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## **The units of length in the Spanish treatises of military engineering**

### **(1) Introduction**

In this article we study the units of length used by the Spanish military engineers from the Renaissance up to the second half of the 19<sup>th</sup> century. To do that, we have considered principally the treatises published for the formation of these professionals.

Many different units of length had been used since the military engineering arose as a new profession in Spain until the full acceptance of the Metric Decimal System in the country. This variety of units was due, first, to the existence of several different kingdoms with their own units in what is nowadays Spain. Also to the fact that the Spanish troops fought in many European countries during the 16<sup>th</sup> and 17<sup>th</sup> centuries. Finally, to the lack of a national tradition in fortification.

At the same time, in Spain, as in other many countries, there was a trend to have a natural coherent system of measurements, reproducible and of easy use. The Crown wanted also the unification of the units of measurement of the kingdom, as in any other country.

To help the comprehension of what is exposed in this communication, it is convenient to begin summarizing the history of the units of measurements in Spain up to the introduction of the Metric Decimal System and the history of the Spanish military engineering.

### **(2) Summary of the history of the Spanish metrology**

A first metrical unification in the Iberian Peninsula took place during the Roman Empire. The Arab domination did not introduce big changes into the Roman units, except for some agrarian measures and units of weight.

During the Middle Ages the Christian kings defined their own system of units, similar to the old Roman system. First Jaime I in 1238 established the “vara de Valencia” (yard of Valence) as unit of this kingdom. In 1261 Alfonso X fixed the “Vara de Toledo” as the unit of length for Castile. The kingdoms of Aragon and Navarre had also their own “vara” (yard) during the Middle Ages. In Catalonia it was used the “cana” (cane, approximately two yards).

In 1512 the unification of the Kingdom of Spain was complete. Some years later, in 1568, the king Felipe II ordered to take the “Vara de Burgos”<sup>1</sup> as the official unit of the kingdom. However the yards of Navarre, Aragon and Valence and the cane of Barcelona and Majorca continued being used in these kingdoms.

The Bourbon dynasty begun to reign in Spain in 1700. In 1707 the old kingdoms of Aragon, Valencia and Catalonia loosed their specific laws. The kings of this dynasty were interested in reinforcing the Crown and in unifying the standards of measurement.

A Royal Order of 26 January 1801 is the first serious attempt of metric unification in Spain. But it is based on the old units. The “Vara de Burgos” was established as the unit of length for the whole kingdom of Spain.

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<sup>1</sup> It was called later “vara de Castilla” or “vara de España”. It is different of the vara de Toledo.

A law of 19 July 1849 given by Queen Isabel II established the Metric Decimal System as the official system of measures of Spain. A plan for the implementation of the new units was proposed. In 1880 the Metric Decimal System became compulsory in education, legal questions and commerce.<sup>2</sup>

### (3) Summary of the history of the military engineering in Spain

The modern fortification began at the end of the Middle Ages when the use of the gunpowder became general in European battlefields.

During the 15th and 16th centuries the most important military engineers of the king of Spain were Italians. Their position inside the army was quite vague. They could be dependent on the king or on the Council of War, or to be in a corps of the army and be subordinate to the Captain General or to the chief of the artillery.

In the 17th century the number and the quality of the military engineers coming from Italy diminished and some academies were created to form military engineers and to increase the number of Spaniards in the profession, with scanty results.

The situation changed with the first king Bourbon of Spain: Felipe V. He organized the military engineers, designating in 1710 the Flemish Verboom Major Engineer of the Kingdom (“Ingeniero Mayor del Reino”) and establishing the military engineers as a branch inside the army, but with only 27 members. This first group was formed mainly by Spaniards who have fought in Flanders and Flemish or Frenchmen serving the king of Spain.

In 1720 the Academia de Matemáticas de Barcelona began to work. Its aim was the formation of military engineers and its first teacher was the Italian Calabro. The Academy became the best way of acceding to this branch of the army.

During the 18th century the military engineers were also in charge of some civil works, as roads, harbours, bridges or some buildings. At the end of the century an Academy of Architecture and a School of Civil Engineering were opened in Madrid and the military engineers gave up these occupations.

