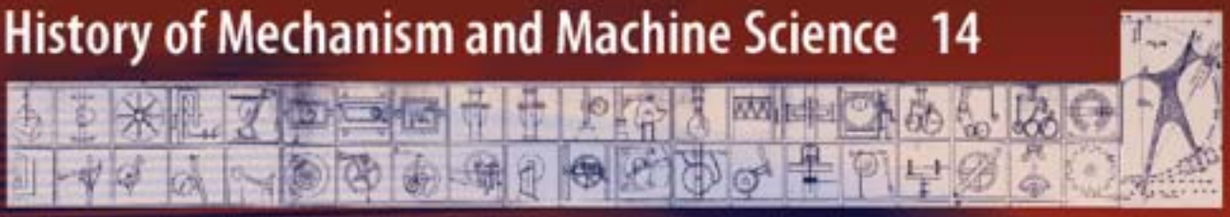
History of Mechanism and Machine Science 14



J. M. de la Portilla
Marco Ceccarelli *Editors*

History of Machines for Heritage and Engineering Development

Springer

History of Machines for Heritage and Engineering Development

HISTORY OF MECHANISM AND MACHINE SCIENCE

Volume 14

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History of Machines for Heritage and Engineering Development

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Preface

This volume contains a selection of papers whose content have been presented in the International conferences CIPHI on Cultural Heritage and History of Engineering in the years 2006, 2007, and 2008 at University of Las Palmas de Gran Canaria in Canary Islands, Spain, The organizers of these yearly conferences are The International Centre for Heritage Preservation (CICOP) and the Polytechnic Faculty of Engineering (EUP) with co-organizing institutions as Forum UNESCO University and Heritage and the TICCIH Spain. The International Centre for Heritage Preservation was created in the Canary Islands in 1992 with the aim to have an headquarter point of coincidence in Spain between Europe and Latin America.

The conference series is aimed at bringing together researchers, scholars and students from the broad ranges of disciplines referring to the History of Engineering and Cultural Heritage, in a unique multidisciplinary forum to stimulate collaborations among historians, architects, restaurateurs, and engineers.

The aim of the book is to collect contributed papers within an interdisciplinary framework that can serve as reference on history of machines for heritage and engineering development, as indicated in the title. The book scope has the characteristic that the papers illustrate, by attaching specific emblematic topics and problems, technical developments in the historical evolution of engineering with an attention of cultural heritage. Thus, emphasis is given to a discussion of matters of cultural heritage with engineering history by reporting authors' experiences and views. Indeed, most the authors of the contributed papers are experts in different topics that usually are far from each other. This has been, indeed, a challenge: convincing technical experts (engineering and architects) and historians to go further in-depth into the background of their topics of expertise with both technical and historical views to the problem of the conservation of material and immaterial goods of cultural heritage as related to the history of machines and engineering.

This volume has been possible thanks to the invited authors who have enthusiastically shared this initiative and who have spent time and effort in preparing the papers in much more details that in the conference presentations.

We believe that readers will take advantage of the papers in this book and future ones by supplying further satisfaction and motivation for her or his work (historical or not) with interdisciplinary activity in valuating the past heritage both in goods and engineering developments.

We grateful to the authors of the articles for their valuable contributions and for preparing their manuscripts on time. Also acknowledged is the professional assistance by the staff of Springer Science + Business Media and especially by Miss Anneke Pot and Miss Nathalie Jacobs, who have enthusiastically supported this book project with their help and advice.

We are grateful to our families. Without their patience and understanding it would not have been possible for us to work on this book and coordination of so many people from different fields of activity.

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Reutilization of Our Industrial Heritage: The Unique Example of the Royal Segovia Mint in Spain (1583)

Glenn Stephen Murray Fantom

In this conference we will explain the reasons for which the Royal Segovia Mint is considered to be the world's oldest, most complete, still standing, complex, departmentalized industrial manufacturing plant designed for in-series, mechanical production. We will also review the project currently under way to convert the historic site into a living workshop museum of coining technology (Fig. 1).

1 Introduction

No industrially manufactured product has been more important to the development of civilization as a whole than that of coinage. Coins -and by extension money- have been the workhorse of mankind for over 2,640 years. It is a manufactured product which has liberated virtually every person on earth from the tedious chore of having to tend to our own crops in order to simply eat, and thus enabling the multifaceted society which we know today.

