Machines and Signs

HISTORY OF MECHANISM AND MACHINE SCIENCE

Volume 17

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Edoardo Rovida

Machines and Signs

A History of the Drawing of Machines

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Contents

Chapter 1
Introduction

Interest among scholars in the history of science and technology (and, particularly, in classical mechanics) is today very high and still increasing. In this preliminary chapter, some general observations and a very short "state of the art" of the history of technology, as a background for the present book, are offered.

1.1 State of the Art

1.1.1 International Level

The first embryos of interest in the history of technology can be found in the literature of the beginning of the nineteenth century, particularly as history of manufacturing methods (D'Aubisson 1802; Barlow 1836) and of specific machines (Farey 1827) appears. The biographies of scientists and technicians and the history of inventions appear particularly interesting (Smiles 1861; Beckman 1784).

During the second part of the twentieth century, world-wide interest in our historical heritage in general, and in the scientific-technical field in particular, continued to grow, attested to by the publication of many papers on a wide range of machines, for example, in the magazine "Transactions of the Newcomen Society" founded in 1920.

Two monumental books, fundamental for the history of technology (Singer et al. 1958; Daumas et al. 1983), were published in the second half of the twentieth century. Papers linking engineering and history appeared in some engineering conferences (Gawrysiak 1995; Dowlen 1997; Calabrò et al. 1997; Tarelko 2006). Furthermore, in the twentieth century, associations and research groups interested in history of technology (http://www.historyoftechnology.org; http://www.icohtec.org) were founded, and in many universities a variety of groups participated in studies of the history of technology. For example, in the website (http://dmd.mpiwg-berlin.mpg.de/home) of the Berlin University, a great collection of Italian technical drawings of the fifteenth to sixteenth centuries is available.

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Another significant and very interesting realization of that period was the foundation and wide application of TRIZ (Michalewicz and Fogel 2000; Altshuller 1996; Orloff 2002), a method of inventing innovative solutions based on the laws of evolution of technical systems. Such laws were formulated by Genrich Altshuller, a manager of the Russian Patent Office in the mid-twentieth century, by critically analyzing a great number of patents. The number of patents submitted reflected the number of new ideas: therefore, the totality of patents is the "summa" of the history of technology. The application of TRIZ can hence be considered as a demonstration of the active role of our historical heritage in the development of new ideas.

1.1.2 Italian Level

During the last few decades, in particular, it has become possible to also see an increase in Italy of interest in the world-wide historical scientific-technical heritage. A prominent example is the Italian translation of the book Singer et al. (1954–1978). Many industries performed researches and studies about their historical heritage (aa. vv. 1946, 1950, 1988, 1991; Ucelli 1961; Morin and Held 1980; Alvarez Garcia 1985; Di Nola 1987; Macchione 1987; Ferrari 1988; Castronovo 1988; Sicola 1988; Cavalieri Ducati 1991; Brunetti and Rovida 2006a, b; Mangone 1976; Wolgensinger 1991). Similar observations can be made for schools (Lori 1941; aa. vv. 1964, 1981; Fratini 1958; Lacaita 1990) and associations (aa. vv. 1997; Calabrò 2002; Montagna 1993).

Strictly related to the history of industries is the foundation of industrial museums that collect artefacts of historical production and display them with critical explanations (Amari 1999, 2001). It is worth noting that the history of technology was originally studied only by economists and physicists but has in recent years been taken up by engineers.

Some Italian authors who are actively investigating the history of technology are represented in (Balboni et al. 1989; Cigola 1995; Ceccarelli 1998, 2001, 2008; Ceccarelli and Cigola 2001; Chirone and Rovida 2004; Chirone 2004; Chirone and Cambiaghi 2007; Santoro 2007).

Many associations and working groups dedicated to the history of technology were also founded in Italy: the ASSTI, Associazione per la Storia della Scienza e della Tecnica in Italia (Association for the History of Science and Technology in Italy), the AISI Associazione Italiana per la Storia dell'Ingegneria (Italian Association for the History of Engineering) (www.aising.it). Since 2007 the AISI has organized an annual scientific conference.

An Italian Association, particularly dedicated to drawing and design problems, the ADM, the Associazione Nazionale Disegno di Macchine (Italian Machine Drawing and Design Association) has a "Historic Group" that organizes workshops and conferences, particularly during the ADM-Congresses (http://adm.ing.unibo.it).

Another significant event is the foundation (2007) of a Working Group "History of Engineering" of the COPI, Conferenza dei Presidi di Ingegneria (Italian Engineering Deans Conference) (http://ingprj.diegm.uniud.it/bricks/confpresing/home.htm). One important activity of such a WG is the organization of an annual workshop, dedicated to the history of a branch of Engineering. The proceedings of the first workshop is dedicated to Electrical Engineering (Cantoni and Silvestri 2009).

1.1.3 Author Level

The author's research on the history of engineering started with the organization, in cooperation with colleagues of other Italian Universities, in 1986 in Udine and in 1987, in Milan at the Museo Nazionale della Scienza e della Tecnica "Leonardo da Vinci", of an exhibition of historical drawings (Pavan and Sabbatini 1987) and another to celebrate the 125th anniversary of the foundation of the Politecnico di Milano (Rovida et al. 1988).

Some papers were presented at international congresses and workshops with the aim of highlighting the important role of the history of technology as a source of ideas for modern design (Rosa and Rovida 2006a; Rosa et al. 2007) as well as for the importance of the history of technology as a tool to develop creativity in engineering design education (Fargnoli and Rovida 2005; Fargnoli et al. 2005; Rosa and Rovida 2006b; Biggioggero et al. 2005).

Other realizations in the above-mentioned field are the foundation of the Drawing Museum (Brunetti and Rovida 2006b), the catalogue of the historical heritage of the Mechanics Department (De Alberti and Rovida 1999) and the critical biographies of some scientists (Rovida 1999).

Starting with the important role of historical constructive solutions, the author, in cooperation with some colleagues, proposed a method to realize a historical evolution of constructive solutions and applied this method to car suspensions, compiling a digital archive of 500 solutions of such suspensions from the first realizations until 2003 (Biggioggero et al. 2003).

In year 2003, the author became a teacher of a course for Industrial Engineering students (Master's degree) "History of Mechanics" (Biggioggero et al. 2005; http://www.kaemart.it/storia-mecc/bovisa/rovida). In this course the student, by following the way indicated in (Biggioggero et al. 2003), realizes historical evolutions, critically commented, of a machine or device of their interest. It is possible to see many such evolutions and a large amount of documentation (e.g., the utilized didactic slides) of the above-mentioned course in (http://ingprj.diegm.uniud.it/bricks/confpresing/home.htm).

1.2 Some Preliminary Considerations About the History of Drawing

"History of technology" means history of technical realizations and the fundamental key to reading such realizations is represented by the art of technical drawing. Therefore, the history of technical drawing is a very important part of the history of technology and a fundamental tool in the study of such an interesting part of the History.

In the field of "History of drawing", very few books are known in the industrial field:

1. Catalogue of the exhibition (Pavan and Sabbatini 1987) (no longer available): is not a systematic history, but a critical description of the exhibited drawings.
2. Catalogue of the Drawing Museum (Brunetti and Rovida 2006b): it is a description of the exhibited drawing instruments available at "Museo Lombardo di Storia dell'Agricoltura" in Sant'Angelo Lodigiano, near Milan.
3. The book (Rovida 1999) written by the author in 1999, but no longer available.
4. In some books about historical scientific instruments, there are chapters devoted to drawing instruments (Rovida 1999; Turner 1987; Catalogo degli strumenti del Museo di Storia della Scienza (1954)).

On the other hand, a systematic book about the critical evolution of representation of industrial objects would be of great interest. Such a book could have the following aims:

(a) Give a general survey about the historical evolution of technical drawing, i.e. methods and means to represent technical (industrial) objects;
(b) Give some ideas and proposals in order to utilize the history of drawing, e.g., for:

   1. engineers and designers, to search for "innovative ideas" by considering their historical evolution;
   2. people active in institutions for standardization, to reach, "innovative" ideas for drawing standards by considering the historical ways of drawing;
   3. teachers in the technical field, who, by considering the history of drawing, can give to the student a historical perspective, useful for a complete comprehension of today's situation;
   4. historians, who from the chronological evolution of a machine, expressed by drawings, can have a key to search for and to read the necessary information.

In Table 1.1, the fundamental steps of the tools of the design activity and the corresponding steps of drawing, as an output of the design phase are represented.

1.3 Conclusions

Drawing, particularly in the first steps of human development, could be regarded as a "substitution" for photography: the human being, after the realization of an artifact, has immediately the idea of expressing such an artifact with graphic representations, obtained by the currently available means, such as painting, engraving, relief, windows. Such representations can be regarded as the first expression of drawing of "machines", where the word "machine" is intended as the first human realizations with technical aims. Starting with the above-mentioned considerations, it is possible to observe that the totality of ancient representations of human products can be an interesting tool to study the history of technical development and of the lives of our ancestors.

Table 1.1 Steps of the design tools and drawing phases

Step	Period	Tools	Drawings
1	Origins"Experience"	Experience and intuition of the designer	Only representation with artistic and documentary purposes
2	Renaissance "First systematic observations"	Beginning of the systematization	First technical drawings (assembly and parts)
3	Sixteenth to seventeenth century "First theories"	Theory of elasticity (basis of structural calculations) by Hooke and De Saint Venant Logarithms (fundament of the regulus, the most important tool of calculation before computers) by Napier First technical schools	Descriptive Geometry and related orthographic projections theory (basis of modern technical drawings) by Monge
4	Nineteenth century "Development of theories"	Beginning of the systematic theories of material and structure strength and, consequently, of calculations First design schools	Application of orthographic projections in drawings. The aesthetic (from an artistic point of view) aspect is still relevant.
5	1900–1950 "Design science"	Development of theories of strength Material behaviour Standardization Development of design schools	Drawing standards: the drawings become more and more uniform, as the drawing standards spread and gain importance. Enrichment of the information enclosed in the drawings: tolerances, materials, components
6	1950–2010 "Design globalization"	Involvement of all fields of technical knowledge with design (information technologies tools, materials, product development, design education, social and psychological sciences)	Application of computerized systems in all phases of design (CAD, CG, CAM, CAE, VR, AR, RE)

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Chapter 2
Motivations of the History of Technique

The study of the history of technique, and, in particular, of mechanics can be very useful for a complete and systematic survey of the technical development of today. The history of mechanics is of great interest from many points of view: the most important could be classified as the following: cultural, technical, aesthetic, ethical.

2.1 Culture

Our historical technical heritage is an important key to understanding and interpreting the history of mechanics as part of human history. The cultural, and, of course, scientific-technical heritage, can be regarded as messages sent by the "inhabitants" of the past, to us, "inhabitants" of today: this viewpoint confirms the great role of our cultural heritage as a key to reading history, e.g., of economics, of construction, of social organization, that are significant parts of the History. This observation is particularly important when observing drawings of machinery and illustrations of perceived physical systems, documents that can be considered as the most significant representations of technical realizations in their respective periods of time.

From the cultural point of view, the scientific historical heritage can be a basis on which to "read" the history of science and of technique.

As an example, Fig. 2.1 represents an Assyrian relief (i.e. an ancient "drawing") relative to a hunting car, with two wheels, driven by horses. (Singer 1958) The relief was found in the palace of Ashur-nasir in Nimrud (Mesopotamia) (ninth century BC).

The relief is a description of an old Assyrian hunting activity and can be considered as a document of the life of such ancient folk.

An Assyrian war ship, driven by oars (Palace of Kuyunjik, Mesopotamia) (seventh century BC), is the object depicted in Fig. 2.2 (Singer 1958). The ship is represented by a relief and is another document of the life and work of ancient Assyrians, particularly with respect to their naval constructions.

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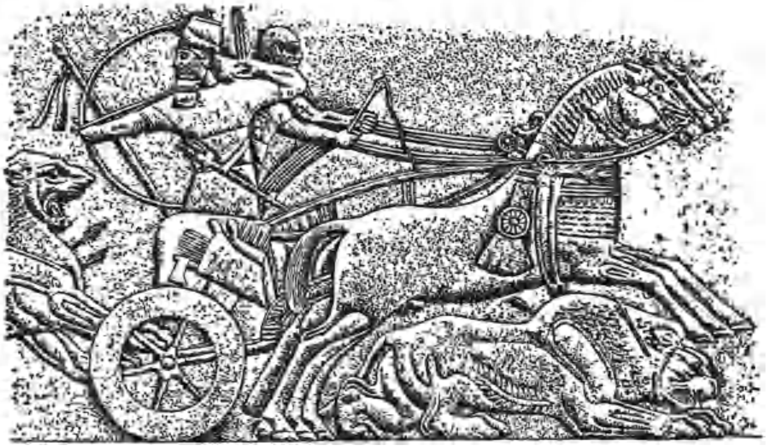

Fig. 2.1 Assyrian relief relative to a hunting car, with two wheels, driven by horses. The relief was found in the palace of Ashur-nasir in Nimrud (Mesopotamia) (ninth century BC). (Singer 1958)

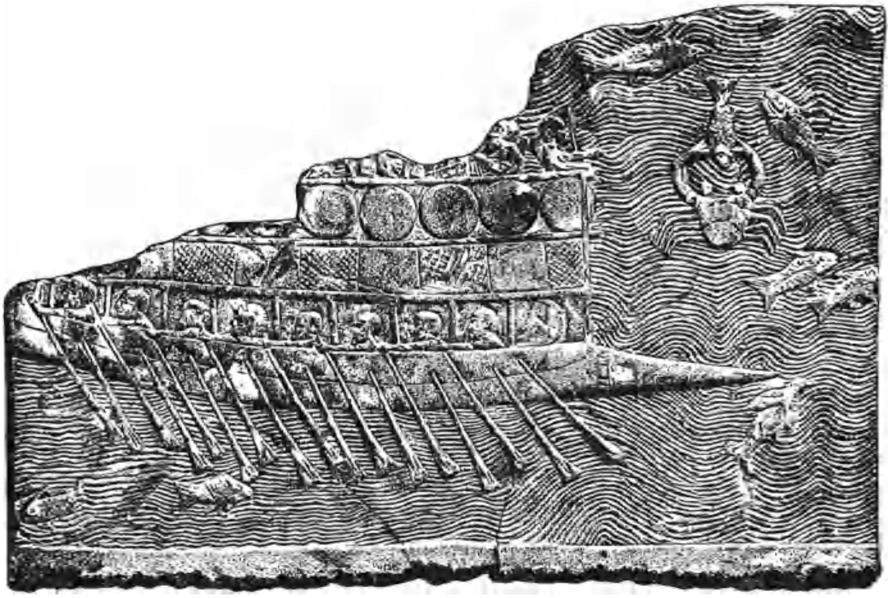

Fig. 2.2 Assyrian war ship driven by oars (Palace of Kuyunjik, Mesopotamia) (seventh century BC) (Singer 1958)

Fig. 2.3 Mosaic called “Del circo”, Villa del Casale, Piazza Armerina, Sicily, Italy

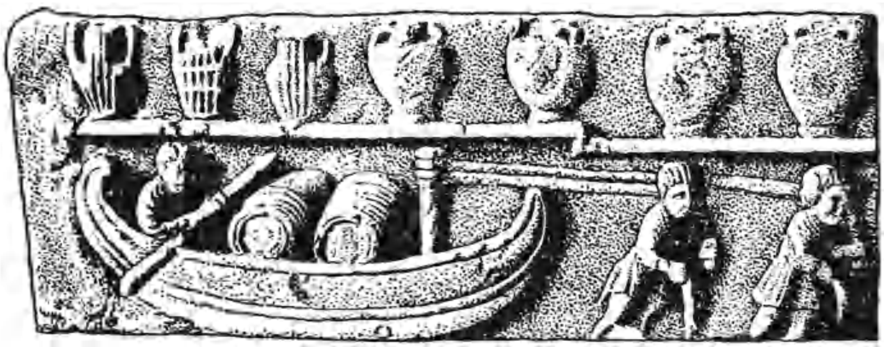

Fig. 2.4 Relief representing a boat used to transport barrels on the Rhone river (second century AC) (Singer 1958)

The Fig. 2.3 shows a mosaic that could be considered a “drawing” from a moment of the life of the ancient Romans. From this mosaic it is possible to “read” the construction of carts by the old Romans.

Another example is the relief in Fig. 2.4 (second century BC) representing a boat used to transport barrels on the Rhone river (Singer 1958). This representation, also, is an interesting source for information about naval and barrel construction of this time and about the transport technique.

These examples should be sufficient to highlight the important role of the representation of technical objects as “key” to reading the history of science, of technique and of work, each of which is a significant part of the History.

2.2 Technique

Collections of old realizations should be of interest to the modern designer. Constructive ideas from long ago could again be proposed with new materials and new technologies. Critical analysis of historical constructions through the medium of relevant drawings can be an analogous "heuristic method" to the TRIZ and CREAX, to develop innovative ideas. Indeed, many ideas conceived in earlier times were abandoned and have been "newly invented" some centuries later. Some examples are here presented.

Leonardo da Vinci conceived and designed a bicycle very similar to a modern one (Fig. 2.5), with chain transmission. Such a transmission was then forgotten and "newly" found only at the end of the nineteenth century.

Another example of the importance of "rediscovering" old and forgotten ideas, is represented by Stephen Farfler (1655), a smart invalid who invented the first wheelchair with gear transmission directly driven by the invalid himself. The self-propulsion mechanism was then forgotten and "newly" invented in 1881, with a "reaction ring" concentric to its wheels.

The "Conservatoire des Arts et Metiers", the most ancient modern scientific-technical museum, was founded in Paris in 1794, but had been proposed by Cartesio in the seventeenth century: the idea was to collect the constructive solutions of the most important machines, in chronological order, with the aim to upgrade the creativity of technicians.

Figure 2.6 shows some very well-known sketches (ca 1920) of Vincenzo Lancia (Genta and Morello 2007) (the founder of the very well-known Italian car factory), used to develop the first ideas of an independent front suspension.

The developed idea was the 4th in the second column, realized on the Lancia Lambda (1923) (Fig. 2.7).

It is however possible to observe some sketches of very "modern" independent suspensions (with transversal double arms, with helical or leaf spring) that would be applied only 10–15 years later (Fig. 2.8).

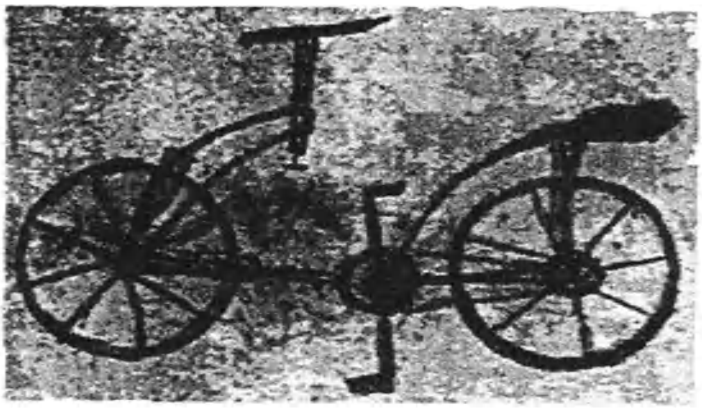

Fig. 2.5 The "bicycle" of Leonardo da Vinci

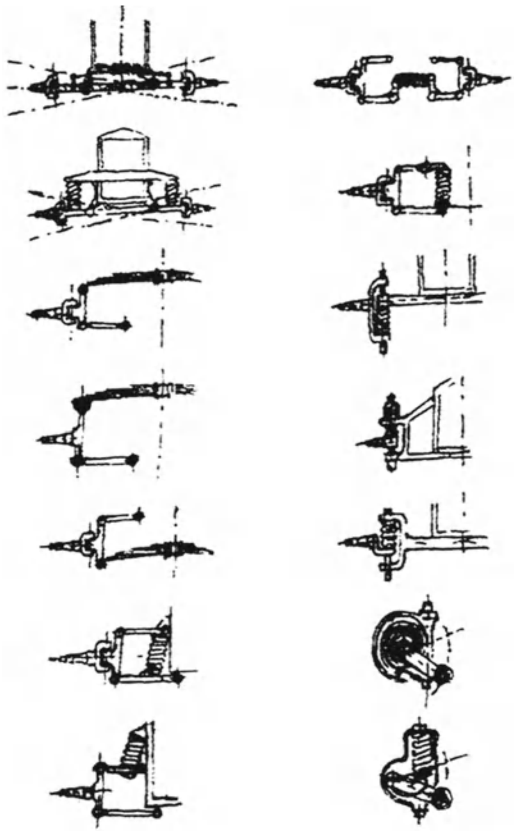

Fig 2.6 "Concepts" of Vincenzo Lancia to reach independent front suspensions (ca 1920) (Genta and Morello 2007)

An old patent Fiat (1926) (left) relative to a car suspension that anticipates the McPherson suspension of the 1950s (right) is represented in Fig. 2.9.

Some historical drawings are interesting not only for the represented objects, but also for their representation: in other words, some historical drawings are interesting because they anticipate modern drawing standards.

In Fig. 2.10 it is possible to see some drawings of Giuseppe Belli, a physicist of Pavia University (nineteenth century) who anticipated modern drawing standards. (On the left are schematic drawings and on the right an application of the "arrows method" to be applied to the theory of orthographic projections: with such a method it is possible to view the object in any position, with the condition that the direction of observation is indicated. The "arrow method" is now recommended by ISO Standards.)

2.3 Aesthetics

From the aesthetic point of view, many old scientific objects (such as instruments or machines) are very beautiful and pleasant to look at (Fig. 2.11).

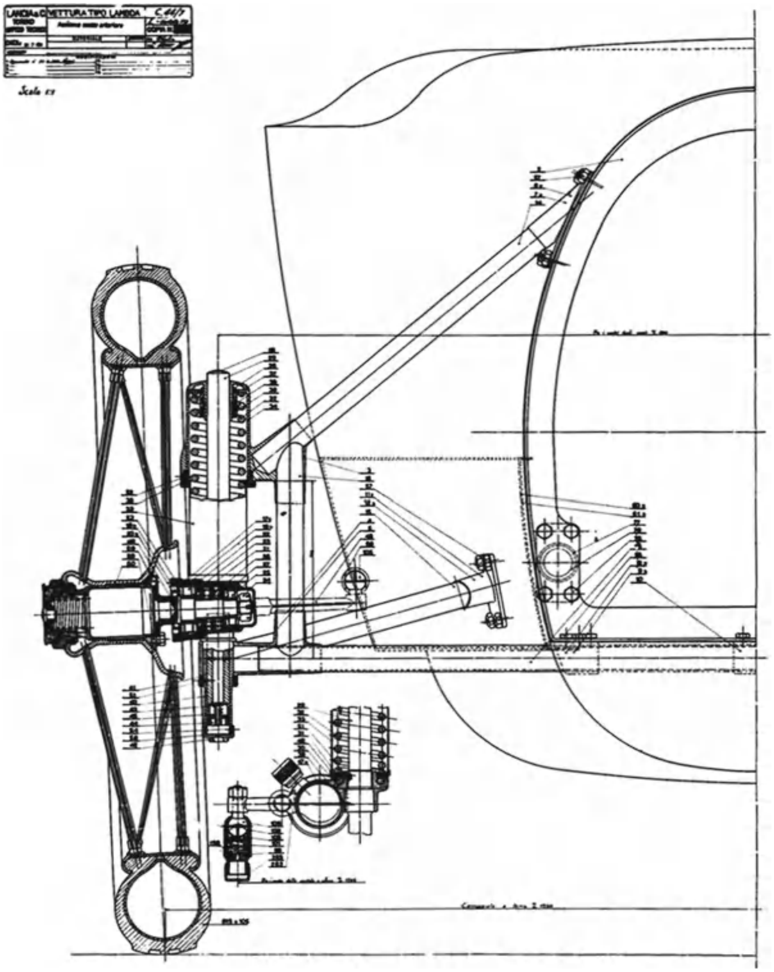

Fig. 2.7 The front independent suspension of Lancia Lambda (1923) (Biggioggero et al. 2003)

Many historical objects (machines, instruments, drawings, etc.) are unique, handmade and very pleasing to the eye.

2.4 Ethics

Genuine historical objects must be, and generally are, realized with great care. They represent an important testimony of previous generations' professional capability and examples for new generations. Figure 2.12 shows, as an example, a geometric compass. Such an instrument of the beginning of the eighteenth century consists of two rods hinged at one end.

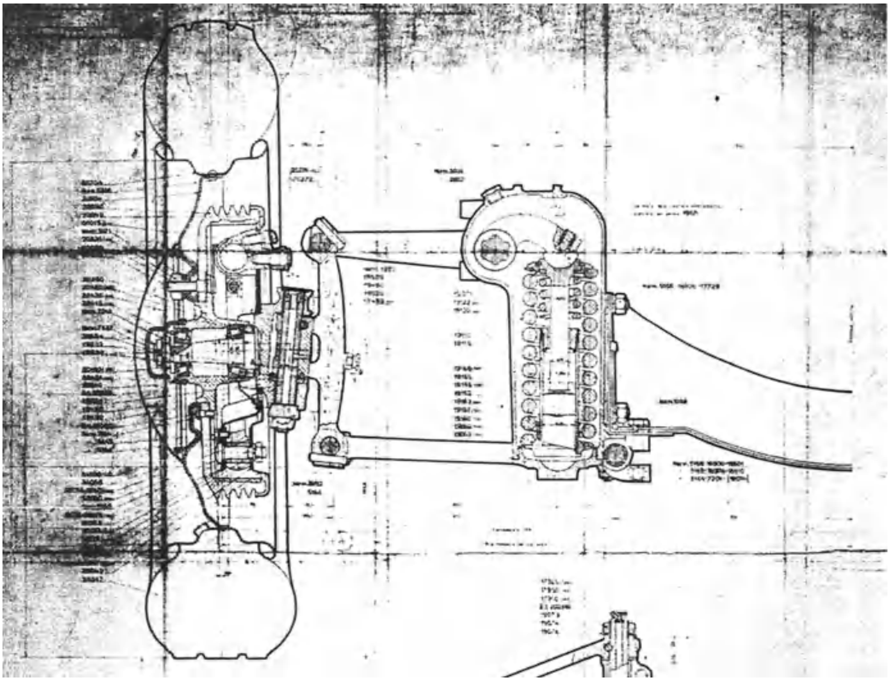

Fig. 2.8 Double transverse arm suspension of Fiat 508 C (1935) (Biggioggero et al. 2003)

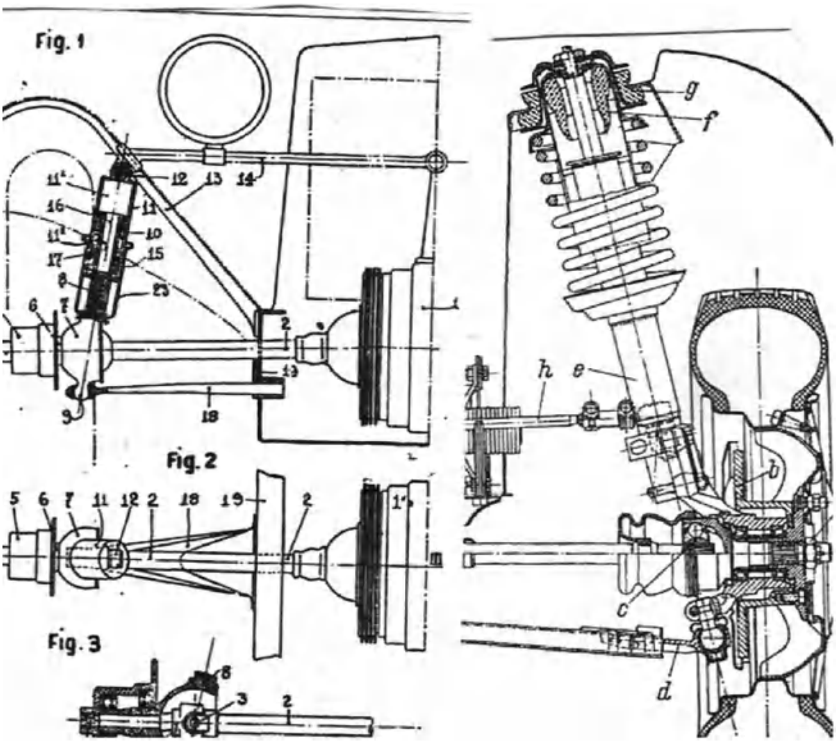

Fig. 2.9 Fiat patent (1926) (anticipating the suspension McPherson 1950s) (Biggioggero et al. 2003)

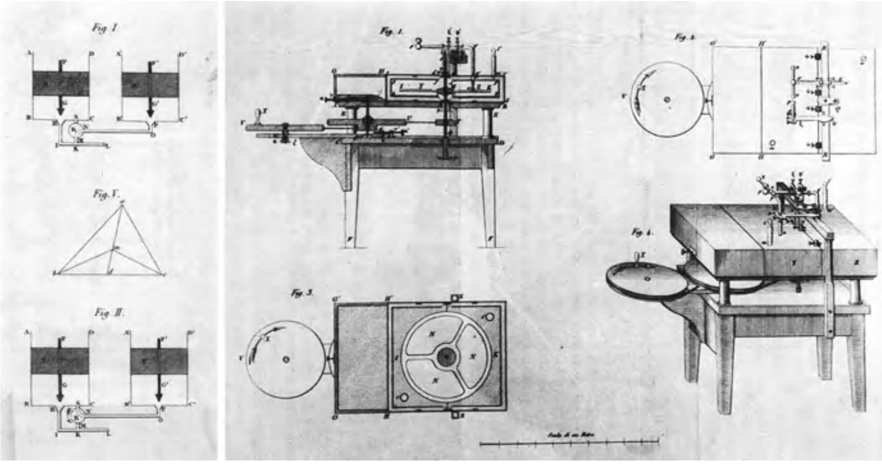

Fig. 2.10 Drawings of Giuseppe Belli, an Italian physicist of the nineteenth century (Rovida 1994)

Fig. 2.11 Drawing instruments (eighteenth century) (11 pieces, among them, drawing pens, compasses, ruler and geometric compass. The case is covered with fish skin, a very common feature in the nineteenth century) (Brunetti and Rovida 2006)

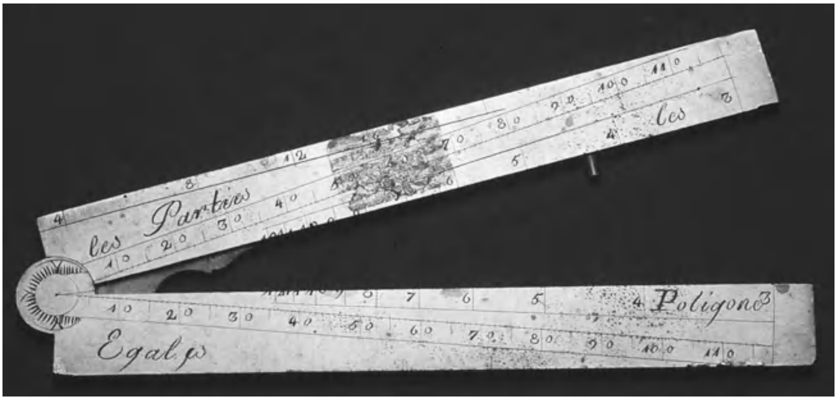

Fig. 2.12 Realization of Butterfield, an engineer of Louis XIV. The represented object is a geometric compass, made with fine workmanship, brass, engraved with figures, is signed by Butterfield and carries the words "Paris Cordes, les Métaux," "the Parties Egales" and "Polygons" (Brunetti and Rovida 2006)

Invented by Galileo, probably in the years 1596–1597, this instrument, considered an ancestor of the slide rule, was realized by Michael Butterfield, a mechanical engineer appointed to the court of Louis XIV. Butterfield specialized in the field of mathematical instruments, was the author of many treatises and realized a sundial. He died in 1724.

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Chapter 3
The First Steps

3.1 Introduction

Prehistoric man was the first “designer”: to kill an animal, he needed a branch of a tree. In this operation, the abovementioned prehistoric man searched for a branch with a form useful for the necessary function (in the modern “methodic design” such an operation is called “design for function”, i.e. to realize a given object with a configuration suitable to perform the wanted function), with a useful diameter (not too little for strength requirements and not too big for need for gripping). In the choice of the dimension, our ancestor realized an optimization process, without the knowledge, of course, of the definition of “optimization”! The branch, also, had to be easy to find: our ancestor solved a problem of “design for manufacturing” (such an operation, in the modern “methodic design” is intended as the realization of an object with a configuration suitable to be realized easily and economically). A big problem in the development of an industrial product is to realize such a product with a configuration able to perform a wanted function and at the same time easy to be manufactured. Our ancestor had to solve this problem.

Of course, all the above mentioned operations had to be performed in a very short time: this is an example of an application of the modern concept of “time to market”.

It is interesting to observe that representation is an important mean for overcoming cultural diversities. From the “space point of view”, graphical representation is common to all cultures and languages and fulfills the role of a universal language.

From the “time point of view”, ancient representations of technical objects are important keys to reading the history of life, of work, of the social organizations of the respective times.