In 1803 the Military Engineering became a normal branch of the army with battalions and regiments, as the infantry or the artillery. Till then they were only officials without troops in charge.<sup>3</sup>

### (4) The Italian period, until 1640

During the 16<sup>th</sup> century and the first decades of the 17<sup>th</sup> the military engineers working for the king of Spain were mostly Italians. They were professionals of renown as Spanochi or Terzi, and some times they belonged to the same family, as the Antonelli or the Fratin. Together with them there were some Spaniards as C. de Rojas. The kings Felipe II and Felipe III were interested in increasing the number of Spanish subjects in the profession and they promoted the formation of engineers. With this purpose some books on fortification were published in this period. The most famous are *Teórica y práctica de fortificación* (1598) by C. de Rojas, and D. Gonzáles de Medinabarba’s *Examen de fortificación* (1599). We have considered also other books such as *Sumario de la milicia antigua y moderna* (1607) and *Compendio de breve resolucion de fortificación* (1613) written also by Rojas and L. Scrivá’s *Apología en excusacion y favor de las fabricas del Reyno de Nápoles* (1538). We have taken into account *Tratado de la artilleria y de fortificación* (1611), written by C. Lechuga, although it is more on artillery than fortification, and some books on artillery such as D. Alava’s *El perfecto capitán* (1590), J. C. Firrufino’s *El perfecto artillero theorica y pratica* (1642) and the Catalan book *Breu tractat de artilleria* (1642) written by F. Barra during the revolt against the king of Spain. At the end of the 16<sup>th</sup> century and during the first decades of the 17<sup>th</sup> some good treatises of artillery were published in Spanish, but we have not taken into account more books about artillery because they use fundamentally the diameter of the bullet as unit, as it is said in Lechuga’s book “it is in the pieces the

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<sup>2</sup> For the introduction of the Metric Decimal System in Spain you can see AZNAR GARCÍA J. V. (1997): *La unificación de los pesos y medidas en España durante el siglo XIX: los proyectos para la reforma y la introducción del sistema métrico decimal*. Doctorate thesis (Universitat de València).

<sup>3</sup> About the history of the military engineering in Spain see, for instance, *Estudio Histórico del Cuerpo de Ingenieros del Ejercito* (Madrid: Sucesores de Ribadeneyra, 1911).

bullet that, with its diameter it forms the scale” (p. 43).<sup>4</sup> However for some questions, as the range of the shots, they used common length units.

In all these books the foot is the principal unity of length because these authors found it quite universal. As C. Rojas wrote:

Because fathoms<sup>5</sup> and canes are not constant measures, because in every province they are different, [...] what it does not happen with the Geometric feet that are everywhere of a same measurement (1598, f. 36 r).

They knew that actually a foot was not of the same length everywhere; but with other units the problem was bigger. The pace, for instance, had from two to five feet, depending on the author and the country. The character anthropomorphic of the foot made it, to some extent, universal and reproducible. If more precision was asked some authors mention the legal pattern of Castile, as Medinabarba does:

For being the measurement more common and known everywhere: because, though I find some difference in feet, those that here we treat are Castilian Geometric, that are the more accepted (p. 84).

Firrufino is who states clearer that he will use the “Castilian yard, doctrine that has been observed in Castile”.

When looking for a standard foot some writers refer to the old Roman unit. This is very net in Alaba who explains “all the measurements that commonly recount the Latin authors” (p. 374)<sup>6</sup> giving eighteen different Roman units, such as “pes”, “uncia”, “digitus”, “palmus”, “cubitus”, “pasus”, or “pertica”. These authors knew that many different measurements were used in different countries and they mention several. For example, Medinabarba cites the foot of Urbino, Ancona or Hungary, the yard of Rome or the cubit of Tuscany, and Lechuga mentions “feet, rods, fathoms, trabucos<sup>7</sup> or canes” (p. 433). On the other hand, even if the foot was taken as the principal unit of length, in practical questions they use other units. For instance, Rojas employs in his book often the yard and Alaba gives the results of the measurements frequently in paces. Lechuga, who lived in Milan, when gives the dimension of the wooden parts of a gun-carriage he uses unities of Brescia or Milan, such as “the forearm that in Milan the carpenters and bricklayers use” (p. 153). But they do not give their values in Castilian feet. In general they are not worried by the lack of precision and they assume that in fortification the measurements are given roughly (“medidas grosso modo” (Rojas (1598), f. 36 r)).

