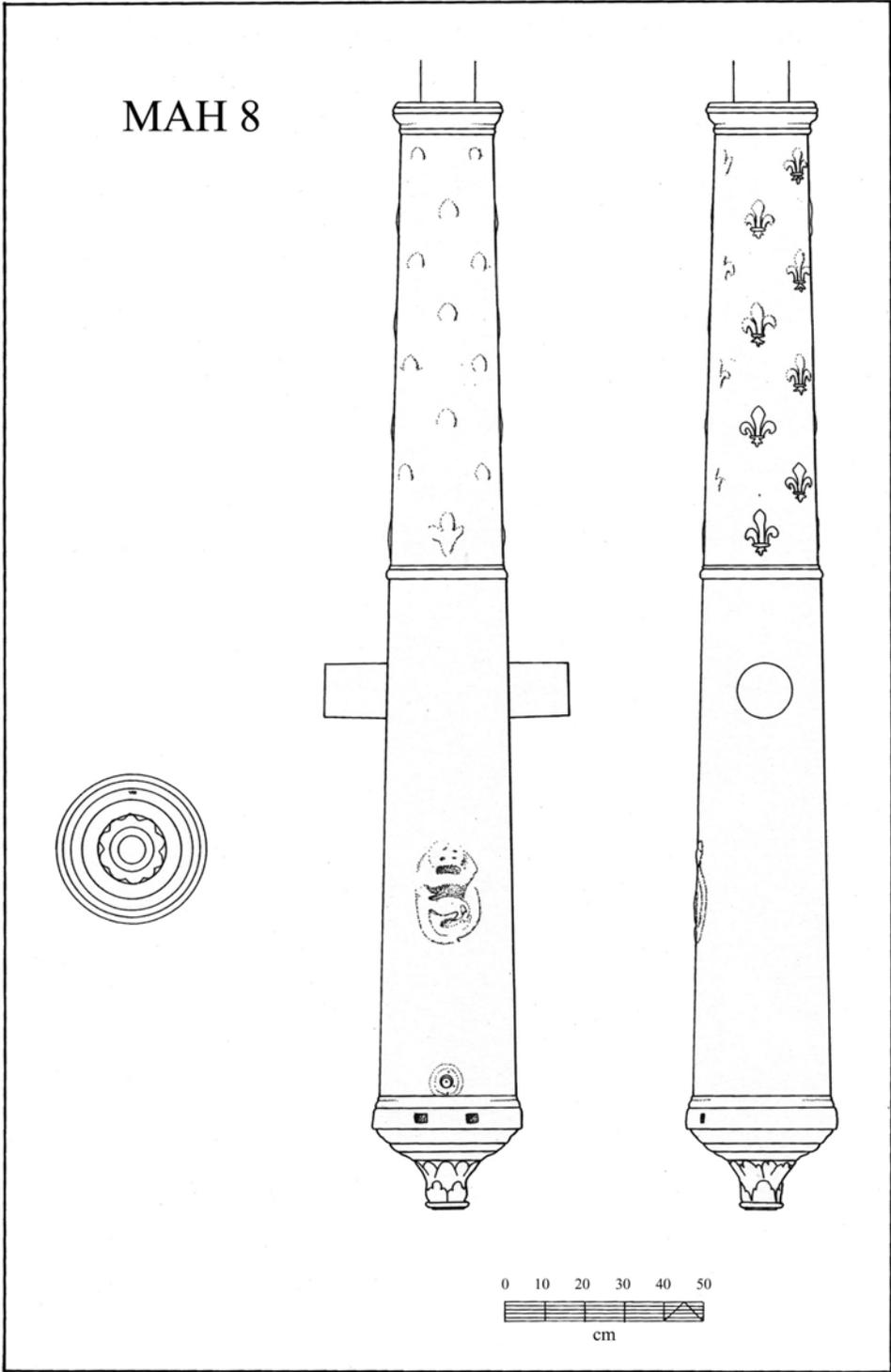


Fig. 36. The French cannon MAH 8.

The touchhole was drilled out of a circular bush that was seated in a round indentation (fig. 37). This bush was likely added only after the gun had seen extensive use and the touchhole required repair. Two square holes are found on the top of the base ring like those on MAH 6, but no lips are visible here. It is safe to assume that these holes served the same purpose as those on MAH 6. Since MAH 6 has touchhole cover lugs on either side of the touchhole, it seems less likely that these holes were related to a touchhole cover, and more likely that they once attached a sight to the gun. French guns in the 17th century appear to have sights cast onto their base rings, and it is possible that this was the case on at least some of their 16th century guns, including MAH 6 and 8.³⁹

There is a leaf pattern to the cascabel, and the Roman numeral VIII is incised on the top of the third outermost ring (fig. 38). As discussed before, it is possible that these numbers indicate the weight of the powder that the gun used. This would make sense because the numbers increase with the length of the guns, and, based on the discussion on gunpowder, a longer gun would require more powder for complete combustion by the time it reached the end of the gun's length.

The French cannon (77) at the Musee de l'Armee that was discussed previously also has a salamander (for Francis I) on the first reinforce, though it is not crowned like the one on MAH 8, and the overall appearances of the two guns are very similar. Another French cannon (79) at the Musee de l'Armee looks all but identical to MAH 8. It bears both a salamander of Francis I (1515-1547) and fleur-de-lys. It has 2 square holes in its base ring, which contain evidence of iron.

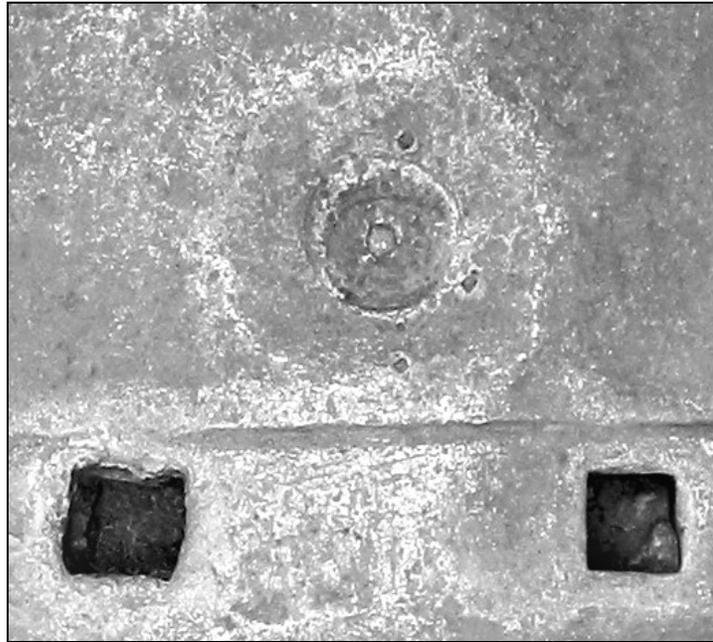


Fig. 37. The touchhole of MAH 8.



Fig. 38. The markings on the cascabel of MAH 8.

MAH R. 98. 14

This French minion⁴⁰ (fig. 39), the smallest gun in the Museu de Angra collection, differs from the others in its general appearance. It is octagonal in shape, and has no reinforcement bands besides those at the breech and muzzle. As mentioned earlier, this shape would support the length of the gun and prevent any sagging or drooping. On the upper panel of the octagonal chase is a salamander (fig. 40) for Francis I, dating the gun to 1515-1547.

This gun's touchhole was once drilled out of an iron bush that was screwed into the threaded hole that now remains. Like the collar arms, the bush has disintegrated through its reaction to the seawater. Five centimeters below the surface, the touchhole's diameter abruptly reduces to 1.7 cm, indicating that the bush was 2.5 centimeters in diameter and 5 centimeters long, not extending all the way to the bore. The use of a circular iron bush is found on the several French guns, such as 77 (a cannon from the reign of Francis I) and 92 (an octagonal culverin for Henry II) at the Musee de l'Armee.

Around the touchhole is a G⁴¹ monogram (fig. 41), which is certainly the mark of the founder. Cannon 79 at the Musee de l'Armee also bears the salamander of Francis I and a G surrounding the touchhole. Another gun with the same mark, but no salamander, is a falcon (XIX.15) at Fort Nelson, which is labeled as French or Flemish and dated to around 1520. This gun is also octagonal, and its the collar arms are located in the same exact positions as those on MAH R. 98. 14, and its touchhole is drilled out of an iron bushing. The muzzle and breech are identical in appearance to those of the MAH minion, as are those found on a French falcon (AR-V-31) at the Maritime

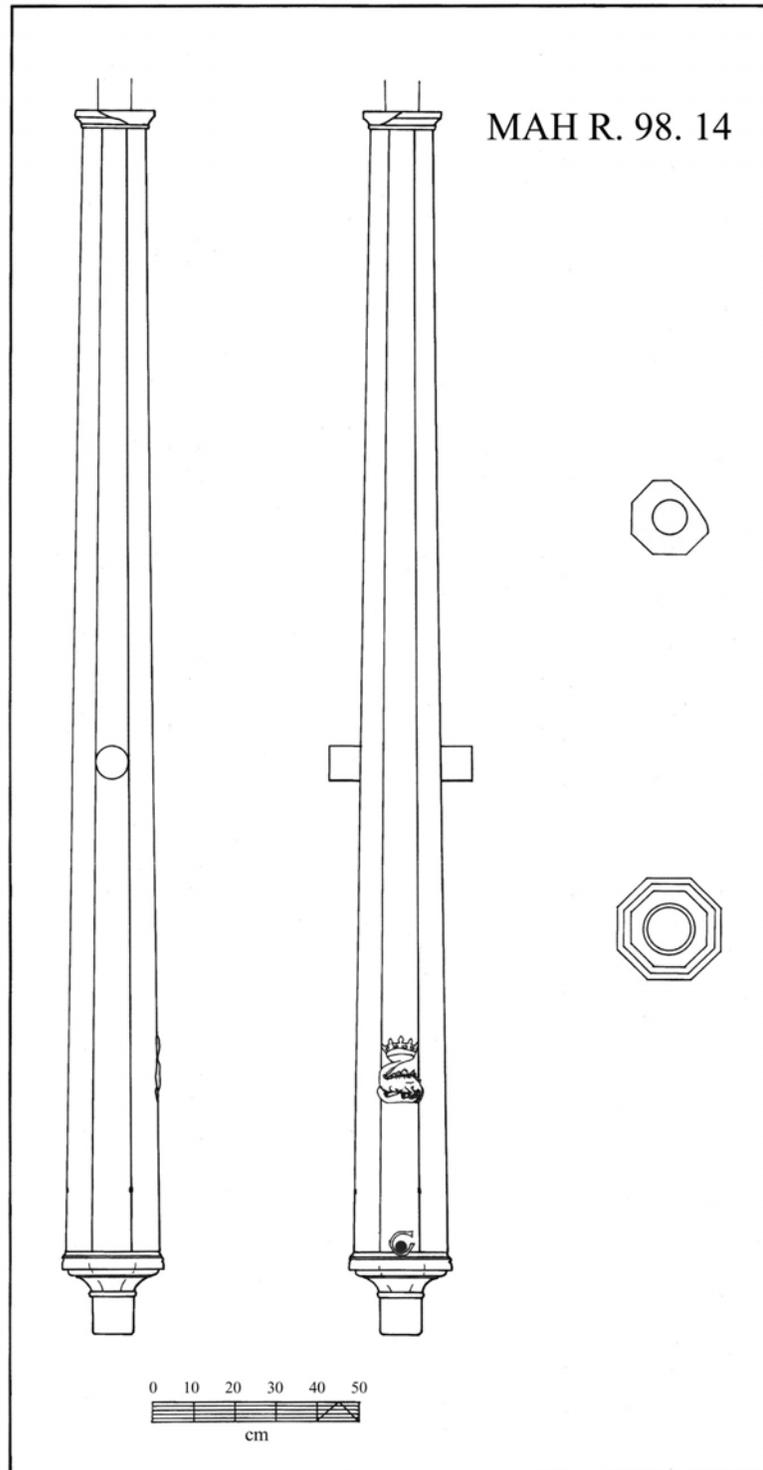


Fig. 39. The French minion MAH R. 98. 14.



Fig. 40. The salamander of Francis I found on MAH R. 98. 14.



Fig. 41. The monogram around the threaded touchhole of
MAH R. 98. 14.

Museum in Lisbon, which also bears the Salamander of Francis I, but the monogram of a B surrounds the touchhole instead of that of a G.

Castle and Collars

Evidence for either iron collars or castles was found in all nine of the guns at the Museu de Angra do Heroísmo. In this collection alone, it is possible to see the variety of options a founder had in choosing a method for centering the core at the breech. He could choose castles or collars of different shapes, sizes, and configurations.