In space: a graphical sign can be read by persons of all cultures. For example, consider road signs. Very often, in many countries, road signs have textual information

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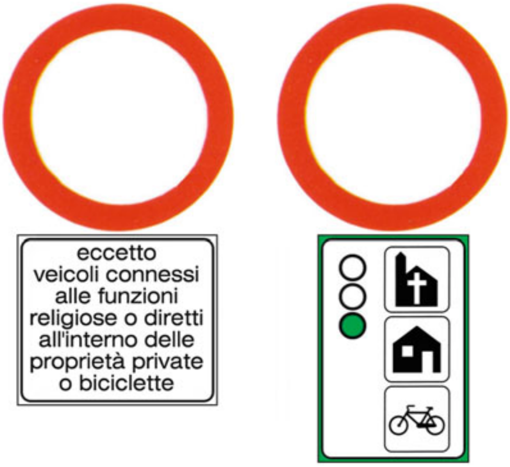

Fig. 3.1 The superiority of the graphical in relation to the textual communication: to the *left* a road sign observed in Milan and to the *right* the proposed graphical translation

written in the language of the country. Such information is not easily read by persons without at least a rudimentary knowledge of the language of the country.

In Fig. 3.1, it is possible to observe a comparison, in the case of road signs, between textual and graphical communication. The much better comprehensibility of the image is evident. To the left is a road sign observed in Milan: the sign means interdiction of transit except for people to the church, or private houses, or also for bicycles. To the right, a proposal of substitution of the textual information with images in accordance with research of the author (Ballardin et al. 2005).

It is important to observe that, until the Renaissance, designers often realized very important machines and products: for example, the lifting machines necessary to build gothic churches. But such realizations are only based on experiences and observations of the designers, without theoretical speculations: scientists and technicians lived and worked on different levels, without reciprocal contact: e.g., the old Greek carpenters were able to build very efficient ships, but, very probably, without the knowledge of Archimedes and of his "principle". In other words, the constructor of ships was not able to express why the very well built ships sailed.

The realizations were very important, but, without a connection to scientific principles, and consequently the development was very slow.

Our ancestors often represented the drawing of the realized products: in prehistoric and ancient times, such a drawing is only a means of documenting the realization, very often with artistic aims, but without technical objectives. Some examples that can be considered as sufficient documentation about the first steps of the representations of technical objects are presented and explained here.

3.2 Prehistoric Age

Representation in the prehistoric Age was often realized by engravings on stones or rocks, where our ancestors described everyday life. Such representations, of course, have only artistic aims and, for us, are important to know the life and the work of prehistoric men. Figure 3.2 (Rovida 1999; Chirone and Colosi 1984), for example, is a description of prehistoric agriculture: prehistoric men used plows pulled by deer.

Figure 3.3 (Rovida 1999; Chirone and Colosi 1984) represents an Italian stone engraving from 850 to 700 AC: the object of the representation is a cart

Fig. 3.2 Prehistoric engraving on stone, representing a plow pulled by deer

Fig. 3.3 Engraving on stones from Valcamonica (Italy) (850–700 BC) representing a cart pulled by horses

pulled by horses. The representation is very beautiful and elegant: it is possible to observe confusion in the planes of observation. The body of the cart is seen from a vertical viewpoint, while the wheels and the horses are seen from a horizontal one This engraving is interesting, because it gives us information about the transportation technique: e.g. the construction of carts, the use of horses to pull a cart.

3.3 Ancient Times

In ancient times, also, the representations of technical objects had only documentary and artistic aims, without technical intentions. The technician works from experience and has no need, in general, for drawings. The ancient representations are interesting as documents to read the history.

In this section, some examples of ancient representations of technical objects are presented: these representations have only "artistic" aims and are interesting documents to "read" ancient life.

Figure 3.4 (Singer et al. 1958) represents an ancient Egyptian potter's workshop. This representation is an interesting document about the activity of construction of vessels. It is possible to recognize some machines, such as the potter's wheel to the right of the figure and all the phases of the manufacturing.

In Fig. 3.5 (Rovida 1999; Chirone and Colosi 1984), for example, an old Egyptian manufacture of a wheel is represented: it is possible to recognize how the wheels were manufactured, the workers, the utilized tools.

Similar considerations could be made for the representations of Figs. 3.6 (Singer et al. 1958), 3.7 (Rovida 1999; Chirone and Colosi 1984), and 3.8 (Rovida 1999; Chirone and Colosi 1984), relative, respectively, to Greek and Roman technical products.

Figure 3.6 (Singer et al. 1958), from an ancient Greek vessel, represents the workshop of the blacksmith and, in particular, the activity of god Hefaestus. This is another document about ancient activities: in this case, manufacturing in the metallurgical field of ancient Greeks. It is easy to recognize that the man to the left has , with pincers, a piece of iron on the fire. The man to the right has a hammer and is getting ready to forge the iron.

Figure 3.8 (Rovida 1999; Chirone and Colosi 1984), particularly, is relative to a Roman lifting machine, the "rota calcatoria", i.e. a wheel actuated by men (in this

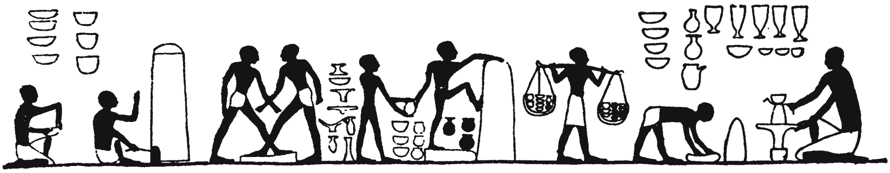

Fig. 3.4 Potter's workshop of ancient Egypt

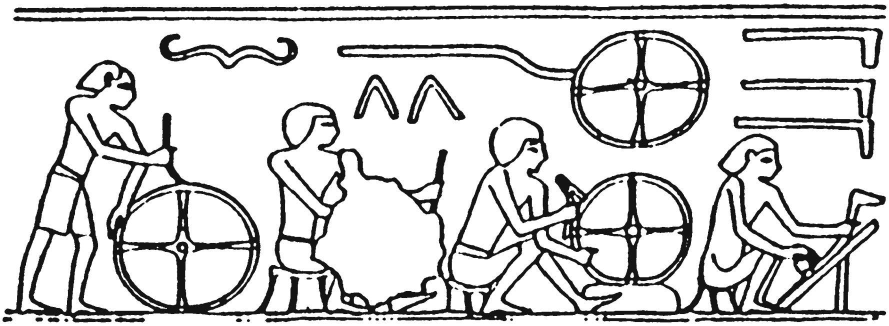

Fig. 3.5 Egyptian bas-relief showing the manufacture of wheels (ca 1500 BC)

Fig. 3.6 Blacksmith's workshop

case) or animals, that, with their weight, allow rotation of the wheel, that, through a rope, moves the weight to be lifted.

Figure 3.9 (Singer et al. 1958) represents a moment of work and particularly a group of miners. The chief (to the left) has a pair of tongs; before him, a miner has a pickaxe and another has a lamp.

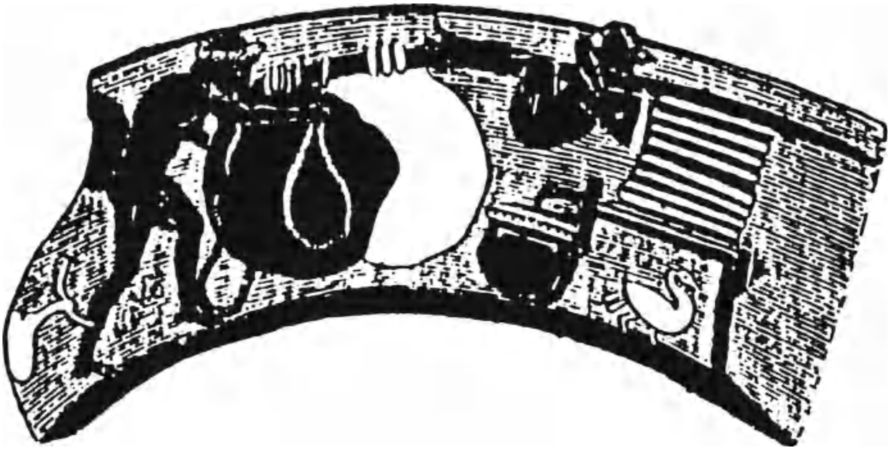

Fig. 3.7 Oil press from a Greek vase (ca 600 BC)

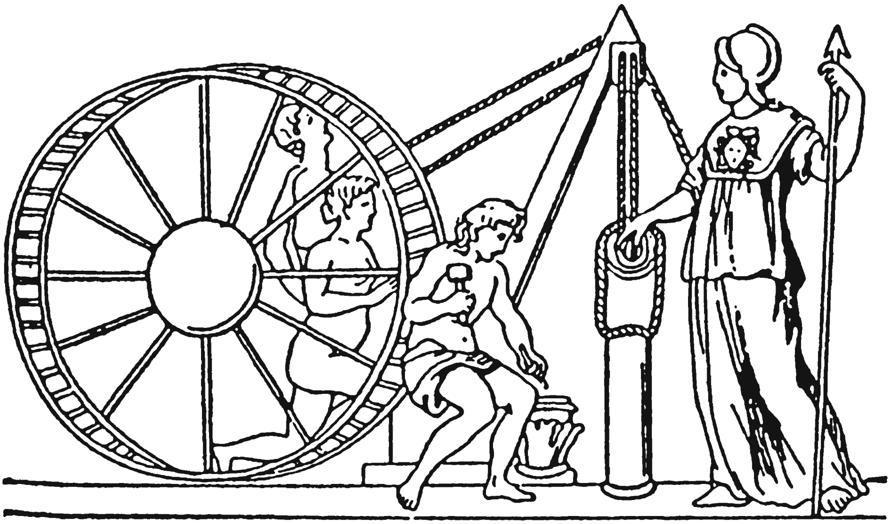

Fig. 3.8 Roman lifting machine (second century AC)

3.4 Middle Ages

The "technical" representations of the Middle Ages are not very different from the representations of ancient times. The cultural interest of the medieval technical representations is very similar to the interest of ancient representations.

The following figures are valid examples.

Figure 3.10 (Rovida 1999; Chirone and Colosi 1984) is relative to a medieval drawing. The particularities of such a drawing are some technical characters of the

Fig. 3.9 Relief representing miners (South of Spain, first or second century AC)

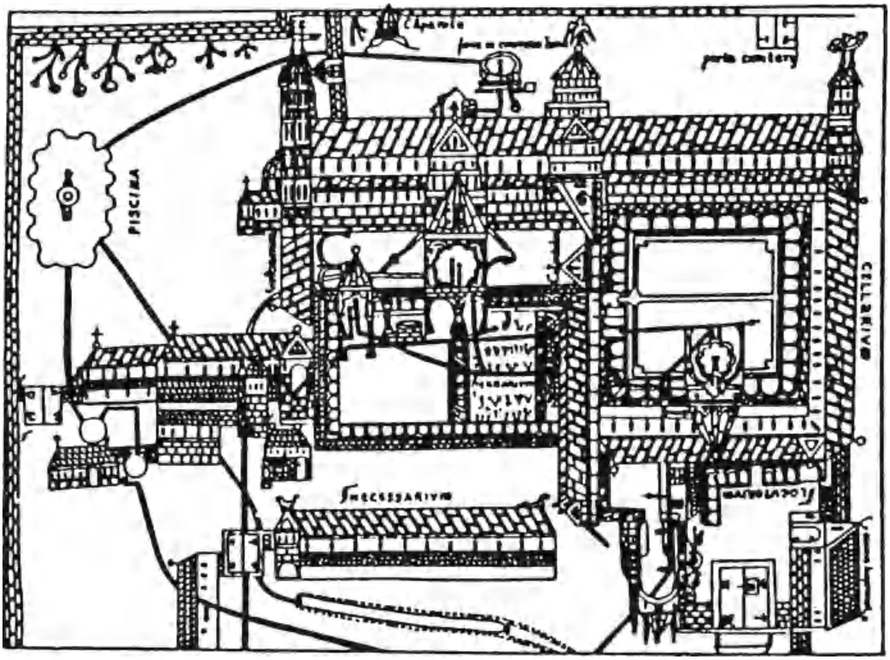

Fig. 3.10 Representation of the *top view* and *side view*: superimposed, layout of water pipes (Prior of Canterbury – ca 1150)

Fig. 3.11 Seal of Middle Ages, with the representation of a ship with stern rudder (Elbing, Poland, ca 1242)

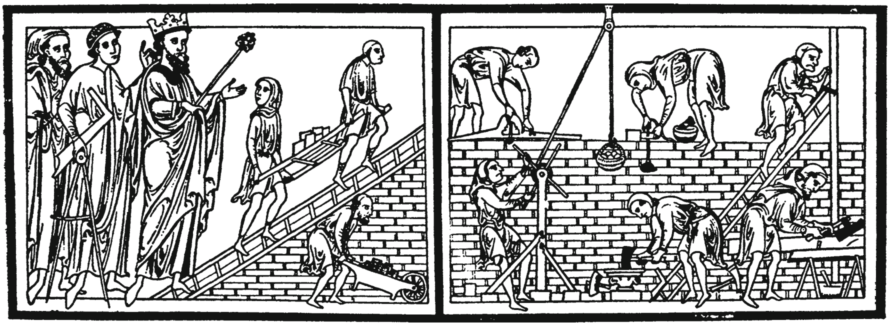

Fig. 3.12 Building works (thirteenth century)

representation, i.e., the drawing of the building is viewed from the top and the side view is superimposed. In this way, with only a drawing, it is possible to represent the two principal views (top and side) of the wanted object , according to the horizontal and vertical direction of observation. In such a drawing also the layout of water pipes and the tank for fish farming (in Latin, “piscina”, from the word “piscis”, that means “fish”) is also interesting.

Figure 3.11 (Singer et al. 1958) represents a seal with a ship that is interesting to give information about the use in Middle Ages of the stern rudder.

Figure 3.12 (Singer et al. 1958) represents two different moments in a building project. The mechanical interest of the above mentioned figures is in the lifting machines that are being utilized. To the left, the lifting of stones is obtained through a barrow actuated by two men; it is also possible to observe the use of a wheel-barrow. To the right, instead, the lifting is realized by a fixed pulley. It is also interesting to observe the use of a plumb-line.

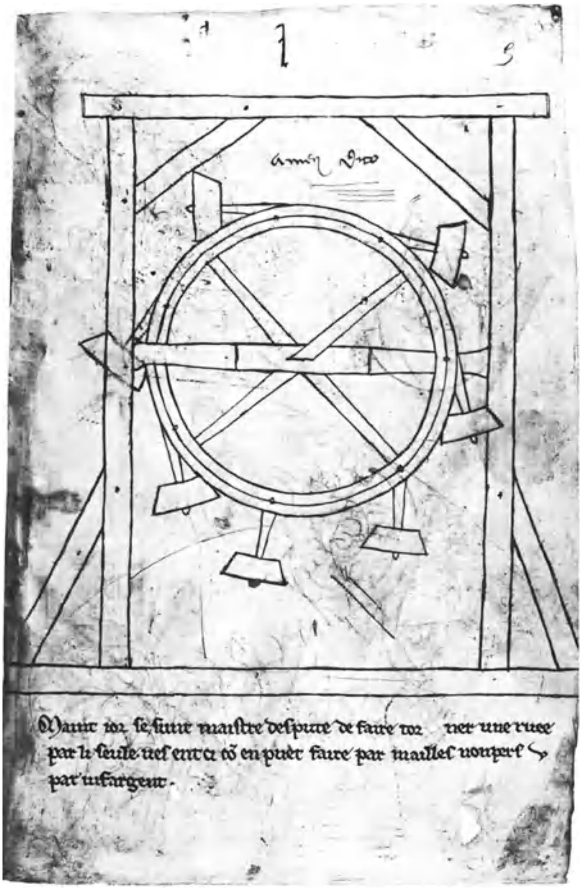

Fig. 3.13 "Perpetuum mobile" by Villard d'Honnecourt

A very interesting medieval figure is the scientist, artist, architect Villard de Honnecourt (Erlande-Brandenburg et al. 1987). He lived in France in the thirteenth century and may have been an itinerant master builder in Picardy, in northern France. Villard de Honnecourt realized a collection of 33 sheets, with about 250 drawings, now conserved in the Bibliothéque Nationale in Paris. Villard had a great interest in practical problems and, particularly, in machines and mechanisms. Many sketches of machines and mechanisms are present in the abovementioned collection. For example, in Fig. 3.13 (Erlande-Brandenburg et al. 1987) a "perpetuum mobile" is represented, which is a mechanism that attempted to reach perpetual motion, the aim of many studies from the Middle Age, until the eighteenth century. The principle of the mechanism proposed by Villard is a system of weights hinged to a wheel: the impossibility of such a mechanism functioning is recognized, however the drawing is an interesting attestation to the effort of many medieval scientists. It is to observe that the

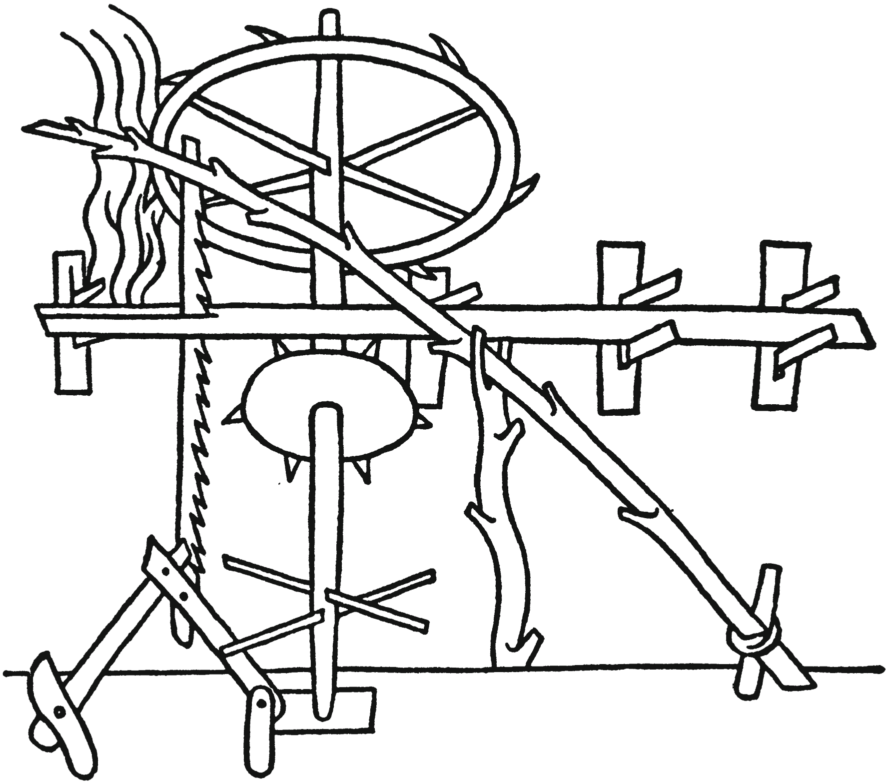

Fig. 3.14 Saw by Villard d'Honnecourt

perpetual motion was demonstrated as impossible by the physical scientific theories: in the eighteenth century, the French Academy of Sciences rejected all "inventions" of perpetual motion. Nevertheless, today also, sometimes some "inventors" of perpetual motion appear.

In Fig. 3.14 (Erlande-Brandenburg et al. 1987; Ceccarelli 1998) a saw to cut trees is represented. The vertical saw is guided by a tree trunk acting as a spring: in this way the cutting motion is obtained. This drawing is an attestation that in the Middle Ages, the elastic trunk of a tree begins to be used as a spring, particularly to obtain the return movement, e.g. of mechanisms or machines. The extension of the cut is obtained by the rotation of a shaft.

Figure 3.15 (Singer et al. 1958) represents a medieval cart, with four wheels, driven by horses and very useful for long travels. The cart is characterized by superior cover and lateral shieldings. The environment of the representation is a gothic building, with a rampant arc.

Fig. 3.15 Cart driven by horses (From a French manuscript, relative to the legend of St. Denis (1317))

3.5 Conclusions

The abovementioned examples could be considered as sufficient samples to understand the importance, from the cultural and documentary points of view, of the first "technical" representations. The number of examples could be vastly enlarged by consultation of the sources indicated in the bibliography: this search would be only a confirmation of the role of these "first steps".

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Chapter 4
Renaissance

4.1 General Considerations

It is significant to observe that, in the present work, we focus on the period of time corresponding to the fifteenth and sixteenth centuries, with some linkages to the first years of the seventeenth century. That significance lies in the sudden discovery and rapid growth of the idea of representation in drawings and illustrations as a mode of communication.

It is important to observe that, until the Renaissance, i.e. in the Ancient Times and in the Middle Ages, designers often realized very important machines and products: as examples, the lifting machines necessary to build gothic churches. But such realizations are only based on experiences and observations of the designers, without theoretical speculations: scientists and technicians live and work on different levels, without reciprocal contacts. Realizations were very important, but, without connection to scientific principles, and consequently the development was very slow.

The Renaissance is very important, because, in this period, science and technique began to converge : the influence was reciprocal and the new science, in embryo, was born. The technical realization began to be based on scientific acquisitions and, on the other hand, the technical realizations (for example, instruments for measurements) allowed better scientific observations and, consequently, a more rapid scientific development. This situation, in other words, represents a virtuous circle that is an introduction to the great development that will characterize the seventeenth and eighteenth centuries.

An example is represented by timepieces: the relative development is an input to better study some mechanical (and, particular, dynamic) problems. The new scientific acquisitions allowed upgrading of the construction of timepieces. As a further example, consider hydraulic machines: the upgrading of suction pumps allowed deepening of vacuum problems. Consequently, other machines, like machines for the extraction of water from mines, were realized.

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In this period began also the first calculations and the experimental method and an embryonic form of design.

This period, in addition, was characterized by the first steps of printing machines, that had a fundamental role in the diffusion of knowledge. From this point of view, this period was characterized by extraordinary cultural vitality and was full of innovations. This was a result of the great experimental laboratory of print, that happened between the end of the 14th and the first half of the 15th centuries. The first steps and the development of the printing machine was an important factor for the birth of treatises: this literary gender was characterized by the birth of books (treatises), with wide collections of representations and descriptions of machines and devices, where the image had greater importance than the text.

The Renaissance was a period of time characterized by many great transformations and much development, from the cultural, economic, social and technical points of view: important geographical discoveries, that widened the horizon of Earth, the development of workshops, with increasing technical character, the general diffusion of culture, also in relation to introduction of the printing machine. The technical activity was fundamentally in the workshops, which were also "schools" and formation centers. Training was conducted through tutoring from the master. The students observed the master and learned by imitation: as an example, the first experiences of the young Leonardo da Vinci were in the workshop of the master Andrea del Verrocchio. In the workshop appeared the first "drawings of machines", i.e. the first representations with not only artistic and documentation aims. In such drawings were often present two levels, the complete and figurative representations and the simplified and schematic.

Another characteristic of the Renaissance, related to technical drawing, was the origin of the first "technical" drawings that could be considered as ancestors of the modern drawings of machines. In the Renaissance, there was, therefore, a great development of technical representation, with more information that gave to the drawing an interesting technical character.

4.2 The Authors

4.2.1 Introduction

Collections of drawings of machines are known in medieval manuscripts, particularly from the South of Germany and from the North-Centrum of Italy. As an example, in Chap. 3, the drawings of Villard de Honnecourt are mentioned and exemplified. In this period of time, some classical authors, such as Vitruvio, were discovered or rediscovered. Furthermore some artists realized drawings of technical objects, such as machines or instruments. In the Renaissance, also, as mentioned above, there appeared a new literary gender, called treatises. This genre of literature was born from the need to organize the great amount of knowledge. The treatises utilized great reliability and immediacy of images in relation to the written text. The images

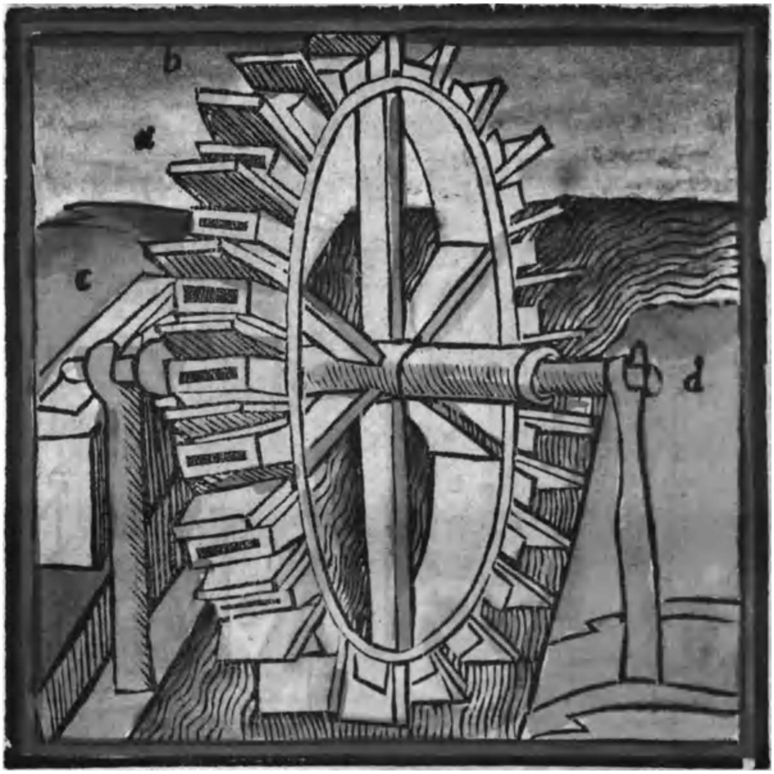


Fig. 4.1 Hydraulic wheel from "De Architectura" of Vitruvio

were very often created with great quality and were pleasant to see. The aim of the treatises, therefore, was, in the Latin language, *utilitas et delectatio*, i.e. utility and pleasure. The appearance of the treatises was very successful, particularly because the images were beautiful (Dolza 2009; Ceccarelli and Cigola 2001).

4.2.2 Examples

Among the classic authors discovered or rediscovered in that time, it is important to remember Vitruvio and Erone.

A great development to the drawing of machines was given by the work of Marco Vitruvio Pollione (in Latin Marcus Vitruvius Pollio) "De architectura" (About architecture) (Figs. 4.1 and 4.2): this book contains also descriptions and drawings of machines. Vitruvio wrote this book in 23–27 BC: the first edition was realized in 1486 by Giovanni da Veroli and Pomponio Leto. Other editions appeared in 1496 and 1497. Very beautiful figures were added in the editions of Fra Giovanni Giocondo (1511), Cesare Cesariano (1521), Daniele Barbaro (1556) and Claude

Fig. 4.2 Mausoleum of Halicarnassus from "De Architectura" of Vitruvio

Perret (1673). Such figures, aside from the aesthetic value, exhibited high accuracy in describing the details.

The tenth book of "De Architectura" is entitled "Mechanics" (in Latin Mechanica) and contains descriptions and illustrations of many mechanisms, such as machines for lifting weights (sheaves, tackle, winch), worms and worm wheels, war machines. Figure 4.1 is a very beautiful representation of a hydraulic wheel: the wheel is mounted on an axis that is supported by two bearings fixed to the ground. Figure 4.2, however, represents the Mausoleum of Halicarnassus. The represented machines are some ships close to each other, in the sea before the building. Interesting also is the representation of a chain wound on a drum.

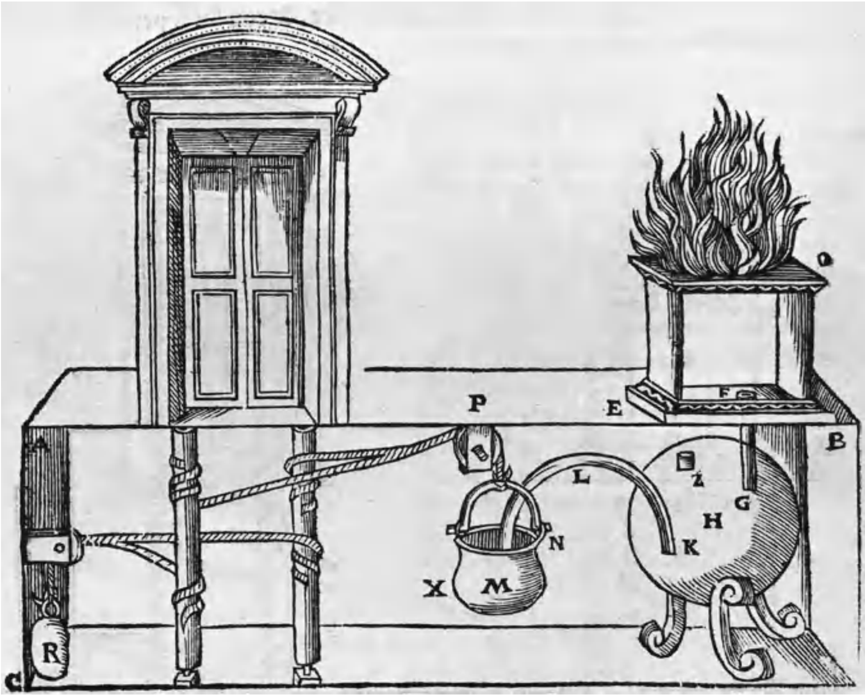


Fig. 4.3 Device invented by Erone, relative to an "automatic" actuation of the door of a temple

Another important classic author was Erone from Alessandria (first century BC). He invented many machines and mechanisms and was the first to make observations about the possibility of utilizing the power of steam. Figure 4.3, edited in the Renaissance, is relative to a device invented by Erone, relative to an "automatic" actuation of the door of a temple.

An important artist that has realized drawings of technical objects is Albrecht Duerer (1471–1528), a very well-known German painter. Figure 4.4 represents a fortress. From the graphical point of view, the high degree of schematization of the cannon and of the man is interesting.

Treatises are books with integration of written text and images, where the images play a great communicative role. The image, in general, is more clear, immediate and complete than the text: therefore, the collections of images are immediately successful. Particularly the non-specialists (it is useful to remember that in those centuries, most of the population was illiterate) appreciate the images, demonstrating that the technique began to be interesting for all people.

The often very high quality of images is in relation to the ability of the authors, but also to the integration of the knowledge that derived from the contemporary progress of other sciences, such as anatomy, zoology, botany, and geology.

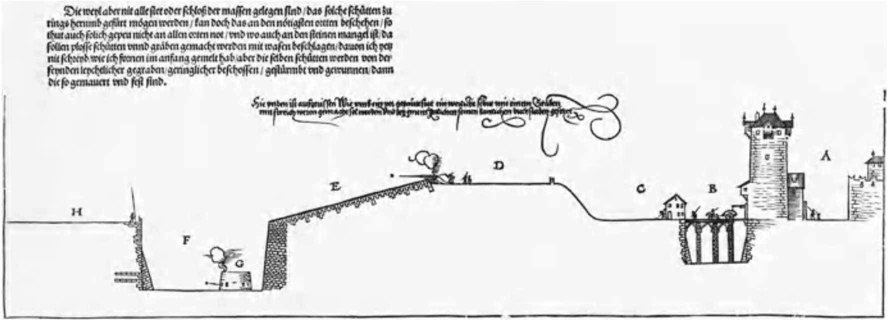


Fig. 4.4 Schematic representation of a fortress with cannon and man by Albrecht Duerer

Among some important authors in the fifteenth to sixteenth centuries, we cite the following:

4.2.2.1 Leon Battista Alberti (1404–1472)

Leon Battista Alberti was a very polyhedral man: architect, writer, mathematician and humanist, in other words, one of the most representative persons of the Italian Renaissance.

A significant characteristic of Leon Battista Alberti was his constant trend to research theoretical or practical rules with the aim to address and to guide artistic activity. As an example, Fig. 4.5, from his book "De statua" (About the statue) is a document of the research to find the correct proportions of the human body.

Figure 4.6, however, represents an idea of Alberti, relative to a device, based on the lever principle, to measuring the weight of carts.

4.2.2.2 Roberto Valturio (1405–1475)

He was the author of "De re military" (About war) (1446–1455), with descriptions and images of war machines (Figs. 4.7, 4.8, 4.9, and 4.10).

Such machines are interesting documents of the constructions and, particularly, of the new ideas of that century and, from the graphical point of view, are intuitive applications of the axonometry.

4.2.2.3 Leonardo da Vinci (1452–1519)

The multi-faceted activity of Leonardo da Vinci is very well known throughout the world. Figs. 4.11 and 4.12 are two examples of Leonardo's that are perhaps not so well known. The first one is a breathing device, based on a tube connecting the free

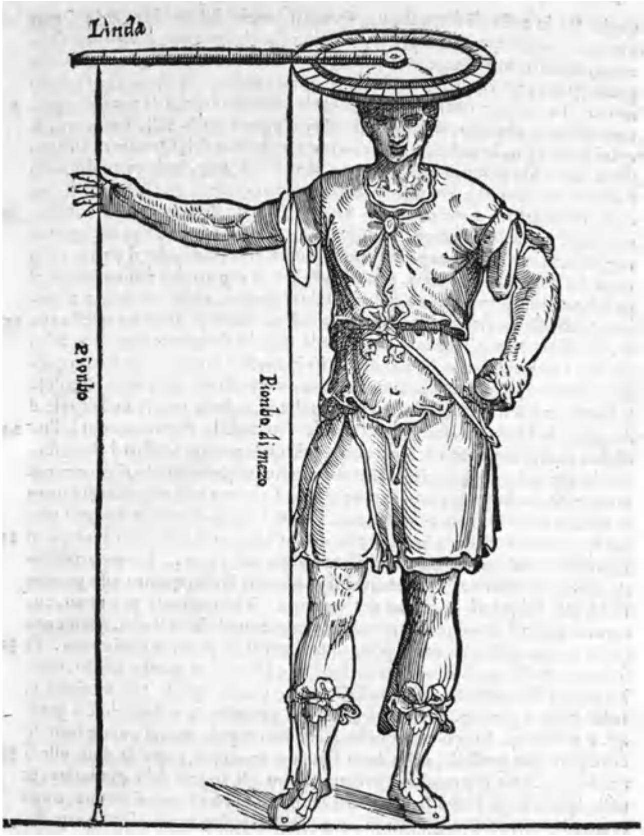


Fig. 4.5 Research to find the correct proportions of the human body

atmosphere with the nose. The second one, however, is a simple lantern, which is yet another confirmation of his versatility. In some cases of other scientists' work, it is difficult to recognize if the drawing has greater artistic or technical value. With Leonardo da Vinci, the technical drawing reaches perfection from the graphical and pictorial point of view and, also, in many cases, in relation to the technical aspects.