At the end of this period Firrufino, professor of the Chair of Mathematics and Artillery of the Captain General of the Artillery in Madrid, showed some concern for the conversion of measurements and when commenting the book of Lechuga he informs he is giving the “measurement in the forearm from Milan converted to the Castilian yard”. In general, the book of Firrufino shows more interest in precision than the previous books. There is an important section at the end about the mathematics needed for the military arts. He explains there the units of lengths used in Castile beginning with the barleycorn, and following with the digit, palm, nail, foot, yard, and geometric pace (f. 184–185). The last units of this series are the itinerary units as the Spanish league, the Italian mile and the Greek stadion. He is the first writer of military books that presents such a long list.

Rojas, Medinabarba, Alaba, Lechuga or Firrufino were subjects of the kingdom of Castile. We have considered for this period the book of Scribà, born in Valence, and Barra, from Barcelona that were not from Castile. Scrivà did not use the yards of Burgos. In his book the lengths are given quite often in cane and palms, units used in the countries surrounding the Mediterranean Sea. Barra published his book one hundred years later. Although he fought against the king of Castile, he follows in his book principally the theories of Firrufino and he gives the measurements in feet and geometric

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<sup>4</sup> The pages for the citations of Lechuga are of the reissue of 1990.

<sup>5</sup> We use also “Toise”, “Toesa”, “Braza” or “Cana”. It was more or less six feet.

<sup>6</sup> The pages are taken from the reissue of 1994.

<sup>7</sup> The Trabuco was approximately 10 feet.

paces, as him. However when he is writing about the results of the experiences that he had done in Catalonia the values are in canes and palms the usual unities of length of Catalonia. The Castilians, on the other hand, generally ignored the unities of Catalonia or Valence. Rojas, for instance, includes the cane between the foreign units.

## (5) The Dutch period, until 1700

From 1640 until the end of the century the Spanish writers of fortification followed Dutch authors, such as Marolois, Goldman, Dogen or Freitag. During the first decades of this period, more or less until 1670, this influence was very important, but during the last decades of the century the French writers acquired more importance.

Belonging to the first half of this period we have studied the books: *Tratado de Fortificacion Militar* (1644) by J. Santans y Tapia, M. Fernández de Villarreal's *Arquitectura militar o Fortificacion moderna* (1649), *Academia de fortificacion de plazas* (1651) by D. Enriquez de Villegas, *Compendio de Modernas Fortificaciones* (1657) by G. Afflitto, *Epitome de la fortificación moderna* (1669) by A. Zepeda y Adrada, and P. A. Folch de Cardona's *Geometria Militar* (1671).

For the majority of the writers of these years (Santans, Enriquez, Zepeda and Folch) the standard unit of length in fortification was the Dutch rod or "Verga holandesa". Santans (p.122) specifies it proposing "rods of twelve geometric feet each one". However they continue supporting the foot as a basic unit. As before in the books they usually does not specify the kind of feet used, though Enriquez de Villegas informs in some cases that he is using the "Rhine foot", the foot of Brussels or the Dutch foot.

The treatise written by the Italian Afflitto is an exception. He proposes:

Because the measurements are different in diverse Kingdoms and Provinces, where some ones measure in forearms and some others in rods, we will take to regulate our fortifications the geometric foot that five compose a pace (p.10).

Another exception is the book of Fernández de Villarreal (1649). This volume is the Spanish translation of the treatise of the French Jesuit Georges Fournier. For this reason the units used are mostly French, as the "toise", more or less equivalent to the fathom. Nevertheless in some plates he uses also the Dutch Rod.

During these decades the precision asked in the measurements continues being scanty. For example Santans writes:

Though they exceed by some fractions in some lines, for not being a very considerable quantity, and for excusing anger it is not put here. The one who want to fit them can do it by a rule of three (p. 118).

The book of Folch de Cardona is the more learned of these editions. E was the only one worried for multiples and submultiples, giving a list (p. 7) similar to Firrufino's, in his book.

The Spanish fortification changed in some aspects during the last three decades of the 17<sup>th</sup> century. The Crown tried to promote again the formation of Spanish engineers and a number of religious, principally Jesuits, wrote some books on fortification. On the other hand the theories of the Dutch authors began their decline and the doctrines of Frenchmen, as De Ville, Pagan and, at the end, Vauban, began to be followed.