Product security has always been the primary concern of governments in the manufacture of coinage from its very invention around 640 B.C. even until today. Every improvement made in the technical process for its elaboration has been purposefully designed specifically to insure product quality and its inviolability once placed in circulation. Indeed, each individual example of this industrially manufactured product was used day in and day out by an infinity of people, as it was passed from one hand to another over an extensive geographic range, for dozens and often up to hundreds of years before finally being melted down, lost, hidden, or eventually winding up in a museum or private collection. Contrary to many other industries, almost all new production techniques were specifically implanted in order to assure governments of this product quality or security, rather than to reduce labor force or cut production costs (Fig. 2).

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Fig. 1 Photo of the Segovia Mint in 1870, one year after all coin production ended (Photo: Laurent, 1870 (I.P.H.E., Madrid))

Fig. 2 Coins with different types of edges. Hammer struck pieces with irregular edges facilitated illicit clipping and filing of metal

Primary in the assurance of a quality product has always been the goal of making each coin not only resemble identically the others of its kind, but to adhere to the exact same specifications regarding weight, fineness, stamped design, etc. Indeed, the principle interest of any government concerning its coinage has always been to avoid its illegal falsification, a truly unique product concept not really appreciated

until modern times. Today we see the falsification and sale of designer watches, apparel, cosmetics, entertainment CD's, etc. As a result, the one factors most important in producing a quality coinage has been the inception of in-series production, and the primary key which has enabled this important goal has been the mechanization of the coining industry, a technological achievement now over 440 years old.

Whereas coin manufacturing plants, or mints, have always been rigorously controlled by governments to assure quality, the mechanization of this process did not begin until around 1551. The origins of this major improvement are to be credited to German technicians from the city of Augsburg, where 100 years earlier, Guttenberg invented the printing press. Slowly spreading to a few mints in the surrounding area on an experimental basis, we can say that the first truly successful mint mechanization project was at the factory in Hall in Tirol, Austria (1567), from where this procedure was soon transferred to the Spanish city of Segovia (1584), in what is considered today to have been the largest, most important and distant transfer of sophisticated industrial technology ever undertaken by mankind up until then.[1] Today, the Royal Segovia Mint is recognized by TICCIH-Spain as the oldest still-standing industrial monument in Spain.[2]

As a general conclusion to this paper, we propose that authorities recognize the Segovia Mint as the world's oldest, most complete, still-standing, complex, departmentalized, industrial manufacturing plant, specifically designed from its origin for in-series, mechanical production of one of mankind's most important, oldest, highly regulated and controlled precision products of exacting specifications: coinage, the single manufactured product used by more people, over more time, than any other ever invented by mankind.

2 Industrial Products of the Sixteenth Century

In order to fully understand the relative importance of coinage as an industrially manufactured product in the sixteenth century, it is necessary to first review the nature of other products produced during the same period of time. We will use the sixteenth century as our base reference point, since that is when the coinage process was first mechanized, and also when the Royal Segovia Mint was built. Therefore this is the period in which we will intend to show that the industrial procedure used in coin manufacturing was the most sophisticated ever used in any industry.

To begin with, the manufactured products of those times were basically limited to relatively primitive manipulations of raw materials such as agricultural grains, textiles, metals, basic chemicals, wood, leather, paper and glass. Production was carried out in simple artisan-like work shops, with a minimum of hand-tools such

[1] García Tapia (1989).

[2] General Assembly of TICCIH-Spain, in Tarrasa (Barcelona), on October 22, 2004.

as hammers, saws, scissors, chisels, bellows, and the like. Occasionally, successive steps were carried out by different people in their own homes or workshops, each passing the unfinished product to the next, but organized manufacturing plants were simply not needed. Many different hand-tools were used, but machines were almost unheard of except for those used to mill, grind or roll, and these were generally powered by hand except in the most sophisticated cases where horses or water wheels were geared by wooden mills to move simple rollers, grinders, or pounders.

Agriculture is said to have been the first industry and the processing of its raw products was undoubtedly the first to benefit from mechanization. Grinding and pressing of grains, olives, sugarcane, etc. with wind, water and horse-powered turnstones, was very common. These procedures were well established prior to the sixteenth century, but were never more than simple tasks able to be performed by one person with no specialized skills in relatively small non-complex factories.

In the mid fifteenth century Gutenberg invented the printing press with movable type, without a doubt a great step forward for mankind. The resulting product -printed pages and books-, though obviously produced in-series, were made in small artisan-like workshops and large staffs of different highly specialized technicians, or departmentalized manufacturing plants, were simply not required.