In comparison with many other authors, Leonardo very often describes the function of a machine with many figures, corresponding to different directions of observation: it would be possible to recognize an anticipation of the orthographic projections, that will appear, on a correct theoretical basis, only in the eighteenth century. Leonardo realized a great number of drawings: we know of approximately 6,000 sheets, but it is estimated that the effective productions could consist of 18,000 sheets.

From the graphical point of view, the technical drawings of Leonardo are interesting because the representation of a given object, as said above, is realized through many views, similar to projections in different directions of observations.

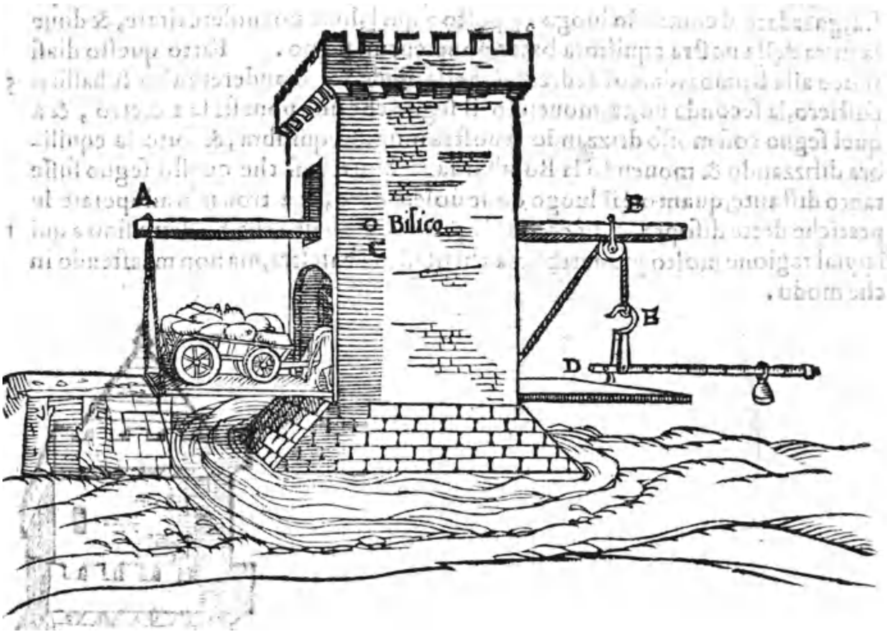


Fig. 4.6 Device, based on the lever principle, to measuring the weight of carts

The trend to represent the inner parts of a machine or an anatomical part (there are parallels in Leonardo's work between the mechanical and the anatomical drawings) is to use transparencies, or different parallel layers.

4.2.2.4 Sebastian Munster (1489–1552)

Sebastian Münster (1488–1552), was a German cartographer and cosmographer. He created the solar watch of Fig. 4.13.

4.2.2.5 Agostino Ramelli (1531–1600)

Agostino Ramelli is the author of the book "Le diverse et artificiose machine del capitano Agostino Ramelli" (The various and artful machines of Captain Agostino Ramelli) (Fig. 4.14) (Dolza 2009).

Three examples of drawings by Agostino Ramelli are presented here. Figure 4.15 is an idea relative to a pliable bridge. Such a bridge is constituted by some articulated segments, that, with relative movements, make the bridge compact.

Figure 4.16 is relative to a water mill that is a good example of such constructions in that time.

Fig. 4.7 War machine to throw stones

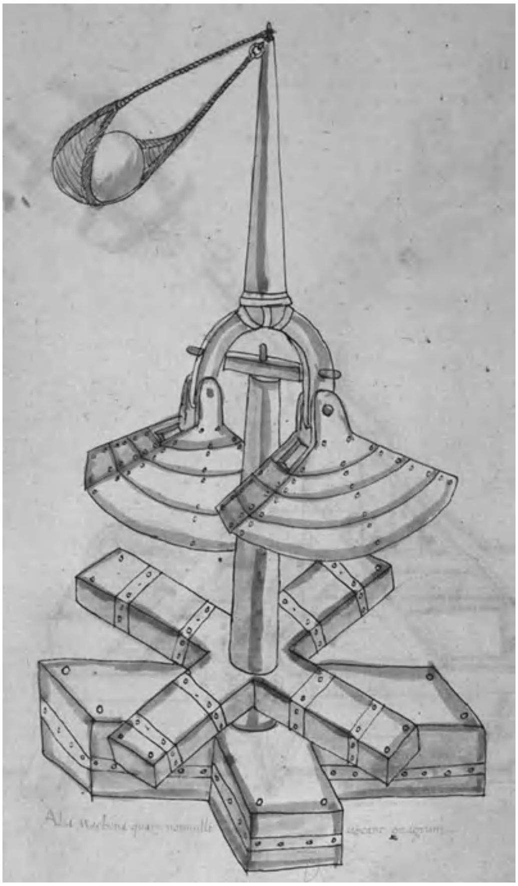


Figure 4.17 is a typical representation with an original idea: the “automatic library”: a large wheel contains many books: the rotation of the wheel permits the positioning of the wanted book before the reader.

4.2.2.6 Jost Amman (1539–1591)

Jost Amman was a Swiss artist, celebrated chiefly for his woodcuts, done mainly for book illustrations. Figure 4.18 is relative to a representation of a gold metallurgical workshop (1568)

4.2.2.7 Giovanni Agostino Pantheo (First Half of the Sixteenth Century)

Giovanni Agostino Pantheo was an alchemist and wrote the book “Voarchadumia contra alchi’miam” edited in Venice in 1530.

Fig. 4.8 Swivel gun

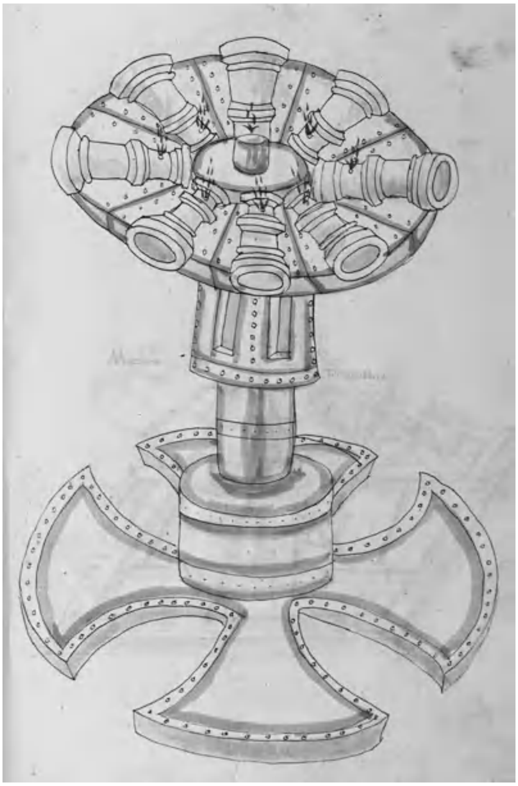
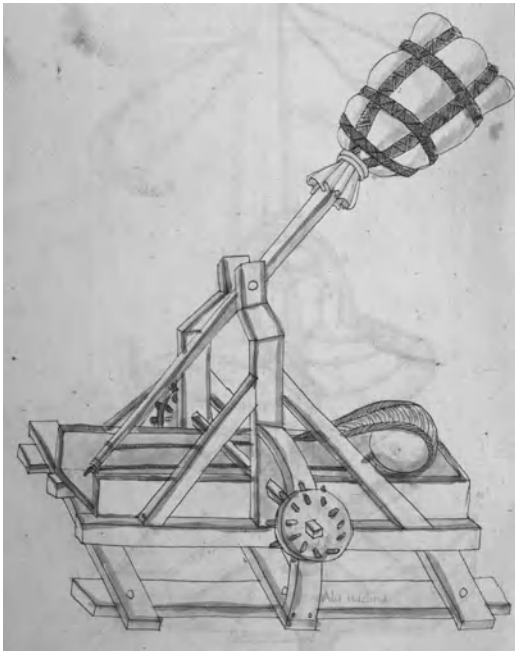


Fig. 4.9 Catapult



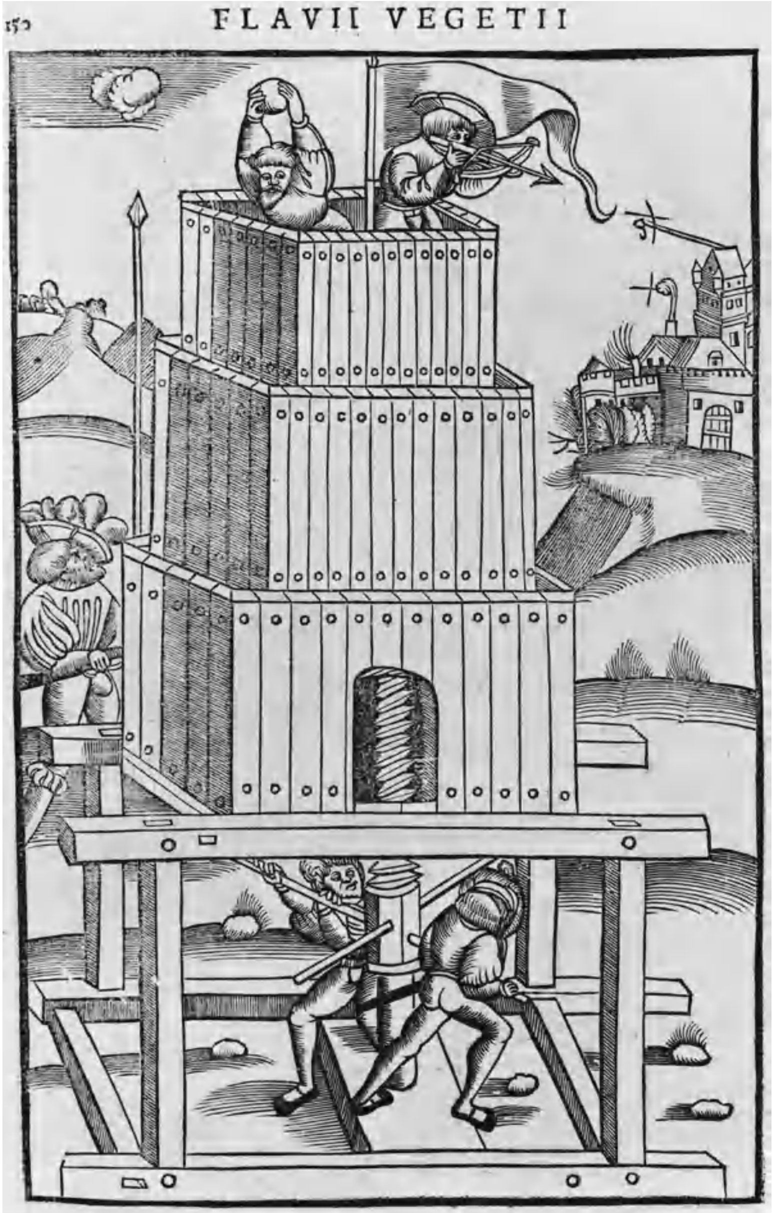


Fig. 4.10 Telescopic tower to conquer walled cities

Fig. 4.11 Device used for breathing during an immersion

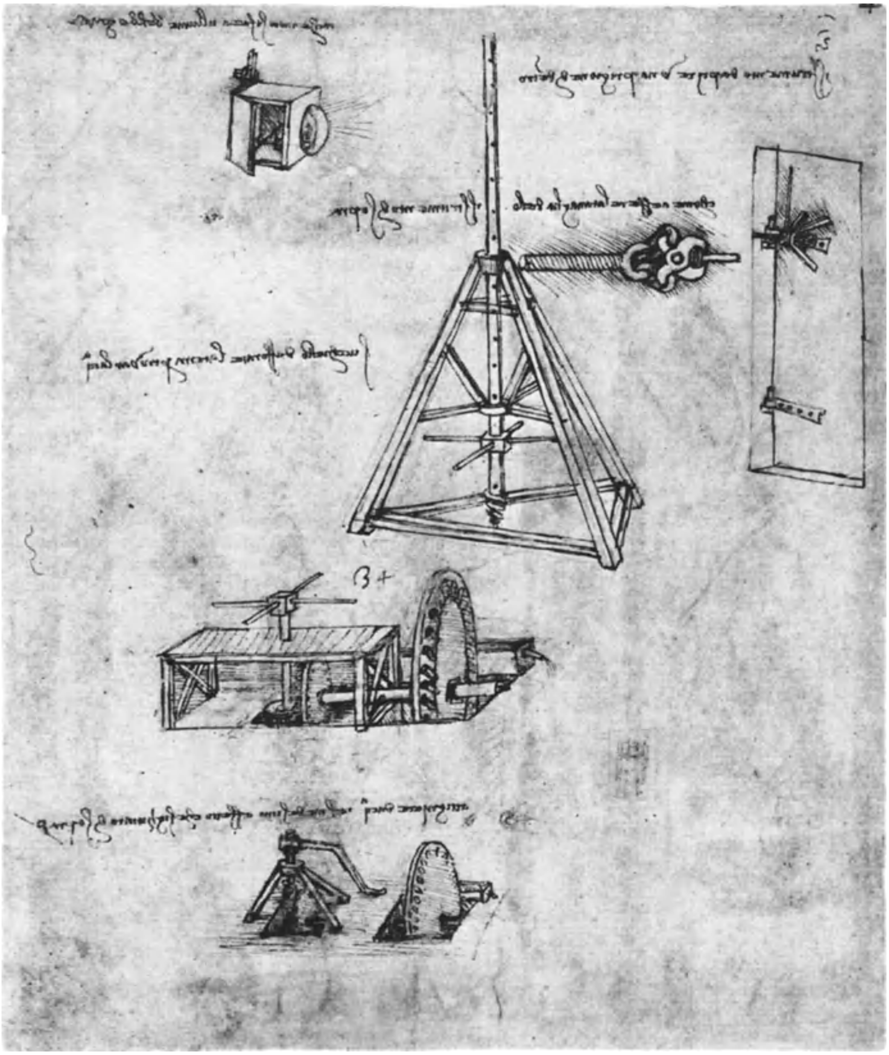


Fig. 4.12 Lantern

This alchemical work is highly unusual for its early use of four-colour printing. Pantheo was a Venetian priest who wrote against "spurious" alchemy. In the above-mentioned work he deals partly with the assay of gold, which is illustrated by drawings of rolling mills, furnaces of various sorts and alchemical apparatus. The volume also includes woodcuts showing the minting of coins, and a bird's-eye view of Venice and its surroundings.

Figure 4.19 represents a metallurgical workshop.

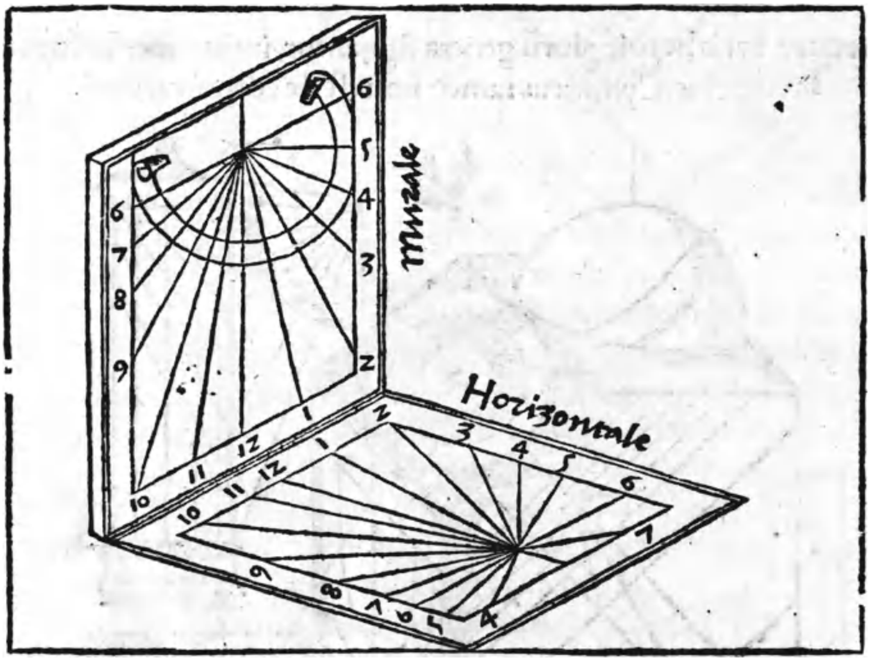


Fig. 4.13 Solar watch by Sebastian Munster

4.2.2.8 Jacques Besson (ca 1540–1573)

Jacques Besson wrote the books "Le Cosmolabe" (Fig. 4.20) and "The theatre, the instruments and the machines"(Fig. 4.21) (Dolza 2009).

4.2.2.9 Fausto Veranzio (ca 1551–1617)

Fausto Veranzio was the author of "Machinae Novae" (New Machines) (1595) (Fig. 4.22) (Dolza 2009).

4.2.2.10 Vittorio Zonca (1568–1603)

Vittorio Zonca wrote the book "Theatre of machines"(1607) (Fig. 4.23), which appeared after his death (Dolza 2009).

4.2.2.11 Giovanni Branca (1571–1645)

Giovanni Branca designed many different mechanical inventions. Branca studied and proposed the first applications of steam. Figure 4.24 is an idea, after Erone of Alessandria, of a steam application to actuate, through a gear transmission, a system of pestles.

LE DIVERSE ET
ARTIFICIOSE
MACHINE
DEL CAPITANO AGOSTINO
RAMELLI
DAL PONTE DELLA TRESIA
Ingegniero del Chriſtianiſſimo
Re di Francia et di pollonia.

Nellequali ſi contengono uarij et induſtriosi Moui-
menti, degni digrandiſſima Speculatione,
per cauarne beneficio infinito in
ogni ſorte d'operatione;

Compoſte in lingua Italiana
et Franceſe.

A parigi in caſa del'autore,
cō priuilegio del Re. 1588.

Fig. 4.14 The book of Agostino Ramelli (Dolza 2009)

4.2.2.12 Salomon de Caus (1576–1626)

Salomon de Caus was a French engineer and once (falsely) credited with the development of the steam engine. Being a Huguenot, he spent his life moving around Europe.

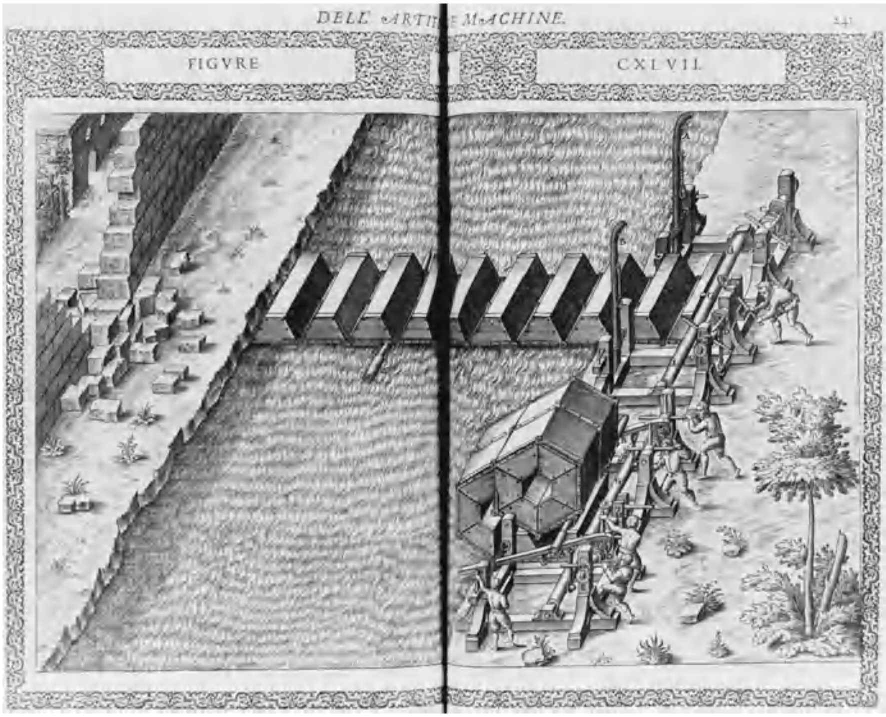


Fig. 4.15 Pliable bridge by Agostino Ramelli

De Caus worked as a hydraulic engineer and architect under Louis XIII. He also designed gardens in England, the one of Somerset House among them; also, the Hortus Palatinus, the Garden of the Palatinate, in Heidelberg, Germany.

Figure 4.25 represents the frontispiece of a book by Salomon de Caus, with the introductive text written in German and with gothic characters, on a plane in perspective. From the graphical point of view, it is interesting as a representation of some drawing instruments.

Figures 4.26 and 4.27 represent two mechanisms by Salomon de Caus and are interesting witness of the ideas of that time.

4.2.2.13 Lazarus Eckert (End of the Sixteenth Century)

Lazarus Eckert was a German author, active in Frankfurt. Figure 4.28 represents a workshop for silver refining.

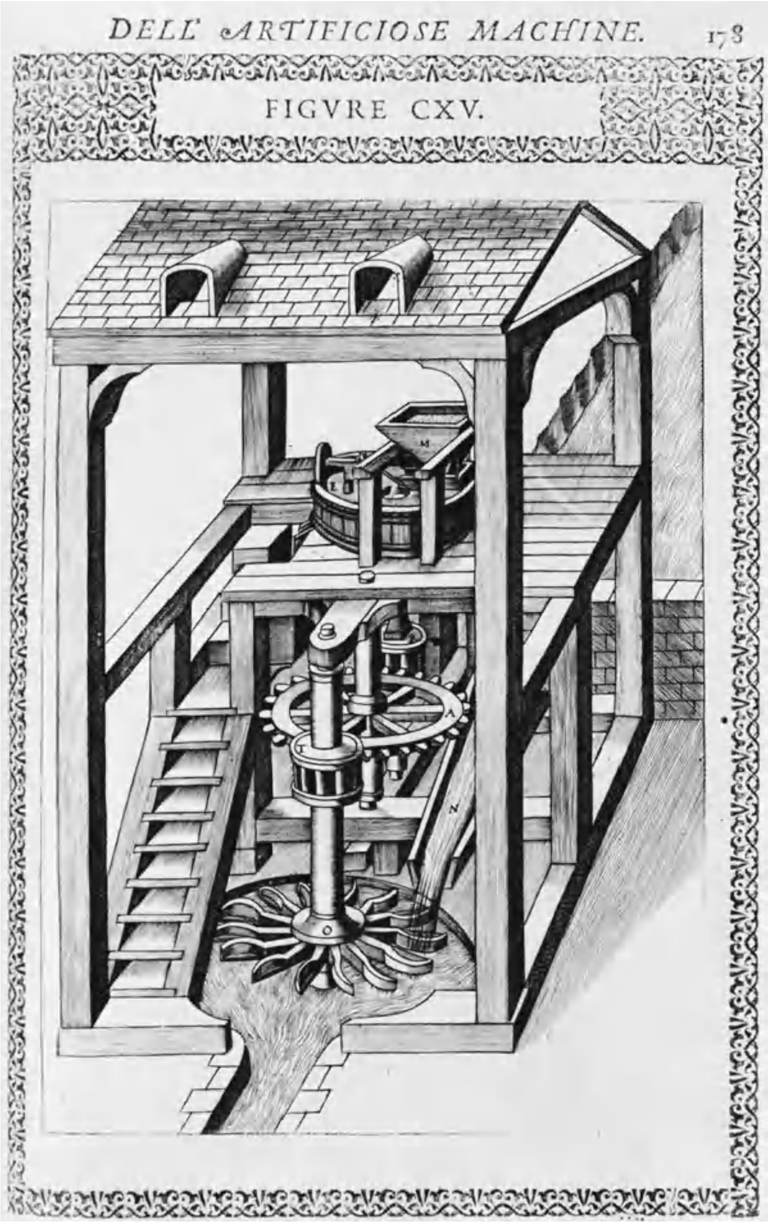


Fig. 4.16 Water mill by Agostino Ramelli

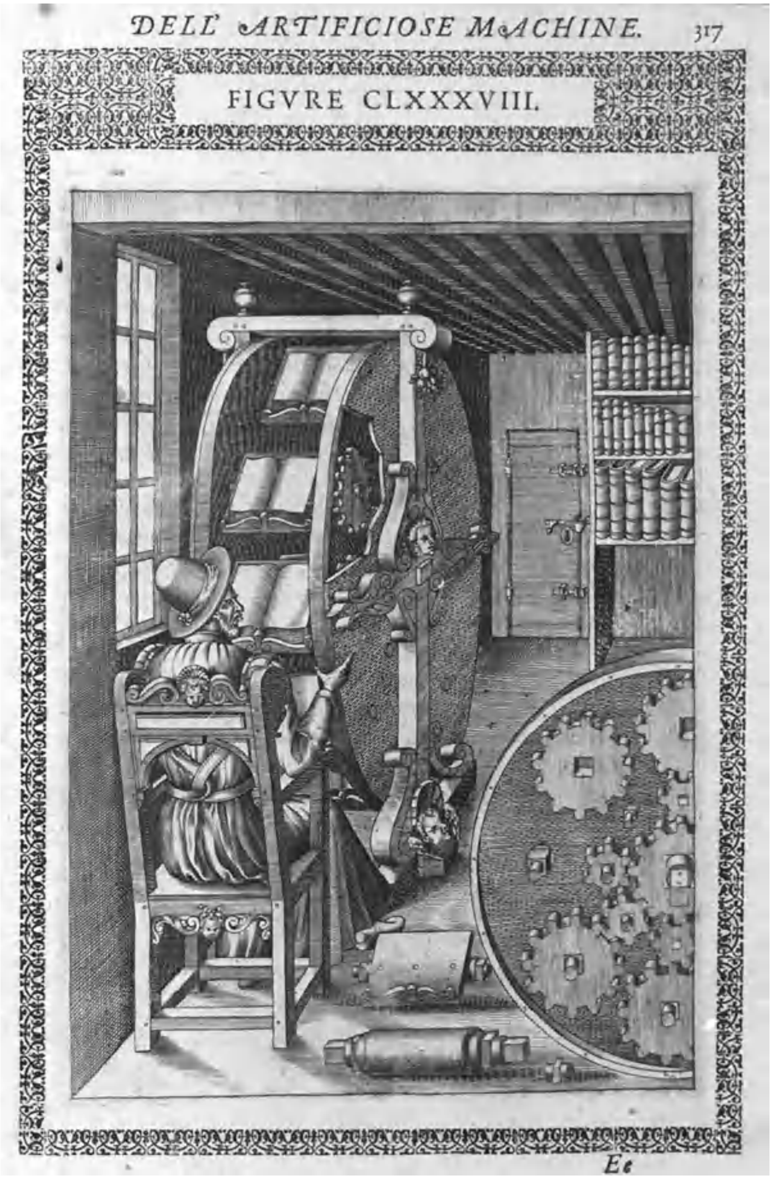


Fig. 4.17 "Automatic library" by Agostino Ramelli

4.3 The First Steps Toward Scientific Documentation

The Renaissance also saw the beginning of the utilization of drawing as a means of documentation of the first steps of scientific development. Scientists, in other words, began to depend on utilizing representation to document their creations and to

Fig. 4.18 Gold metallurgical workshop by Jost Amman (1568)

communicate their acquired knowledge. Such a trend was particularly characteristic of the last years of the sixteenth century and especially of the successive centuries.

Some examples are here mentioned.

4.3.1 William Gilbert (1544–1603)

Physician at the court of England, Gilbert was the author of experiments about electrostatics and of the hypothesis of the terrestrial magnetism. A unit of magneto motive force, also known as magnetic potential, was named the "gilbert" in his honour.

Fig. 4.19 Metallurgical workshop by Giovanni Agostino Pantheo

Figure 4.29 shows an example of pages of a book written by Gilbert with some drawings illustrative of experiments.

4.3.2 Gaspar Schott (1608–1666)

Gaspar Schott was a German Jesuit and scientist, specializing in the fields of physics, mathematics and natural philosophy, and known for his piety. In his book "Organum mathematicum" (Mathematical organ), he describes and represents a calculation machine, of course, realized only with mechanical elements. Figure 4.30

Fig. 4.20 The book of Jacques Besson (Dolza 2009)

represents such a machine, through an intuitive axonometry. In Fig. 4.31, however, Schott represents the principle of photography, through a "camera obscura". The image shown is from the book of Schott "Physica curiosa".

4.3.3 Blaise Pascal (1623–1662)

Pascal developed a calculation machine based, of course, only on mechanical principles, such as systems of wheels (Fig. 4.32).

Fig. 4.21 A mechanism from the book "The theatre, the instruments and the machines" of Jacques Besson (Dolza 2009)

4.3.4 Robert Hooke (1635–1703)

Hooke was a well-known English physicist who, among other developed researches (e.g. optical), was the founder of the theory of elasticity. Figure 4.33 documents his optical studies and represents a microscope.

Fig. 4.22 The book of Fausto Veranzio (Dolza 2009).

Figure 4.34, however, represents a spring and documents studies about the relation between force and deformation. The proportion between applied force and consequent deformation (i.e. Hook’s law) was self expressed by Hooke with the Latin sentence “ut tension, sic vis”(as deformation, so force).

4.4 The First “Technical” Drawings

Drawings of machines were present also in the Middle Ages, particularly in South Germany and in North-Centrum Italy. Such drawings were very simple and ingenuous representations. With the Renaissance began a more systematic use of drawing

Fig. 4.23 The book “Novo teatro di machine et edifici” (New theatre of machines and buildings) by Vittorio Zonca (Dolza 2009)

from a technical point of view. Particularly, the authors of treatises celebrated the important role of the image, which they saw as more complete and reliable, from the communication point of view, than the written text.

The need for a complete and reliable description through an image motivated authors to apply drawing rules (perspective and pictorial), with the aim to give to the

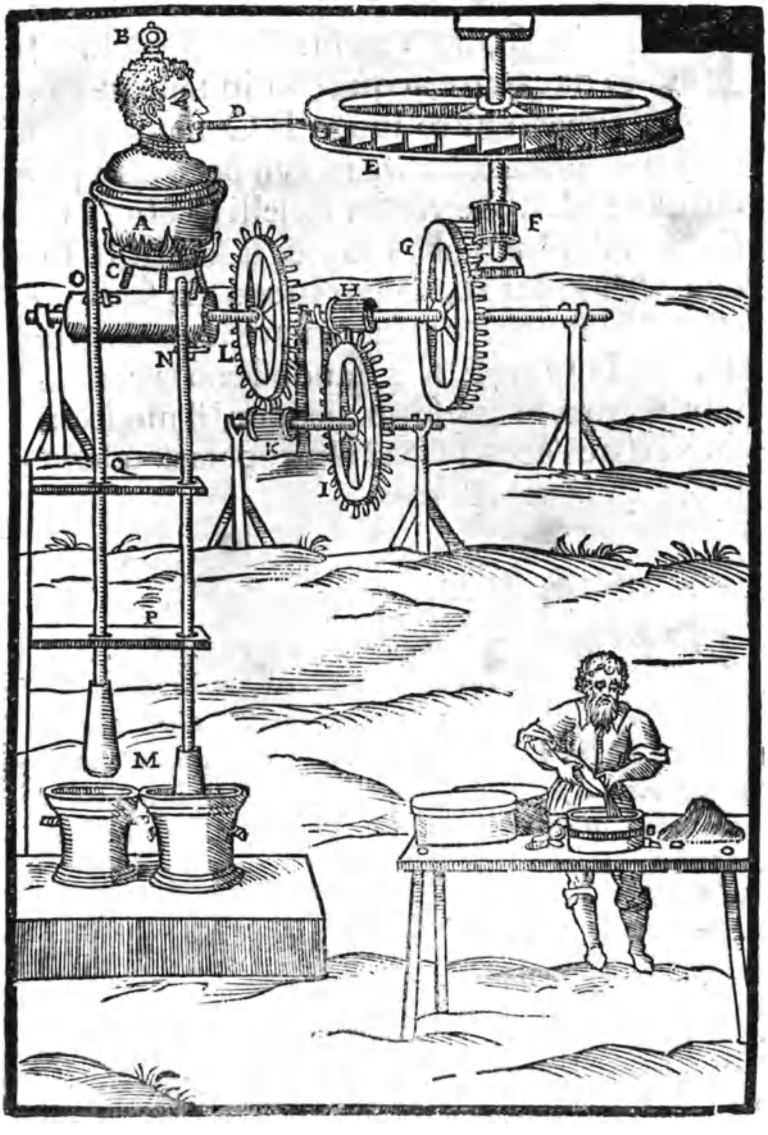


Fig. 4.24 Idea to apply the steam by Branca

drawing the wanted aspects. By considering the drawings of technical devices in the Renaissance, it is important to distinguish the authors in two fundamental categories:

The artists, who express in the technical drawings their ability and represent machines with the techniques typical of painting. The results are often very interesting from the aesthetic point of view.