The shapes and sizes of the collar arms on four of the guns were determined because the iron had corroded during their time under water, leaving visible holes. Circular arms, 1 centimeter (0.4 in) in diameter, were found in MAH 2, while square ones, 1 centimeter (0.4 in) by 1 centimeter (0.4 in), were found in MAH 3 and 5, and MAH R. 98. 14 had rectangular arms, 1.2 centimeters (0.5 in) by 0.5 centimeters (0.2 in). The shapes and sizes of the arms in MAH 1, 4, 7, and 8 could not be established because no holes were visible, but nonetheless, their configurations were determined by the use of a stud-finder magnet, and are shown, along with those of MAH 2, 3, 5 and R. 98. 14, in appendix F. The most noticeable difference in the configuration of these eight collars is that the collar in MAH 3 has only three arms, while the rest have four.

When MAH 6 was cast, the core was held in place not by a collar like the other guns, but by a castle. At the top of the castle, where the core was fit into place, there was an additional bar of iron that protruded to the gun's surface, measuring 3 centimeters (1.2 in) by 3 centimeters (1.2 in), which served as a permanent bush out of

which the touchhole was drilled. This iron tube would last longer than a bronze vent, and the reason it was attached to the collar was likely to ensure its correct placement.⁴²

The likely reason that no arms were visible on the surfaces of MAH 1, 4, 7 and 8 is their short period of submersion. Wignall originally found no evidence of a collar in MAH 4, but using a stud-finder magnet I was able to locate it. If this gun came from the *Revenge*, as Wignall suggests, then it spent relatively little time underwater, allowing less time for the iron of the arms to be affected by the corrosive nature of seawater and dislodge the bronze surface plugs. Based on these arguments and lack of visible evidence of the collar arms on the surface of MAH 1, 7 and 8, we can conclude that they were also likely underwater for a minimal amount of time.

The arms in MAH 1 were not all located equidistant from the base ring, a case also seen in MAH 2 and 3, the consequence of which could have been a bore that was slightly out of true. In these cases, the differences were only a matter of 1 or 2 centimeters, and the bores appeared to be true. This is likely a result of the casting process, which called for the founder to secure and center the core at the muzzle end as well as at the breech and this may have corrected for any misalignment.

Trunnions

The trunnions on MAH 1 and R. 98. 14 were placed along the centerlines of the guns, while those on MAH 2, 5, 6, and 8 were set slightly lower. The founders of MAH 3, 4, and 7 placed the trunnions closer still to the bottom of the gun. They were located between $\frac{3}{5}$ and $\frac{3}{4}$ of the diameter of the gun from the top, as seems typical of Spanish

guns, allowing their axes to line up with the bottoms of the bores, while their tops lined up with the bores' centers, as per Moretti's suggestion.⁴³ On the majority of the guns, the trunnions were around $3/7$ the length of the gun from the base ring, but the founders of MAH 7 and 9 positioned them around $3/7$ the length of the bore from the touchhole.

Notes

¹ The key measurements for each gun are listed in appendix E.

² The great length of this gun alone is enough to classify it into this type, but its bore diameter also fits into this classification.

³ Baptista de Lima n.d., 527.

⁴ Viterbo 1901, 35.

⁵ Wignall 1973, 94.

⁶ At the Museu Militar in Lisbon, R-16, D-5, D-6, C-6, C-4, B-6, B-5, and C-5/A are all 16th century Portuguese guns with four lifting loops, as is XIX.91 at Fort Nelson.

⁷ Caruana 1994, xvii; Tucker 1976, 58; Bourne 1587, 12; Wignall 1973, 94.

⁸ As described by the plaque accompanying the gun.

⁹ The gun's length in feet and in calibers, as well as its bore size, all fit into this class of gun.

¹⁰ Museu de Angra do Heroísmo 1976.

¹¹ Cordeiro 1895, 66.

¹² The bore diameter fits best into this category. The gun is shorter than called for in this type, so I have labeled it as a bastard.

¹³ Museu de Angra do Heroísmo 1976.

¹⁴ Martin 1988, 58, fig. 1, 61, 64; 1975, 211; Flanagan 1988, 69.

¹⁵ I have placed this gun into this category based on bore diameter. It is labeled a bastard because its length is shorter than called for.

¹⁶ Ffoulkes 1969, 28.

¹⁷ 1973, 92.

¹⁸ L'Hour et al. 1989, 117.

¹⁹ 1994, 42-4.

²⁰ Hodgkinson 2000, 34-5.

²¹ 1973, 92.

²² 1961, 32.

²³ It must be noted, however, that museum literature (Museu de Angra do Heroísmo 1976) states that it was cast for Henry VIII.

²⁴ 1973, 92, pl. 9; Caruana 1994, 38.

²⁵ The bore size, as well as the length in both feet and calibers, places this gun into the demi-culverin category.

²⁶ The weight markings were defined by Barker (1996, 58).

²⁷ Guilmartin 1982, 133, 136, fig. 4.

²⁸ Viterbo 1901, 34.

²⁹ Ruth Brown 2003, pers. comm.

³⁰ The bore size of this gun corresponds to those in this class. Its length in both feet and calibers are within the limits listed, though they are on the short end, and this gun might also be referred to as a bastard.

³¹ 1973, 89, pl. 5.

³² Ruth Brown 2003, pers. comm.

³³ Figueiredo 1987, fig. 15, fig. 18.

³⁴ The bore size of this gun places it into this class, but it is considered a bastard because its length in feet and calibers falls short of those specified for this class in Table 3.

³⁵ 1994, 30-2.

³⁶ Figueiredo 1987, fig. 21, fig. 22.

³⁷ Ruth Brown 2003, pers. comm.

³⁸ This classification is based on the gun's length in calibers because of its early date. Based on its bore size alone, it could be classified as a bastard culverin.

³⁹ Based on the illustrations appearing in Boudriot's "French Sea Service Brass Guns" (1997).

⁴⁰ The bore size of this gun corresponds best with those of this class, though the gun is longer than called for, in both feet and calibers.

⁴¹ It is possible that this is a C monogram, but based on my research, I believe that it to be a G.

⁴² Wignall 1973, 89-90.

⁴³ 1683, 27.

CHAPTER IX

CONCLUSION

In the 16th century, bronze guns stood as symbols of power and wealth. Bronze was an expensive commodity and the demand for ordnance was increasing with the quest for power in newly discovered lands as well as the advent of placing cannon on board ships. The information that each of the nine cast-bronze guns from the Museu de Angra do Heroísmo (Terceira Island, Azores) contains includes both cutting-edge military technology as well as the artistic statement of the founder. Some of the finest metalwork of the period was displayed in cast-bronze guns, and due to the founding techniques, no two are the same, making each an important piece of history.

The overseas expansion of Western Europeans in the 16th century allowed for ships and their guns to travel throughout the world. Thus, by war, piracy, wrecking and salvaging, and trade guns ended up in other countries, or even at the bottom of the ocean. The Museu de Angra possesses a collection that represents this movement of ordnance, having guns from principal maritime powers of the era: Portugal, Spain, France, and England. Some of these guns may have arrived there because of alliances, while others undoubtedly came from ships that wrecked on the coast.

These guns show how different countries found their own solutions to the problems in gunfounding. Each country had its own standards that they followed, and these standards dictated the forms for the various types of guns. Within this collection

alone five different types are represented: cannon, demi-cannon, culverin, demi-culverin, and minion.

With these standards in place, it was up to the founder to follow them and produce a usable gun. Some founders, however, followed methods that produced flawed guns. In the Museu de Angra collection, we can see the results of faulty founding, at times combined with improper gun use. The most common founding problem appears to have been the use of an insufficient amount of metal during casting. Another problem was the improper drying of the model, leading to the formation of cracks on the surface.

The most obvious difference in casting techniques used to produce the guns in the Museu de Angra collection is the use of a castle instead of a collar in the French culverin (MAH 6). Another striking difference is the presence of an iron element throughout the Spanish reinforced bastard demi-cannon (MAH 3) whose purpose and exact structure will require further investigation.

The documentation and research of the MAH guns adds to our understanding of gunfounding in the 16th century, and shows that the process may be more complex than previously believed. Though most of the guns in the Museu de Angra collection appear to have been made using the process discussed in chapter VI, it appears that MAH 3 at least was founded using a more complicated method.

Great care was taken in decorating and designing bronze guns in the 16th century, as they served as artistic statements of the founders and their countries. Though many countries commissioned ornate guns, England, under the Tudor rule, produced guns of a more simple nature. During the reign Henry VIII, England's founders proved that they

were capable of producing elaborate guns, like those that were onboard the *Mary Rose*, but as the demand for guns increased, the guns of England became less ornate, like MAH 4 and 7.

The guns presented here are important pieces of history because cast-bronze guns were not only works of art, but also were of great technological and military importance during the 16th century. As Europeans traveled the world and conquered new lands, they took bronze ordnance with them to serve as powerful new weapons. As guns were taken to sea they inspired a new design for the ships that would carry them and redefined the art of naval warfare.

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APPENDIX A
RULERS OF THE 16TH CENTURY

Spain

Carlos I (Charles V)	_____	1516-1556
Philip II	_____	1556-1598
Philip III	_____	1598-1621

England

Henry VIII	_____	1509-1547
Edward VI	_____	1547-1553
Mary I	_____	1553-1558
Elizabeth I	_____	1558-1603

France

Louis XII	_____	1498-1515
Francis I	_____	1515-1547
Henri II	_____	1547-1559
Francis II	_____	1559-1560
Charles IX	_____	1560-1574
Henry III	_____	1574-1589
Henry IV	_____	1589-1610

Portugal

Manuel I	_____	1495-1521
João III	_____	1521-1557
Sebastian	_____	1557-1578
Henrique	_____	1578-1580
Philip I (Philip II of Spain)	_____	1580-1598
Philip II (Philip III of Spain)	_____	1598-1621

APPENDIX B
GUN TYPES[‡]

Cannon

Source	Date Of guns	Gun Nationality	Length in Calibers	Length ft (cm)	Bore Diameter in (cm)
Biringuccio 1966, 225*	1540	Italian		10.5 (321) – 11.5 (350)	
Lad 1586	1586	English	16 – 17	335 (11)	7.75 (19.69)- 8.25 (20.96)
Tartaglia 1588, 29-30	1588	English, French		7 (213) 8 (244) 8.5 (259) 9.5 (290) 10 (305)	
Collado 1592, folio 29	1592	Italian/ Spanish	18		
Smith 1627, 70	1627	English			8 (20.32)
Norton 1628, 53	1520s - 1628	English	18.8	11 (335)	7 (17.78)
Norton 1628, 45	1520s - 1628 -	Spanish	18 18 18		
Nye 1670, 71-2	1670	English		12 (366)	8 (20.32)
Love 1705, 184	1705	English			7 (17.78) 8 (20.32)
Cordeiro 1895, 91	16 th century	Portuguese	18		
Lewis 1961, 39	16 th century	Spanish	18	10.9 (332)	7.25 (18.42)
Valle 1962, 383, 388	16 th century	Portuguese	18-20		
Ffoulkes 1969, 92	1574	English			7 (17.78) 8 (20.32)
Caruana 1994, 9	16 th century	English			8.25 (20.96)
Norris 2000, 63	16 th century	Europe	19.5	13 (396)	8 (20.32)

[‡] All measurements from primary sources are in 16th or 17th century units.

* These figures refer to all guns within the cannon type (cannon royal, cannon, and demi-cannon).

Demi-Cannon

Source	Date Of guns	Gun Nationality	Length in Calibers	Length ft (cm)	Bore Diameter in (cm)
Biringuccio 1966, p. 225	1540	Italian		10.5 (321) – 11.5 (350)	
Ffoulkes 1969, 92	1574	English			6.5 (16.51)
Lad 1586	1586	English	23 – 25.1	12 (366)	5.75 (14.61)- 6.25 (15.88)
Bourne 1587, 66-7	1587	English	19.2 – 21.1 18.5 – 20.3 19.5 – 21.3	10 (305)- 11 (335) 10 (3.05)- 11 (335) 11 (335)- 12 (366)	6.25 (15.88) 6.5 (16.52) 6.75 (17.15)
Bourne 1587, 66-7	1587	French and continental nations	22	11 (335)	6 (15.24)
Collado 1592, folio 27	1592	Italian/Spanish	22-24		
Smith 1627, 70	1627	English			6.5 (16.51)
Norton 1628, 53	1520s - 1628	English	18.5	10 (305)	6.5 (16.51)
Norton 1628m 45	1520s - 1628	Spanish	20		
Nye 1670, 72-3	1670	English		10 (305)- 12 (366) 10 (305)- 11 (335) 12 (366)	6.25 (15.88) 6.5 (16.51) 6.75 (17.15)
W. T. 1672, 3	1672	English	19.2 – 23 20.3 22.3 20.6	10 (305)- 12 (366) 11 (335) 12 (366) 12 (366)	6.25 (15.88) 6.5 (16.52) 6.5 (16.52) 7 (17.78)
Love 1705, 184	1705	English			6.3 (16.00)
Cordeiro 1895, 91	16 th century	Portuguese	20 – 21		
Lewis 1961, 22, 39	16 th century	Spanish	20 – 22	10.4 (318) – 11.5 (349)	6.25 (15.88)
Caruana 1994, 9	16 th century	English			6.25 (15.88)
Norris 2000, 63	16 th century	Europe	20.3	11 (335)	6.5 (16.51)

* These figures refer to all guns within the cannon type (cannon royal, cannon, and demi-cannon).