From this period we have considered: V. Mut's *Arquitectura Militar* (1664), A. Dávila y Heredia's *Clavel Geométrico de Medidas* (1669), J. Zaragoza's *Fabrica y uso de varios instrumentos mathematicos* (1675), J. Caramuel's *Arquitectura Civil Recta, y Obliqua* (1678), the treatises *Rudimentos Geometricos y Militares* (1677) and *El Ingeniero* (1687) written by S. Fernández de Medrano, *Theses Mathematicas* (1688) by I. Manrique de Lara, the anonymous book (attributed to J. Chafrión) *Escuela de Palas* (1693) and F. Larrando de Mauleón's *Estoque de la Guerra, y Arte Militar* (1699). Though they were published in the first years of the 18<sup>th</sup> century, the books *Escuela Militar de fortificación ofensiva y defensiva* (1705) written by the Jesuit J. Cassini and the part of T. V. Tosca's *Compendio Mathematico* (1712) about fortification (vol. V) can be considered also inside this group of publications.

The authors of this period are more worried by the precision than the writers of previous times. That is shown by the fact that they specify which is the standard of foot they used, and by the inclusion of tables with the conversions to their standard foot of the units of length of several countries. This does not mean that they demand a lot of accuracy in their calculations. For instance, Caramuel in his book, dedicated principally to the civil architecture, wrote about the divisions of the foot:

The Foot is not divided when it is a question of fortifications; because a town never got lost for having been a Curtain (a Bastion, a Demi-lune and c.) few fingers shorter or less high (p. 45).

The foot is the basic unit of length for these authors, as before. The Cistercian Caramuel explains it saying in Latin “Omnes measure à pedes pendent” (p. 44), that is all the measures are hanging by the feet. These writers specified in their books the concrete foot that they were using as the unit of length. Surprisingly, the unit more accepted is not the foot of Burgos, used by the Spanish Crown. Only Cassani states clearly that in fortification it must be used the foot official in the kingdom. A great majority said that the standard unit for the military engineering has to be the former Roman foot. However, there is no uniformity with regard to its value. The writers who lived in Flanders and a good part of those who worked in Italy and even in Spain (Mut, Caramuel, Medrano, *Escuela de Palas*, Mauleón) believed that the Roman foot was that engraved in the “marble Colatino”. This was the value proposed by Snell in his writings and it was equal to the Rhine foot, used in the north of Germany, in the Netherlands and in the North-East of France. But the writers born in the kingdom of Valencia (Zaragoza, Tosca) supported that the former Roman foot was the foot of “Congio”, slightly longer, and equal to the foot official in the kingdom of Valence.

In spite of the general acceptance of the Roman foot as the unit of reference, it is not used as unit in practical questions in many books. Mut, for instance, prefers “the geometric pace that consists of five feet for being the more employed measure” (p. 5). Zaragoza uses feet and paces, Medrano (1687, p. 7) feet, but those of Paris or Brabante “that we use commonly in Germany, France and Flanders” (p. 7).

Another question that shows a bigger worry for the precision of the measurement is the presence in many books of this period of tables of conversion between units of different regions. Mut, for instance compares in his book the palm of his natal Majorca with the old foot of Rome, the palms of Castile, Barcelone, Valence and Montpellier, and the feet of Bolonia, Paris, Venice, Amsterdam and London. J. Zaragoza gives the values in foot of Valence, of the feet of Majorca, Barcelone, Amsterdam, Castilia, Dantzic, Köln, Bayern, Antwerp, Denmark, Goes of Zeeland, Middelburg, London, Prague, Rhine, Viena, Turin, Naples, Dordrecht, Briel, Paris and Verona. Caramuel suppose the Rhine foot equal to 1000 and indicates the corresponding value in that unit of the feet of: Amsterdam, Antwerp, Dutch, Bremen, Briel, Dordrecht, Goes, Hanse, Lithuania, London, Louvain, Mechelen, Middelburg, Nuremburg, Paris, Poland, Toledo, Venice, Ciren, and several more, including eight feet used in the Antiquity as the Greek or Babylonian. In the book *Escuela de Palas*, and the treatises of Mauleón and Tosca a long list of feet and their equivalent values can be also found.