Fig. 4.25 Frontispiece by Salomon de Caus, with representation of some drawing instruments

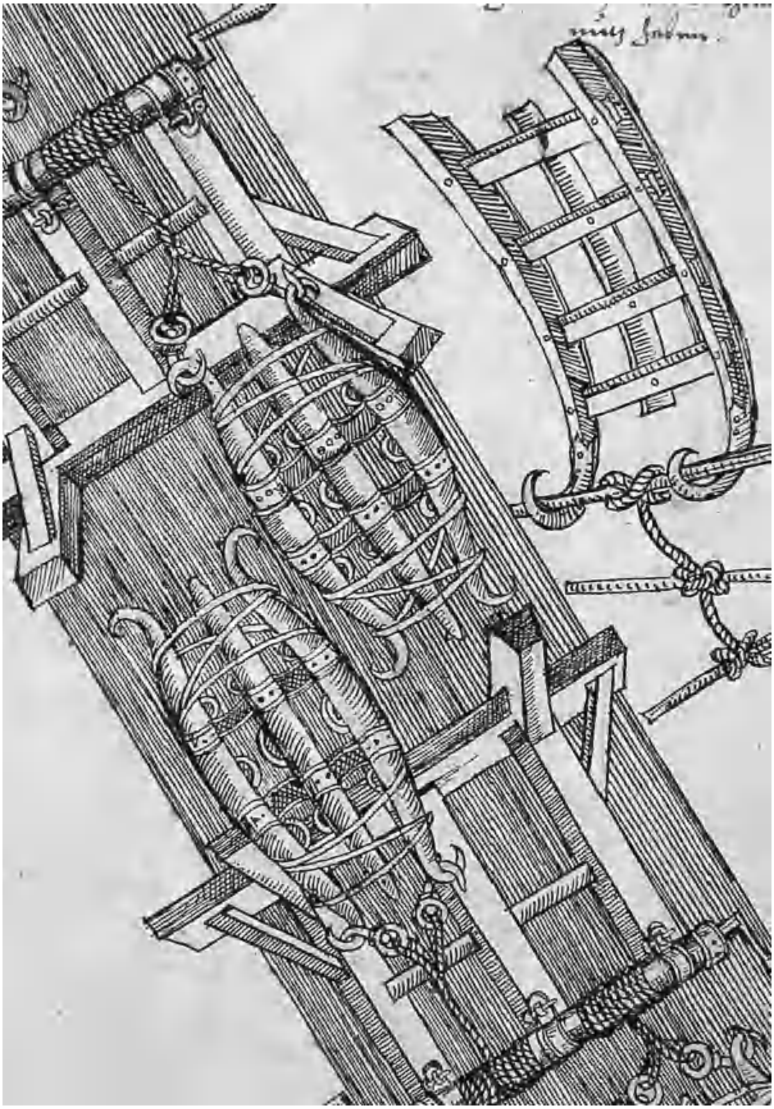


Fig. 4.26 Mechanism in a drawing by Salomon de Caus

The technicians, who tended to simplify with the aim of representing all the particulars of the machines. These authors utilized some shared criteria, such as exploded views, separate drawings of the parts of the machine, transparencies, etc.

As an example, consider the same device, a war machine to climb walls (Fig. 4.35), represented by two authors: Roberto Valturio to the right and Vegezio to the left.

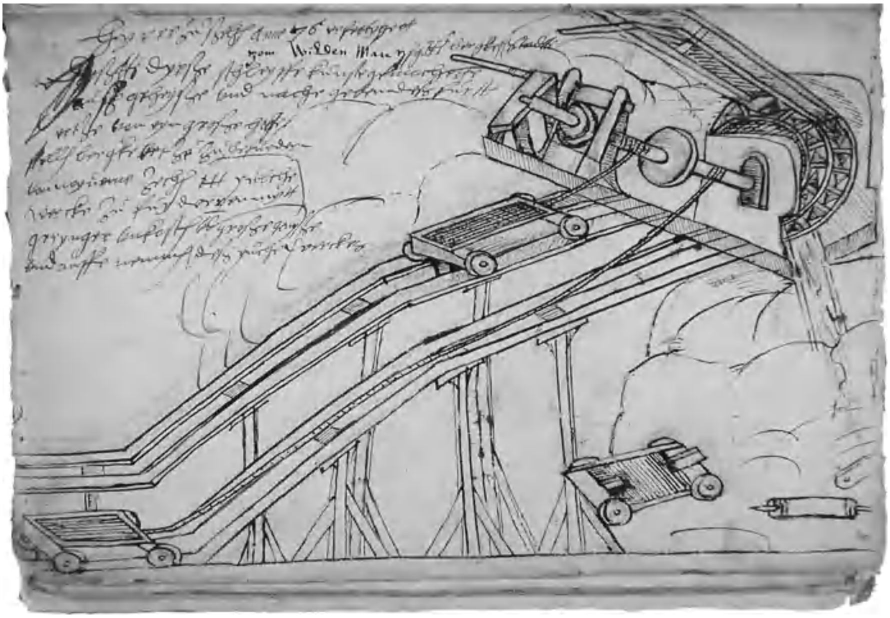


Fig. 4.27 Mechanism in a drawing by Salomon de Caus

The different styles are evident: Valturio is influenced by the style of the Middle Ages, the representation is more simple and concise, while the drawing of Vegezio is more studied, with an efficient three-dimensional study and chiaroscuro techniques.

The most important aspects of technical drawing in this period can be summarized as follows:

(a) First steps of the exploded drawing, to illustrate a complex of mechanical parts and, particularly, the assembling order and the functional principles of such a complex (Fig. 4.36).
(b) Begin the differentiation among assembly drawing (representation of the complex of a machine) and particular drawing (representation of all parts that constitute the machine, with an embryo of the information necessary to the construction) (Fig. 4.37) (Marchis 1994).
(c) First embryo of the indication of quantitative information, i.e. the dimensions, through a graphical scale expressed by a graduated segment. In Fig. 4.38 (Marchis 1994) it is interesting to observe a mechanism with worm and worm wheel : it is easy to recognize the assembly drawing, the parts drawings and the graphical scale.
(d) Transparencies to illustrate the internal details of a technical object.

Fig. 4.28 Workshop for silver refining by Lazarus Eckert (end of the sixteenth century)

(e) Some drawings of the Renaissance began to have the character of "modern" design. As an example, a Japanese staff realized in 1996 an axial bearing, starting from a drawing of Leonardo da Vinci, assumed as his design (Fig. 4.39) (Tsuboi 1996).

Fig. 4.29 Representation of some experiments of William Gilbert

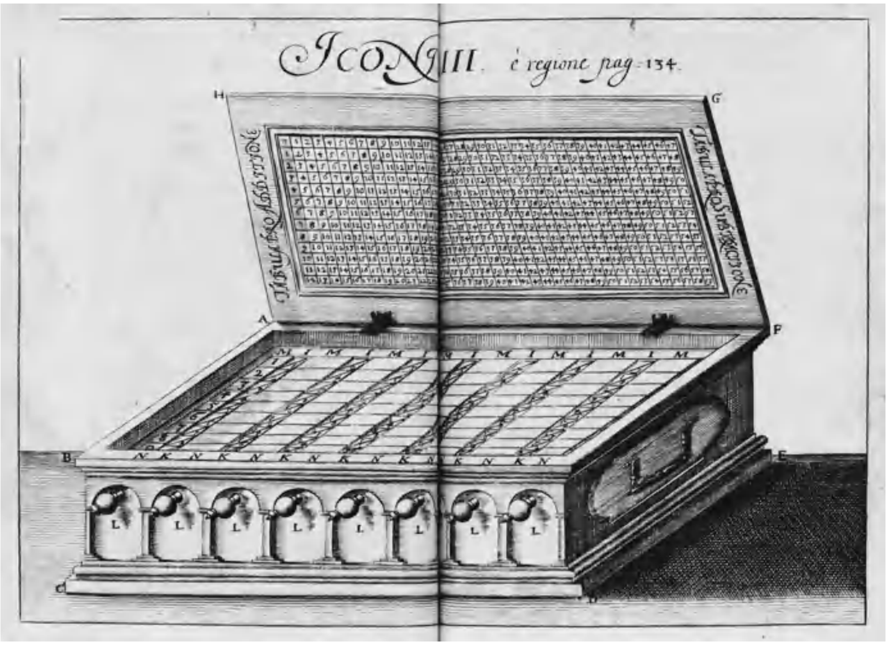


Fig. 4.30 Calculation machine by Gaspar Schott

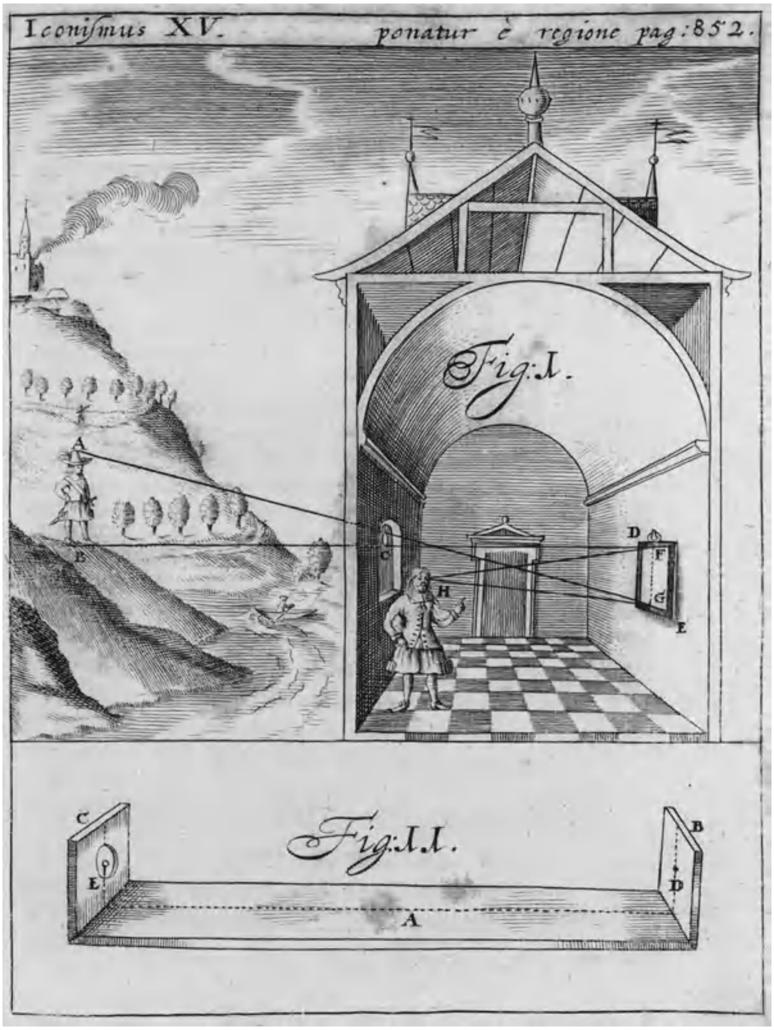


Fig. 4.31 The principle of photography by Gaspar Schott

4.5 Some Conclusions

The abovementioned example could represent a good survey about some fundamental aspects of the drawing of technical objects in the Renaissance.

A complete collection of the drawings of the Renaissance would provide important information about the development of ideas in that time. For a correct and complete utilization of such drawings, a computer archive would be very useful. As a basis, the archive (Database machine drawings), realized in a University of Berlin could be a good example.

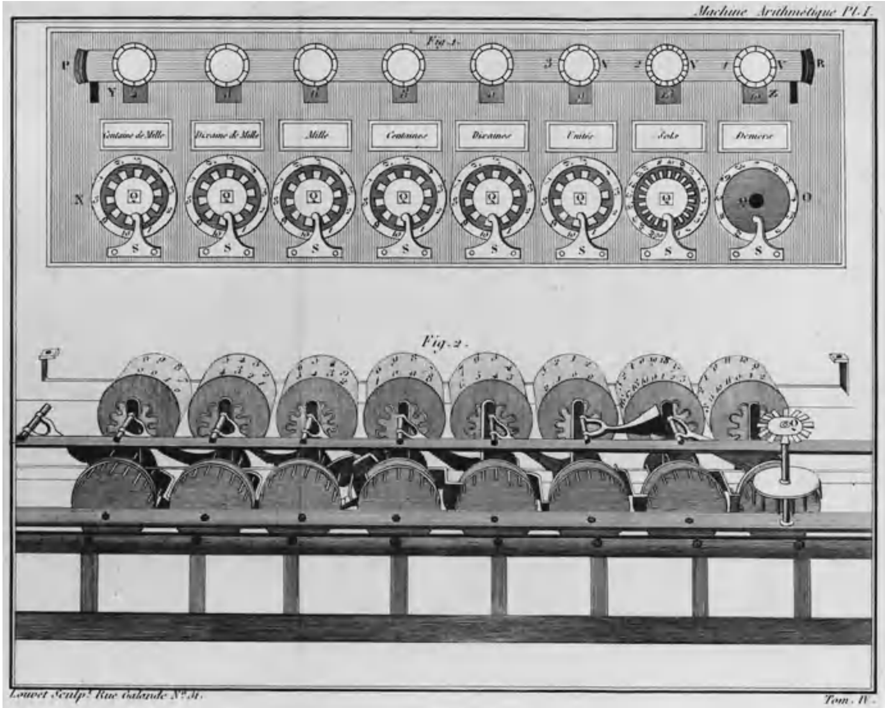


Fig. 4.32 Representation of the calculation machine as an idea of Pascal

The first steps of modern science have been documented by the drawings of scientists of the Renaissance. The consideration and the study of such drawings, will be an important tool in writing the history of physics and mechanics. The first technical drawings appeared in this period and, in some cases, they have transmitted the first technical information, such as, e.g., dimensions, to be expressed on a graphical scale.

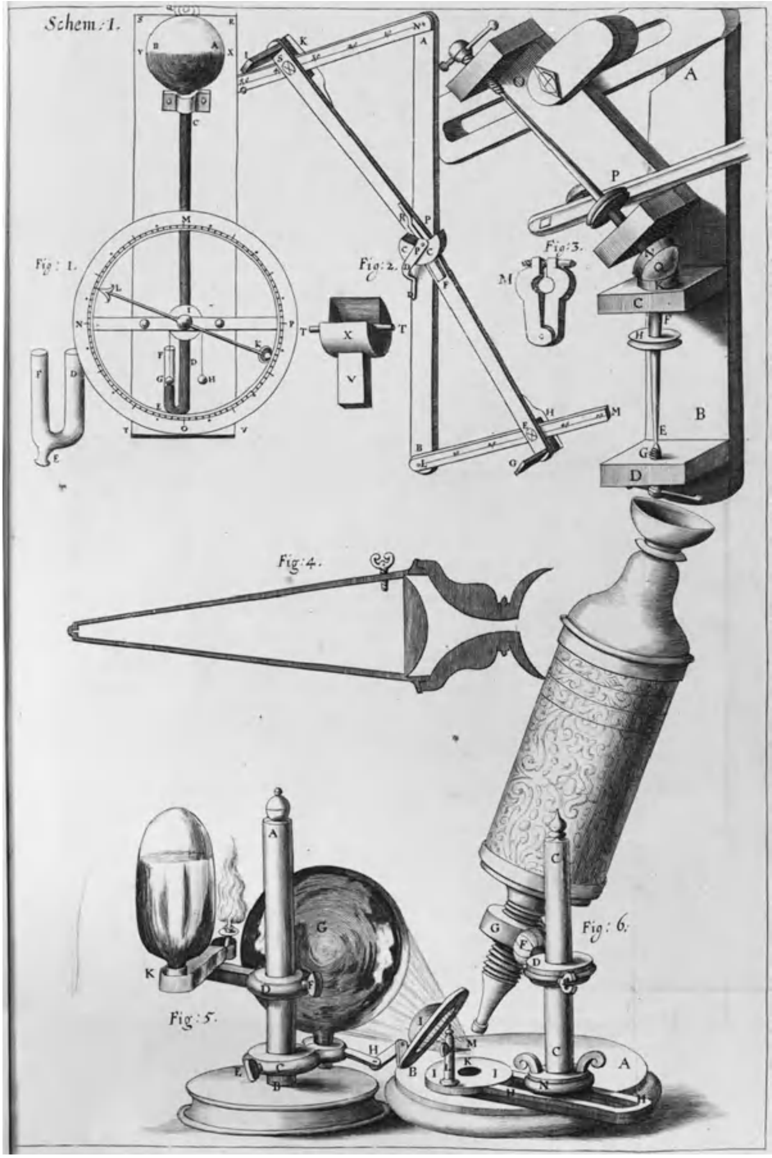


Fig. 4.33 Optical experiments of Robert Hooke: the microscope

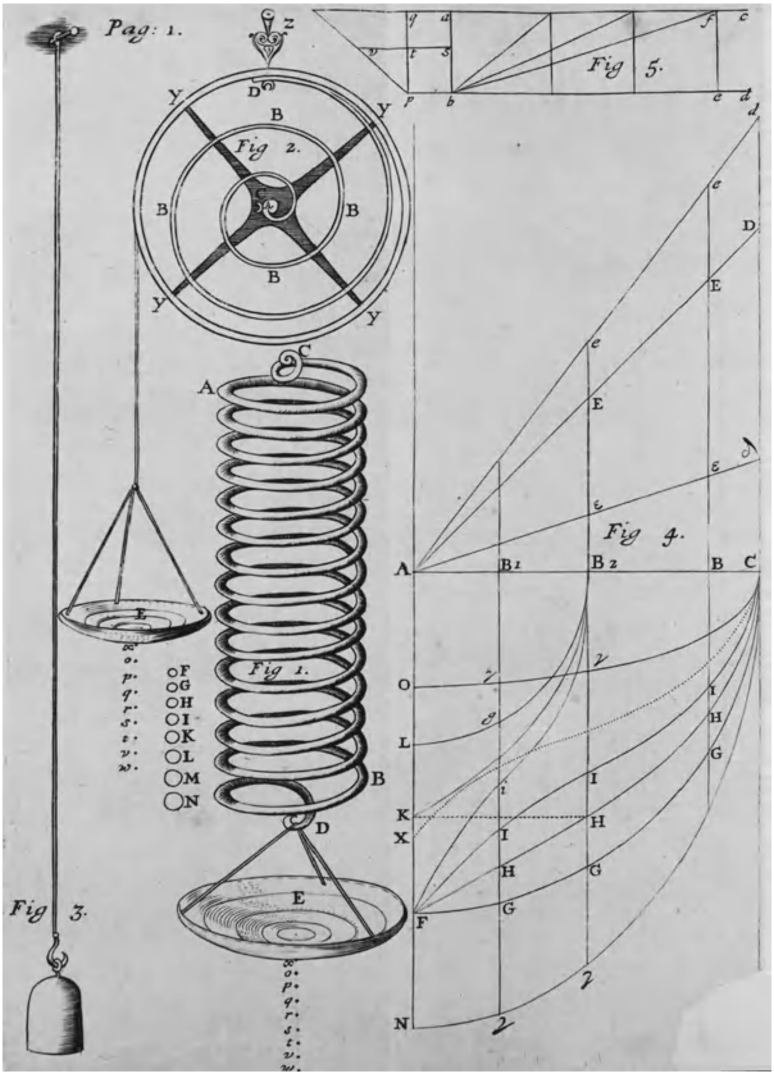


Fig. 4.34 Mechanical experiments of Robert Hooke: deformation of a spring, as fundamental basis of the “Hooke’s Law”, relative to the relation between applied force and consequent deformation

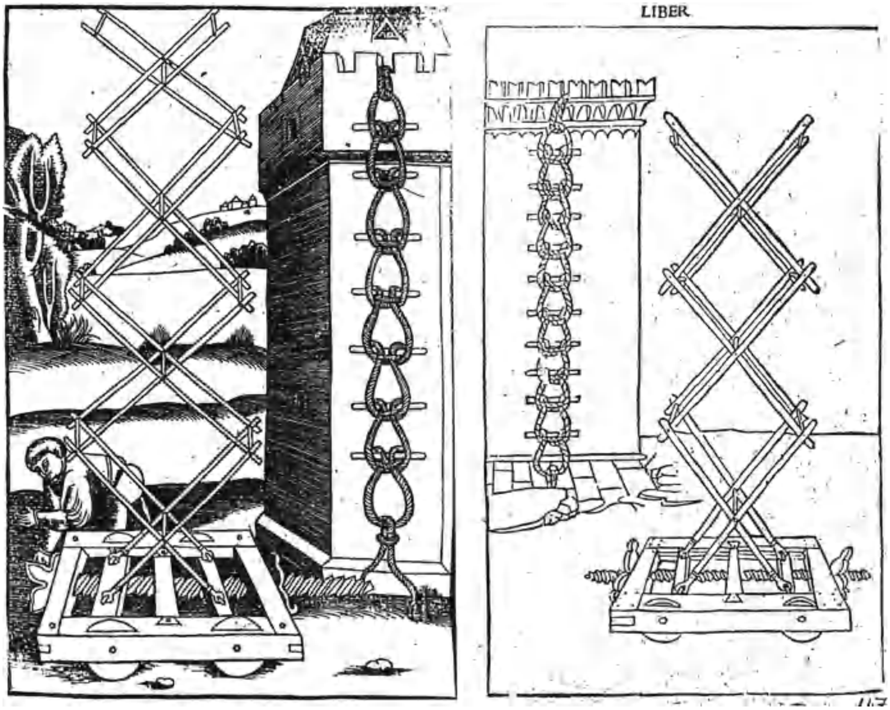


Fig. 4.35 Different representations, by Vegezio (1535) to the *left* and by Valturio (1473) to the *right*, of the same object: a war machine to climb walls (Ceccarelli and Cigola 2001)

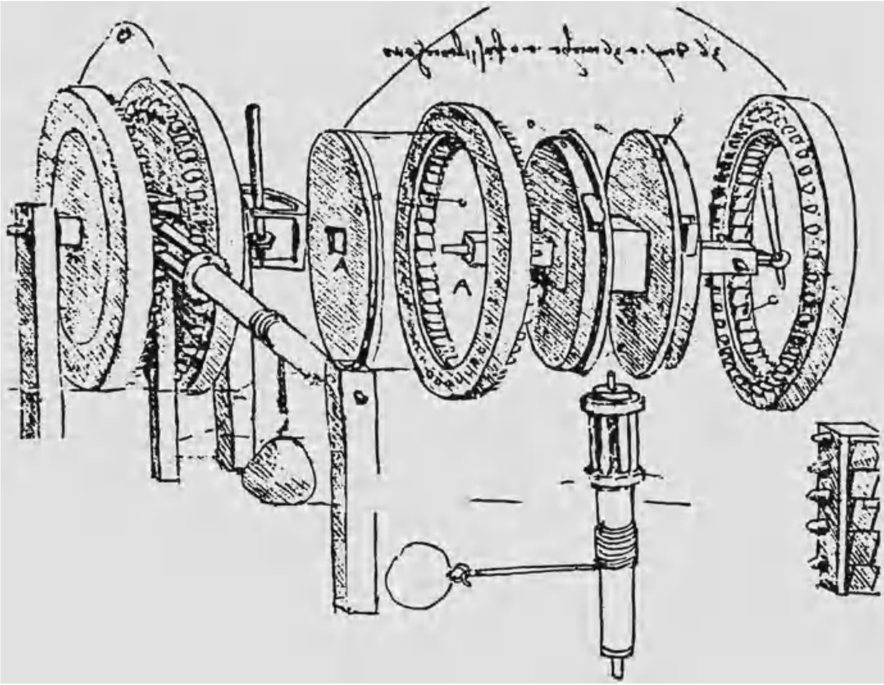


Fig. 4.36 Drawing of Leonardo da Vinci, that can be considered an anticipation of the exploded drawing: to the *left*, the assembled mechanism, and to the *right* the same mechanism exploded, with all parts in assembly position

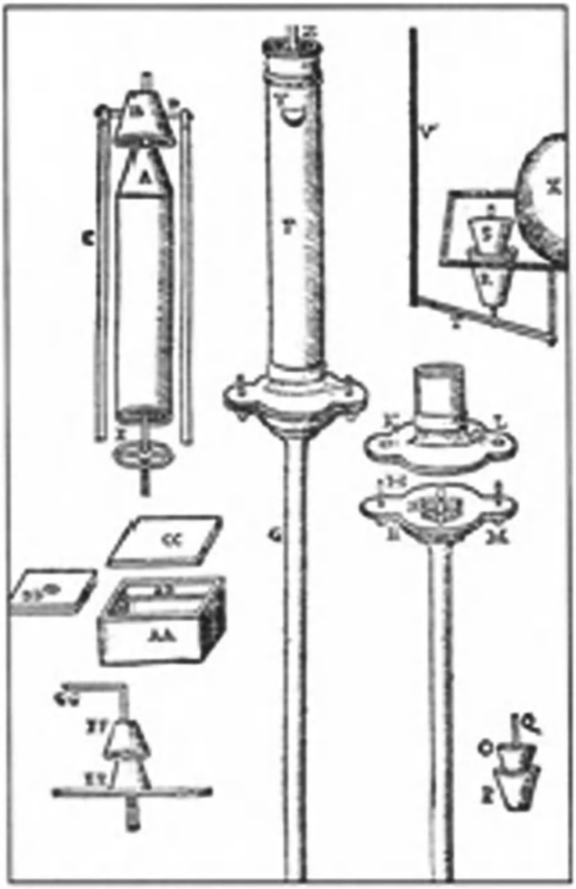


Fig. 4.37 Assembly and particulars drawings, by Branca

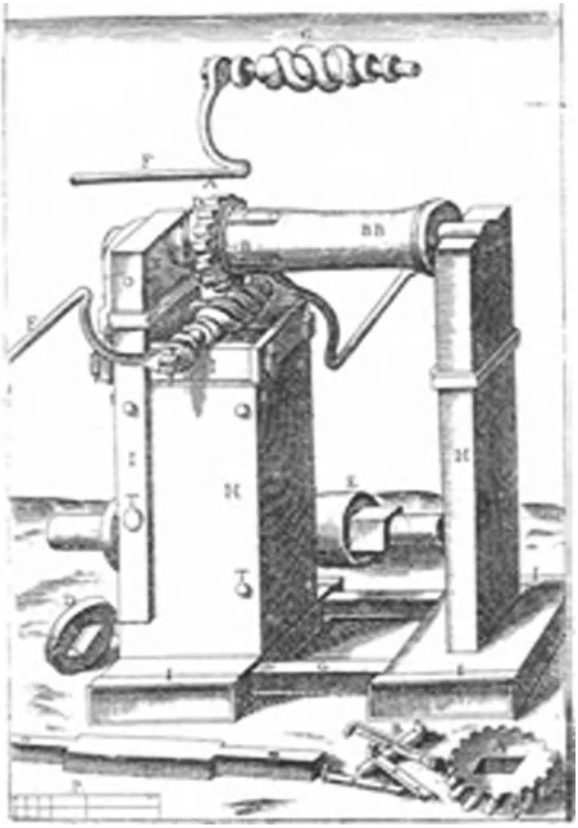


Fig. 4.38 Mechanism with worm and worm wheel: assembly drawing, parts drawings and graphical scale

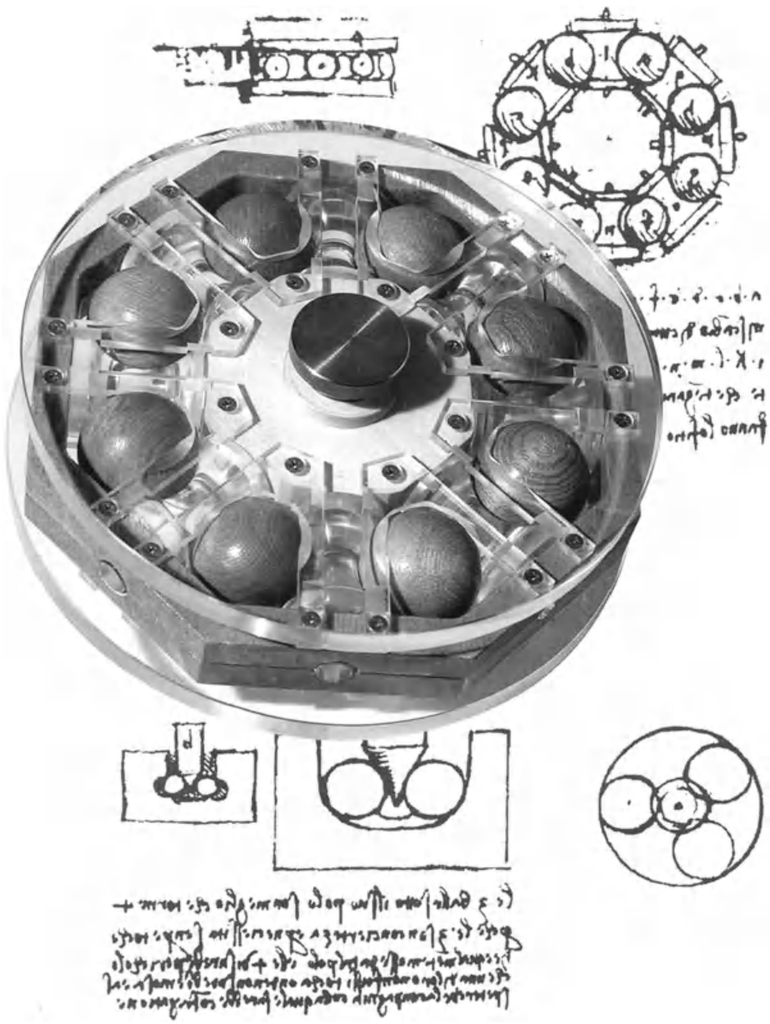


Fig. 4.39 Drawings of Leonardo utilized as "constructive drawings" for the construction (Tsuboi 1996) of an axial roll bearing

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Chapter 5
The Eighteenth Century

5.1 Introduction

The eighteenth century was dominated, from the point of view of technical drawing, by some important events, such as the activity of the mathematician Gaspard Monge (the father of Descriptive Geometry), the first steps of industry and the utilization of orthographic projections, the first encyclopedic books and the growing use of drawing as a documentary tool for use by scientists.

5.2 Gaspard Monge

The eighteenth century was dominated by the great figure of the French mathematician Gaspard Monge (Beaune 1746- Paris 1818) (Cardone 1996).

He was first educated at the college of the Oratorians in Beaune, and then at their college in Lyon where he had been learning physics. Returning to Beaune for a vacation, he made, on a large scale, a plan of the town, inventing methods of observation and constructing the necessary instruments; the plan was presented to the town, and preserved in their library. An officer of engineers, on seeing it, wrote to recommend Monge to the commandant of the military school at Mézières, and he was received as a draftsman and pupil in the practical school attached to that institution. In 1768 Monge became a professor of mathematics, and in 1771 a professor of physics, at Mézières.

In 1783, in the Academy of Sciences, he became an examiner of students ; in 1788 he wrote the "Traité de statique" (Treaty of statics).

After the establishment of the Ecole Normale he became responsible for the teaching of descriptive geometry, then, at the Ecole Polytechnique, he lectured on the theory of surfaces.

Monge is the author of many books about military and mathematical items, e.g. "Dictionnaire du Physique" (Dictionary of Physics) (1793–1822), "Description de

E. Rovida, *Machines and Signs*, History of Mechanism and Machine Science 17, DOI 10.1007/978-94-007-5407-2_5, © Springer Science+Business Media Dordrecht 2013

l'art de fabriquer le canons" (Description of the art to realize cannons) (1794), "Feuilles d'analyse appliqué a la geometrie" (Notes about analysis applied to geometry) (1795), "Géométrie descriptive" (Descriptive geometry) (1794), "Theorie des ombres et de la perspective" (Theory of shadows and perspective) (1819).

The work of Monge, wide and fruitful, involves many scientific and technical areas. In particular, he played a key role in the history of drawing as it formalizes the basis of orthographic projections.

From the scientific point of view, Monge was the founder of descriptive geometry, which is enshrined in his great work "Géométrie descriptive" of 1794. Figures 5.1, 5.2, 5.3, 5.4, 5.5, and 5.6 are examples from "Géométrie descriptive" (the original text is the property of Istituto Lombardo Accademia di Scienze e Lettere (Lombard Institut of Science and Literature), Milan).

Gaspard Monge was interred in a mausoleum in Le Père Lachaise Cemetery, in Paris. His body was later transferred to the Pantheon. Place Monge and Rue Monge (5me Arrondissement) in Paris, as well as a monument in his hometown Beaune, were dedicated to him.

5.3 Orthographic Projections

Descriptive geometry is the science of representing three-dimensional objects on planes by using certain geometric constructions.

Such representations can be designed to see objects that already exist, as in relief (mostly architectural), and / or objects mentally conceived, as in the design of three-dimensional artifacts. A fundamental element of descriptive geometry consists of orthographic projections: they allow one to "describe" a complete and unique three-dimensional object on a plane, and thus they quickly became the most essential means of representation of technical objects.

The general principle of projections is represented in Fig. 5.7. The rays of projection, from the center, realize a correspondence between the points of the three-dimensional object and the points of the plane of projection that constitute the image of the object.

In Fig. 5.8, however, a principle of orthographic projections is represented: the centers of projection are infinitely distant and the projections' rays are, consequently, parallel. The projection planes are orthogonal, in relation to the direction of rays, and the object to be represented is oriented with significative surfaces parallel to the projection planes. In Fig. 5.9 an example of general orthographic projection of a parallelepiped is represented.

Projections, in the eighteenth century, also before Monge, were known in instinctive and non-formalized ways. The great contribution of Monge is the theoretically correct formalization of orthographic projections, also today called "projections of Monge".