Culverin

Source	Date Of guns	Gun Nationality	Length in Caliber	Length ft (cm)	Bore Diameter in (cm)
Biringuccio 1966, 226	1540	Italian		15.3 (467)- 17.2 (525)	
Ffoulkes 1969, 92	1574	English			5.5 (13.97)
Lad 1586	1586	English	32 – 33.6	14 (427)	5 (12.70)- 5.25 (13.34)
Bourne 1587, 67-8	1587	English	28.8 27.4 26.2 – 28.3	12 (366) ± 12 (366) 12 (366)- 13 (396)	5 (12.70) 5.25 (13.34) 5.5 (13.97)
Tartaglia 1588, 29-30	1588	English, French		7.5 (229) 8.5 (259) 10 (305) 10.5 (320) 12 (366) 15 (457)	
Collado 1592, folio 12	1592	Italian/ Spanish	32 – 34		
Smith 1627, 70	1627	English			5.5 (13.97)
Norton 1628, 53	1520s - 1628	English	28.8 27.4 26.2	12 (366) 12 (366) 12 (366)	5 (12.70) 5.25 (13.34) 5.5 (13.97)
Norton 1628, 45	1520s - 1628	Spanish	28		
Nye 1670, 73-4	1670	English		12 (366) 12 (366) 10 (305)- 13 (3.96)	5 (12.70) 5.25(13.34) 5.5 (13.97)
W. T. 1672, 3-4	1672	English	28.8 27.4 19.2 – 23	12 (366) 12 (366) 10 (305)- 12 (366)	5 (12.70) 5.25 (13.34) 6.25 (15.88)
Moretii 1683, 29	1683	Europe	26-41		
Love 1705, 184	1705	English			4.46 (11.30) 5.32 (13.5)
Cordeiro 1895, 91	16 th century	Portuguese	28-32 bastard 24-27		
Lewis 1961, 39	16 th century	Spanish	18 – 32	7.9 (240)- 14 (427)	5.25 (13.34)
Valle 1962, 383	16 th century	Portuguese	25 – 29 ≥ 30		
Caruana 1994, 9	16 th century	English			5.25 (13.34)
Norris 2000, 63	16 th century	Europe	25.4	11 (335)	5.2 (13.21)

* These figures refer to all guns within the culverin type (culverin, demi-culverin, and saker).

Demi-Culverin

Source	Date Of guns	Gun Nationality	Length in Calibers	Length ft (cm)	Bore Diameter in (cm)
Biringuccio 1966, 226'	1540	Italian		15.3 (467)- 17.2 (525)	
Ffoulkes 1969, 92	1574	English			4.5 (11.43)
Lad 1586	1586	English	36.7 – 39	13 (396)	4 (10.16) 4.25 (10.80) 4.5 (11.43)
Bourne 1587, 68-9	1587	English	25.4 – 28.2 26.7 30.3	9 (274)- 10 (305) 10 (305) 12 (366)	4.25 (10.80) 4.5 (11.43) 4.75 (12.07)
Collado 1592, folio 12	1592	Italian/Spanish	32 – 34		
Smith 1627, 70	1627	English			4.5 (11.43)
Norton 1628, 53	1520s - 1628	English	31 29.3 27.7	11 (335) 11 (335) 11 (335)	4.25 (10.80) 4.5 (11.43) 4.75 (12.07)
Norton 1628, 45	1520s - 1628	Spanish	30		
Nye 1670, 74-5	1670	English		9 (274)- 10 (305) 10 (305) 10 (305)- 13 (396)	4.25 (10.80) 4.5 (11.43) 4.75 (12.07)
W. T. 1672, 4	1672	English	25.4 – 28.2 26.7 – 32 25.3 – 30.3	9 (274)- 10 (305) 10 (305)- 12 (366) 10 (305)- 12 (366)	4.25 (10.80) 4.5 (11.43) 4.75 (12.07)
Love 1705, 184	16 th century	English			4.5 (11.43)
Cordeiro 1895, 91	16 th century	Portuguese	31		
Lewis 1961, 33, 39	16 th century	Spanish	32.5	11.5 (351)	4.25 (10.80)
Caruana 1994, 9	16 th century	English			4.5 (11.43)
Norris 2000, 63	16 th century	Europe	24.3	8.5 (259)	4.2 (10.67)

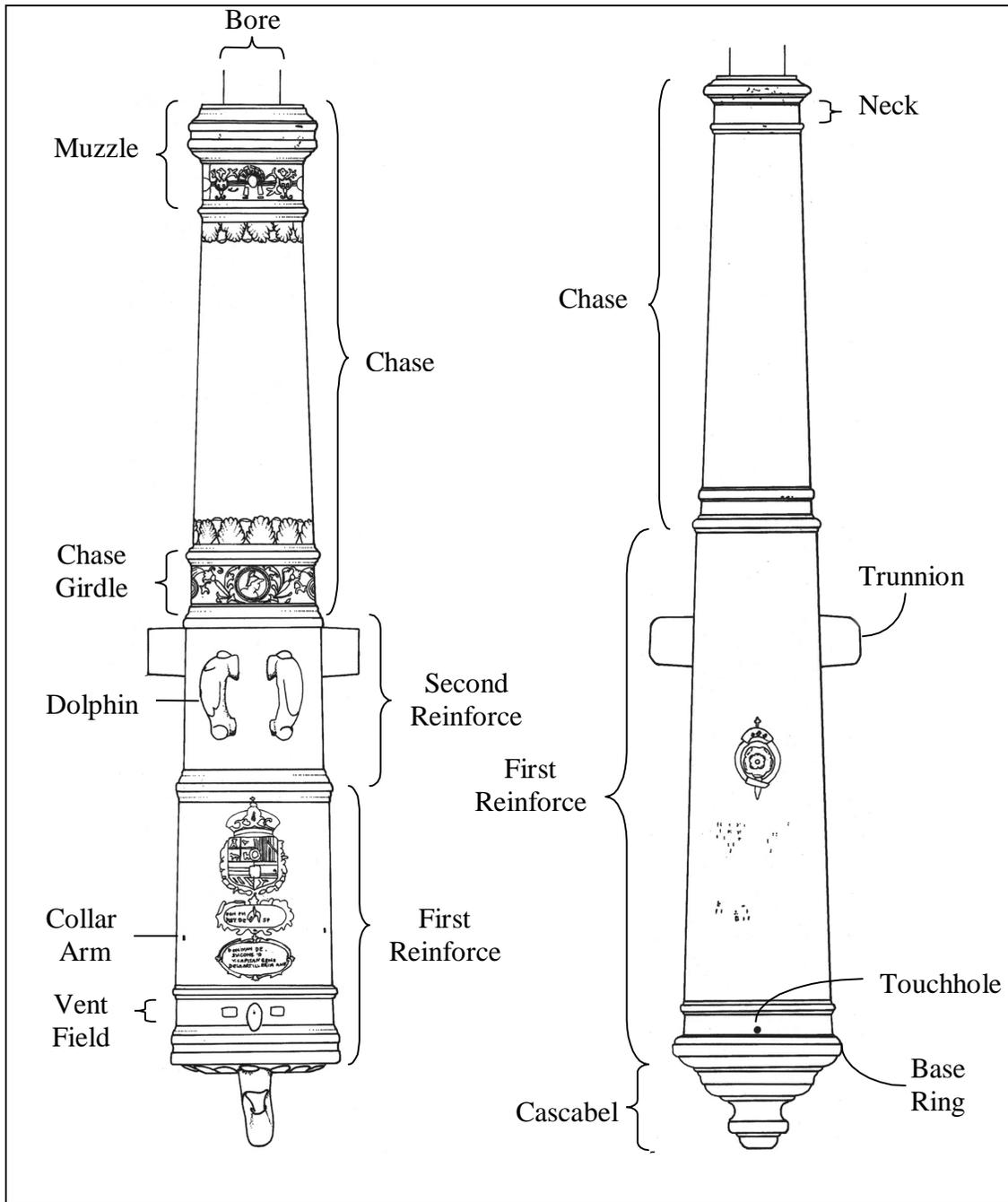
* These figures refer to all guns within the culverin type (culverin, demi-culverin, and saker).

Minion

Source	Date Of guns	Gun Nationality	Length in Calibers	Length ft (cm)	Bore Diameter in (cm)
Ffoulkes 1969, 92	1574	English			3.25 (8.26)
Lad 1586	1586	English	29.5	8 (244)	3.25 (8.26)
Bourne 1587, 70	1587	English	29.5	8 (244) ±	3.25 (8.26)
Smith 1627, 70	1627	English			3.25 (8.26)
Norton 1628, 53	1520s - 1628	English	27.7	7.5 (229)	3.25 (8.26)
Norton 1628, 45	1520s - 1628	Spanish			
W. T. 1672, 4	1672	English	28 29.5	7 (213) 8 (244)	3 (7.62) 3.25 (8.26)
Nye 1670, 77	1670	English	28 29.5	7 (213) 8 (244)	3 (7.62) 3.25 (8.26)
Love 1705, 184	1705	English			3.35 (8.51)
Lewis 1961, 33, 39	16 th century	Spanish	32	8.7 (264)	3.25 (8.26)
Caruana 1994, 9	16 th century	English			3.25 (8.26)

APPENDIX C

PARTS OF 16TH CENTURY CAST-BRONZE GUNS



APPENDIX D
SAMPLE DATA RECORDING SHEET

Date :

MAH 4

Sketch of Gun:



MAH 4

Dimensions

Length of Gun :

Overall Length :

Bore Length :

Bore Diameter :

Distance from base to touchhole:

Diameter of touchhole :

Rings

Number of Reinforcement Rings (not including base ring) :

Distance between ring sets :

base to 1 :

1 to 2 :

2 to 3 :

3 to 4 :

4 to muzzle :

Trunnions

Right :

Left :

Diameter at base :

Diameter at base :

Diameter at end :

Diameter at end :

Length on top :

Length on top :

Distance from face of muzzle to axis of trunnions :

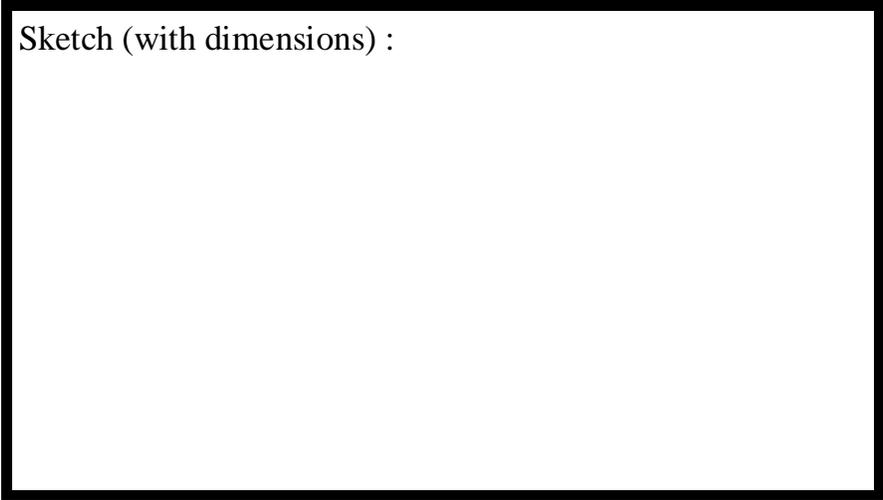
Diameter of barrel at axis of trunnions :

Distance from top of gun to axis of trunnions :

Muzzle front

MAH 4

Sketch (with dimensions) :