The production of textiles is also an ancient craft which required no specialized skills or machinery, though different steps were often carried out by different people, often organized, each in their own home or workshop. Looms were primitive and manual. Certain government imposed specifications, often quite detailed, were applied to the manufacturing procedure in order to assure a quality product, but none of these can compare to those imposed on the coining industry, which of course used gold and silver as a raw product, not wool or cotton. Regarding textiles, no industrial or manufacturing plant was needed until the mechanization of the process took place towards the end of the eighteenth century, leading to what we know today as the Industrial Revolution.

Metallurgical products -among which we find coinage- were quite varied in the sixteenth century, and their manufacturing procedures were, without a doubt, the most sophisticated of those times. Specialized plants worked to extract metals from ore or mineral, often refining them to a specific degree. Completely different plants specialized in manufacturing consumer products from the raw metal. Metallurgical expertise, though basically empirical in nature, has been fundamental in the advancement of civilization. However, complex manufacturing plants for in-series mass production of consumer ready products did not come about until the Industrial Revolution was well under way.

Smelters were plants where the raw ores were fused in order to extract the metallic constituents. Documents from as early as 1335 attest to the fact that these factories in northern Spain had water wheel driven drop hammers. By the sixteenth century, there were over 200 of these smelters in the Basque country alone, each one producing up to 100 t of iron a year. The factories were often quite large, had their own weir, canals and as many as six large water wheels. There were separate departments for the drop hammers, bellows, charcoal bins, warehouses, living quarters for up to 20 or more workers, etc. Vast quantities of charcoal and mineral were

needed, and were often transported locally in specially designed boats. These operations were quite expensive to set up and run. After the fourteenth and fifteenth centuries the installations were gradually modernized and enlarged with bigger water wheels and drop hammers. The wooden canals used in the fifteenth century were replaced by stone canals towards the eighteenth century. Successive modernizations almost always obliterated or buried the remains of the previous plant to such a point that practically all of the ruins existing today date from the eighteenth century (Fig. 3).

Smelting plants were extremely important as a raw source of metal for other industries. These were quite possibly the factories that most resemble what we could call an industrial complex of the sixteenth century. But the process -though mechanized with drop hammers and bellows- technically speaking, was empirical in nature, requiring a specific skill, but not complex in that numerous very different highly specialized experts were needed. We should also consider that their final product was not a finished consumer-ready item (such as coinage), but a raw material -metal- that was later used by various other industries that subsequently produced the final product. Nor can the production of these smelting plants be considered an item mass produced in series. Indeed many historians of industry consider smelters to be examples of paleoindustry. For all these reasons, we should not confuse the smelting industry and its often large plants, with the type of industrial process being carried out at the Segovia Mint in the 1580s, and its highly complex, departmentalized manufacturing plant.

Refined metal served as a raw product for other industries, such as those which produced tools like saws, hammers, chisels, agricultural utensils, nails, sheet metal, wire, etc., produced by blacksmiths in small artisan-like forges or workshops. None

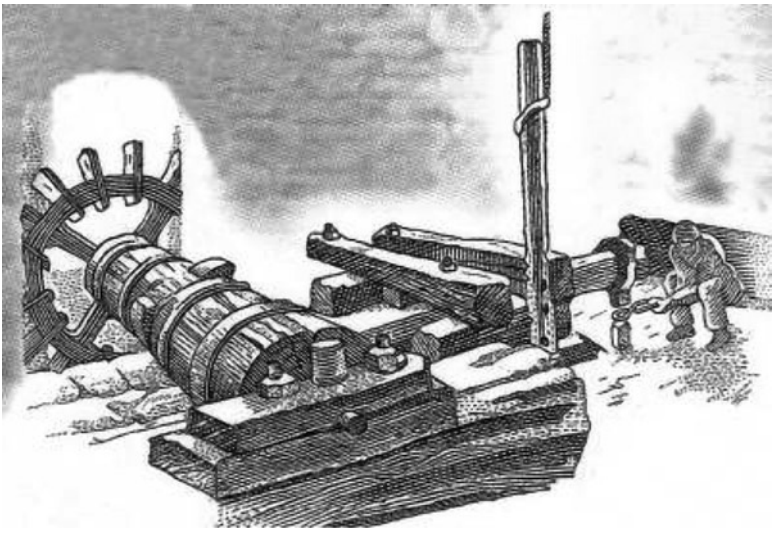

Fig. 3 The smelting plant at Compludo, Leon (Spain)

of these products were mechanically produced in-series until the Industrial Revolution. Jewelers and silversmiths have handcrafted magnificent works of art since the times of ancient Egyptians, Aztecs and Inca, and by the sixteenth century many of these were indeed quite elaborate. But these items were not mass produced in series or by mechanical methods until the Industrial Revolution.