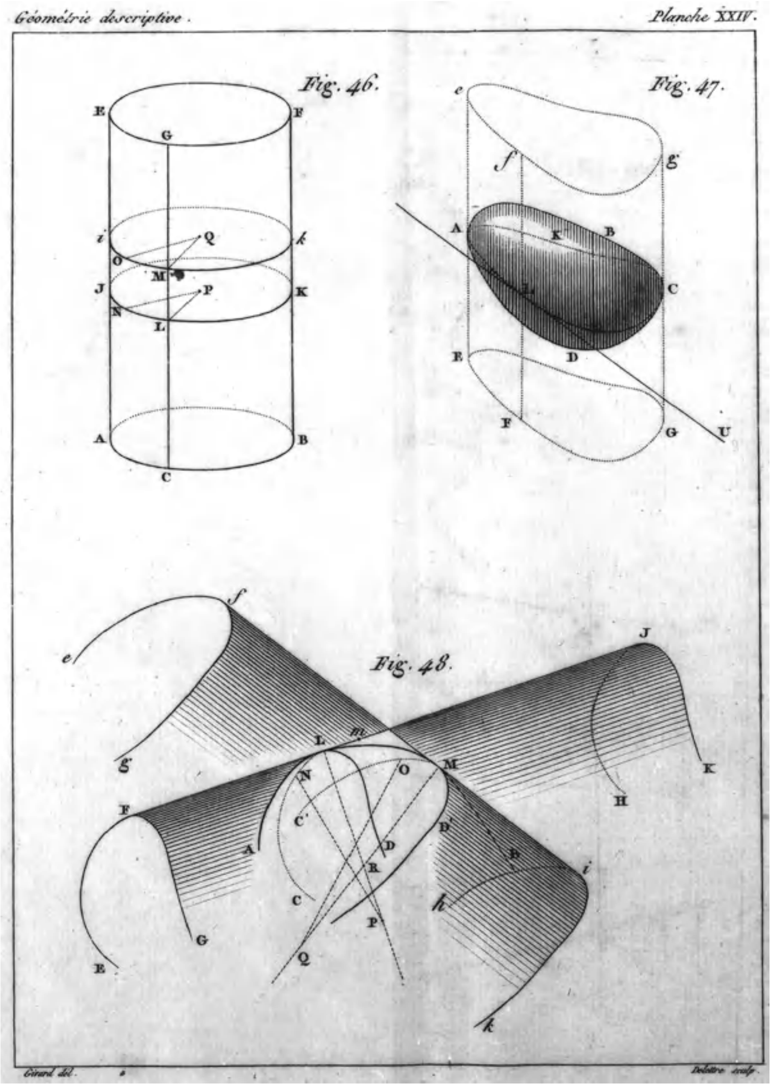
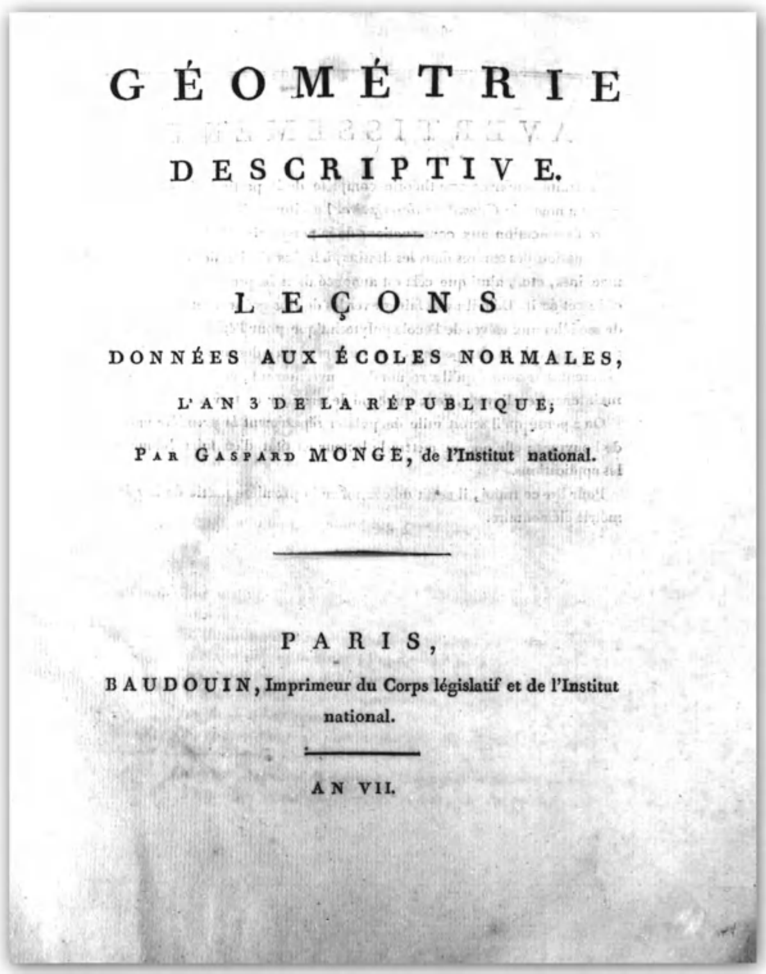


Fig. 5.1 Intersection of surfaces from "Géométrie descriptive"

5.4 The First Applications of Orthographic Projections

The projections of Monge were immediately utilized by technicians to represent technical objects, such as machines and instruments.

Figure 5.10 represents the two orthographic projections (front and side) of a coin minting machine (Chirone 1987): the clarity and expressivity of the representation is evident.



GÉOMÉTRIE
DESCRIPTIVE.

LEÇONS
DONNÉES AUX ÉCOLES NORMALES,
L'AN 3 DE LA RÉPUBLIQUE;
PAR GASPARD MONGE, de l'Institut national.

PARIS,
BAUDOUIN, Imprimeur du Corps législatif et de l'Institut national.

AN VII.

Fig. 5.2 Title page of "Géométrie descriptive"

The drawing represented in Fig. 5.11 (Landriani 1784) is also very interesting: such a drawing is relative to a particular part of a building. This drawing shows a building and, specifically, a tower with a lightning rod on the top. It is important to observe some details of the drawing. The representation is obtained with a section of the interior (now to be defined, according to modern drawing ISO standards, "cut") that shows the thickness of the walls and the trend of the stairs.

Another "modern" particular part is the magnified representation of the lightning rod and cable.

Figures 5.12, 5.13, 5.14, and 5.15 (aa. vv. 1981) represent technical drawings of military machines and instruments. Figure 5.12 is relative to a drawing of all parts of a cannon, with all technical details of each part: today, we would call such a drawing a "constructive drawing".

TABLE
DES
MATIÈRES CONTENUES DANS CE VOLUME.

Fig. 5.3 Table of contents of "Géométrie descriptive"

Figure 5.13, however, is relative to a same (or very similar) cannon, in assembled configuration: today, the official name, would be "assembly drawing". This drawing is in axonometric projection.

Figure 5.14 is relative to a particular type of cannon (a mortar). The representation is obtained by a cut, to illustrate the interior of the cannon. The graphic scale is also interesting as it indicates the quantitative aspect of the drawing: the graphic scale could be considered an ancestor of the modern dimensioning of technical drawings.

Figure 5.15 is relative to a table with a collection of types of disposable nails: such a drawing is an ancestor of the modern standard tables that collect all forms and dimensions of components and machine elements.

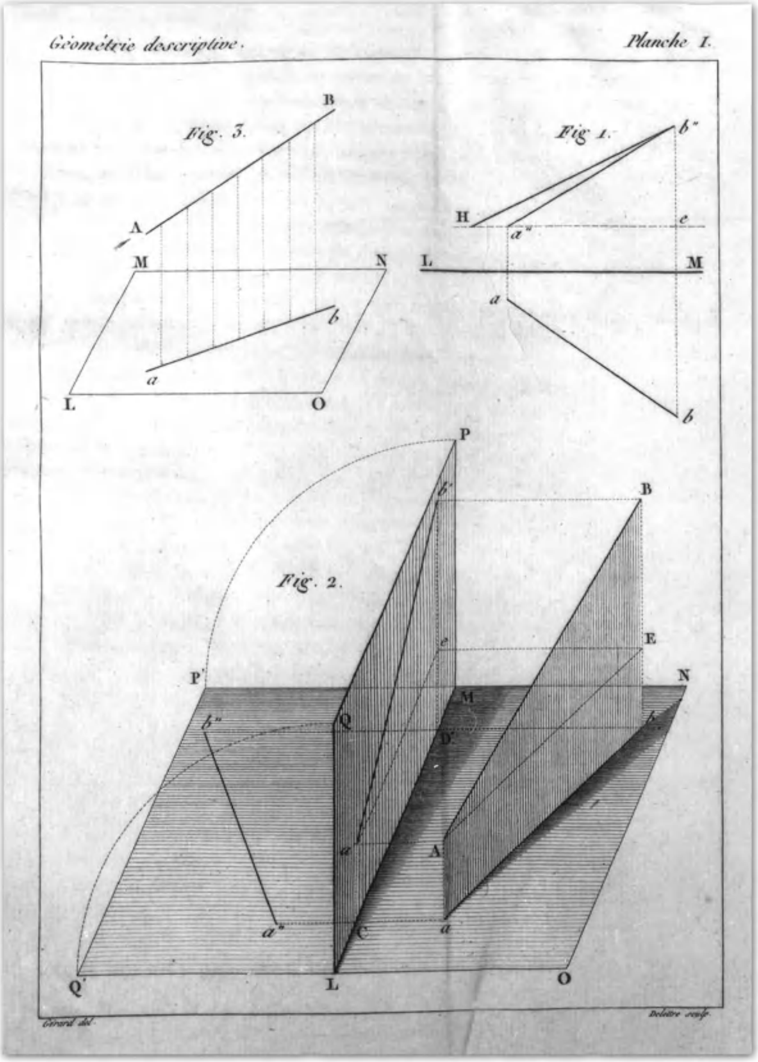


Fig. 5.4 Example of projection of segments and plans from “Géométrie descriptive”

Figure 5.16 is relative to a military cart represented through a lateral and top view and details of its axle: it is a correct application of orthographic projections.

Figure 5.17 is a drawing of Nicola Zabaglia (1664–1750), a maker of buildings and designer of lifting machines. The abovementioned figure represents a building in axonometric projections. From the point of view of drawing of machines, the figure is interesting because there are represented some lifting machines, utilized in building works. The figure is, therefore, an interesting document about building construction and relevant machines utilized.

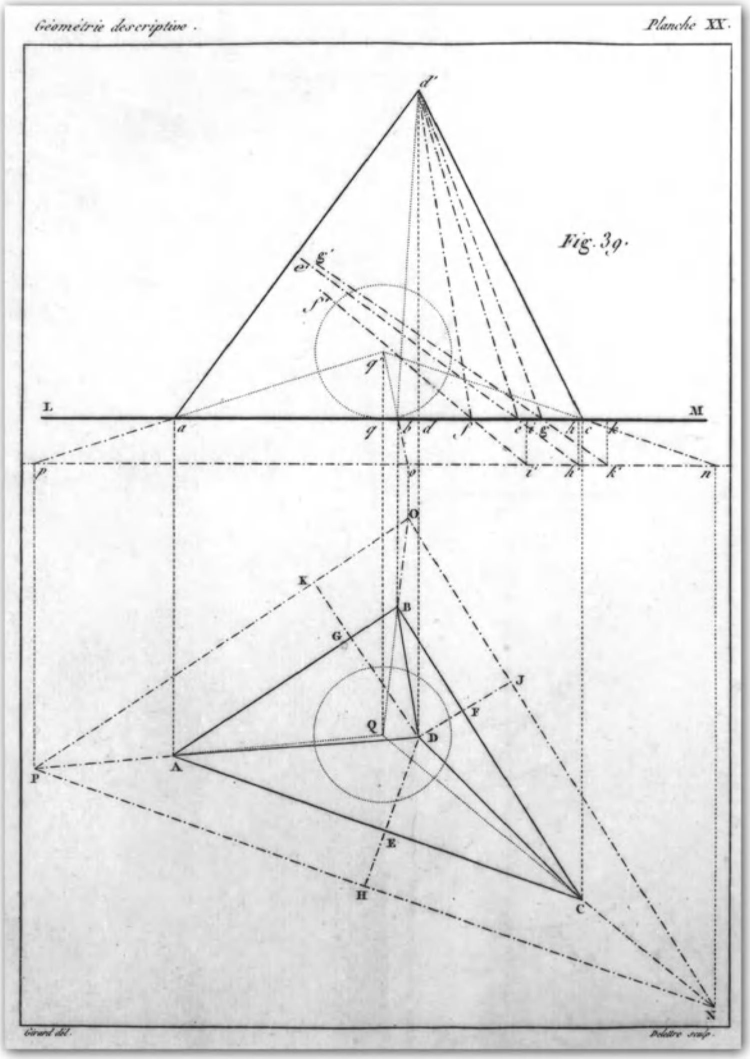


Fig. 5.5 Example of projection of triangles from “Géométrie descriptive”

5.5 The Encyclopedic Books

An interesting phenomenon characterizing the eighteenth century is the development of encyclopedic trends. This literary gender is represented by many works and many authors. Such works are relative to the totality of human science. Such a gender was represented in the past, e.g., by the “Etimologia” or “Origines” (Etymology or

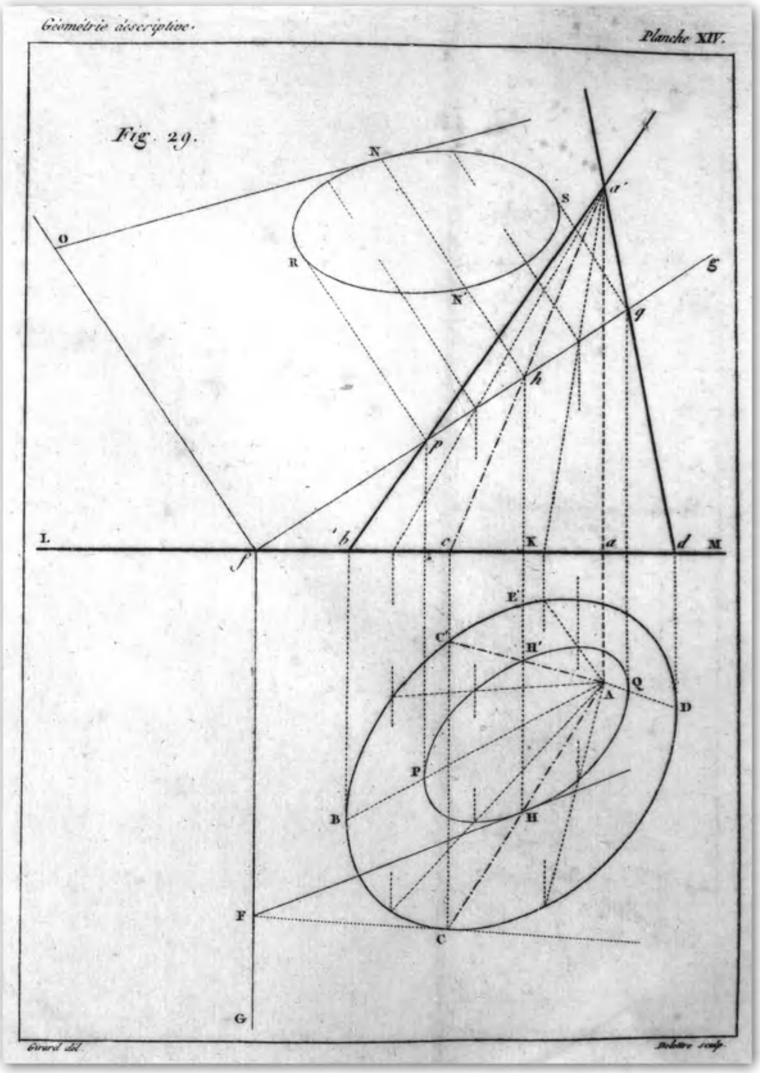


Fig. 5.6 Example of projection of an ellipse from “Géométrie descriptive”

Origins) written by Isidoro of Sevilla (560–636), structured assuming as starting point the etymologies of many words, and the “Tesoretto” (Little Treasure) written by Brunetto Latini (ca 1220 –ca 1294), but only in this century does the encyclopedic trend reach great development. The most famous work is the “Encyclopédie” of Diderot and d’Alembert, realized in 35 volumes (11 of drawings), in years 1751–1772. Denis Diderot, the father of the “Encyclopédie”, French writer and philosopher and important and representative figure of the Enlightment, is the author of many works: the “Encyclopédie” is the most important, particularly from the point of

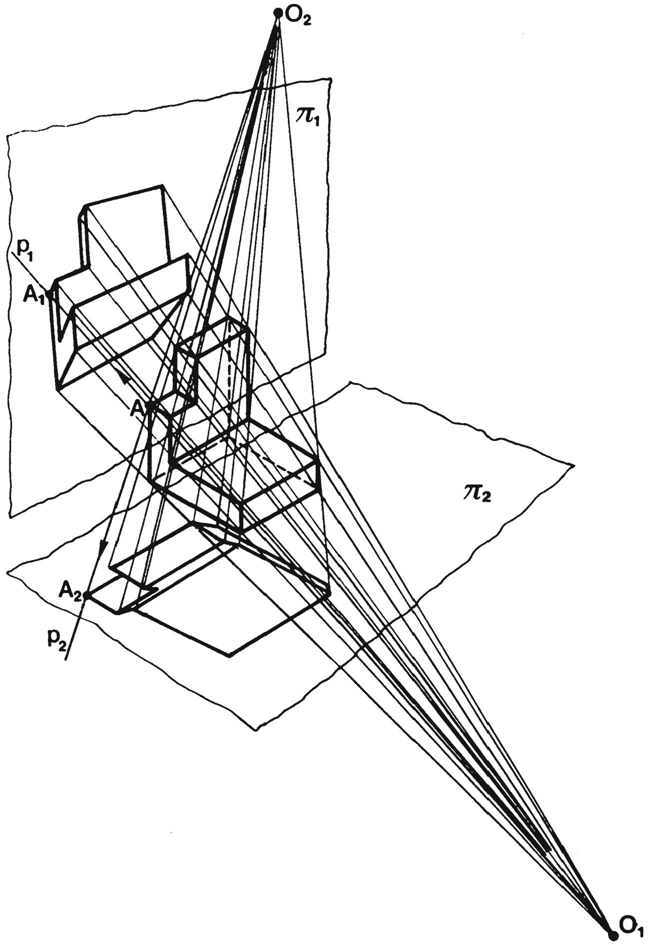


Fig. 5.7 General principle of projections (Biggioggero and Giannattasio 1988)

view of drawing. The "Encyclopédie" was realized in cooperation with the most important names of culture and science. Some of those names are, e.g. F.M. Voltaire, C.Montesquieu, J.J.Rousseau, and E.Condillac. The "Encyclopédie" largely utilizes drawings as explicative and documentary tools, particularly in relation to scientific machinery and activities and definitions of different scientific professions. The aim of such a work was to present the scientific – technical progress that mankind continued to successfully pursue.

The great number of drawings comprises a very interesting and wide collection of representations of instruments, tools and machines relative to all professions and very useful as a "key" to reading the technical life of the eighteenth century. Such drawings are complementary to the written text, starting from the point of view that graphical communication is irreplaceable for clarity and completeness. The drawings

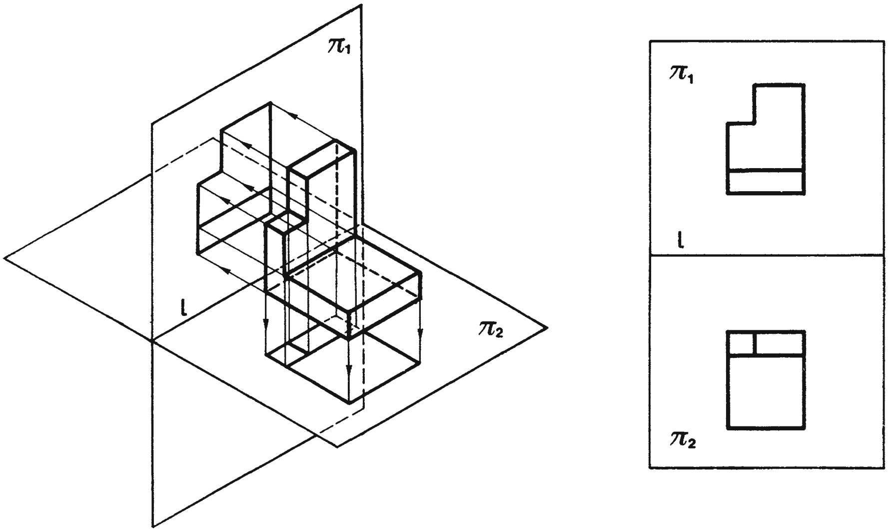


Fig. 5.8 General principle of orthographic projections (Biggioggero and Giannattasio 1988)

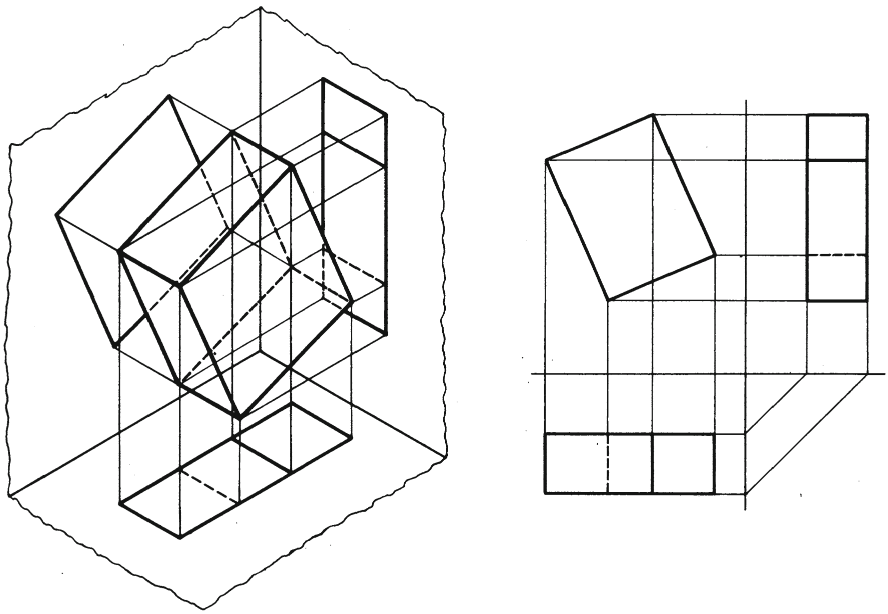


Fig. 5.9 General orthographic projection of a parallelepiped (Biggioggero and Giannattasio 1988)

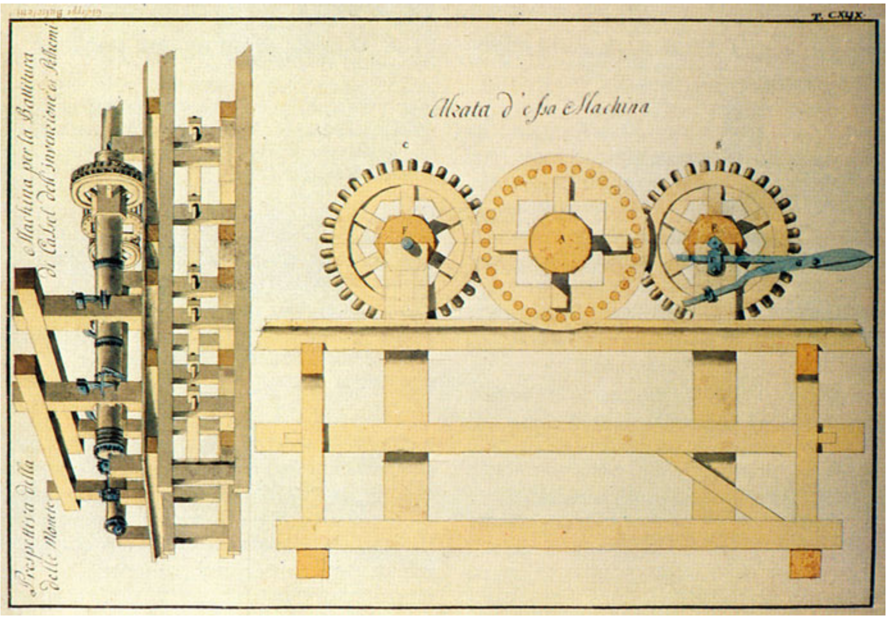


Fig. 5.10 Coin minting machine, represented by front and side projections. (Chirone (1987))

of the “Encyclopédie” are executed with great ability and the representative criteria are very good: the results, also from the aesthetic point of view, are excellent. Figure 5.18 is an informative example of a drawing from the “Encyclopédie”.

5.6 The Drawing as a Didactic and Popular Tool

The new scientific and technical realizations found the theory of projections to be an important tool of transmission of information to people who were not scientists. In this period, in effect, institutionalized teaching and disclosure to the general public of scientific knowledge took its first steps. Through drawings in axonometric or orthographic projections, the new machines and the new instruments and devices could easily be described to all people in terms of configuration, structure and behavior.

During this time, in fact, many people were illiterate and images had an important communicative role, similar to that of treatises in the era of the Renaissance. But in the eighteenth century, the represented machines were very often concrete realizations: the art of drawing, therefore, had an important didactic and popular function. As examples, Figs. 5.19, 5.20, 5.21, 5.22, 5.23, 5.24, 5.25, 5.26, 5.27, 5.28, and 5.29 are applications of axonometric and orthographic projections that demonstrate how the represented machines function and behave. Such figures, also, have an important role in documenting the “state of the art” of the scientific-technical construction of the eighteenth century.

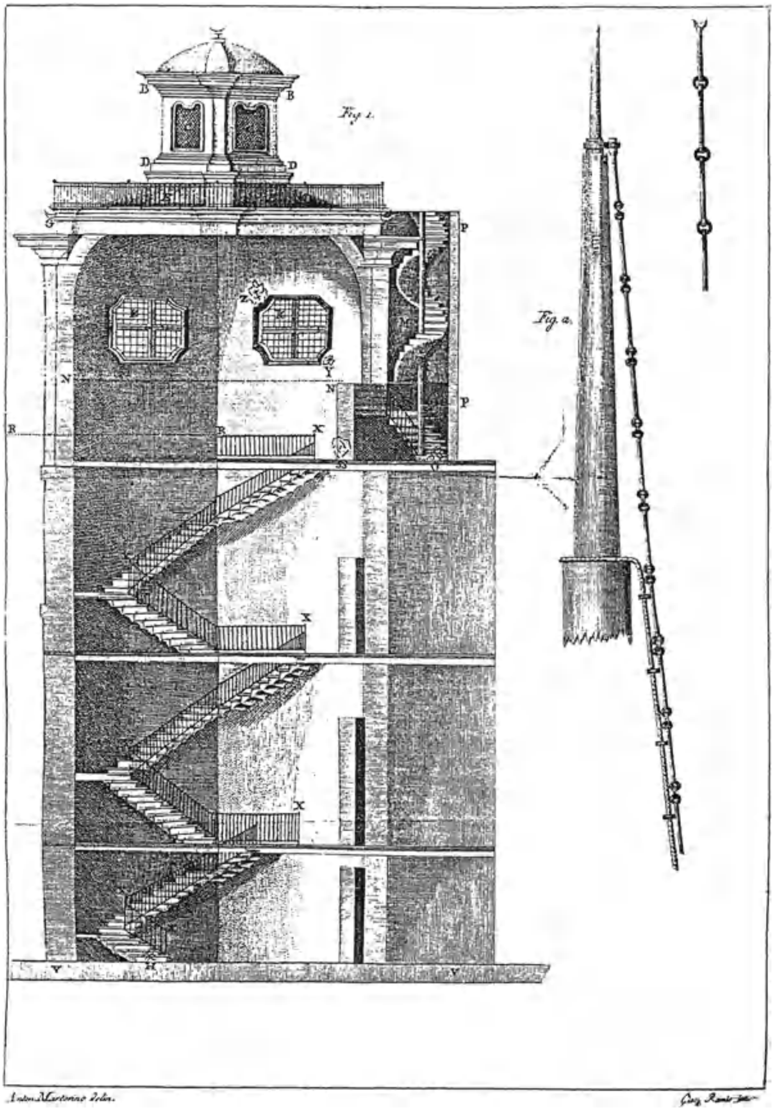


Fig. 5.11 Example of application of orthographic projections to the drawing of a building: an interesting detail is the "cut" representation, to show the thickness of the wall and the trend of the wall. Also interesting is the magnified representation of the lightning rod and of the cable (Landriani 1784)

5.7 The Drawing as Documentary Tool for Scientists

In the great development of scientific research that distinguished the eighteenth century, drawing was an important means of expression, characterized by great explanatory and documentary value, widely used by scientists of the time.

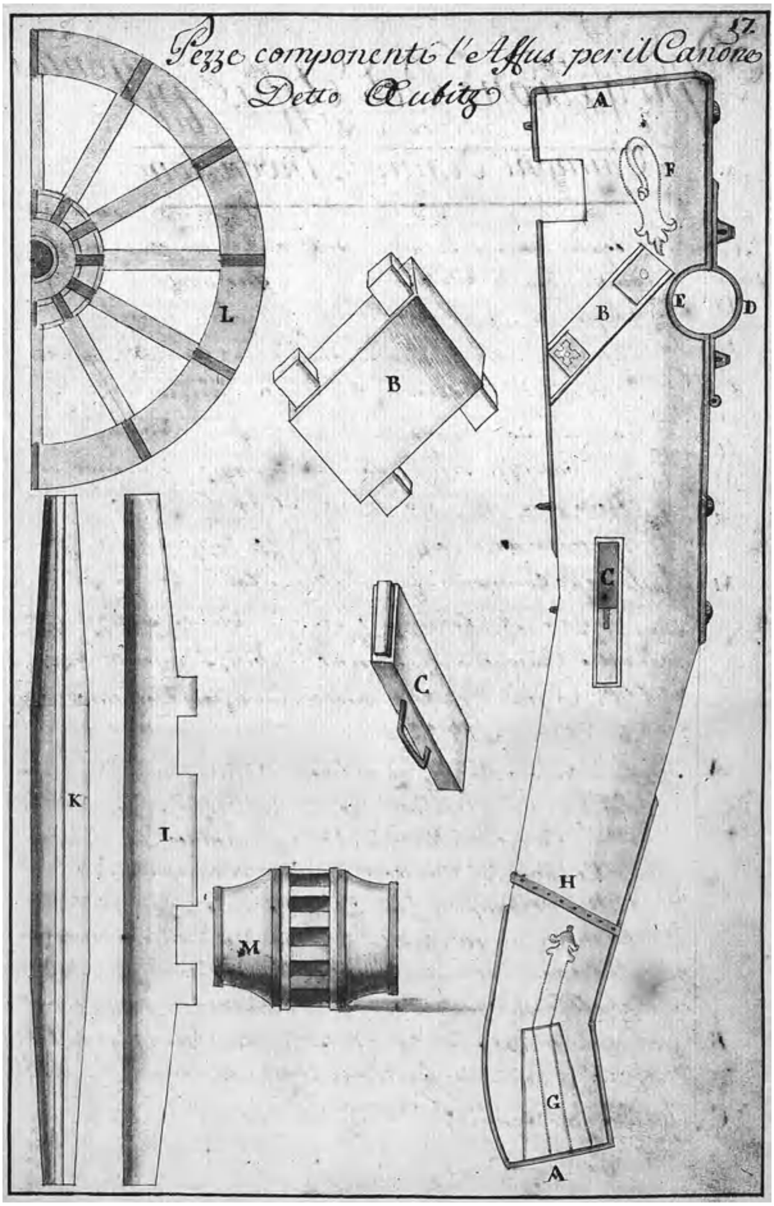


Fig. 5.12 "Constructive drawings" of parts of a cannon

Particularly significant are the drawings of Alessandro Volta: he certainly knew the Renaissance treatises and the principles of descriptive geometry.

The drawings in his works were realized by pen, by the same pen with which he wrote the scientific notes. They were an integral part of the text, almost an "extension" of the text itself: they explained, clarified, and completed the thinking of the author.

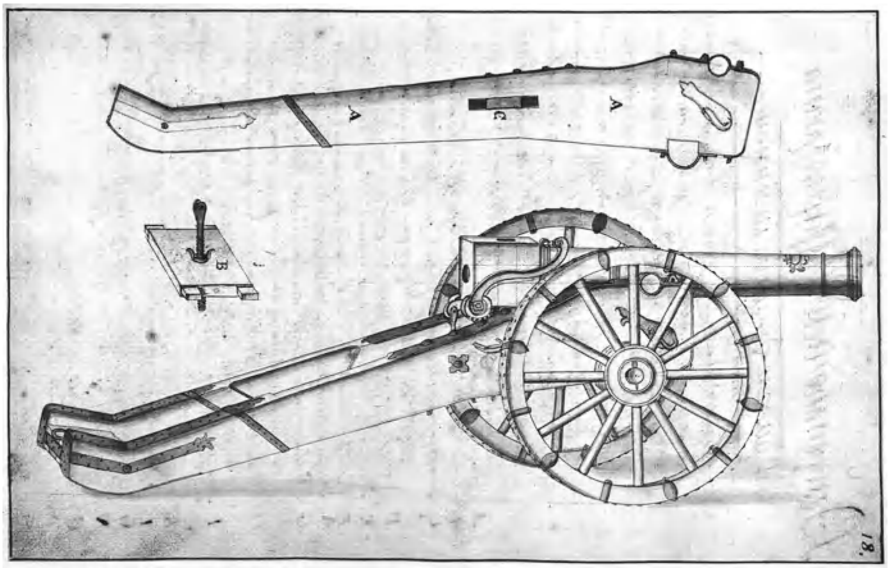


Fig. 5.13 "Assembly drawing" of a cannon

In many cases they also had a constructive character and were useful as the basis for building instruments and performing experiments.