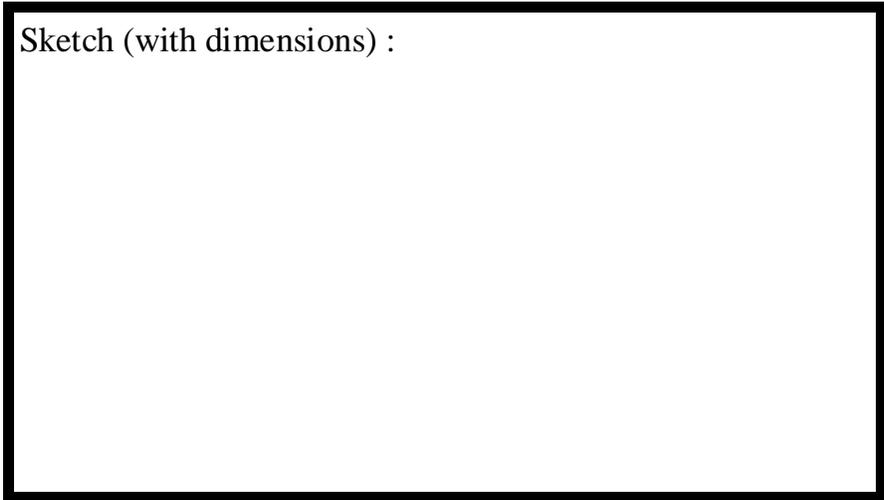


Diameter at face :

Maximum diameter:

Muzzle side

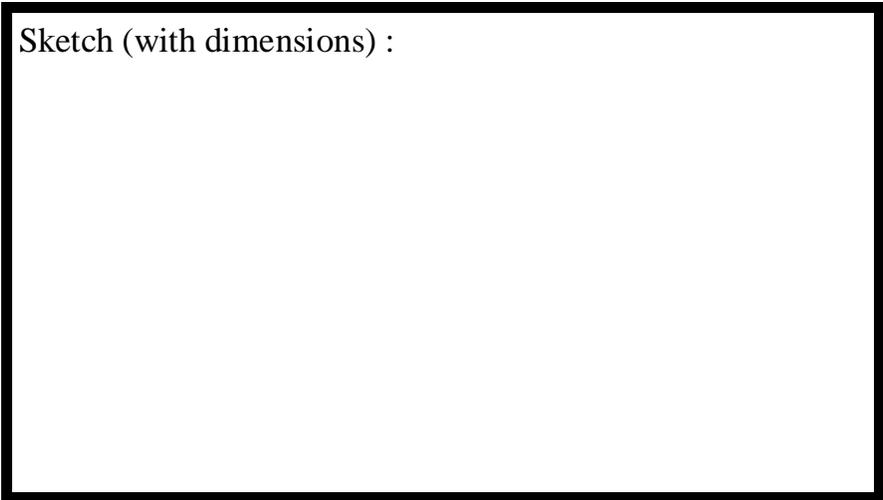
Sketch (with dimensions) :



Cascabel front

MAH 4

Sketch (with dimensions) :

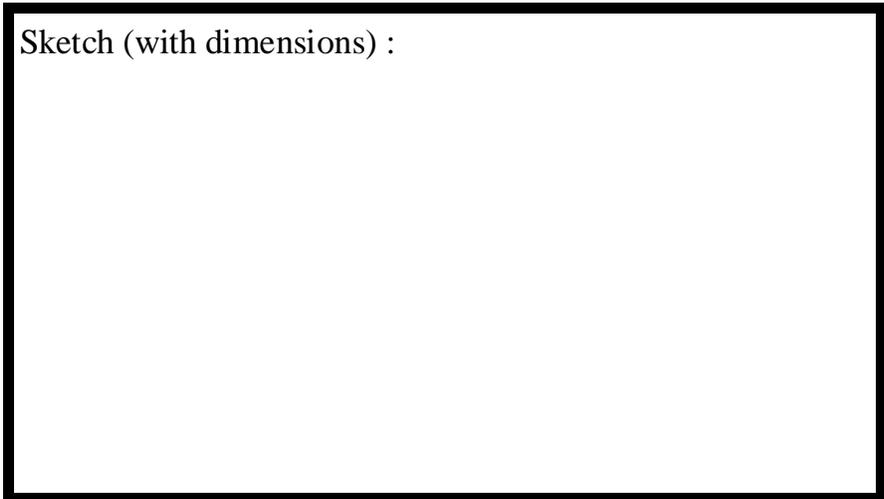


Diameter at breech :

Maximum diameter:

Cascabel side

Sketch (with dimensions) :



Profile of base rings

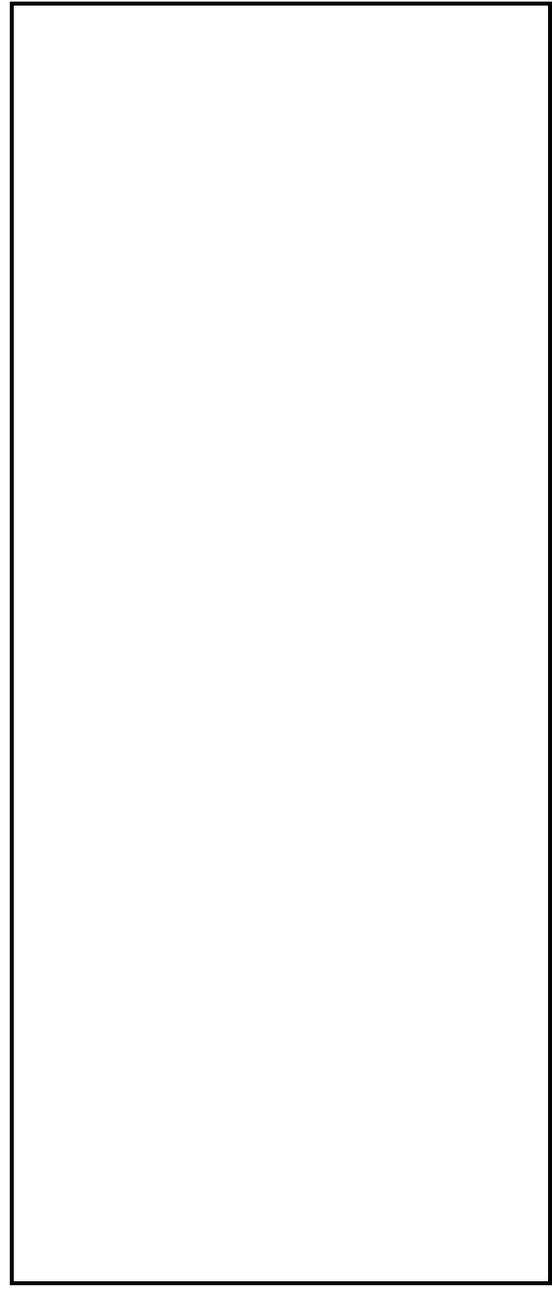
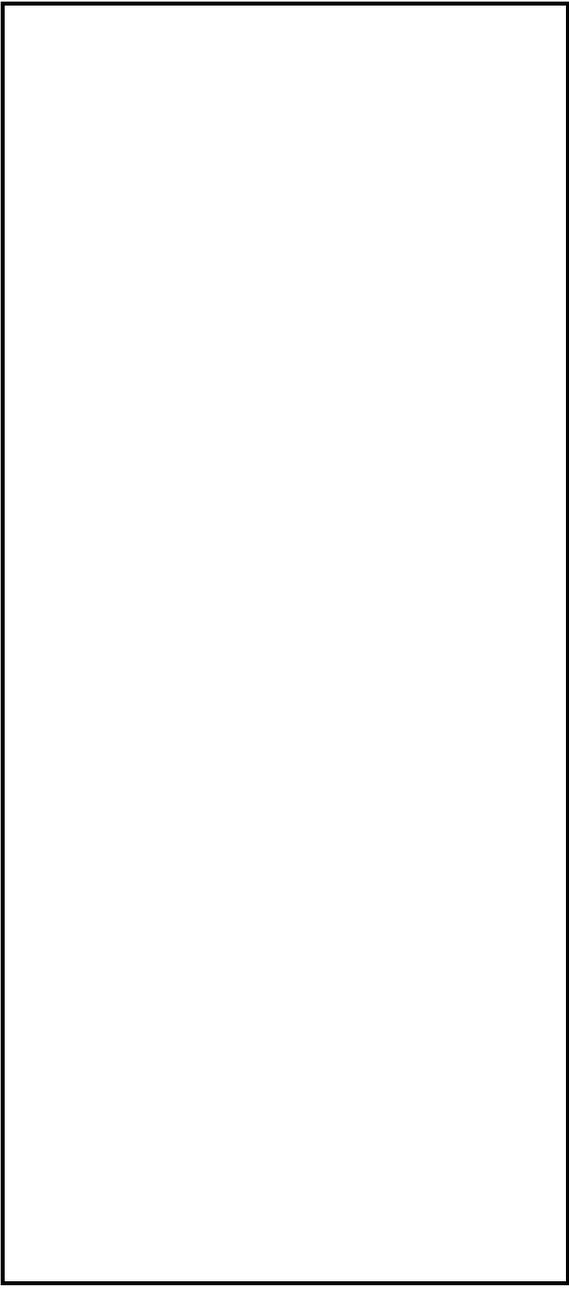
Profile of ring set 1

MAH 4

Breech

Diameter

Diameter



Diameter

Muzzle

Diameter

Profile of ring set 2

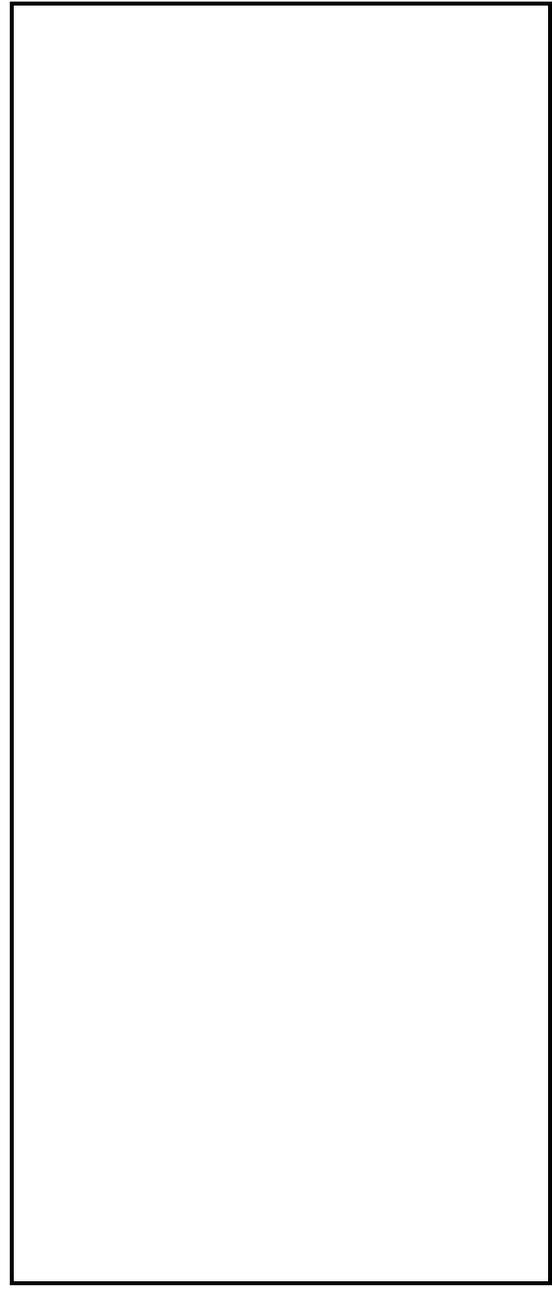
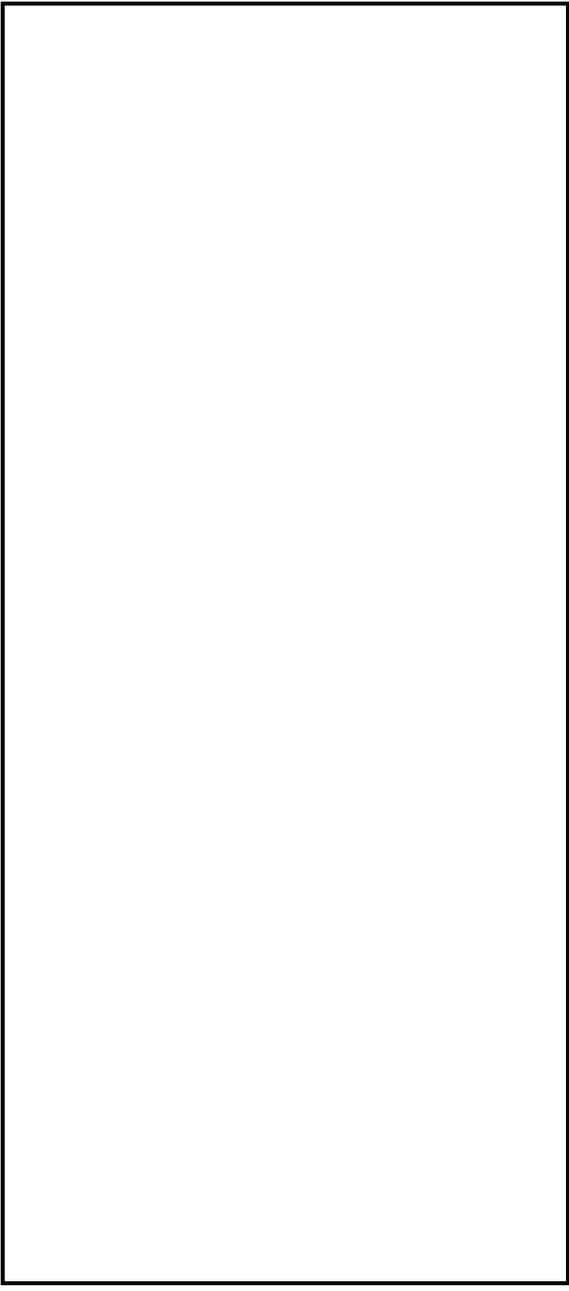
Profile of ring set 3