Weapons manufacturing in the sixteenth century, just as today, has always enjoyed great interest from governments, and thus from inventors, technicians, and business enterprises. Finding money to fund this industry, then as today, was rarely a problem. Light arms such as pistols, harquebuses, muskets and the like were all being produced with a combination of metallic and wooden components. Nevertheless, production was always carried out in small artisan like workshops each one dedicated to a certain part of the weapon -barrel, lock, wooden handle, etc.- and another assembled the pieces together. The workers were often organized into guilds. The entire process was manual except for the boring of the barrel which was typically done with a water wheel driven machine.

Roller-dies used for the mechanical in-series production of coinage beginning in the second half of the sixteenth century, were high-precision tools made from specially hardened Milanese steel, using the combination of expertise of two specialized technicians: a highly skilled smith, and a master engraver. These two professionals, together with their assistants, worked in separate and specialized departments of the industrial plant, or mint: the smithy and the engraving office. The difficulty of preparing these roller-dies, coupled with the fact that they could only be used in specially designed water-powered mills, represents the maximum expression of purposely designed product security ever achieved by mankind until then. Spanish King Phillip II (d., 1598) often said that the best guarantee that existed against the falsification of his coins, was that no one else had similar dies or machinery (Fig. 4).

In Spain, King Phillip II constructed a building in 1558 for the purpose of receiving the arms which were bought from individual producers, testing them one by one, and later storing them until their distribution. This plant was named the Royal Arms Factory of Plasencia de las Armas, in the Basque country, but the production of the weapons was carried out externally by different artisans, and the royal

Fig. 4 Segovia roller die (Madrid Mint Museum)

organization was limited to placing orders, supervising, testing, storing and distributing the weapons. Another royal gun factory was built in Oviedo towards the end of the eighteenth century where weapons were built and assembled, but in general this artisan-type of organizational system lasted until the nineteenth century. Interchangeable musket parts were not designed until 1785 (Le Blanc). Eli Whitney (1765–1825) after inventing the cotton gin also worked on interchangeable parts for weapons, obviously requiring much greater precision than the interchangeable type letters used by Gutenberg. Samuel Colt obtained a patent for his revolver in 1836, but by 1851 still was not able to produce interchangeable parts for this famous weapon. This type of in-series production depended on high precision machine tools, and of course the industrial plants which eventually housed this type of industry were subsequent and essentially define today what we consider a "modern factory". These inventions are of course much later in time than the Segovia Mint, a factory we propose to be called the first truly modern factory. Nevertheless, we mention them to emphasize the importance that mechanized precision had in the development of industry, while pointing out that both the weapons and the coining industries were heavily patronized by governments and thus of relative priority.

The heavy arms industry, such as the manufacturing of cannons was another metallurgical based process, composed principally of founding large pieces of bronze, and later boring their center. The construction of these pieces was somewhat difficult and cumbersome due to their size and weight, but not complex in nature nor did it require specialists other than a skilled founder and a few well trained assistants. These same founders could also make large church bells, anchors, and other similar items, but always using one-by-one, artisan-like methods. Small items were in fact made in-series since early times by using molds, but again the only expert needed was a founder and his assistants. The same can be said for the manufacture of side arms such as swords and knives, generally made by blacksmiths in small artisan-like workshops often equipped with water wheel driven drop hammers and grinders. None of these products were mass produced in-series in large manufacturing plants by a highly diversified staff of specialized technicians during the sixteenth century, as was coinage. And certainly none were as influenced by specific efforts aimed at designing product security, as was coinage.[3]

Chemical products ranged from gunpowder to dies for tinting, but these were relatively simple products whose procedures were mostly carried out in artisan-like workshops where different ingredients were ground and mixed. Other products like paper and glass were also simple in nature and not demanding of industrial plants, mechanized procedures, or highly specialized technicians. A machine to automatically manufacture glass bottles was not developed until 1907 (Owen).