General features of the drawings of Volta are clarity, expressivity (with a few strokes of the pen, he expressed his ideas), essentiality (the ability to prune the drawing of everything that is not essential, of the unnecessary details).

By examining Volta's drawings, it is possible to reach considerations that anticipate modern standards of representation; for example, the representation of sectioned parts and of installed and "exploded" assemblies, simplified and schematic representations, sometimes with the use of alphanumeric characters, quantitative information through graduations marked on the plan, identification of the constituent parts of an assembly with position numbers or letters , representation of interchangeable parts, anticipation of the "arrows" method (orthographic projections not in fixed positions, but where it is more convenient, with appropriate indications).

Figures 5.30, 5.31, 5.32, 5.33, 5.34, 5.35, 5.36, 5.37, 5.38, 5.39, 5.40, and 5.41 represent some examples of Voltaic instruments (Rovida 1999). It is interesting to observe that all of Volta's manuscripts are conserved in the Istituto Lombardo Accademia di Scienze e Lettere (Lombard Institute of Science and Literature), in Milan.

We mention here other examples of scientists who utilized the skill of drawing as a documentation tool of respective ideas and realizations.

Figure 5.42 is an application of axonometric and orthographic projections to the calculation machine realized by Gottfried Wilhelm Leibnitz (1646–1716). Such a machine, of course, is realized only by mechanical devices.

Similar observations could be made for the drawing of Fig. 5.43, representing a detail of the watch realized by the English watchmaker John Harrison (1693–1776). The drawing is relative to some parts of the watch, represented by orthographic projections.

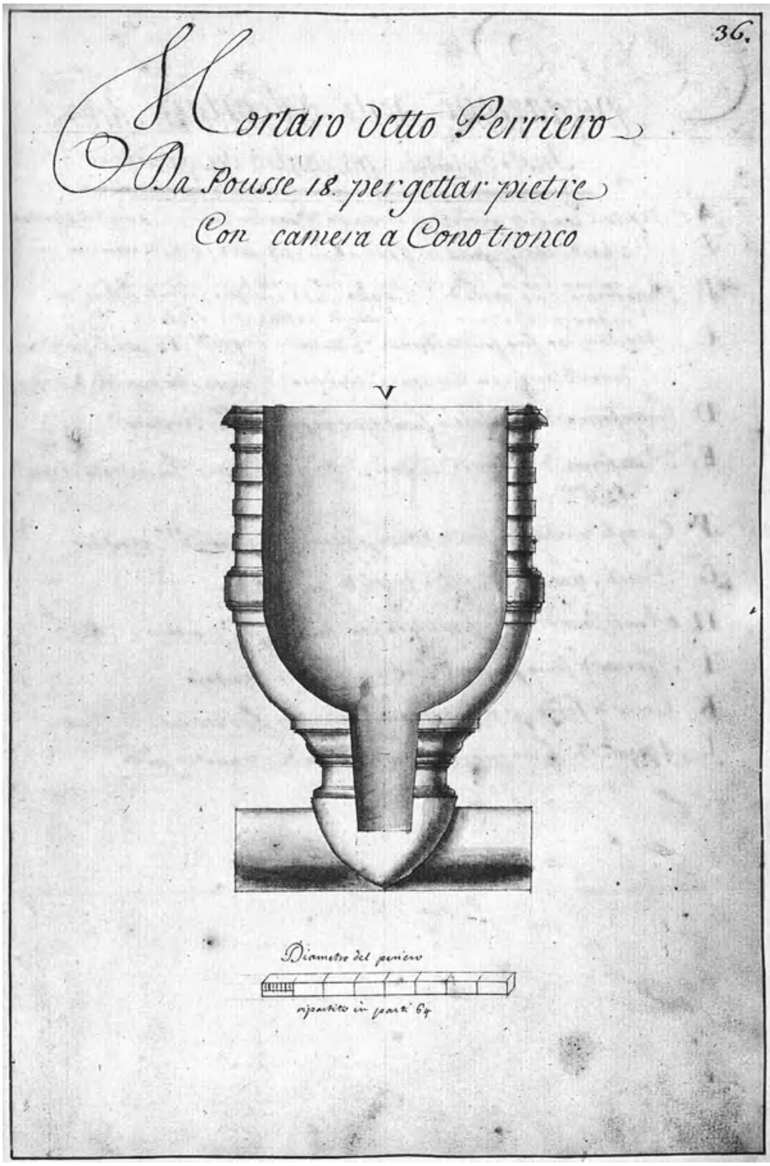


Fig. 5.14 Cannon represented with a cut and dimensioned with the graphic scale

Figures 5.44 and 5.45 are relative to drawings by Giuseppe Antonio Alberti (1715–1768) who authored the book “Istruzioni per lo ingegnero civile, ossia perito agrimensore e perito d’acqua” (Instructions for the civil engineer and the expert surveyor and water expert).

Figure 5.44 is relative to some instruments for surveying, represented through axonometric and orthographic projections.

Fig. 5.15 "Standard table" of nails

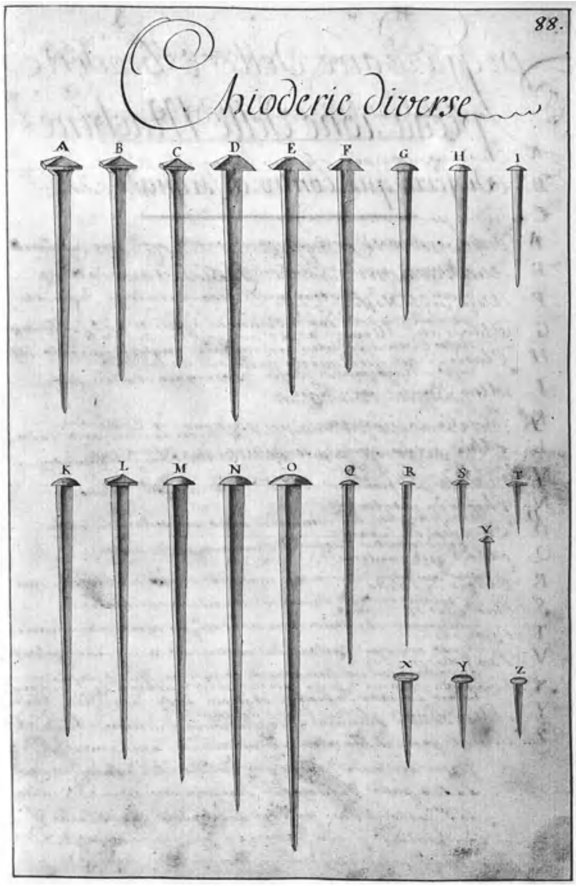


Figure 5.45, however, is another interesting example of axonometric and orthographic projections, applied, in this case, to structures of a bridge.

Figures 5.46, 5.47, 5.48, 5.49, and 5.50 are examples of drawings relative to scientific experiments of the French chemist and physicist Antoine-Laurent Lavoisier (1743–1794). Such drawings represent layouts of instruments utilized by Lavoisier to realize some of his most famous experiments. The drawings are all applications of orthographic and axonometric projections and, as a description of the experiments of a foremost scientist of his time, are a significant contribution to the history of chemistry and physics.

Figure 5.51 represents some chemical instruments of the Dutch physician Hermannus Boerhaave (1668–1738).

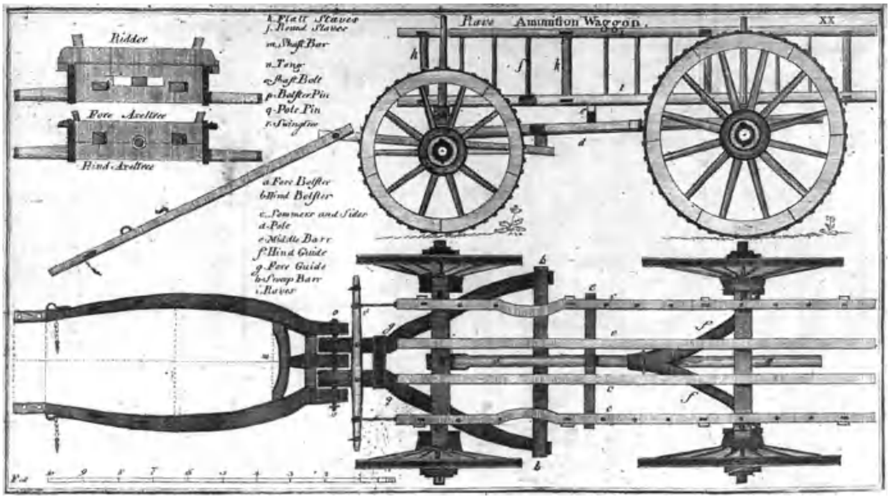


Fig. 5.16 Drawing of a military cart: lateral and top view

Fig. 5.17 Building and lifting machines, by Nicola Zabaglia (1664–1750)

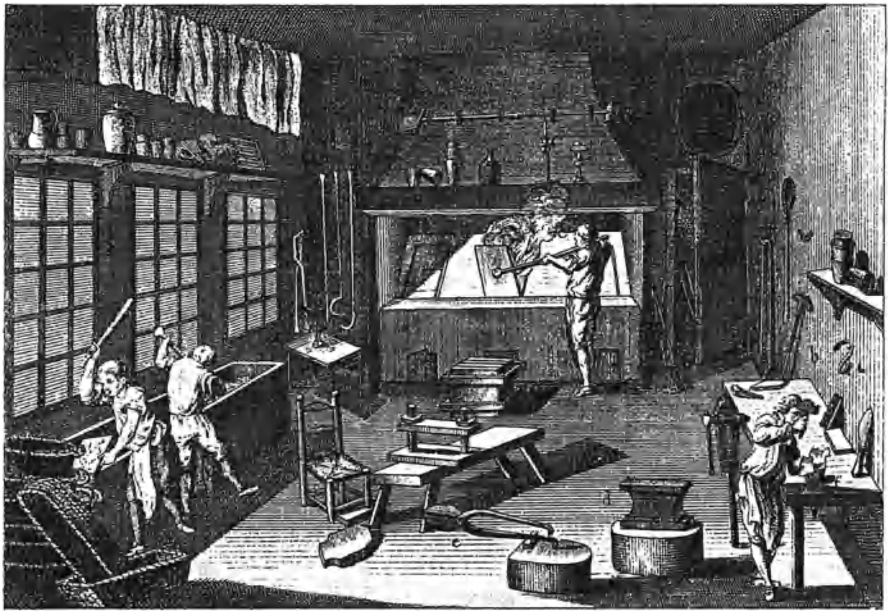


Fig. 5.18 An example of a table from the "Encyclopédie" of Diderot e d'Alembert

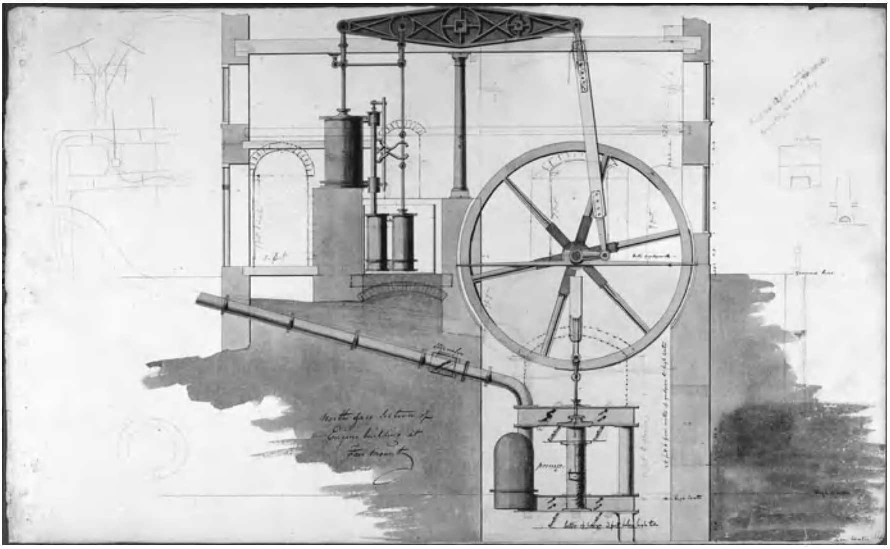


Fig. 5.19 Steam machine of Watt and Boulton

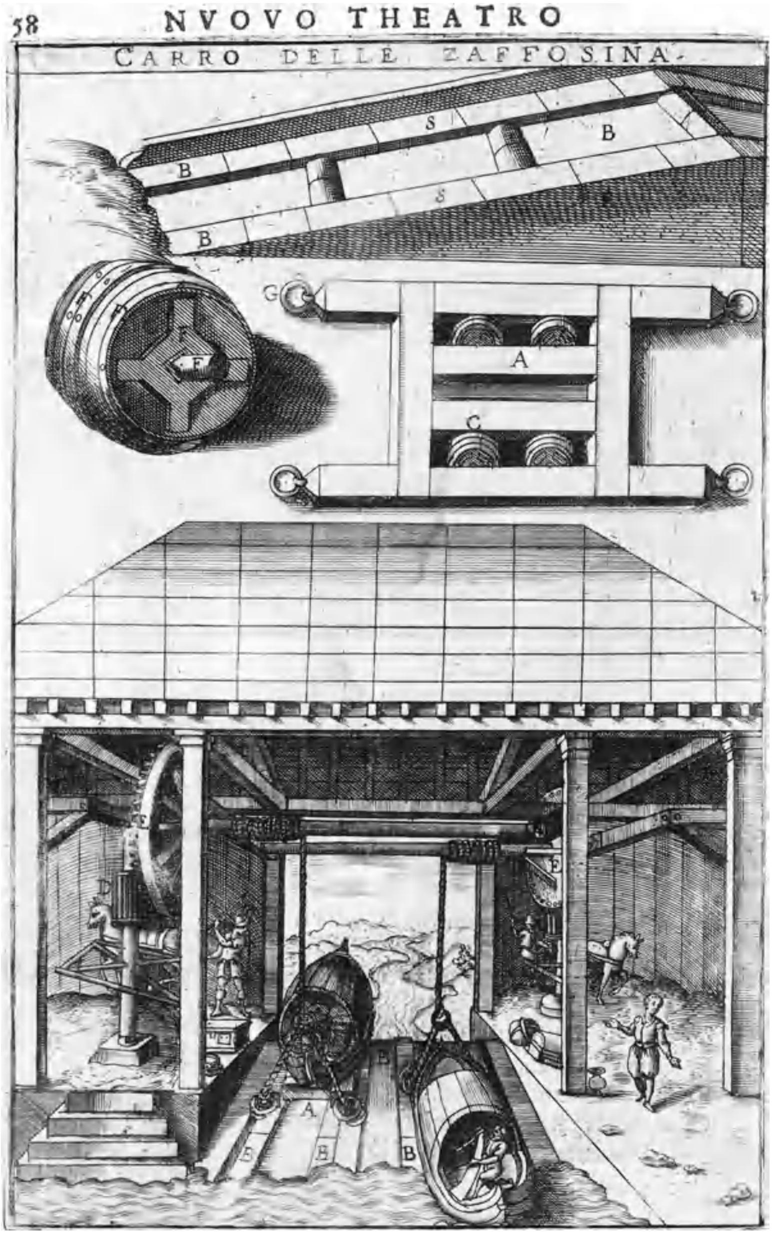


Fig. 5.20 Boat transport

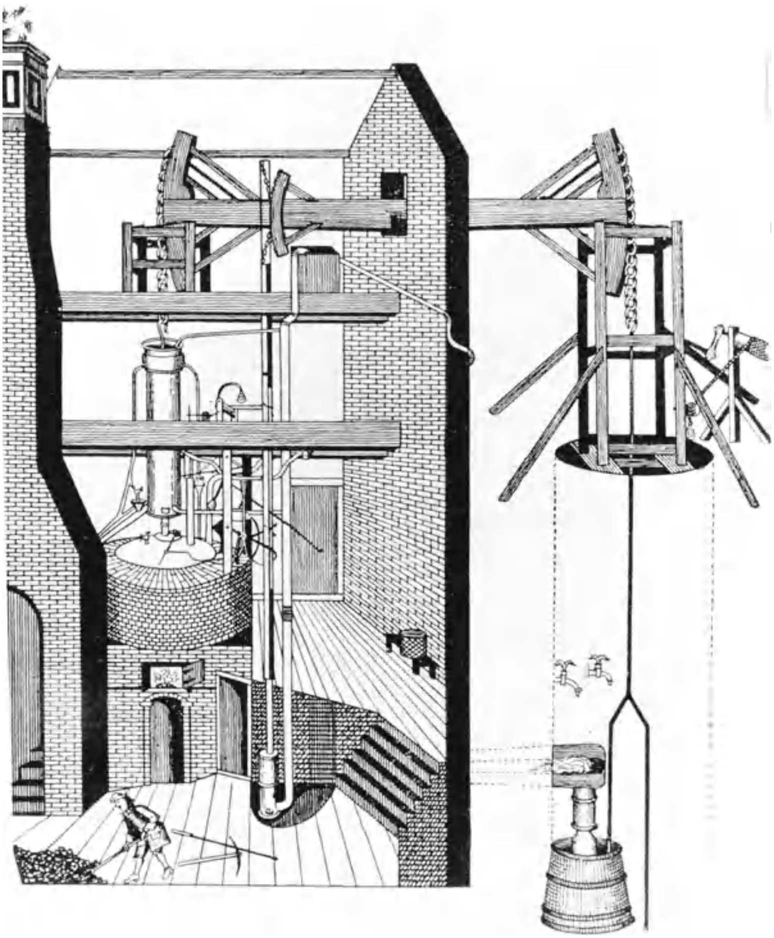


Fig. 5.21 Steam machine of Newcomen

5.8 The Drawing Instruments

As the demand for diffusion of scientific knowledge grew and the need for drawing in industry widened, precision of construction of drawing instruments and skill in their proper use became crucial issues. For example, Fig. 2.12 in the Chap. 2 shows a typical eighteenth century instrument, i.e. a geometric compass.

In Fig. 5.52, however, it is possible to see a characteristic eighteenth century complex of drawing instruments, signed by Jo Anningson and constituted by a spoon, pencil, and block of notes, consisting of thin sheets of ivory. The case is covered with fish skin, much in use at the time.

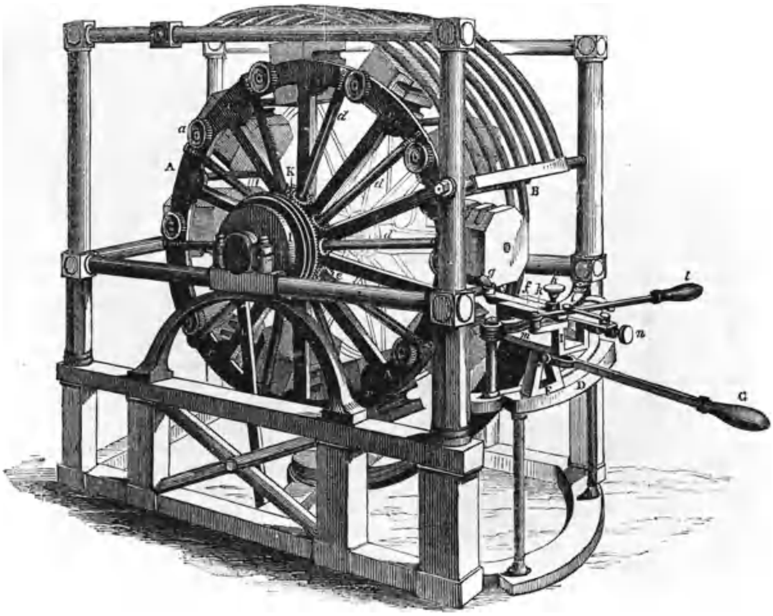


Fig. 5.22 Machine for wood working

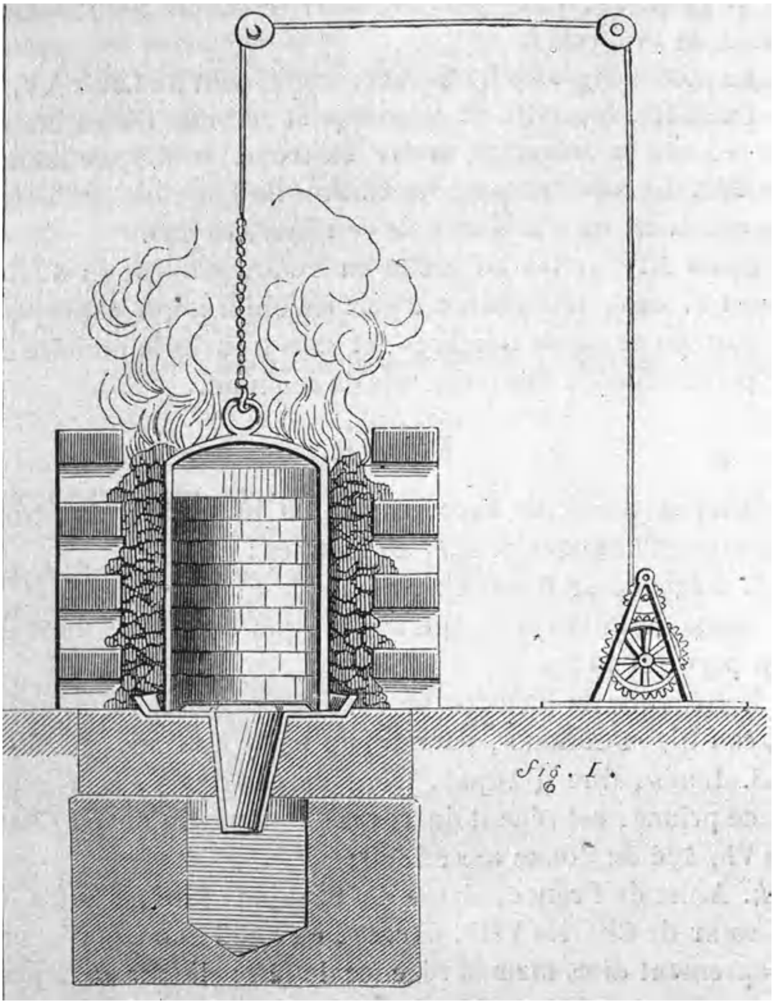


Fig. 5.23 Machine to process silver

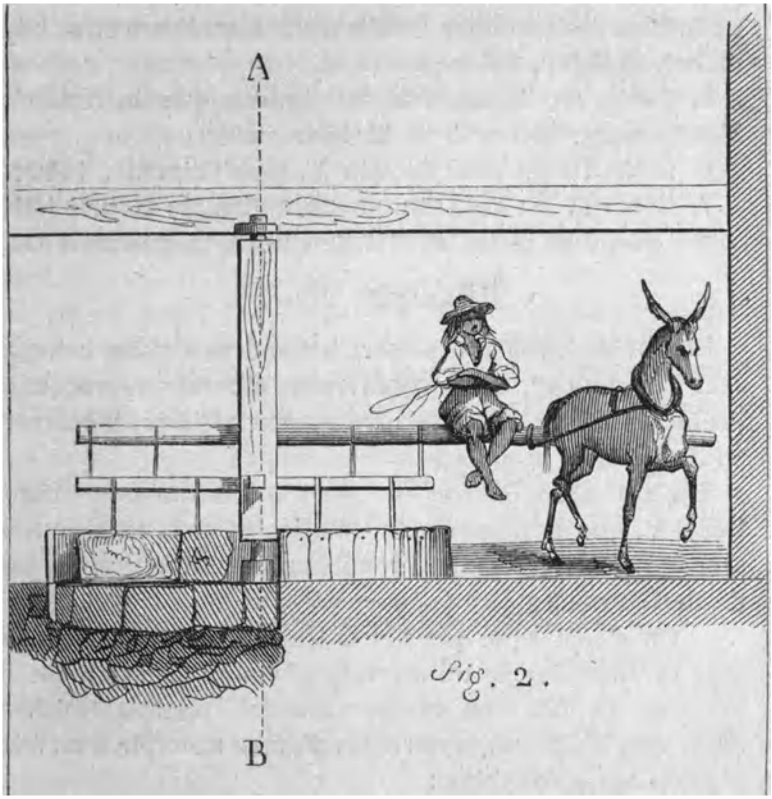


Fig. 5.24 Shredding of silver

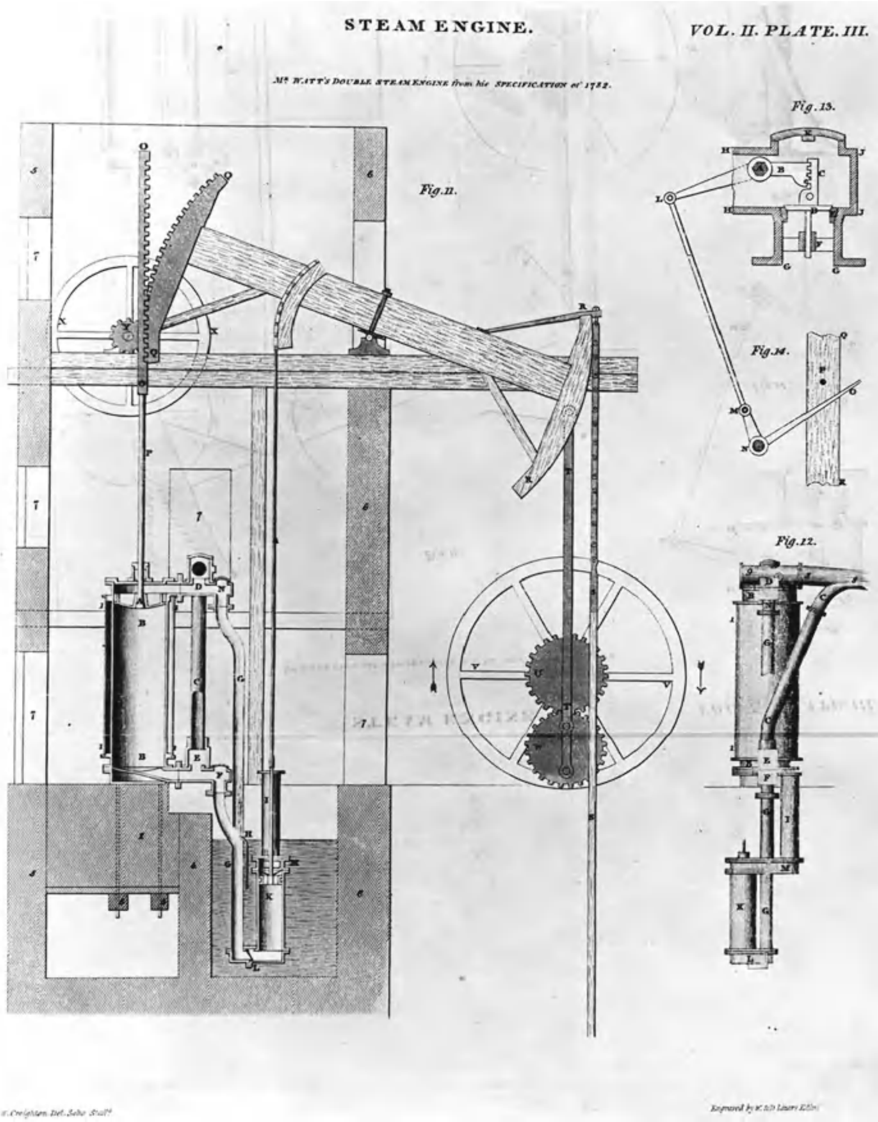


Fig. 5.25 Steam machine of Watt

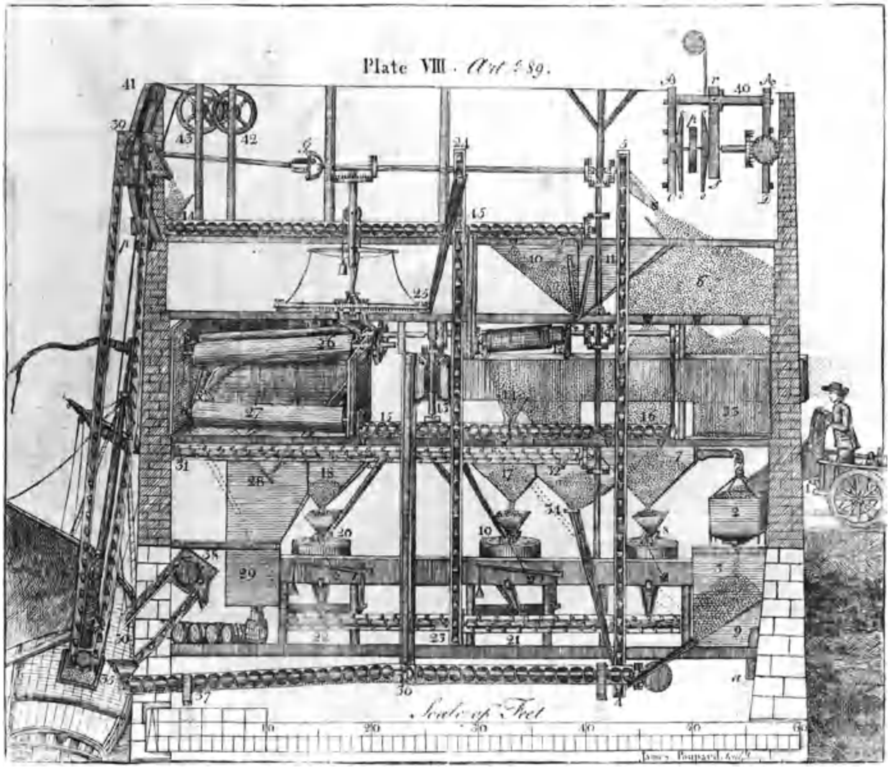


Fig. 5.26 Automated mill

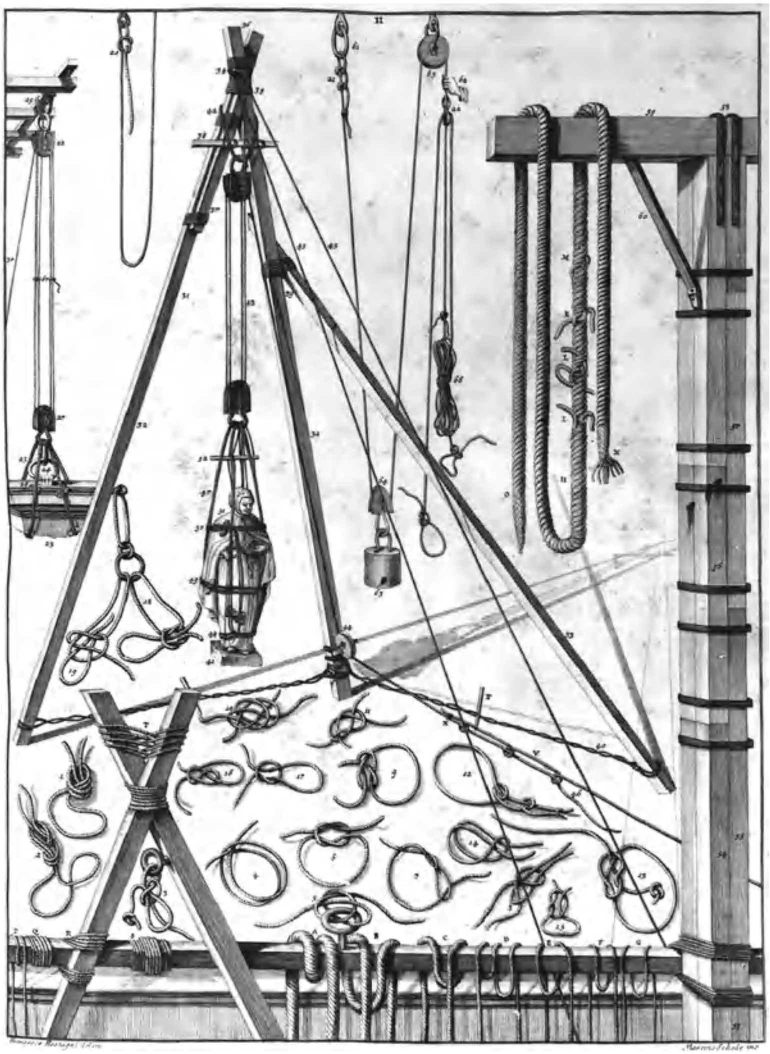


Fig. 5.27 Lifting machine

Fig. 5.28 Pneumatic machine

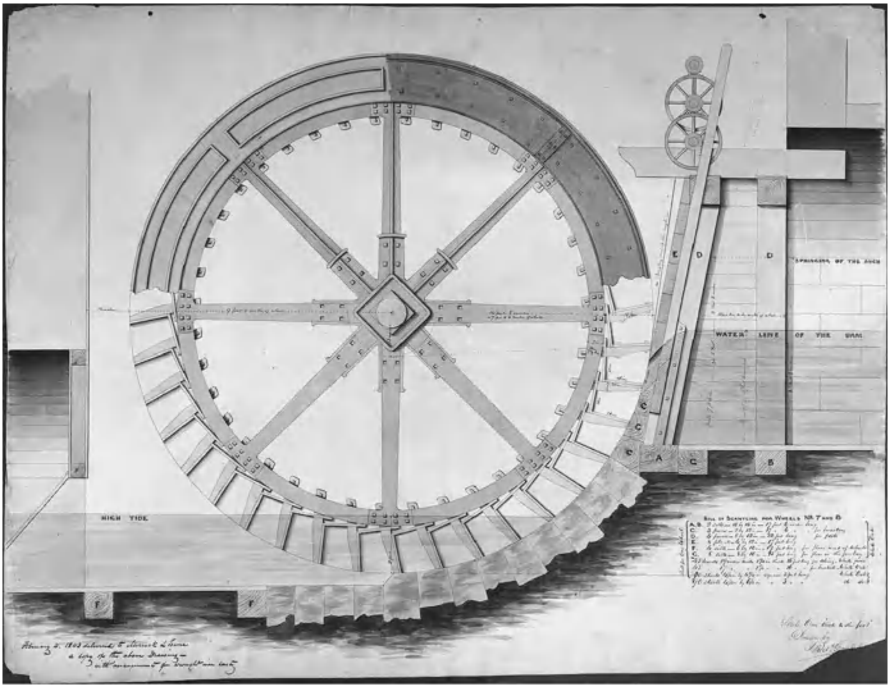


Fig. 5.29 Hydraulic wheel

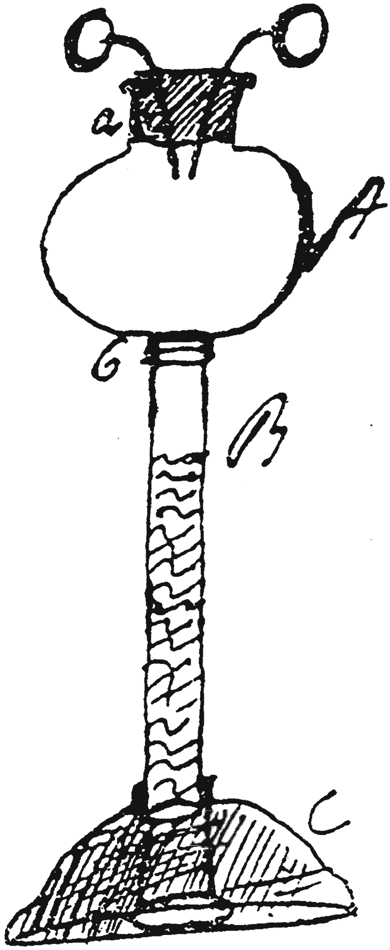


Fig. 5.30 Example of Volta's sketch of an instrument : the pedestal is represented with two parts characterized by different section linings