MAH 4

Breech

Diameter

Diameter



Diameter

Muzzle

Diameter

Profile of ring set 4

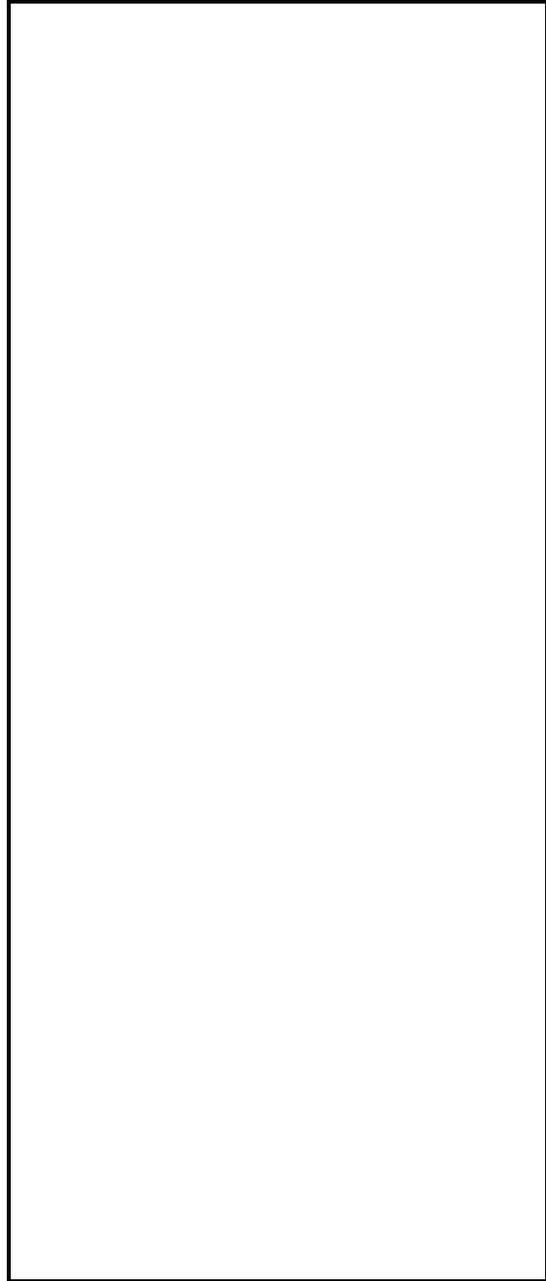
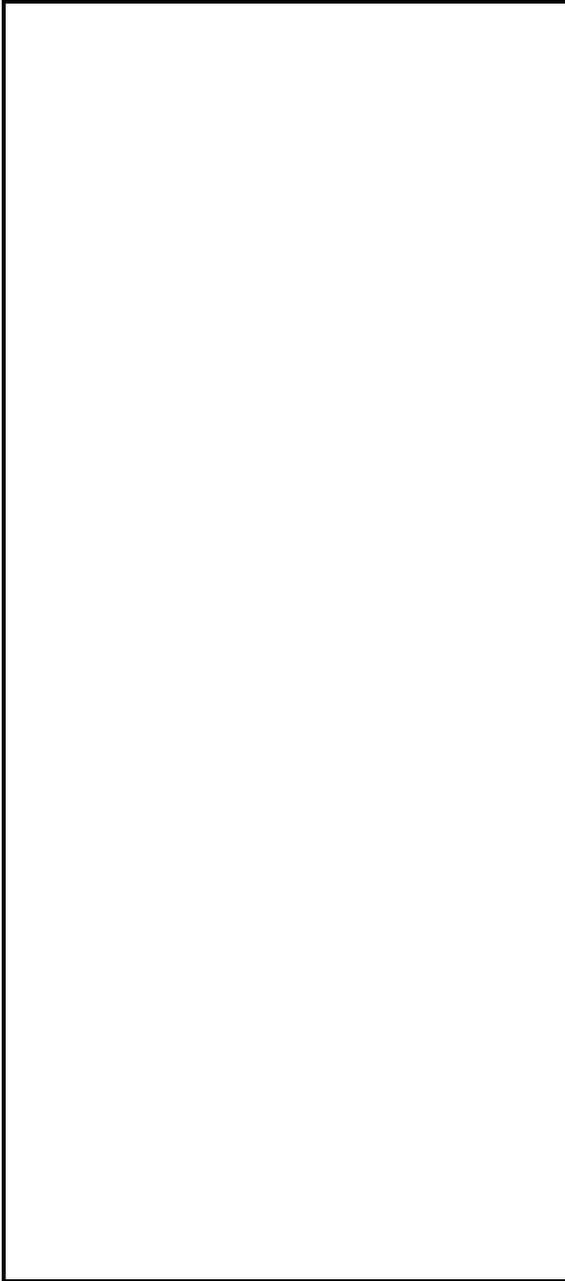
Profile of muzzle rings

MAH 4

Breech

Diameter

Diameter



Diameter

Muzzle

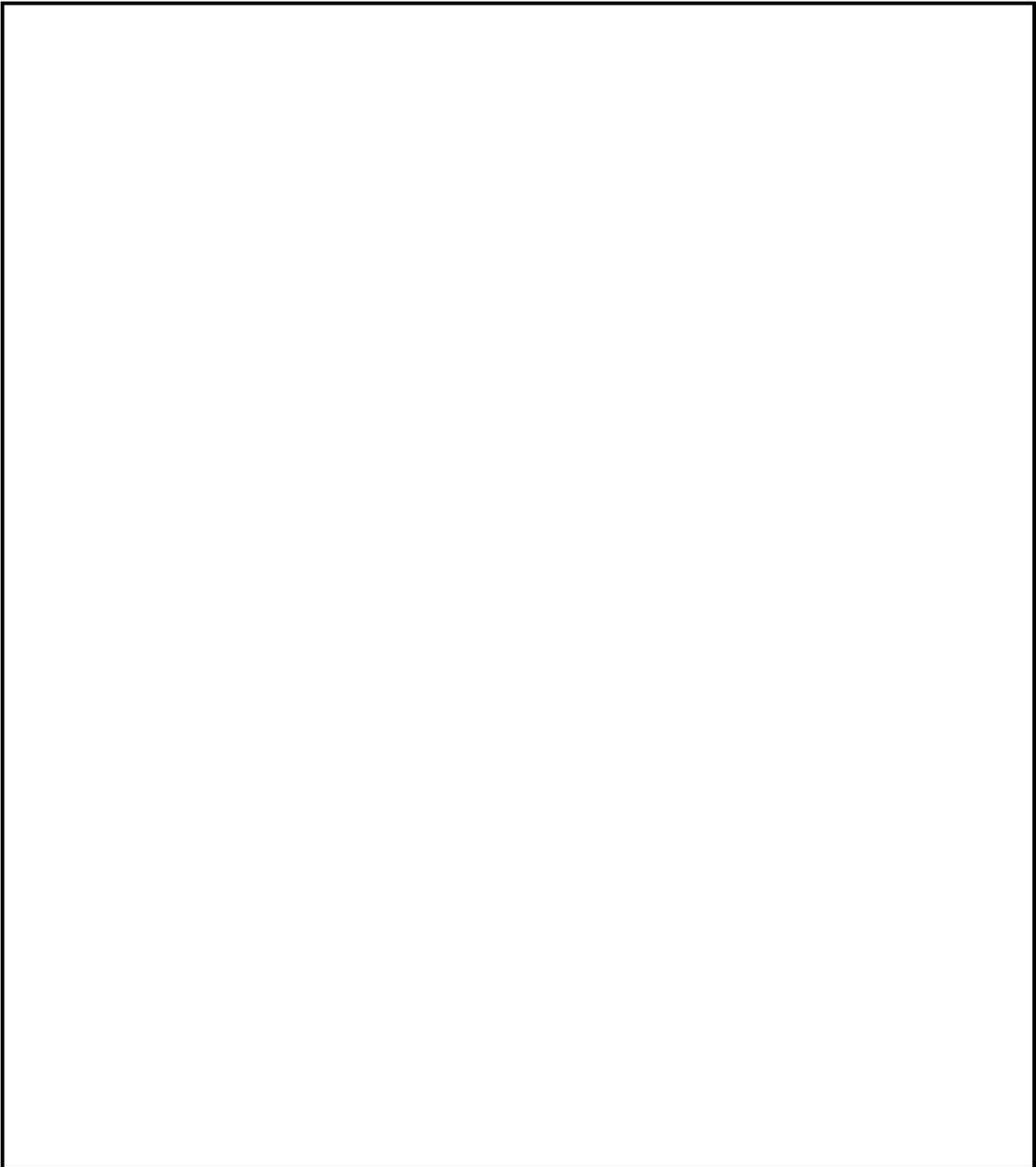
Diameter

Ornamental
Feature 1

Sketch (with dimensions) :

MAH 4

Breech



Muzzle

APPENDIX E
KEY GUN MEASUREMENTS

MAH 1

1	Overall Length of Gun	438 cm (14.4 ft) ¹
2	Length of Gun Excluding Cascabel	432.5 cm (14.2 ft)
3	Bore Diameter	12.3 cm (4.8 in) ²
4	Bore Length	427 cm (14 ft)
5	Muzzle to Axis of Trunnions	250 cm (8.2 ft)
6	Diameter of Trunnions at the Barrel	13 cm (5.1 in)
7	Diameter of Trunnions at the End	12 cm (4.7 in)
8	Base Ring to the Collar ³	32, 31, 31, 30 cm (12.6, 12.2, 12.2, 11.8 in)
9	Base Ring to Touchhole Center	8.6 cm (3.4 in)
10	Diameter of Touchhole	2.2 cm (0.9 in)
11	Weight	2750 kg (6062.7 lbs) ⁴

MAH 2

1	Overall Length of Gun	363 cm (11.9 ft) ⁵
2	Length of Gun Excluding Cascabel	352 cm (11.5 ft)
3	Bore Diameter	11.5 cm (4.5 in)
4	Bore Length	338 cm (11.1 ft)
5	Muzzle to Axis of Trunnions	207 cm (6.8 ft)
6	Diameter of Trunnions at the Barrel	13 cm (5.1 in)
7	Diameter of Trunnions at the End	13 cm (5.1 in)
8	Base Ring to the Collar	22, 23, 23, 22 cm (8.7, 9, 9, 8.7 in)
9	Base Ring to Touchhole Center	11.5 cm (4.5 in)
10	Diameter of Touchhole	1 cm (0.4 in)

MAH 3

1	Overall Length of Gun	280 cm (9.2 ft)
2	Length of Gun Excluding Cascabel	258 cm (8.5 ft)
3	Bore Diameter	15 cm (5.9 in)
4	Bore Length	243 cm (8 ft)
5	Muzzle to Axis of Trunnions	148.5 cm (4.9 ft)
6	Diameter of Trunnions at the Barrel	13.5 cm (5.3 in)
7	Diameter of Trunnions at the End	12.2 cm (4.8 in)
8	Base Ring to the Collar	36, 35.5, 34 cm (14.2, 14, 13.4 in)
9	Base Ring to Touchhole Center	13 cm (5.1 in)
10	Diameter of Touchhole	0.5 cm (0.2 in)

MAH 4

1	Overall Length of Gun	276 cm (9 ft) ⁶
2	Length of Gun Excluding Cascabel	252 cm (8.3 ft)
3	Bore Diameter	14 cm (5.5 in) ⁷
4	Bore Length	246 cm (8 ft)
5	Muzzle to Axis of Trunnions	146 cm (4.8 ft)
6	Diameter of Trunnions at the Barrel	13.4 cm (5.3 in)
7	Diameter of Trunnions at the End	11.7 cm (4.6 in)
8	Base Ring to the Collar	32 cm (12.6 in)
9	Base Ring to Touchhole Center	7.1 cm (2.8 in)
10	Diameter of Touchhole	1.2 cm (0.5 in)