In this period several authors (Caramuel, Medrano, *Escuela de Palas*, Mauleón, and Tosca) underline the importance of using decimals for the calculations. They proposed the “foot decempedal”, that is the one obtained when the “verga” or Dutch Rod is divided in 10 parts instead of 12.

## (6) The French period, until 1801

In 1700 when the last king of the Spanish Habsbourg, Carlos II, died, Felipe V was nominated king of Spain, as was stated in the testament. He was the first king of the French dynasty of Bourbon. The Habsbourg of Austria, and the kings of England and Holland were against this nomination and the war of Spanish Succession begun. It lasted from 1701 to 1715. The French and Spanish Bourbon won the war. The kingdom became more centralized and the Spanish army was deeply changed.

The military engineers were organized in 1711 as a branch of the army, though with officials only. Some regulations were published to unify the activity of the engineers of the royal army. One of them is the Ordinance of 4/ 6/ 1718 that is of great interest in this study. There it is said:

26. [...] and for the measurements they will use the fathom / and foot of France, as it has been referred in the Article 14, in order that being general and common in the whole Spain, they would be avoided / the doubts and confusions that cause the ordinary measurements of every province.<sup>8</sup>

Another important question was the establishment of the *Academia de Matemáticas de Barcelona* to prepare the new military engineers. Its first professor was Mateo Calabro, a follower of Vauban.

On the other hand, the new dynasty tried to improve and reinforce the authority and the control of the king. For that the Crown needed to unify the standards of measurement used in the kingdom. This was possible only stimulating the use everywhere of the traditional patterns of Castile, as the foot or the yard of Burgos. This action and the utilization of the fathom as the official unit of length in military engineering were contradictories.

We have studied *Tratado de la defensa de las plazas que escribió Mr. de Vauban* (1743) prepared by I. Sala, *La gran defensa, nuevo método de fortificación* (1744) by F. Prospero, the notes of the course given by M. Calabro in 1633 *Tratado de fortificación o arquitectura militar* (1992), M. Centurion's *Ciencia de Militares* (1757), *El Arquitecto Practico, Civil, Militar y Agrimensor* (1767) by A. Pló, P. Lucuze's *Principios de fortificación* (1772), J. Muller's *Tratado de fortificación* (1769) translated by M. Sánchez Taramas, the Spanish version of Leblond's *Elementos de Fortificación* (1776) and the part on fortification of the *Compendio de matemáticas* (v. 6, 1791) by F. X. Rovira. We have considered also the *Curso Matemático*, t. V, *Prácticas de Geometría y Trigonometría* (1784) by the professor of mathematics of the Academia de Artillería de Segovia P. Giannini.

Together with this treatises P. Lucuze's *Disertacion sobre las medidas militares: que contiene la razon de preferir el uso de las Nacionales al de las Forastera*<sup>9</sup> (1773) and the *Memoria elemental sobre los nuevos pesos y medidas decimales* (1800) written by the officer of the Navy G. Ciscar are also important for our study.

During this century, from 1720 until 1750, the books about fortification used the fathom, that is the French "toise", called in Spanish "Toesa". This unit of length was employed by Calabro in his courses and is also in Sala's treatise. Even Prospero who was born in Italy and wrote and published his book in Mexico used the Toesa.

The situation changed when the king Fernando VI, looking for the generalization of the units of Castile to the whole kingdom, ordered the use of the yard of Burgos in military questions, instead of the fathom, by an Order given the 14/ 7/ 1750 and completed by a Circular of the 25 of that month specifying its application. The head of the Academia of Barcelona from 1738, the Spaniard Pedro de Lucuce, helped this return to the Castilian system. This order had its reflex in the treatises of fortification. For instance, Centurión uses the Spanish yard, except for citations.

During the 18th century it was quite usual that the military engineers were in charge of public works, like roads, channels, ports or some buildings. For these civil works the foot or yard of Burgos was more convenient, even before Fernando VI. A. Pló in his book about civil and military engineering proposes their use:

because in the majority of Provinces the foot is the measurement more universal, and this it is in some major and in others minor [...] I use of the foot of Castile [...] The ordinary measurement is a yard, which length is of 3 feet, and it is usual in this Kingdom of Spain (p.106).