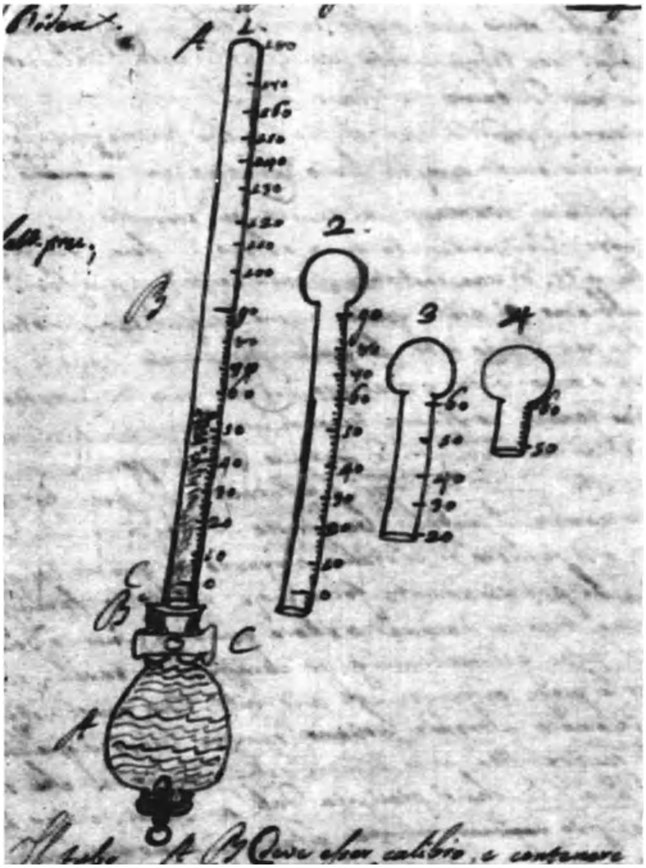


Fig. 5.31 Sketch of Volta with two interesting aspects: dimensioning, by graduation of the instruments and representation of interchangeable parts

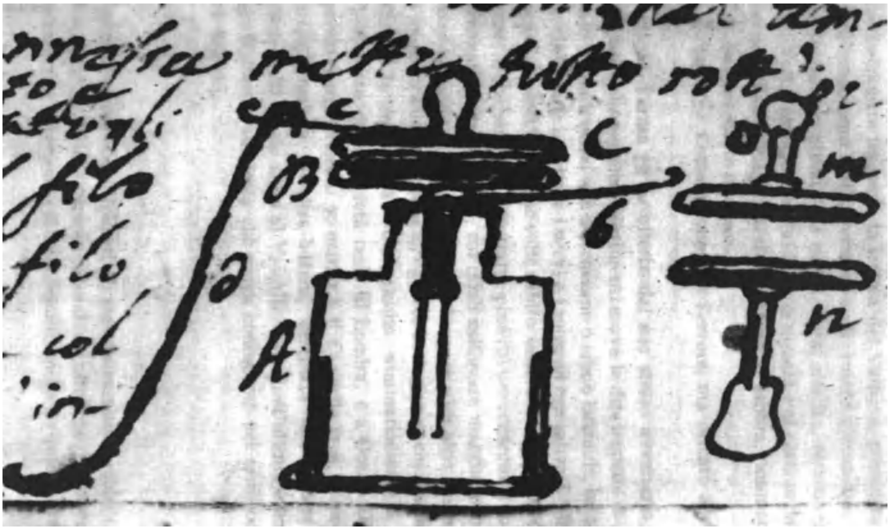


Fig. 5.32 Representation of an instrument constituted by two drawings, assembled and "exploded"

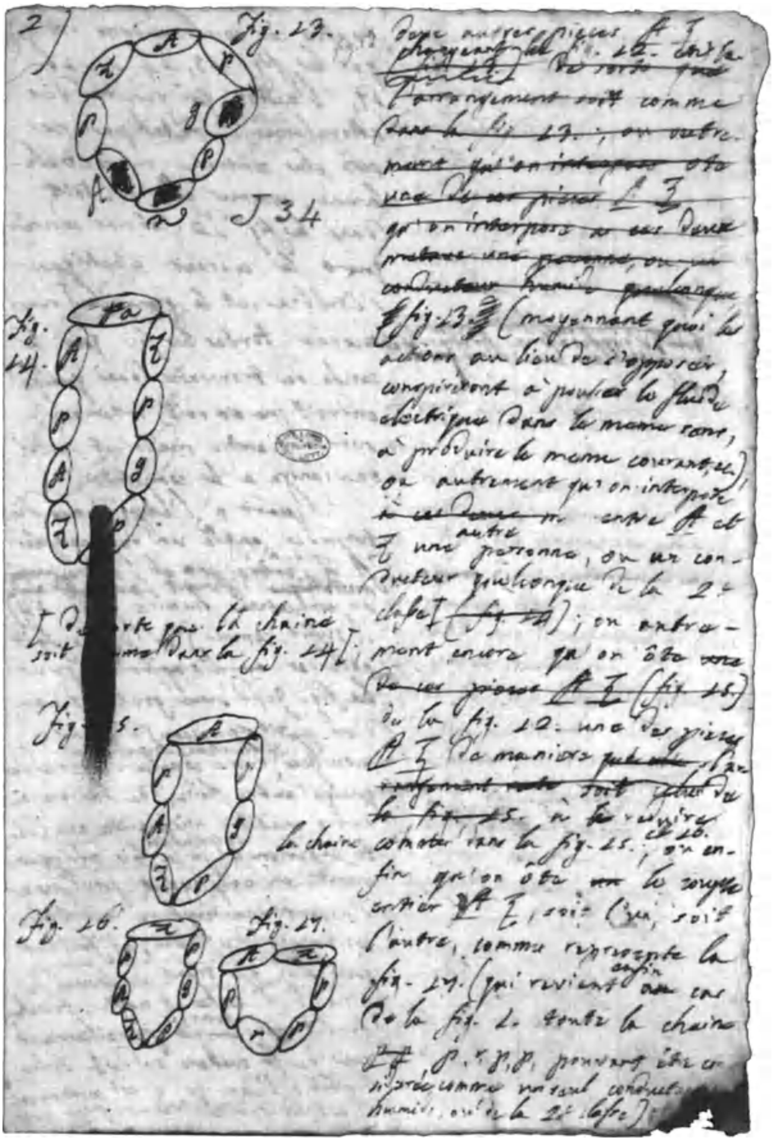


Fig. 5.33 Schematic representation of electric contacts. To observe, also, the use of alphanumeric characters for better individuation of the parts in contact

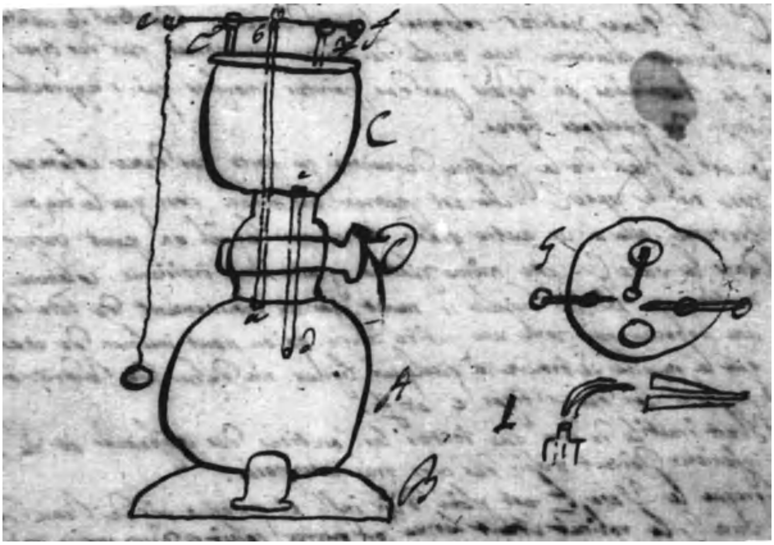


Fig. 5.34 Instrument represented by two projections, front and vertical: the position of the two projections can be considered as an anticipation of the arrows method

Fig. 5.35 Representation of the Voltaic pile: interesting is the section lining, to represent the "section" of the liquid

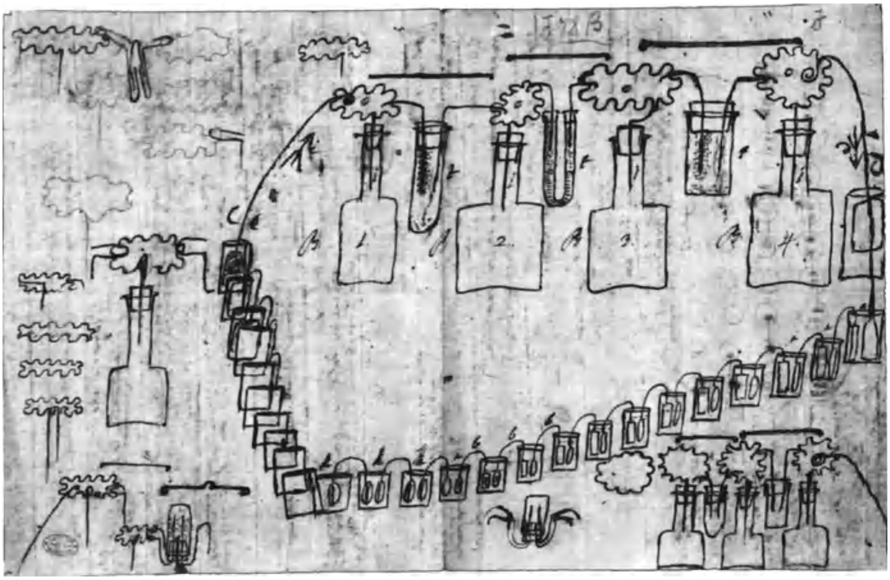


Fig. 5.36 Another example of Voltaic pile represented with a very high schematization level

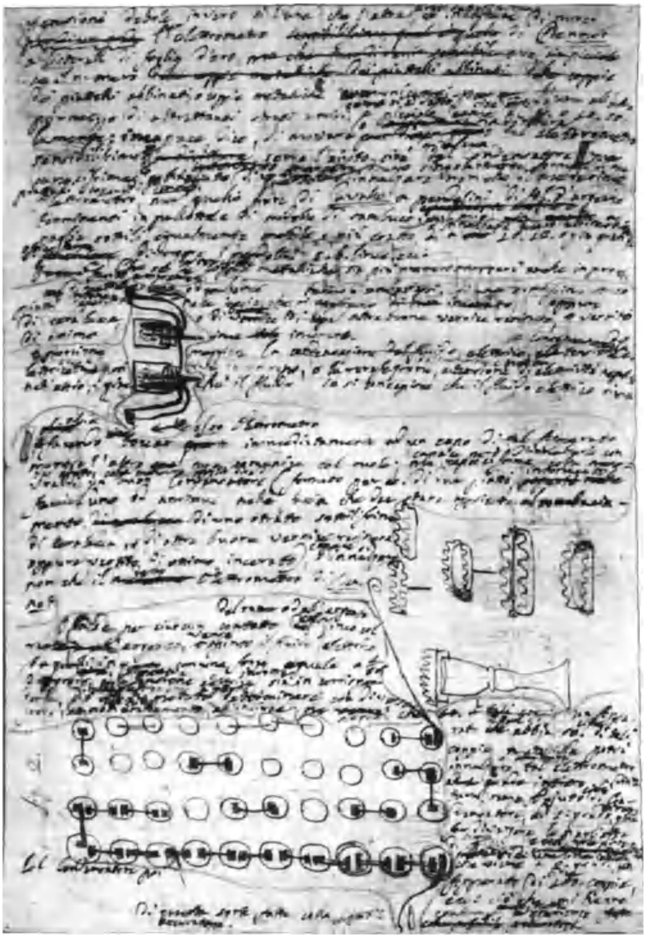


Fig. 5.37 Representation, probably, of an experiment, with high schematization

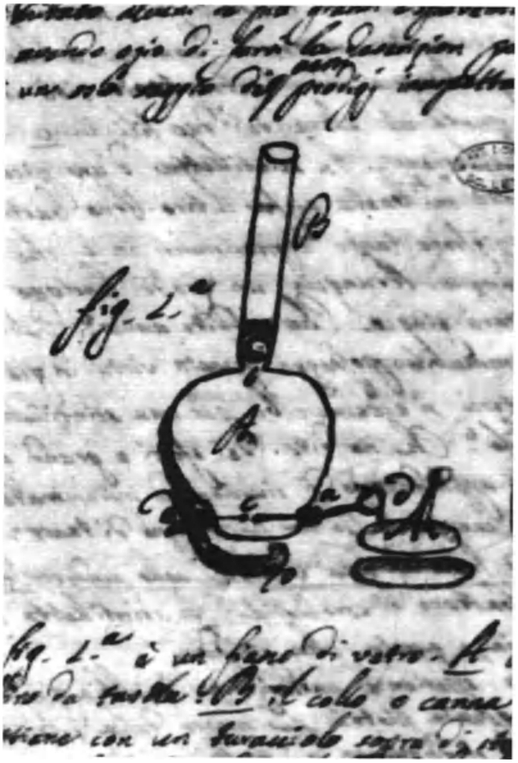


Fig. 5.38 Another Voltaic instrument

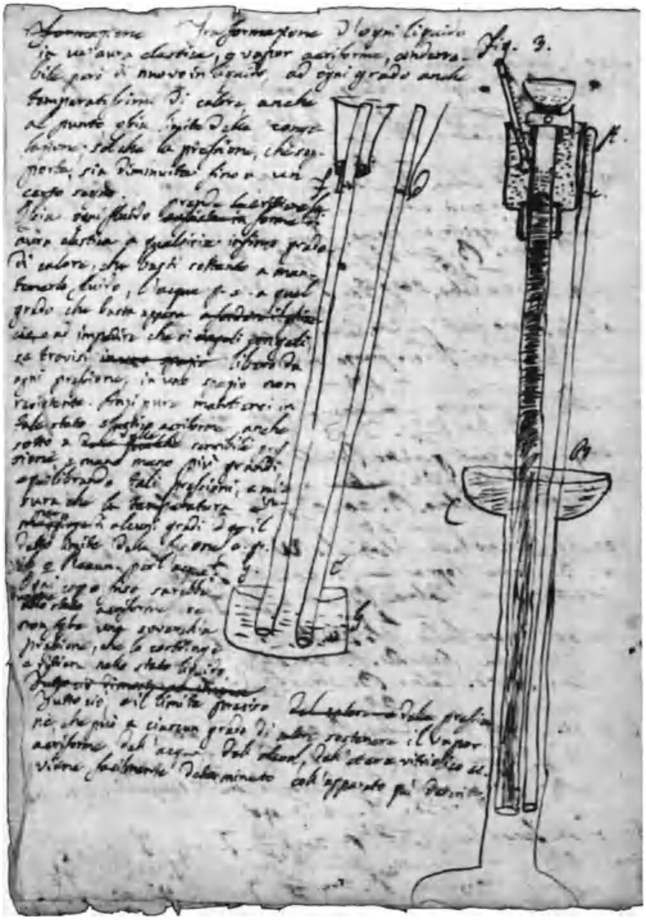


Fig. 5.39 Another representation of an experiment: interesting is the section lining to represent the “section” of liquid and of gas

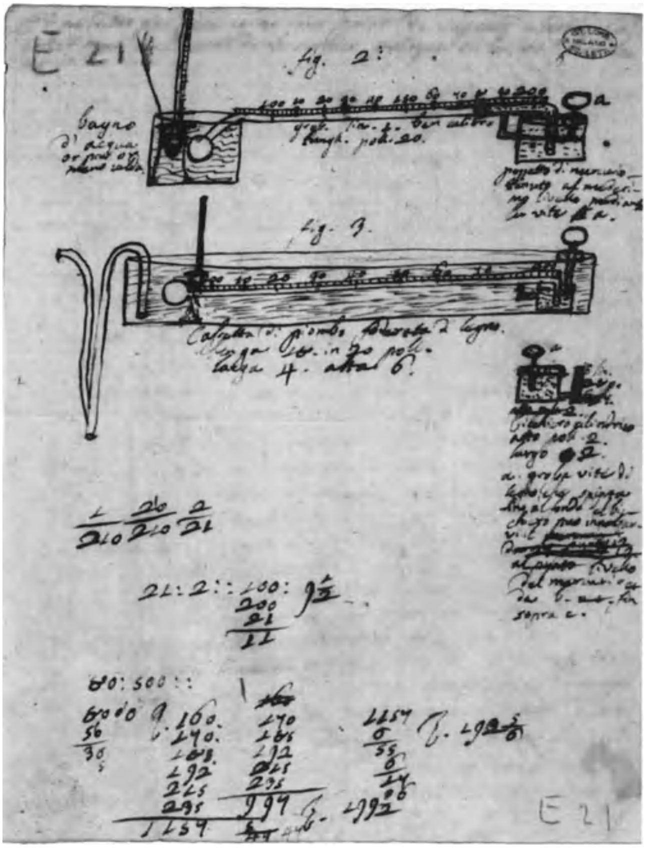


Fig. 5.40 Layout of Voltaic experiments: the quantitative aspect is expressed by graduations on the instruments

Fig. 5.41 Layout of an experiment with conjugated conductors, with very high schematization

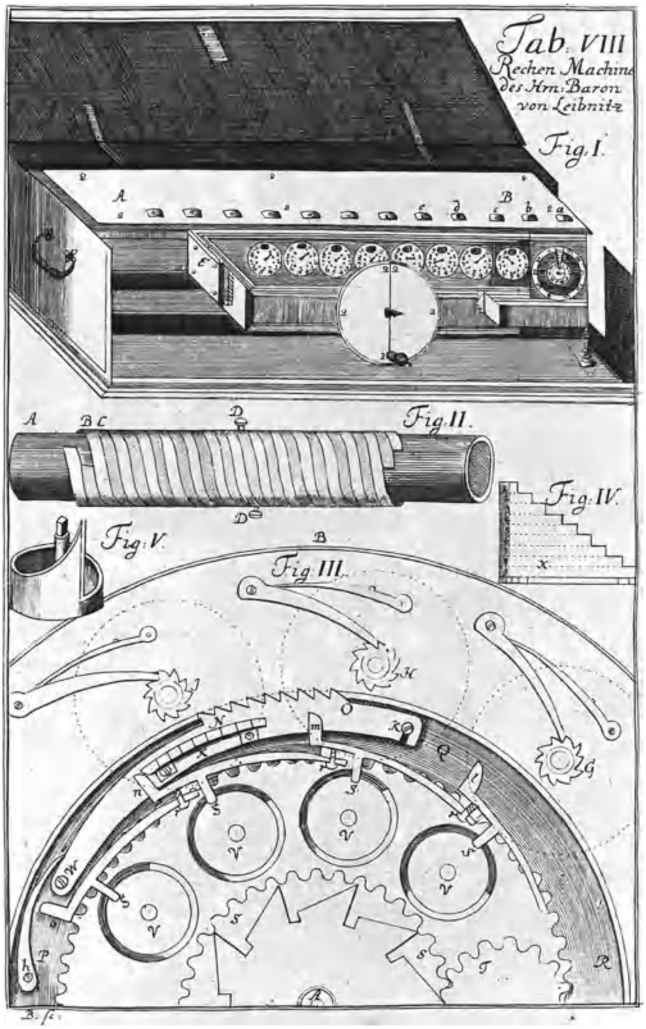


Fig. 5.42 Detail of the calculation machine realized by Leibnitz

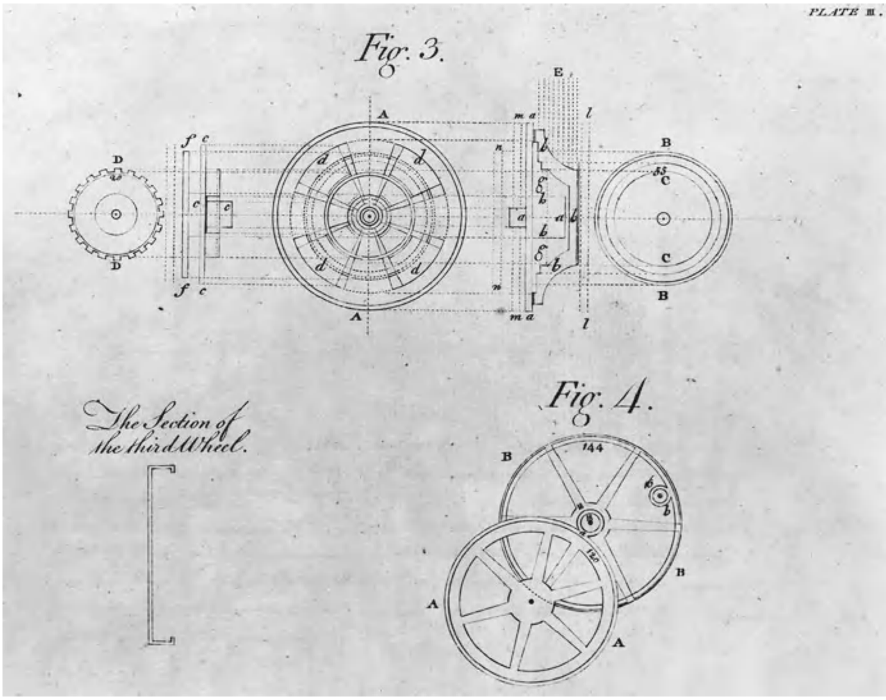


Fig. 5.43 Detail of the watch realized by the English watchmaker John Harrison

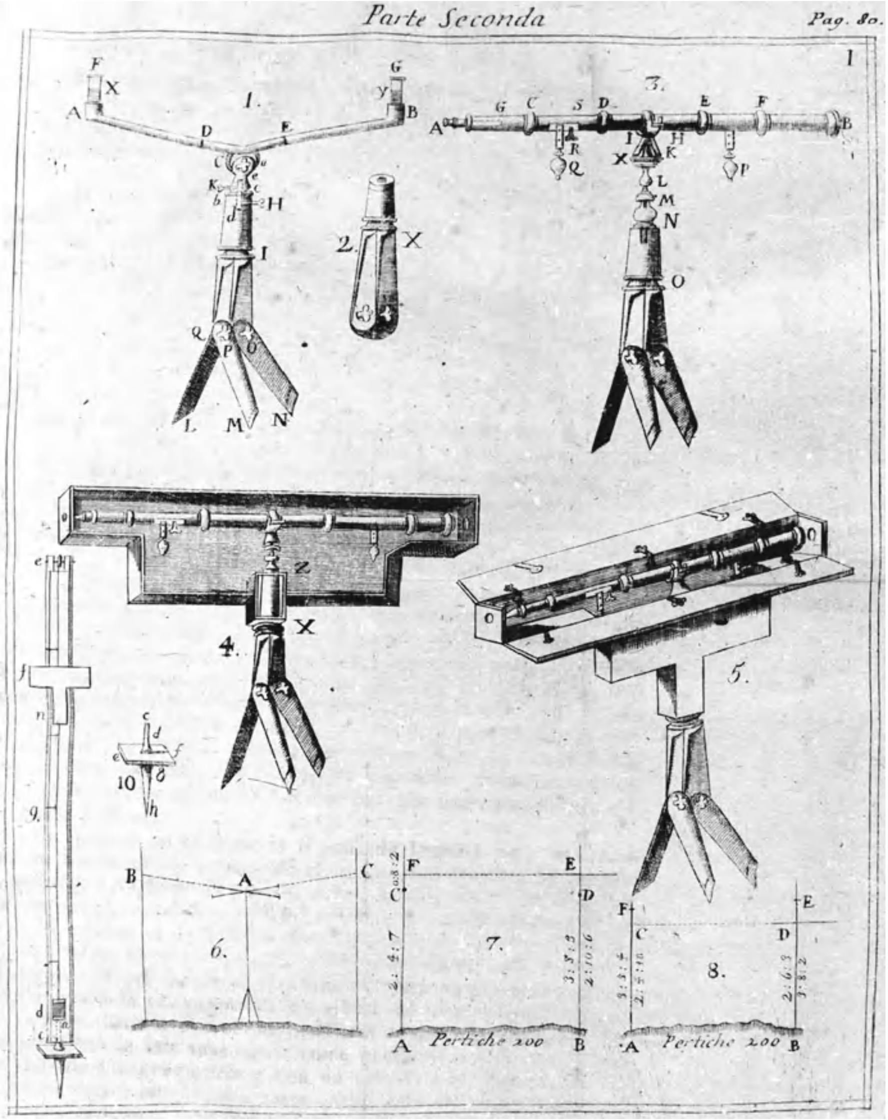


Fig. 5.44 Drawing by Giuseppe Antonio Alberti (1715–1768), relative to surveying instruments

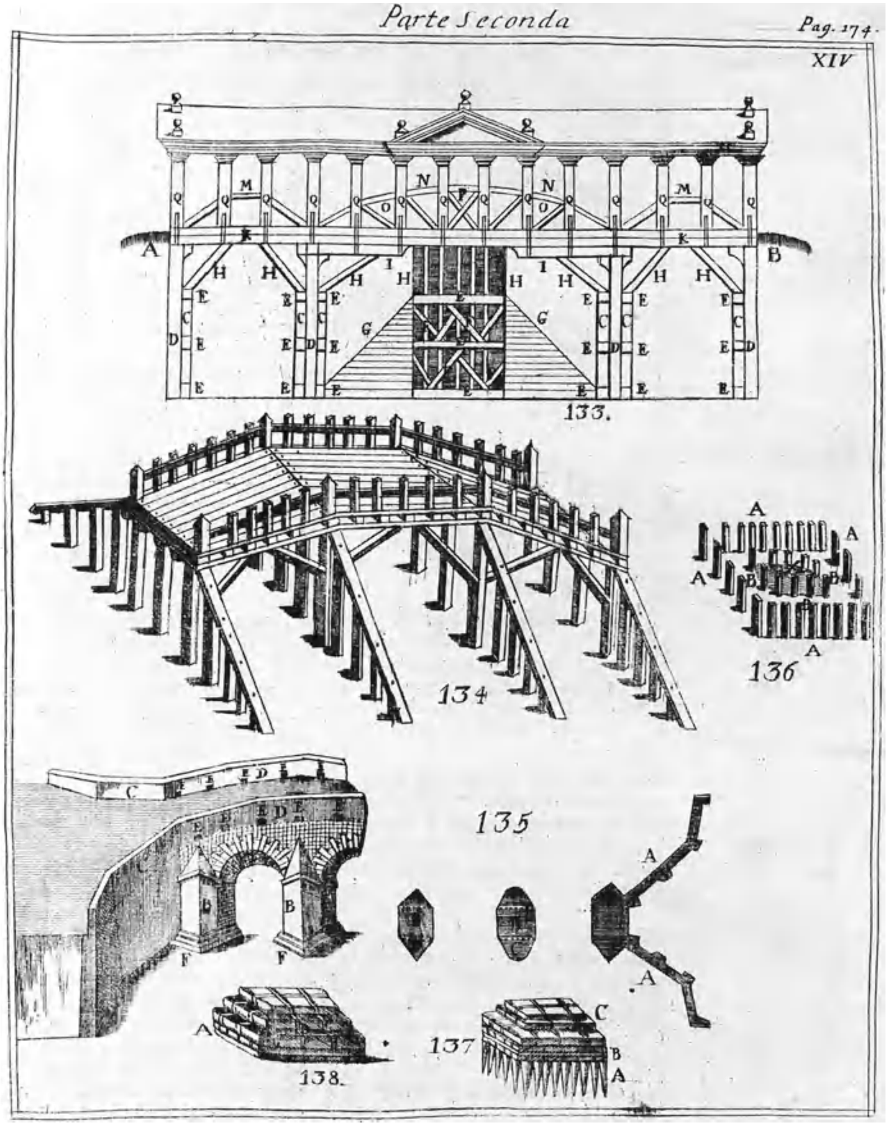


Fig. 5.45 Drawing by Giuseppe Antonio Alberti (1715–1768), relative to the structure of a bridge