MAH 5

1	Overall Length of Gun	326 cm (10.7 ft) ⁸
2	Length of Gun Excluding Cascabel	307 cm (10 ft)
3	Bore Diameter	11.5 cm (4.5 in)
4	Bore Length	N/A ⁹
5	Muzzle to Axis of Trunnions	175 cm (5.7 ft)
6	Diameter of Trunnions at the Barrel	11.2 cm (4.4 in)
7	Diameter of Trunnions at the End	11 cm (4.3 in)
8	Base Ring to the Collar	24 cm (9.4 in)
9	Base Ring to Touchhole Center	5.5 cm (2.2 in)
10	Diameter of Touchhole	1 cm (0.4 in)

MAH 6

1	Overall Length of Gun	341 cm (11.2 ft)
2	Length of Gun Excluding Cascabel	317.5 cm (10.4 ft)
3	Bore Diameter	14 cm (5.5 in)
4	Bore Length	309 cm (10.1 ft)
5	Muzzle to Axis of Trunnions	179 cm (5.9 ft)
6	Diameter of Trunnions at the Barrel	12.5 cm (4.9 in)
7	Diameter of Trunnions at the End	12 cm (4.7 in)
8	Base Ring to the Collar	N/A
9	Base Ring to Touchhole Center	11 cm (4.3 in)
10	Diameter of Touchhole	3 cm x 3 cm (1.2 in x 1.2 in)

MAH 7

1	Overall Length of Gun	274 cm (9 ft)
2	Length of Gun Excluding Cascabel	243 cm (8 ft)
3	Bore Diameter	14 cm (5.5 in)
4	Bore Length	N/A ¹⁰
5	Muzzle to Axis of Trunnions	135 cm (4.4 ft)
6	Diameter of Trunnions at the Barrel	13.6 cm (5.4 in)
7	Diameter of Trunnions at the End	12.5 cm (4.9 in)
8	Base Ring to the Collar	31 cm (1 ft)
9	Base Ring to Touchhole Center	6.9 cm (2.7 in)
10	Diameter of Touchhole	0.7 cm (0.3 in)

MAH 8

1	Overall Length of Gun	282 cm (9.3 ft)
2	Length of Gun Excluding Cascabel	261.5 cm (8.6 ft)
3	Bore Diameter	14 cm (5.5 in)
4	Bore Length	N/A ¹¹
5	Muzzle to Axis of Trunnions	148 cm (4.9 ft)
6	Diameter of Trunnions at the Barrel	14 cm (5.5 in)
7	Diameter of Trunnions at the End	13.5 cm (5.3 in)
8	Base Ring to the Collar	21, 22, 23.5, 22.5 cm (8.3, 8.7, 9.3, 8.9 in)
9	Base Ring to Touchhole Center	10.6 cm (4.2 in)
10	Diameter of Touchhole	0.8 cm (0.3 in)

MAHR. 98. 14

1	Overall Length of Gun	299.5 cm (9.8 ft) ¹²
2	Length of Gun Excluding Cascabel	283.5 cm (9.3 ft) ¹³
3	Bore Diameter	8 cm (3.1 in) ¹⁴
4	Bore Length	279.4 cm (9.2 ft)
5	Muzzle to Axis of Trunnions	159 cm (5.2 ft)
6	Diameter of Trunnions at the Barrel	8.7 cm (3.4 in)
7	Diameter of Trunnions at the End	8.3 cm (3.3 in)
8	Base Ring to the Collar	20 cm (7.9 in)
9	Base Ring to Touchhole Center	6.3 cm (2.5 in)
10	Diameter of Touchhole	2.5 cm (1 in)
11	Weight	900 kg ¹⁵ (1984.2 lbs)

Notes

¹ Wignall (1973, pl. 12) recorded a length of 450 cm (14.8 ft), while the Museu de Angra do Heroísmo (1976) and Baptista de Lima (n.d., 525) recorded a length of 440 cm (14.4 ft).

² Wignall (1973, pl. 12), the Museu de Angra do Heroísmo (1976), and Baptista de Lima (n.d., 525) recorded a bore diameter of 13 cm (5.1 in).

³ When different, these measurements are listed starting from the top collar arms, moving clockwise, as looking from the breech to the muzzle.

⁴ Wignall 1973, 93; Baptista de Lima (n.d., 525) records the weight at 2570 kg (5665.9); the discrepancy is likely due to a transposition of numbers in the Baptista de Lima article.

⁵ The Museu de Angra do Heroísmo (1976) recorded a length of 362 cm (11.9 ft).

⁶ Wignall (1973, 92) recorded a length of 274 cm (9.0 ft), while the Museu de Angra do Heroísmo (1976) recorded a length of 278 cm (9.1 ft).

⁷ Wignall (1973, 92) recorded this same bore diameter, but the Museu de Angra do Heroísmo (1976) recorded a bore diameter of 11.5 cm (4.5 in).

⁸ The Museu de Angra do Heroísmo (1976) recorded a length of 323 cm (10.6 ft).

⁹ The bore was obstructed and this measurement could not be taken.

¹⁰ The tampion was still in place in the bore, so this measurement could not be taken.

¹¹ The tampion was still in place in the bore, so this measurement could not be taken.

¹² Monteiro (1996, 6) recorded a total length of 297 cm (9.7 ft).

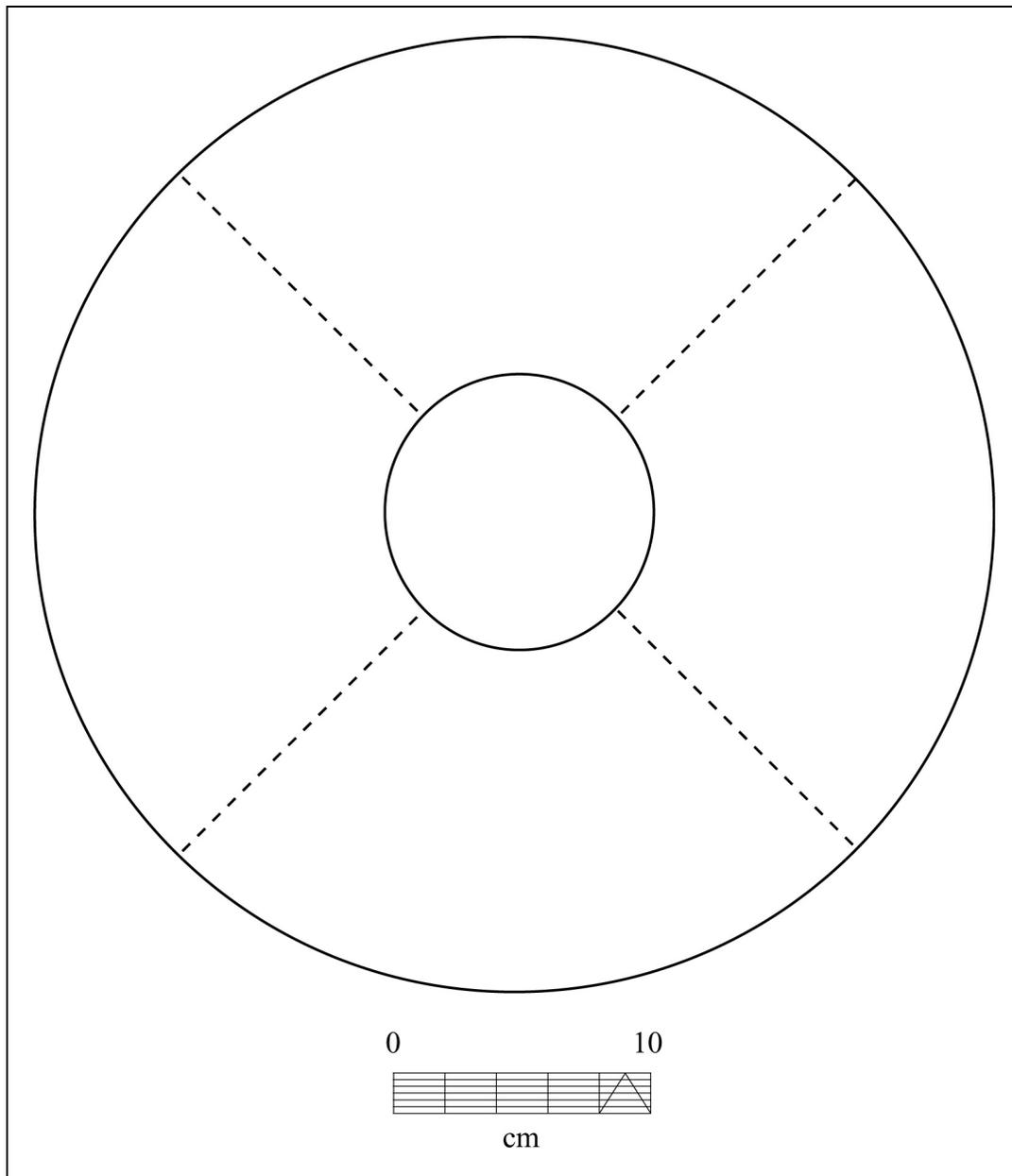
¹³ Monteiro (1996, 6) recorded a length of 284 cm (9.3 ft).

¹⁴ Monteiro (1996, 6) recorded this same bore diameter.

¹⁵ Museu de Angra do Heroísmo 1998.