But the French fathom had been the unit used by the military engineers in practical works during more than 40 years. To change the habits is always difficult and it was some resistance against the "vara de Burgos". In 1760 the new king Carlos III ordered the use of the toesa for the fortification, leaving the Spanish yard for the "buildings and civil things" (Lucuce, 1773, p. 67). A discussion

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<sup>8</sup> J. A. Portugués, *Colección General de las ordenanzas militares*, p. 766/767.

<sup>9</sup> That is: "Dissertation on the military measurements: that contains the reason of preferring the use of Nationals to that of the Foreign ones".

followed and in 1768 the inspector of the military academies asked to Lucuze, his opinion. His answer was published in 1773. Lucuze defends the use of the “vara de Burgos” and the measurements of Castile. He explains that the problem of so many different unities can not be solved adopting a new foreign unit for military questions. He adds that the coherence of the kingdom of Spain was asking a unification of the systems of measurements, saying: “The idea of the equality is directed by the political maxim that a Nation’s body become firm, sure and permanent by the unity of the Religion, of language, of laws, of measurements, of coins, and of customs” (p. 82). He think the yard of Castile is the best pattern for this unification. He can accept others, as the yard of Valence, but not a foreign unit as the toise or toesa.

The defence of the Spanish unities by Lucuze had an important failure: the length of the yard of Burgos was not known with accuracy and that of the French toesa it was, because it had been measured accurately by the French *Académie Royal des Sciences*. On the other hand, in Spain in this century there was not any workshop capable of reproducing the yard standard in sufficient quantity for the needs. In fact, the precision of the yard was subordinated to the toesa, as it is said in the book of Muller:

By test and check that by order of the Señor Rey Don Fernando VI, were done on the foot of Castile and on that of Paris by the Chief of Squadron Don Jorge Juan and other mathematicians of credit, it was decided that 6 feet of Paris taken together are 7 of Castile. (p. 123)

Therefore, the precision of a measurement in Spanish yards was depending on the value of the foot of France. This was later one the reason that gave Ciscar to promote the meter and not the “vara” as unit of length in Spain in his book:

H. M. Don Fernando VI's Royal Resolution, seeking that in the dependences of War and Navy would be used the yard of Burgos, supposing that seven of its thirds or feet were equal to the toesa of Paris. This is equivalent to take this foreign unit as standard for the Spanish measurements. (p. 40).

The head of the engineers P. M. Cermeño ordered in 1768 the use of the yard of Castile in maps and designs, but the use of the French toise or fathom continued in fortification until the 19<sup>th</sup> century. Among the books of fortification published after 1768, Lucuze used the Spanish yard as unit of length. So did Sanchez Taramas in his translation of the book of the professor of the Academy of Woolwich J. Muller, telling at the beginning:

The measurements, as fathom, yard, foot and c. that one mentions frequently in the speech of this Work, must be understood that they are relative to the framework of Burgos, to whom those of the original one have been reduced, exempting those who are explained in some definite passage, like belonging to other Kingdoms or Provinces.

Nevertheless, in the translation of the last edition of a Leblond's treatise the toesas are used everywhere. The professor of mathematics of the Academy of the Navy in Cadiz F. X. Rovira used also toesas in his book.

During this century the military engineers were better structured and trained, and they did not need reading foreign books as before. On the other hand, the kingdom had lost their possession in Europe. As a result of that the authors of the books of fortification had little concern with the values of unities different of the Spanish yard or the French toise in the 18<sup>th</sup> century.<sup>10</sup> Only P. Giannini’s book contains some long tables with equivalences between different unities. Among them there is one in which are given the values of the feet of 73 different places, taking as reference the foot of Paris, measured by the “Royal Academy of Sciences of Paris”. In the table there are four regions of Spain, sixteen places of France, thirteen of Germany, twelve of Italy, three of the Netherlands and another three of Belgium, two of Poland and Switzerland and one of Denmark, England, Portugal, Macedonia, Czech Republic, Sweden and Austria. Out of Europe only Cairo and China appear. The American possessions of the

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<sup>10</sup> Of course, in Muller’s book the equivalence of the Spanish yard with the English one is given.

king of Spain do not figure because they had the same system of units as Castile. There are also other tables with equivalences of diverse yards and with regional units of Spain.