Finally, we should point out that the Industrial Revolution itself is defined as the totality of the changes in economic and social organization that began about 1760 in England and later in other countries, characterized chiefly by the replacement of

[3]Special thanks to José María Izaga Reiner for his assistance on non-coining industries.

hand tools with power driven machines, as the power loom and the steam engine, and by the concentration of industry in large establishments.[4] In these respects, the Segovia Mint, as we will see below, with its mechanized in-series production technique was truly -as numerous historic documents attest- the vanguard industrial plant of its days, successfully fulfilling a wide range of complex operational goals nearly 200 years before the Industrial Revolution began.

3 The Case of Coinage

The manufacture of the first coinage is today attributed by some experts to merchants, and by others to government authorities, and dates from around 640 B.C. in Lydia (Turkey), when bits of metal (electrolyte: a naturally occurring combination of mostly silver and gold) of uniform weight were stamped with identical designs for easy identification as they passed from one person to the next. Regardless of which sector first invented coins, governments rapidly realized that the new invention was an ideal manner in which to pay salaries of distant troops and a safer and more effective way to amass wealth. Obviously, the mass storage of grain, animals and the like, over time, as well as their transport, or division into fractions, had serious drawbacks.

As a result of government intervention in the new product -whose importance is difficult to exaggerate- specifications for its production were quickly mandated. First to appear was a symbol to identify the city of origin: a mintmark. Next, coinage weights were standardized and metal quality, or fineness, was also quickly established. While early Greek coins were stamped with designs of animals or gods, Roman authorities wasted no time in putting the ruler's effigy on their coinage, a truly effective manner to show power and exercise authority over each and every citizen in times before other media could constantly remind people of who their ruler was, as well as what he looked like. Indeed, due to these early characteristics, we can venture to say that coinage was the first mass produced product to carry a symbol of origin or guarantee (mintmark) and the first means ever used for mass publicity or propaganda (the ruler's name and effigy) (Fig. 5).

Over the centuries, other improvements were gradually incorporated into coinage. An assayer mark or symbol was to appear on each piece to identify the person responsible for the proper fineness of the alloy used to strike the coin. The date of production appearing on each piece provided an additional method of control which was first begun in Spain at the Segovia Mint in 1586 and ordered at all other mints in 1588. The combination of the mintmark, assayer symbol and date on each coin struck enabled the easy identification of the workers responsible for the quality of its production, and thus facilitated their punishment in cases of fraud, no matter when or where the piece was found in circulation. Indeed, we can venture to say

[4] *Websters Encyclopedic Unabridged Dictionary*, Portland House, New York, 1989.

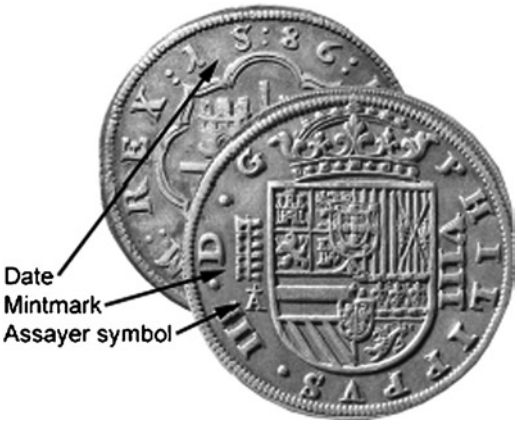

Fig. 5 National Museum of Archaeology, Spain

that coinage was the first mass produced product, intended for general use, which carried three different symbols or marks of guarantee, or government control, a truly modern concept in industry. Each of these individual improvements -regulated and controlled by way of specific mandates issued by the highest government authority as a matter of state- were carefully designed and implemented methods of assuring product security.

4 Problems of Early Coinage

During the first 2000 years of coinage production, the product had always been manufactured by the ancient hammer-struck technique. And though we can venture to say that at the dawn of the sixteenth century -the start of the Modern Era- coinage was perhaps the most sophisticated of all mass produced, industrial products, it was not without specific problems which needed to be solved. Among the most important of these were: obtaining an exact uniformity from one die to the next used for striking coins of the same kind; assuring that the design engraved on the die appeared fully on each coin struck; obtaining perfectly flat and uniformly circular blanks, all of the exact same weight; and perhaps one of the most important of all, finding a way to thwart the illicit art of those who clipped and filed bits of gold and silver from coins once placed in circulation; not to mention problems posed by counterfeiting (Fig. 6).

The solution to practically all of these problems was to be found in the mechanization of the manufacturing process. In this regard, it is important for us to realize that the primary goal of the minting industry has always been, and still is, the mass production in series of exactly identical pieces. The designing of product security in this industry has always been foremost in the minds of governments, inventors, and technicians. Considering the fact that the predominant value of coinage in