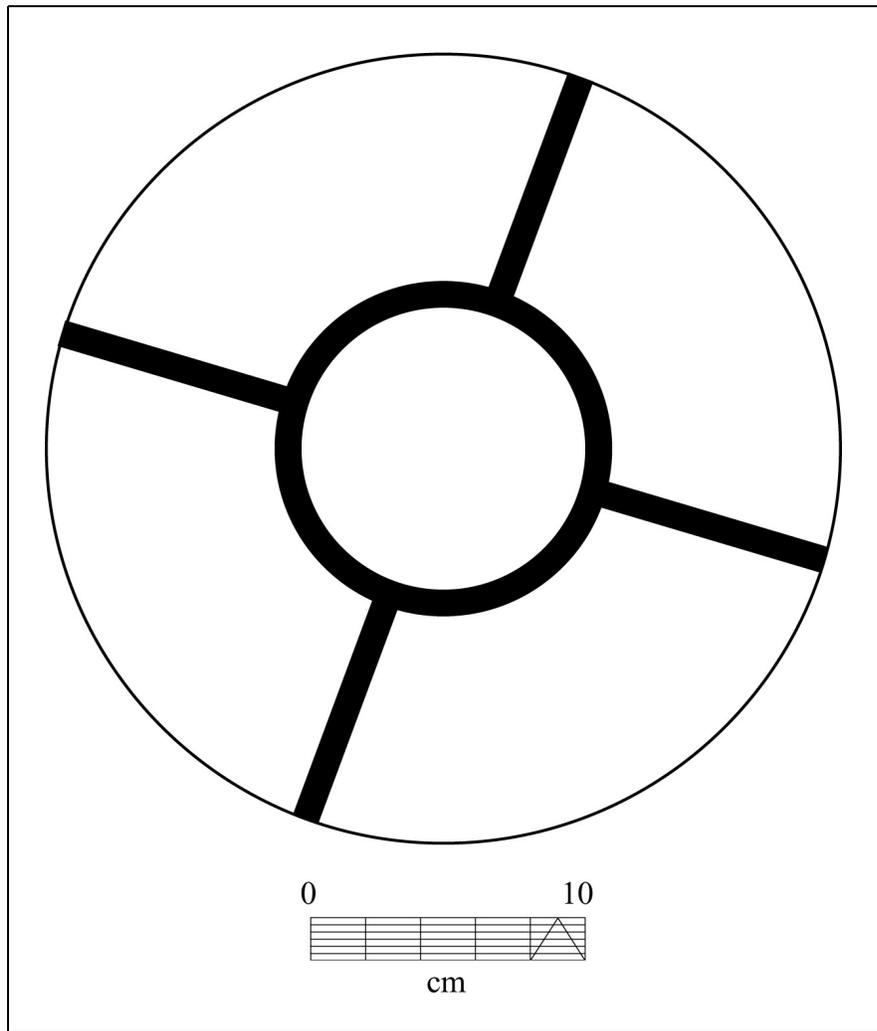
APPENDIX F

COLLAR AND CASTLE CONFIGURATIONS FOR THE MAH GUNS*

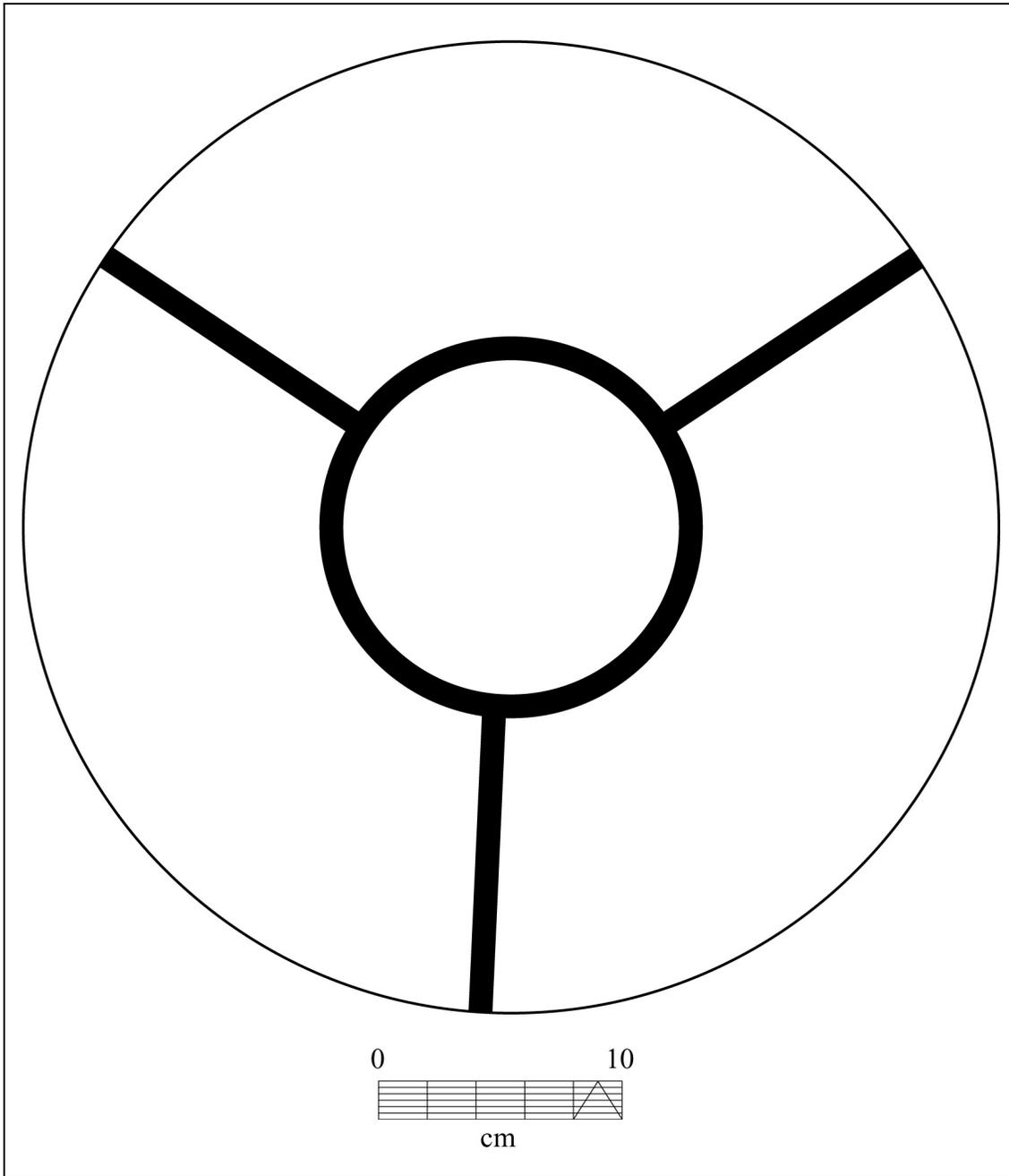
MAH 1

* The figures are depicted looking from the breech to the muzzle.