From 1790 the situation changed. The French Revolution promoted the creation of a new universal, natural, reproducible, practical and decimal system of measurements. Some Spaniards took part in the committees and meetings carried out with that aim. The officer of the Navy José Mendoza y Rios collaborated with the first works in Paris in 1790 and 1791. Later, in 1792 and 1793, the lieutenant of the Navy Jose Gonzalez collaborated with Méchain in measuring the meridian in Catalonia. The captain Gabriel Ciscar, member of the Navy, went to the International Meeting of Paris of 1798, together with the mathematician Pedrayes. In the prolongation of the measurement of the meridian up to the Balearic Islands that begun Machain in 1802 and continued Biot and Arago from 1806 until 1808, collaborated the mathematicians José Rodríguez y José Chaix and the Spanish Navy with the brigantine La Prueba. The help of the Spanish military engineers in all these works was very scanty. The professor of mathematics of the Academia de Matemáticas de Barcelona Agustín Bueno, collaborated with Méchain in 1792, but in general the role of the engineers was very modest.<sup>11</sup>

## (7) The last period, until the success of the Metric System

At the beginning the Metric System was not accepted in Spain. The Crown preferred to adopt the old measures of Castile. The R. O. de 1801 fixed the yard as the legal unity of length in Spain and in its colonies. The reasons for adopting that system were political. The government was afraid of anything coming from the revolutionary France. Afterwards, when the brother of Napoleon became king of Spain and a revolt took place, there were also patriotic reasons. However, as time went by the Spanish national system was difficult to maintain and the Metric System became a practical system first, that, in 1849, was finally adopted in Spain.

The military engineers were not very involved in the metric discussions of these decades. We have studied: *Tratado de Castramentación* (1800) written by Vicente Feraz, *Tratado completo de Arte Militar* (1812) by José María Vallejo, *Curso Elemental de Fortificación* (1827) by Andrés Vallejo and Francisco Serrallach's *Tratado de fortificación* (1813?). In these books the Spanish vara is commonly used. Only Serrallach uses sometimes the old French Toesa.

From 1849 onwards the legal system in Spain was the Metric Decimal System. We have studied Frutos Saavedra's *Fortificación del relieve* (1855), *La fortificación moderna* (1860), by Emilio Bernaldez, and J. Wurmb's *Tratado de arquitectura militar* (1857) translated from the German. The first two use the meter. Saavedra, for instance says: "all the dimensions will refer to the metric decimal system, ordered to adopt in Spain" (p. 3). But in J. Wurmb text the original units are kept: "The measurements and the weight of all classes that are mentioned in this writing, are used in the Empire of Austria" (p.11). Consequently the "klafter" or "toesa" is used everywhere, and a table with the conversions between the Austrian units, the new metrics and the old Spanish ones is given at the beginning.

In the last decades of the 19<sup>th</sup> century, in books as Joaquín de La Llave's *Fortificación de Campaña* (1880), the anonymous *Nociones de fortificación de campaña* (1882) or José María Soroa's *Lecciones de Fortificación* (1886) the Metric Decimal System is used everywhere, without any problem.

They were not big differences between the military engineering and other professions when incorporating the Metric Decimal System. The autonomy that the profession had had during past centuries did not exist in the 19<sup>th</sup>. However, as in other social sectors there were some engineers reticent to the acceptance of the new system. In 1853 the professional magazine *Memorial de Ingenieros* published an anonymous article entitled "Observaciones sobre el Sistema Métrico Decimal" against the new units. It was criticized the imprecision of the measurements of the quadrant of meridian, also the cacophony of the proposed names. The advantages of the decimal division were accepted, but only for the scientists. It was affirmed that for common people it was easier the old system with halves and quarts. Besides it is said that the Metric Decimal System is a product of the "scientific revolutionary

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<sup>11</sup> For the collaboration of Spaniards in the implementation of the Metric Decimal System see A.E. TEN, (1989): "El Sistema métrico decimal y España", *Arbor*, nº 134, p. 100–121.



fever” of France. Though this article shows the existence of an opposition to the new units among the engineers, it was not the opinion of the majority, since this journal agreed to publish the same year a response defending the metre written by the teacher of mathematics Antonio Suárez in spite of the fact that the collaboration to the *Memorial de Ingenieros* was open only to military men.

The introduction of the Metric Decimal System into the Spanish military engineering was more complicated than in other professions. If highlighting two aspects of this evolution we would take the importance that the theories had had in the units that had been adopted and the consequences that the lack of a strong organization had in the abundance of different units existing simultaneously during several centuries.