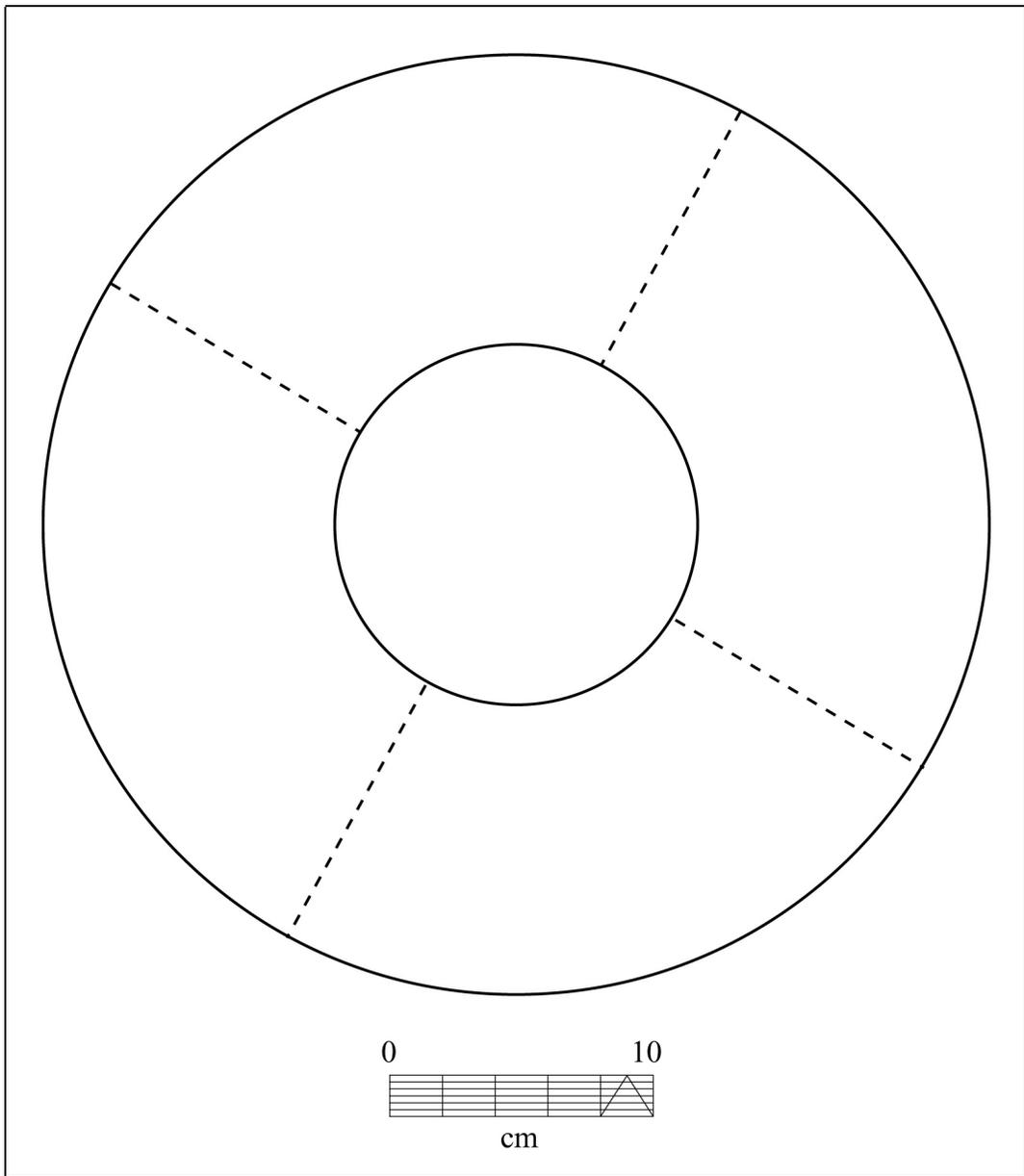
MAH 2



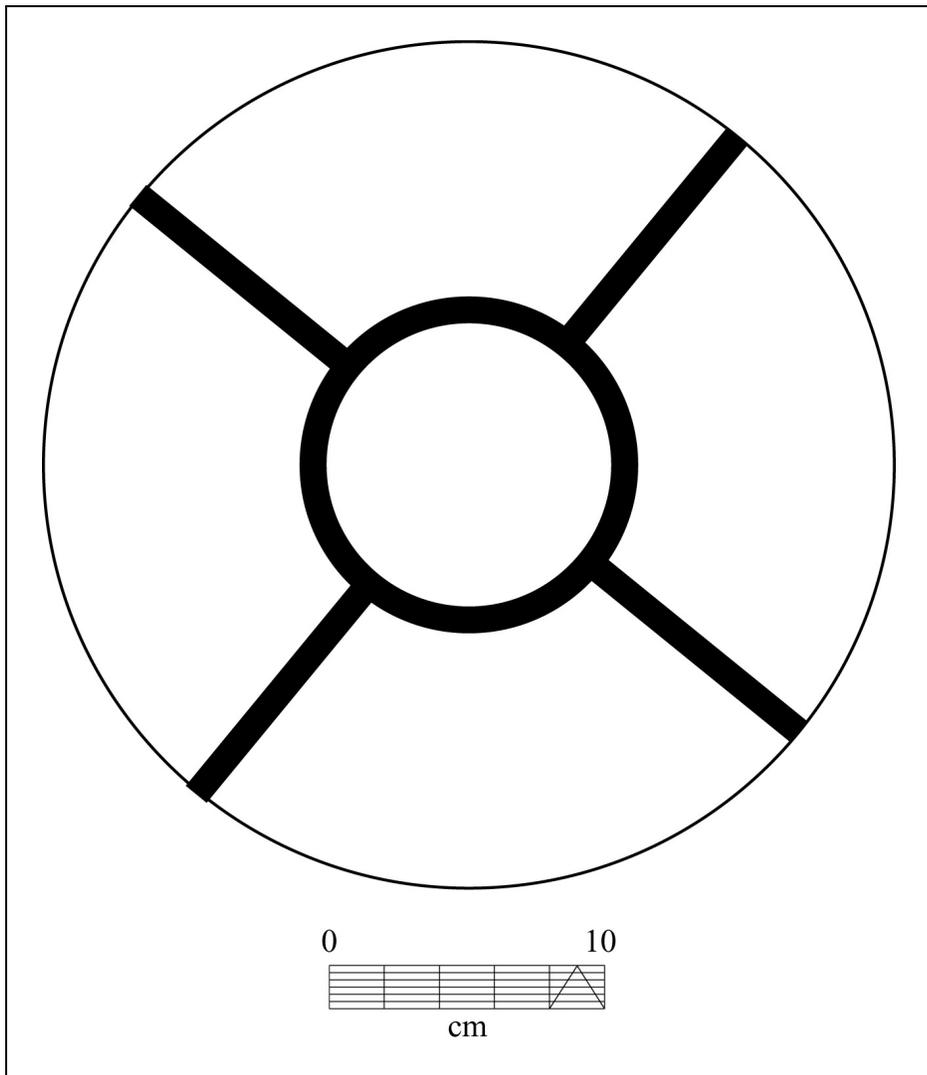
MAH 3



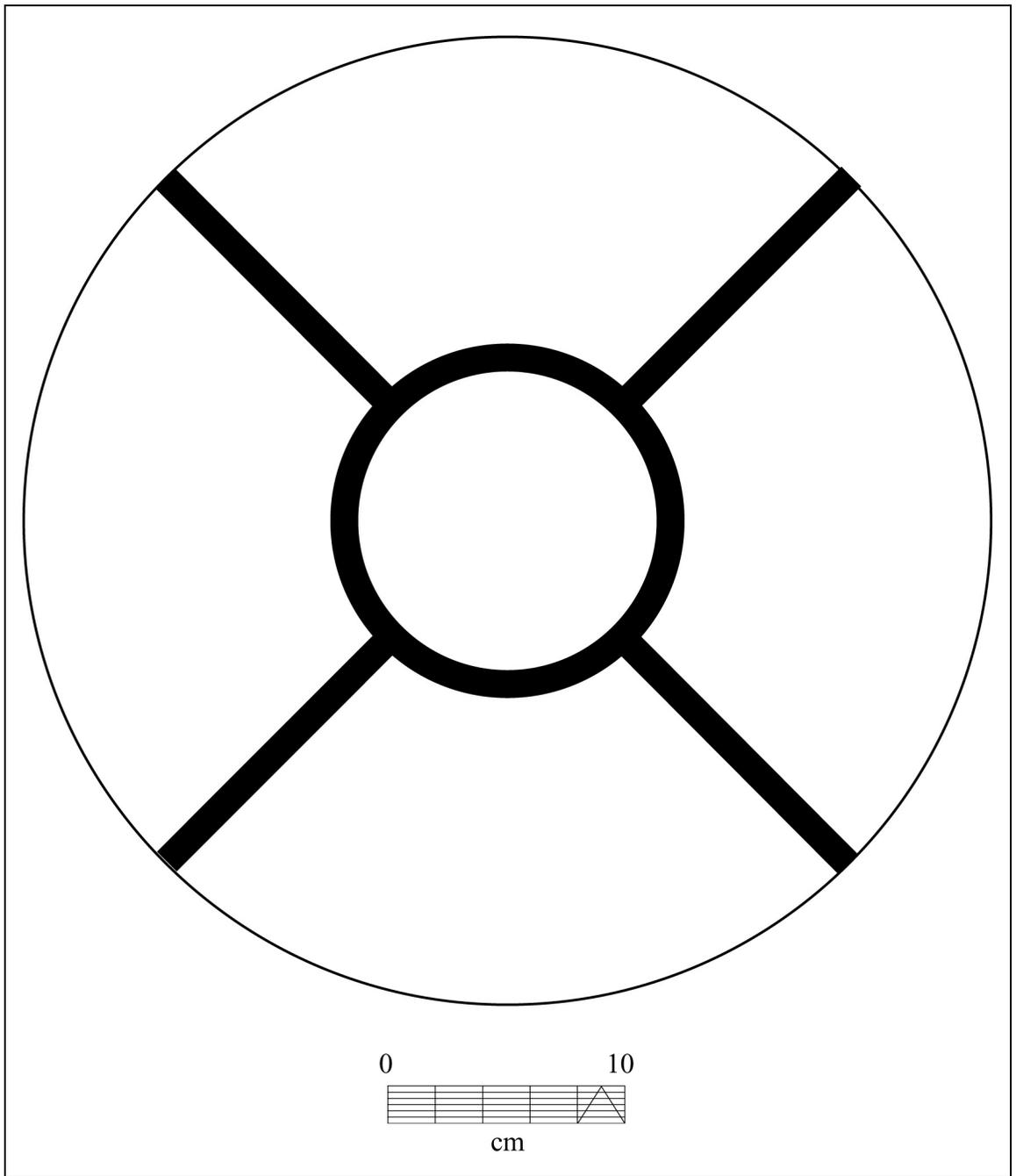
MAH 4



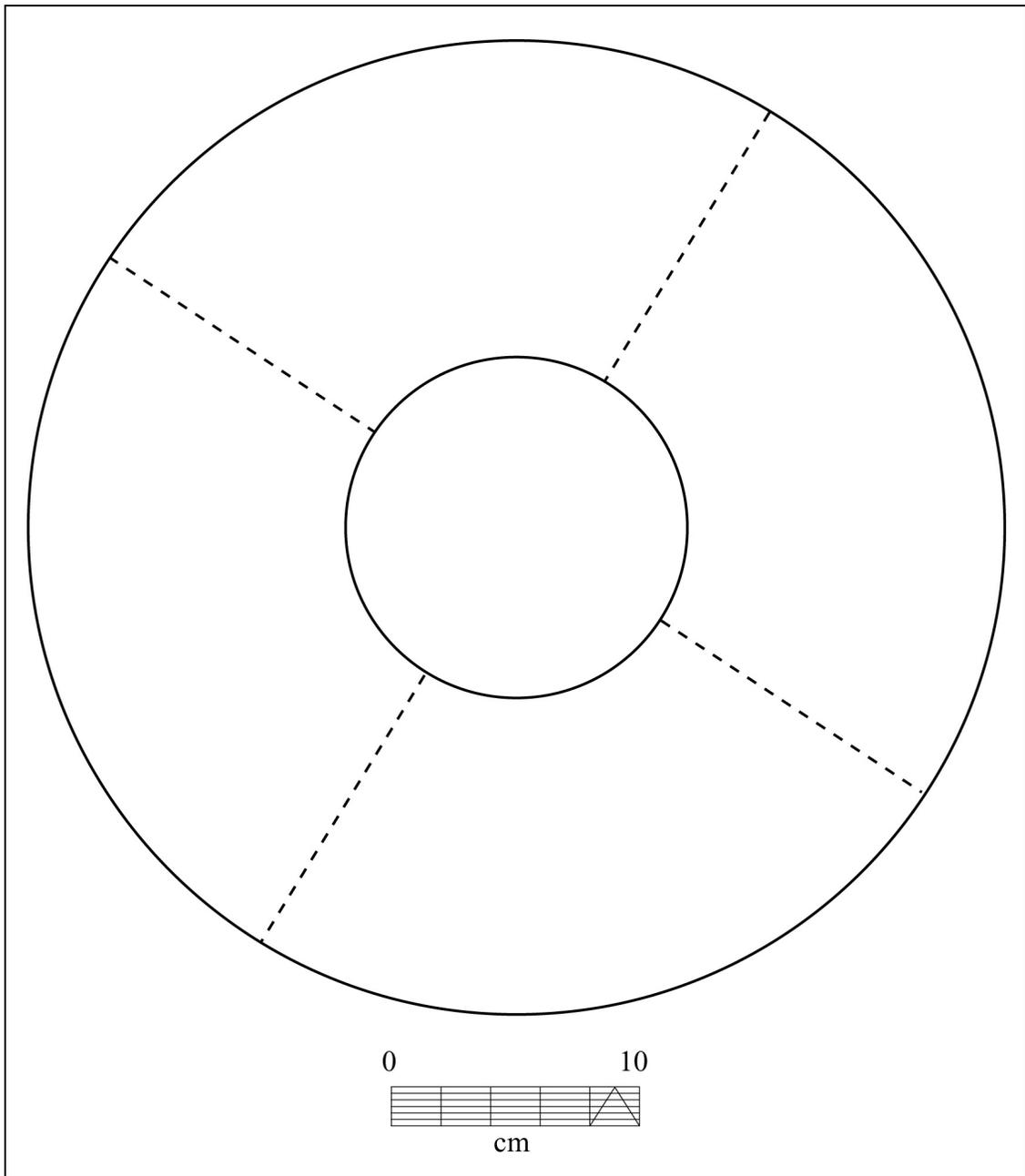
MAH 5



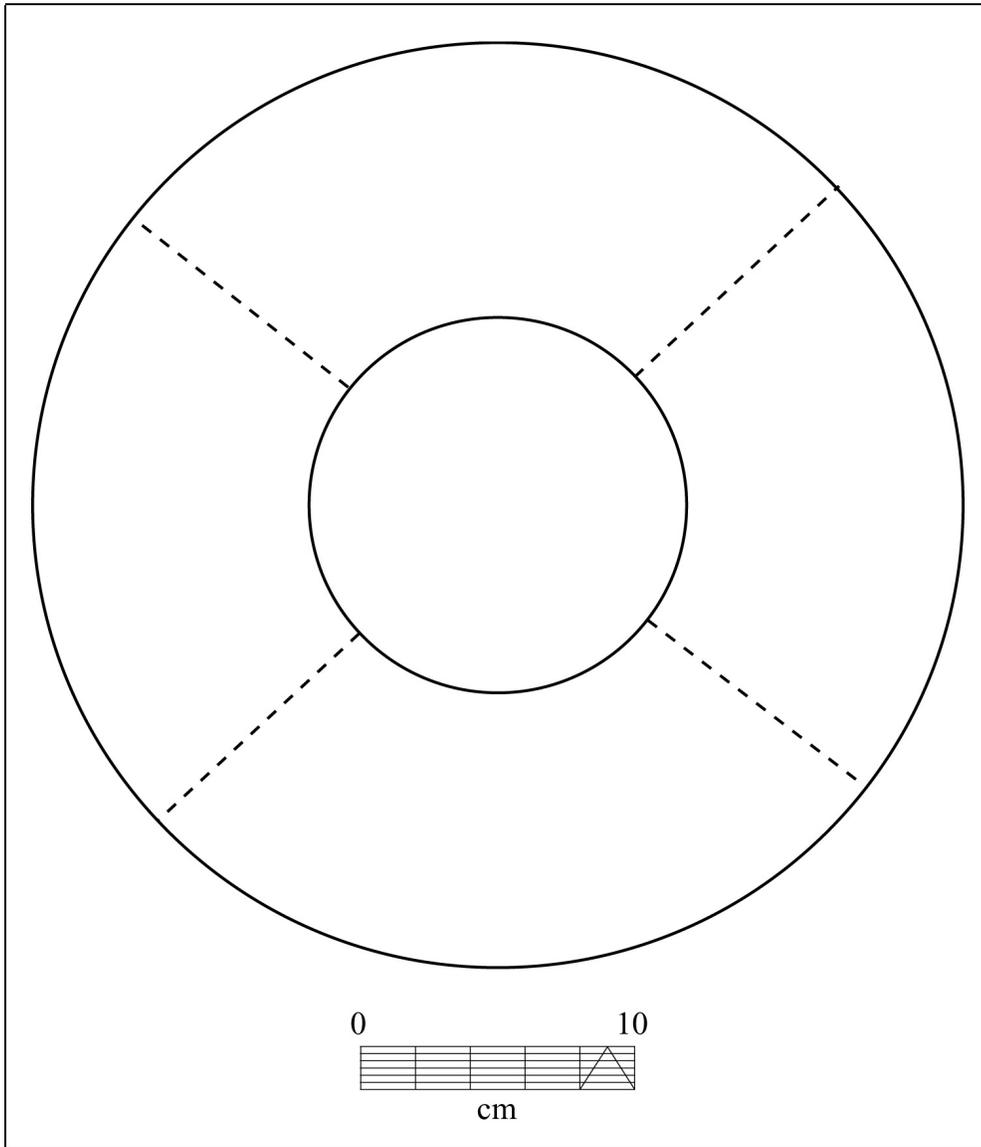
MAH 6



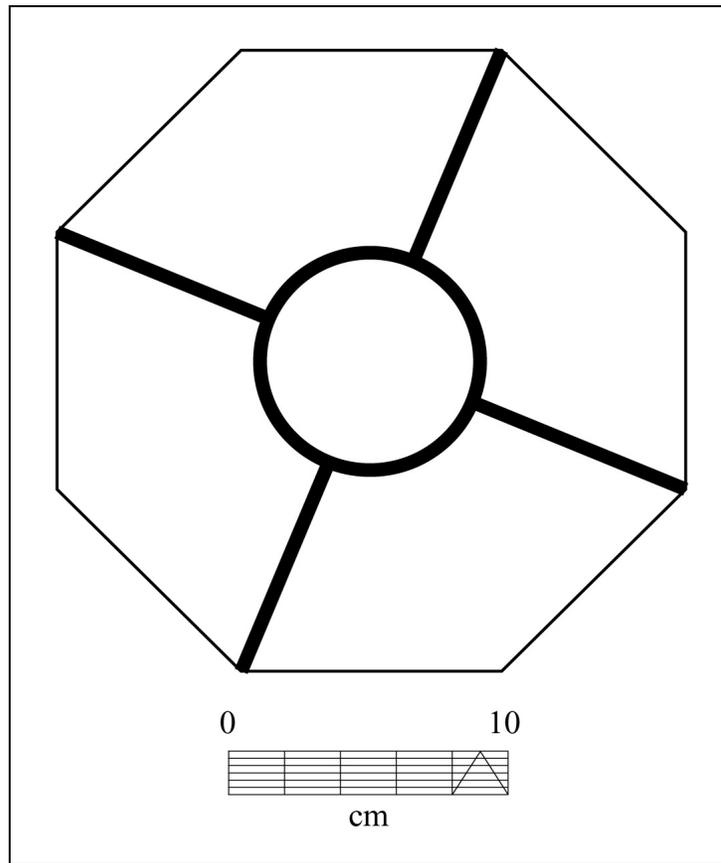
MAH 7



MAH 8



MAH R. 98. 14



VITA

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Education

2000-Present Texas A&M University, College Station, Texas
M.A. in Anthropology, December 2003
1997-1999 Texas A&M University, College Station, Texas
B.A. in Anthropology, August 1999, cum laude
1994-1997 University of North Texas, Denton, Texas

Professional Experience

2003 Dominican Republic Survey Project. Co-director.
A magnetometer and visual survey of a portion of the Dominican Republic's southern coast in conjunction with the Institute of Nautical Archaeology and RPM Nautical Foundation.
2002 Cais do Sodr  Ship Timber Project. Archaeological Assistant.
Recording of timbers from a shipwreck in Lisbon, Portugal.
2001 Azores Project. Archaeological Field Assistant.
Archaeological study of a seventeenth century shipwreck located in Angra Bay, Terceira, Azores.
2001 RPM Nautical Foundation Internship. Intern.
Recording the hull of the late seventeenth-century slave ship *Henrietta Marie*, and conservation of waterlogged iron artifacts.
2000 Gault Site Excavation. Field School Participant.
Excavation of a prehistoric site in central Texas in a field school.

Employment

2002-2003 Graduate Assistant to Dr. Kevin Crisman, Nautical Archaeology Program
Texas A&M University, College Station, Texas
Editing, computer graphics, drafting, museum exhibit and display preparation.
2001-2002 Research Assistant, Conservation Research Laboratory
Texas A&M University, College Station, Texas
Conservation of waterlogged artifacts recovered from *La Belle*.