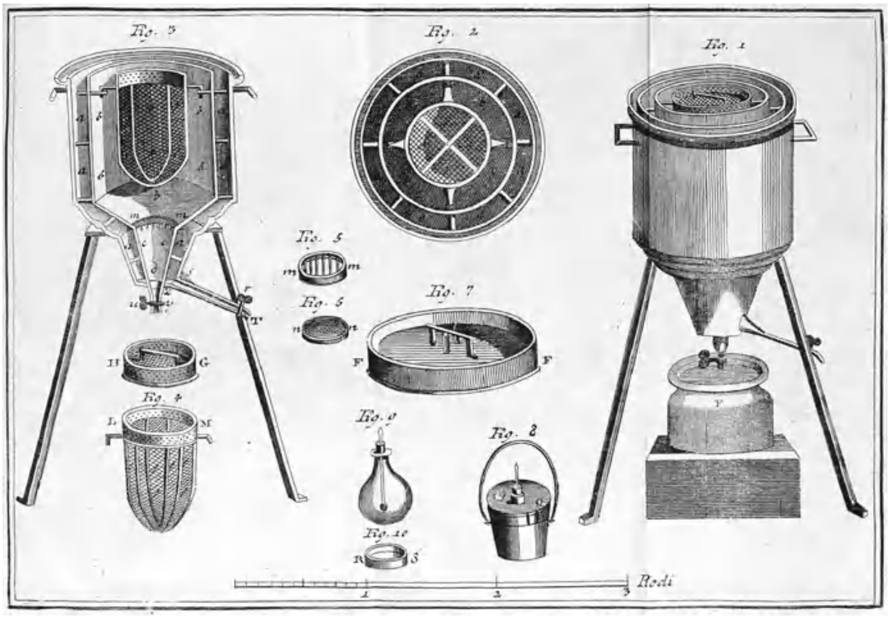


Fig. 5.46 Calorimeter by Antoine-Laurent Lavoisier

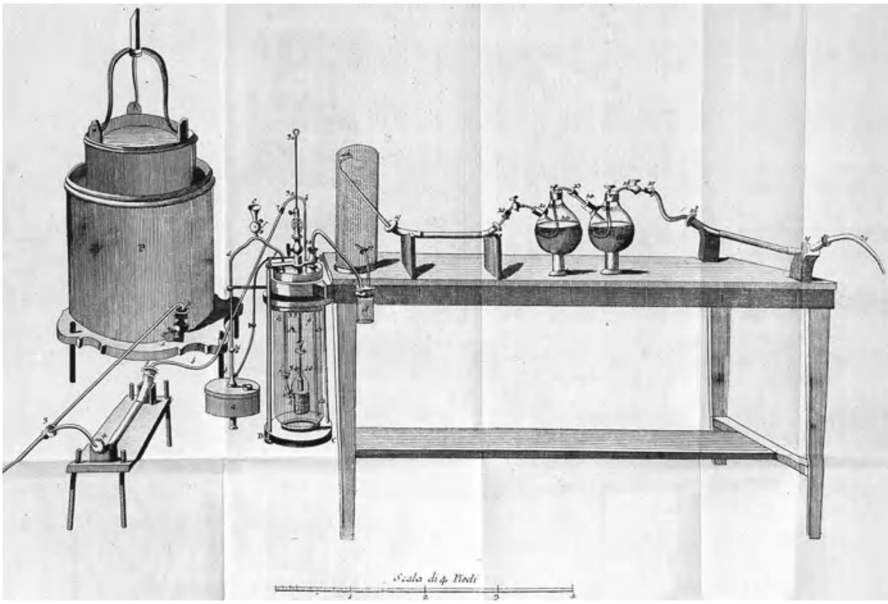


Fig. 5.47 Table for experiments by Antoine-Laurent Lavoisier

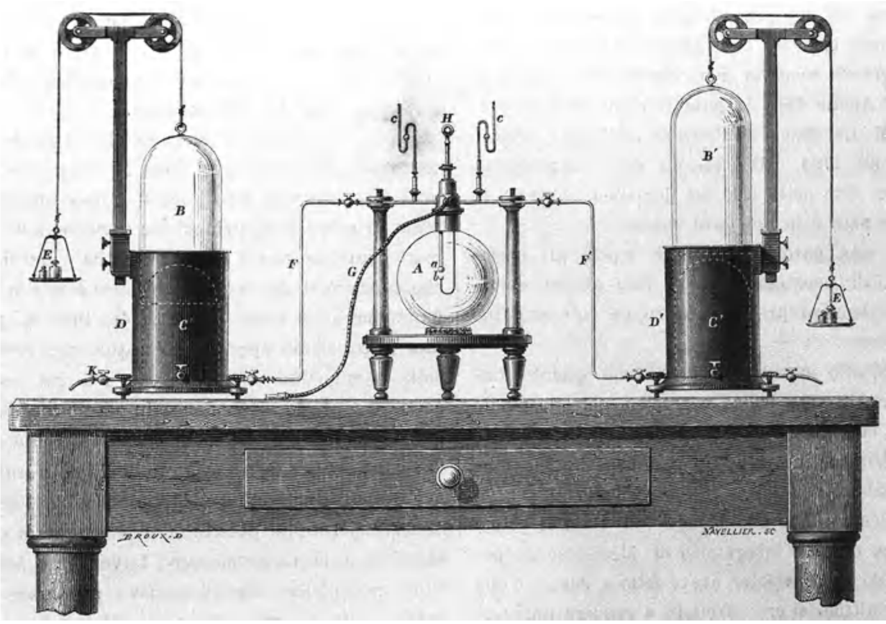


Fig. 5.48 Table for experiments by Antoine-Laurent Lavoisier

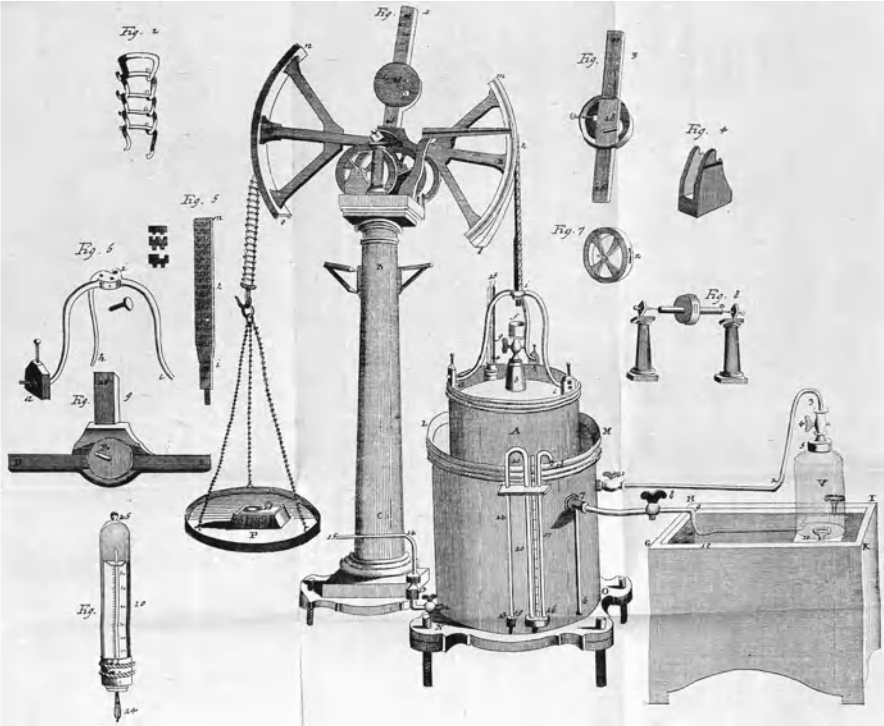


Fig. 5.49 Gasometer by Antoine-Laurent Lavoisier

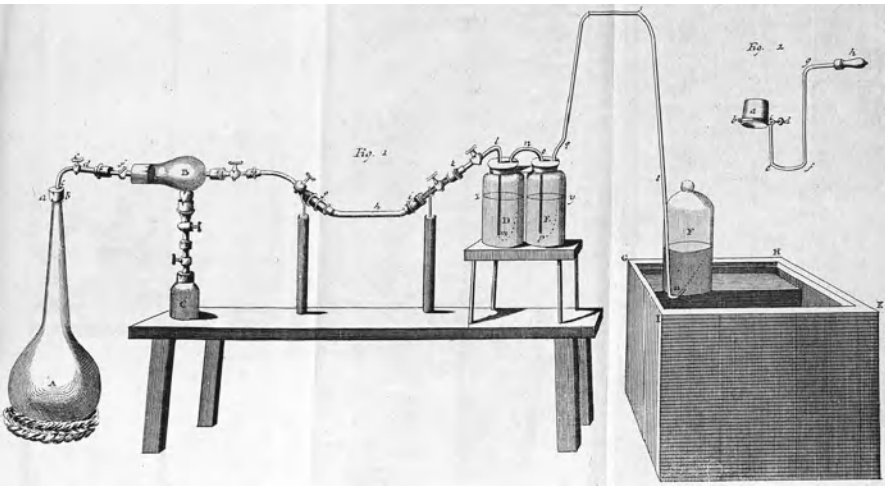


Fig. 5.50 Table of experiments by Antoine-Laurent Lavoisier

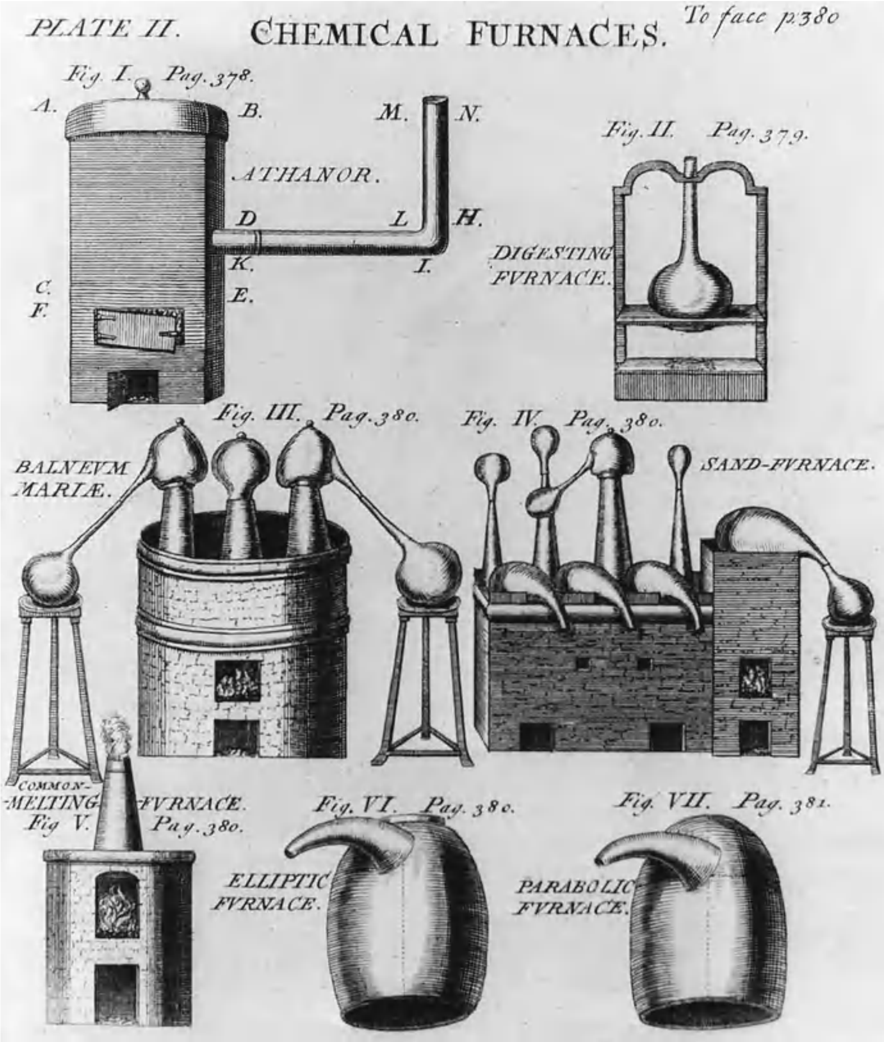


Fig. 5.51 Some chemical instruments of the Dutch physician Hermannus Boerhaave (1668–1738)

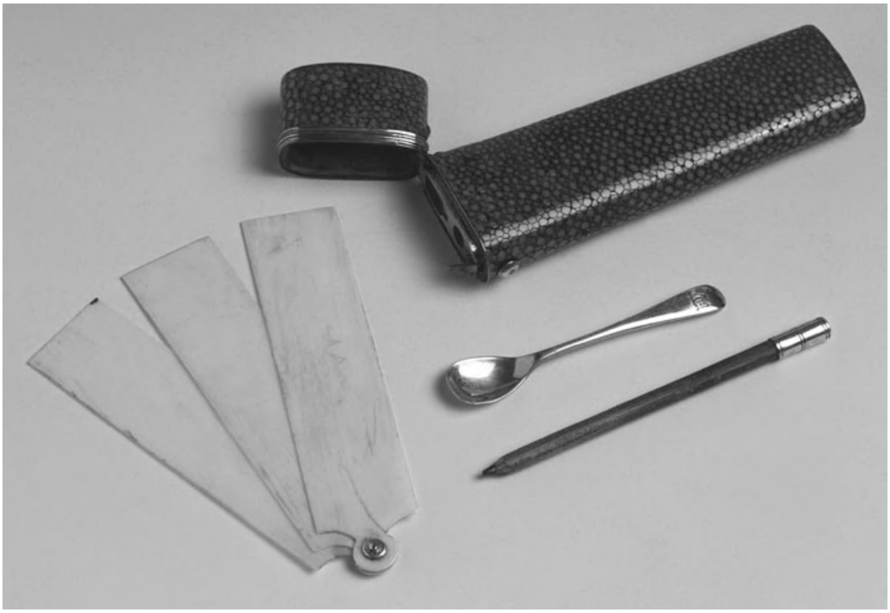


Fig. 5.52 Complex of drawing instruments, signed Jo. Anningson, constituted by a spoon, a pencil and a block notes, consisting of thin sheets of ivory (Brunetti and Rovida 2006)

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Chapter 6
The Nineteenth Century

6.1 Introduction

Some important events related to the drawing of machines in the nineteenth century are as follows:

- the first steps of modern industry;
- as a consequence of industrialization's requirements, the first steps of institutionalized teaching;
- drawing reaches great development as a documentation tool in scientific fields;
- drawing also reaches an important role as divulgation tool;
- great development in the construction of instruments for drawing.

6.2 The First Modern Industries

The nineteenth century saw the beginning of activity of the first industries in the mechanical field. In Table 6.1 some of the most important industries born in this period of time in Northern Italy are presented (Capello and Rovida 1996).

Many of the abovementioned industries were founded by "old" students of Politecnico di Milano. Such students maintained close cultural and affective links with the "old" professors. The counseling of professors was often very important to address the needs of "old" students in their continuing education and in the acquisition of new information to upgrade the industries where they began to work.

For example, Giovanni Battista Pirelli (who received his doctor's degree at Politecnico di Milano in 1870) followed the counseling of Professor Giuseppe Colombo (founder of the Politecnico) "to see and learn the most knowledge possible in each industrial field and, particularly, to study in depth the new industry of rubber, with the aim of transferring this acquired knowledge to Italy". Giovanni Battista Pirelli followed very well the recommendations of the teacher and, after his return to Italy, founded the now universally known rubber industrial enterprise "Pirelli".

E. Rovida, *Machines and Signs*, History of Mechanism and Machine Science 17,
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Table 6.1 Industries in Northern Italy (19th Century)

Industry	Year of foundation	Field of activity
Badoni	End of eighteenth century	Mechanical structures and constructions
Breda (Archivio Storico Breda 1986)	1840	Energy, railway vehicles
Falck	1840	Steel
Real Opificio di Pietrarsa	1840	Railway constructions
Elvetica	1847	Mechanical constructions
Grondona	1847	Mechanical constructions
Ansaldo	1853	Energy, railway vehicles
Riva Calzoni (Ucelli 1961; Sicola 1988)	1861	Energy
Tecnomasio Italiano Brown Boveri (aa.vv. 1988)	1863	Electromechanical constructions
Pirelli	1872	Rubber components
Filotecnica Salmoiraghi (Selvini 1986)	1875	Precision instruments and engineering
Franco Tosi (Alvarez Garcia 1985; Macchione 1987)	1879	Energy
Metallurgica Bresciana	1884	Metallurgy
Pomini (Pomini 1968)	1886	Mechanical transmissions and gear mechanisms
Ercole Marelli	1891	Electromechanical constructions
Ceretti & Tanfani	1894	Lifting Machines
Borletti	1895	Precision instruments and engineering
Fiat (aa.vv. 1950; Pansa and Romiti 1988)	1899	Automotive construction

The example of Giovanni Battista Pirelli was followed by many technicians of important industries. Interesting examples are as follows:

- Alberto Riva: after receiving his doctoral degree (1870) at Politecnico di Milano, he gained his first work experience in Switzerland, in the industrial firm of Caspar Honegger. After his return to Italy, he founded the turbine manufacturing company Riva, which came to be known as "Riva Calzoni".
- Ottorino Pomini: after receiving his doctoral degree (1904) at Politecnico di Milano, he gained work experience in England. The knowledge acquired there was later utilized in the family's industry, Pomini, active in mechanical transmissions, and in his appointment as professor in the field of Machine Design at Politecnico di Milano.

With these cultural exchanges, the scientific-technical experiences of the most industrialized countries, such as Germany, France, England, and Switzerland, became very important for the industrial development of Italy.

The industrial community, in its first steps, largely utilized the orthographic projections that had been very well codified in the eighteenth century by the work of Monge. These projections became immediately the fundamental tool of

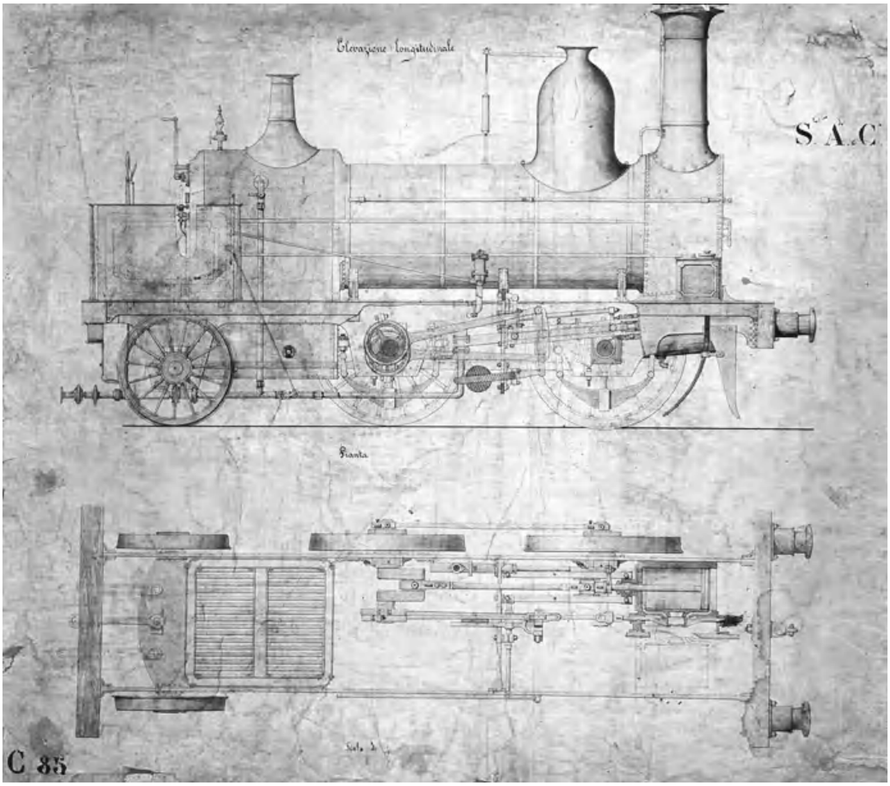


Fig. 6.1 Drawing of a railway vehicle by Ansaldo (1856)

communication among technicians. Designers began to utilize orthographic projections to describe machines and the parts of machines and to inform manufacturers and assemblers how the parts of the machines must be realized and assembled.

The drawings were realized with very different styles, because there were not yet any drawings standards: the theory of orthographic projections was “interpreted” differently by each designer, by following personal tendencies. In general, the drawings are realized with great care and the aesthetic effect often is very good. The machines are represented by many views, corresponding to different directions of observation. The quantitative information is given by the dimensioning: i.e. the dimensions of all particulars are expressed by numbers written on dimension lines, bounded by extension lines.

Figure 6.1 represents a railway vehicle realized in 1856 by Ansaldo, a well-known Italian mechanics industry. Their application of orthographic projections is particularly interesting: the vehicle is represented by a side view and a vertical view It is also represented partially sectioned. Interesting also is the use of a reduction scale and the application of colors.

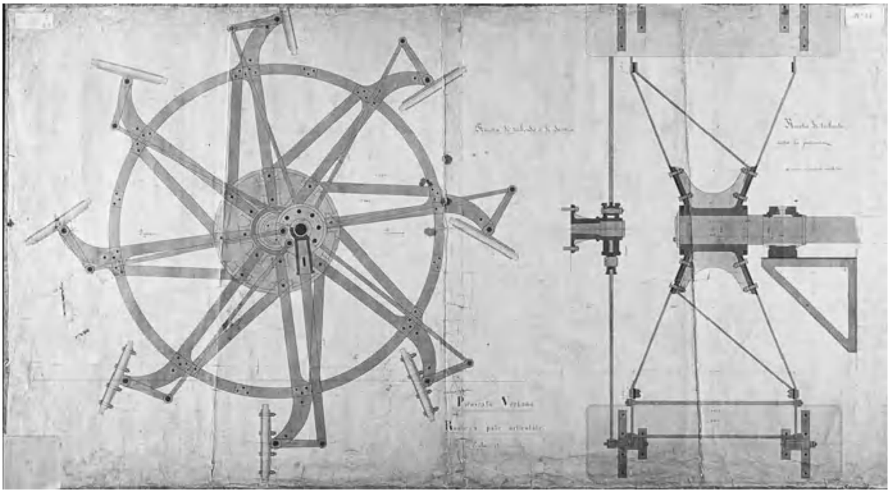


Fig. 6.2 Mechanism relative to the propulsion of a steam ship by Ansaldo (1856)

Figure 6.2 is related to another drawing by Ansaldo and represents a mechanism relative to the propulsion of a steam ship for an Italian lake (1856–1857). The orthographic projections are identified with texts in "nautical" language. The applied reduction scale is 1:5 and the different materials are identified with different colours.

The drawing is an example of an "assembly drawing", because the represented object is a complex of many different connected parts, and the relative interactions are graphically expressed. The drawing has many dimensions and can be considered constructive.

Figure 6.3 represents a tender for a vehicle of the Railway of Piemont, Italy (1858). The drawing is executed with the reduction scale 1:10 (a scale that is still used today) and the vehicle is represented by three principal views. The hidden parts are represented by dotted lines or by cuts. Interesting, also in this drawing, is the horizontal view represented partially sectioned.

The dimensions are on the drawing: such a drawing therefore, can be considered both assembly and constructive drawing.

The use of colours allows us to reach a good aesthetic level.

Figure 6.4 represents a steam machine, with power of 20 HP, characterized by a horizontal cylinder. The representation scale is 1:10, also today included in drawing standards. Such a scale allows representation of the complete machine, with all components parts, i.e. cylinder, connecting rod, crankshaft, crosshead, flywheel and regulator. The use of colours allows a good differentiation of parts and materials and, of course, a high aesthetic value.

The drawing of Fig. 6.5 is relative to a steam machine for the very well-known Italian factory of chinaware, Ginori. The drawing is interesting because it has the character of a plant drawing: it is possible to see all the industrial elements connected

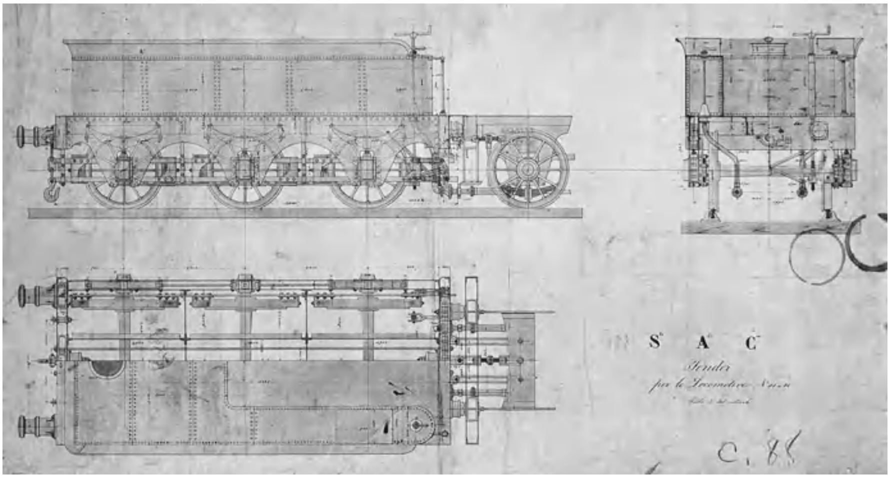


Fig. 6.3 Tender for the railway of Piemont, Italy by Ansaldo (1856)

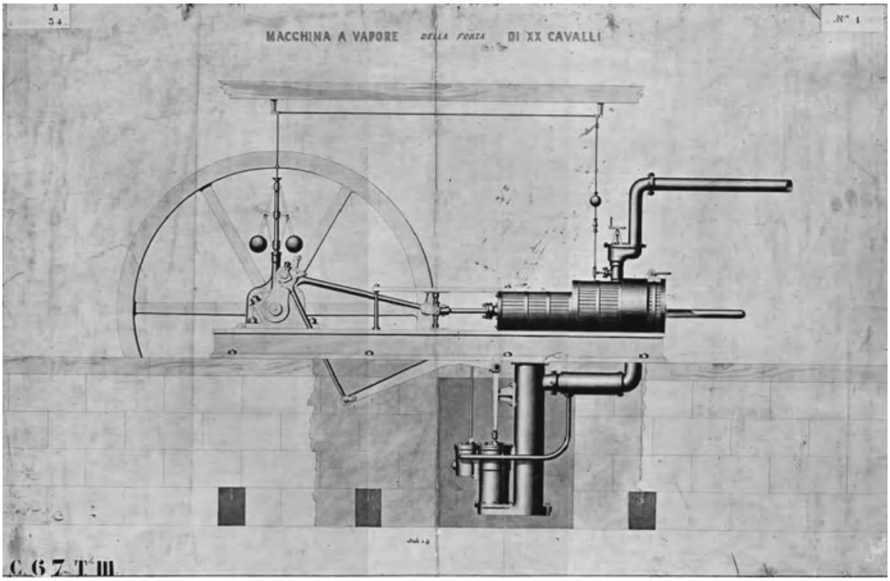


Fig. 6.4 Steam machine with horizontal cylinder by Ansaldo (1856)

with the machine. The use of colour, as usual, reaches a very important aesthetic level and allows acute comprehension of the drawing.

The drawing (realized by Ansaldo 1876) of Fig. 6.6 is relative to a compressor (in the drawing called an "air pump") for the ship called "Forte". The drawing represents an assembly with some schematic particulars, similar to a plant's drawings.

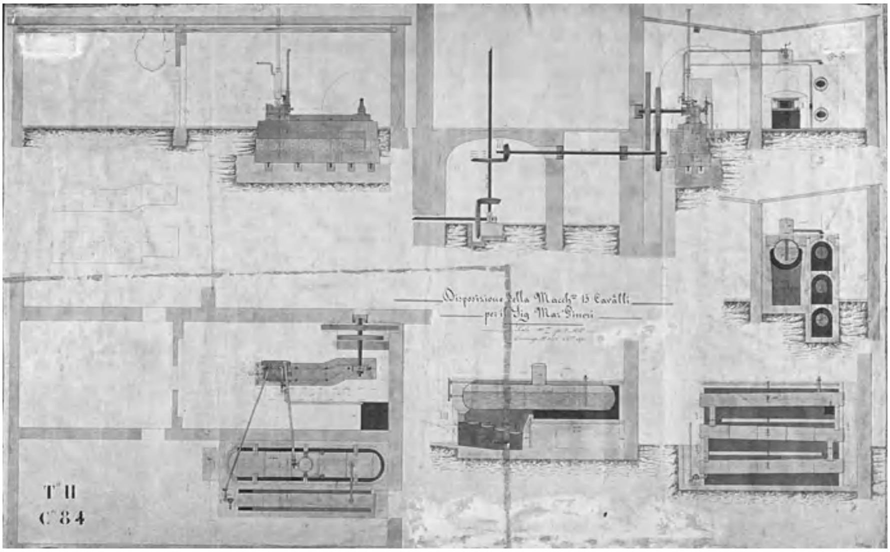


Fig. 6.5 Steam machine for an Italian factory by Ansaldo (1856)

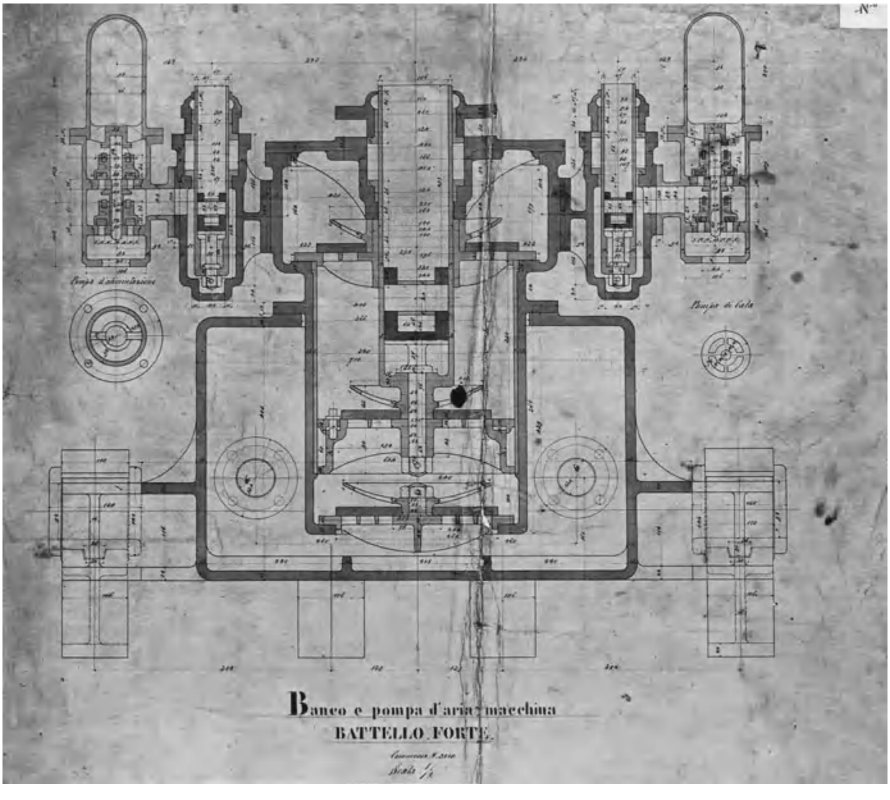


Fig. 6.6 Compressor for the ship “Forte” by Ansaldo (1856)

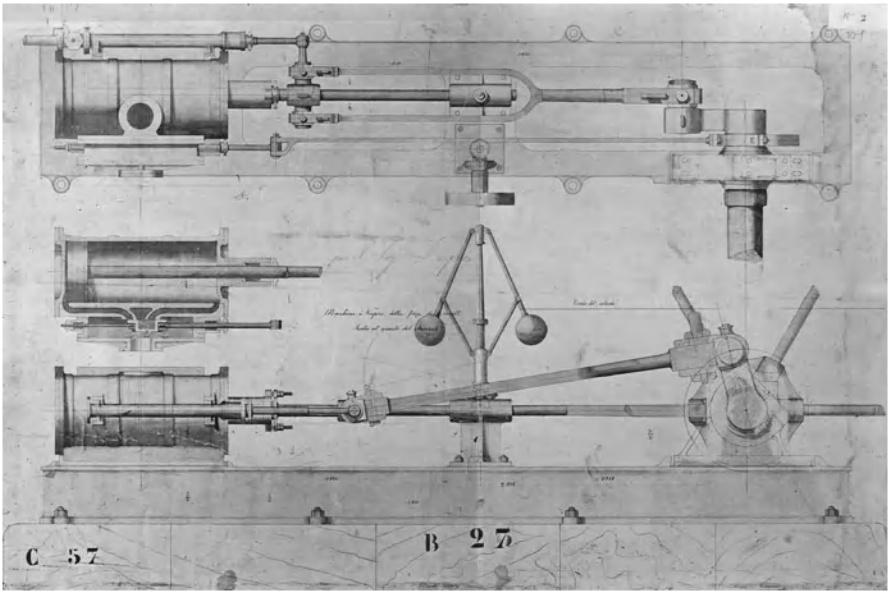


Fig. 6.7 Steam machine by Ansaldo (1856)

The reduction scale is 1:2. it is interesting to observe that, in the past, the scale 1:2 was sometimes not recommended, because it "could give some wrong impression of the proportions". Instead of the scale 1:2, the first drawing standards recommended the use of the scale 1:2.5, to avoid the above mentioned inconvenience. The problem of the scale 1.2 was eventually demonstrated as non-existent (Biggioggero and Rovida 1976) and such a scale was admitted in the ISO standards in 1980.

The colours highlight the different parts and materials and reach good aesthetic level. Some dimensions in the drawing give it constructive value.

The object in Fig. 6.7 is a drawing (1880, by Ansaldo) of a steam machine, with horizontal cylinder. The representation is an assembly drawing, with some dimensions and, therefore, with constructive character.

Figure 6.8 is relative to a hydroelectric plant: the cuts are highlighted with colours. Observe that it represents only one half of the turbine group to the right. A symmetry axis means that the represented parts should be rotated by a mirror, to represent the real group.

On the drawing, the fundamental dimensions are indicated.

Figure 6.9 represents steam machines realized by Franco Tosi. Such drawing is an assembly drawing, very carefully realized, with some use of colours. The dimensions and the scales are very similar to modern drawing standards.

A closely related factor in the development of drawings was their use in applications for patents. The granting of patents is a very old institution, but in the nineteenth century, with the development of industry, the system had reached a great diffusion. In fact, the complex of patents can be considered the "summa" of all ideas realized, but also only thought of. As an example, the TRIZ is a widely

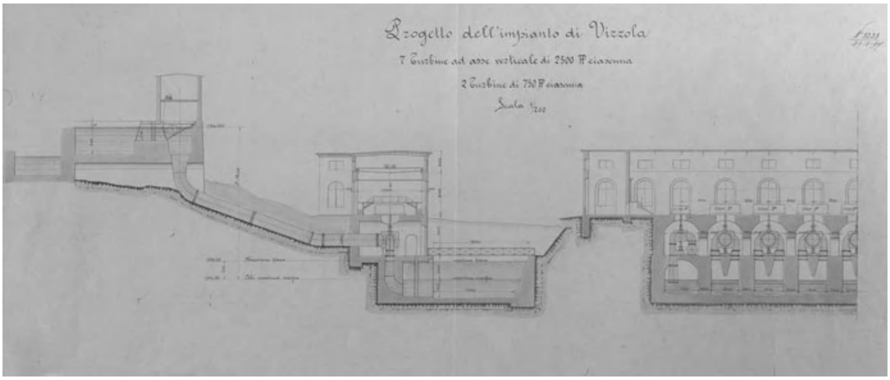


Fig. 6.8 Hydroelectric plant (by Riva Calzoni 1897)

diffused tool in the development of innovative solutions to problems and is based on the laws of evolution of technical systems, deducted from an analysis of a great number of patents (Michalewicz and Fogel 2000; Altshuller 1996; Orloff 2002).

Figures 6.10 and 6.11 are relative to patents of the Italian pioneer of aeronautics, Enrico Forlanini: such patents were studied at the end of the nineteenth century and published in the first years of the twentieth century.

6.3 First Steps Toward Institutionalized Teaching

In the nineteenth century, institutionalized teaching in a systematic configuration began. The first technical Universities and Schools appeared (Table 6.2) and an important item in their curricula was technical drawing. Drawing, from the didactic point of view, has two different aspects: it is an item to be transmitted to the students and, also, it is a tool for the scientific-technical disciplines. Industry needs people with good professional ability and an important skill is the drawing of machines. Such an item, particularly, is related to the axonometric and orthographic projections that created to represent elements and parts of machines, for use in manufacturing by the first industries. The aim of technical drawing in the schools is not only to teach students how machines are structured, but also to train them in manual ability, observation skill, and precision. The role of technical drawing is, thus, not only informative, but it has also a strong formative component.

For this reason, artistic drawing is considered a good manual exercise and represents an important part in the graphical exercise in both art and technical universities. It is significant that the "Sommario di progetto" (Abstract of project) for the foundation of Politecnico di Milano (according to the Italian law 12 November 1859) provides, for the admission of students, a mandatory test in artistic drawing. Such a test consists consists of making a copy of a given simple artistic drawing.

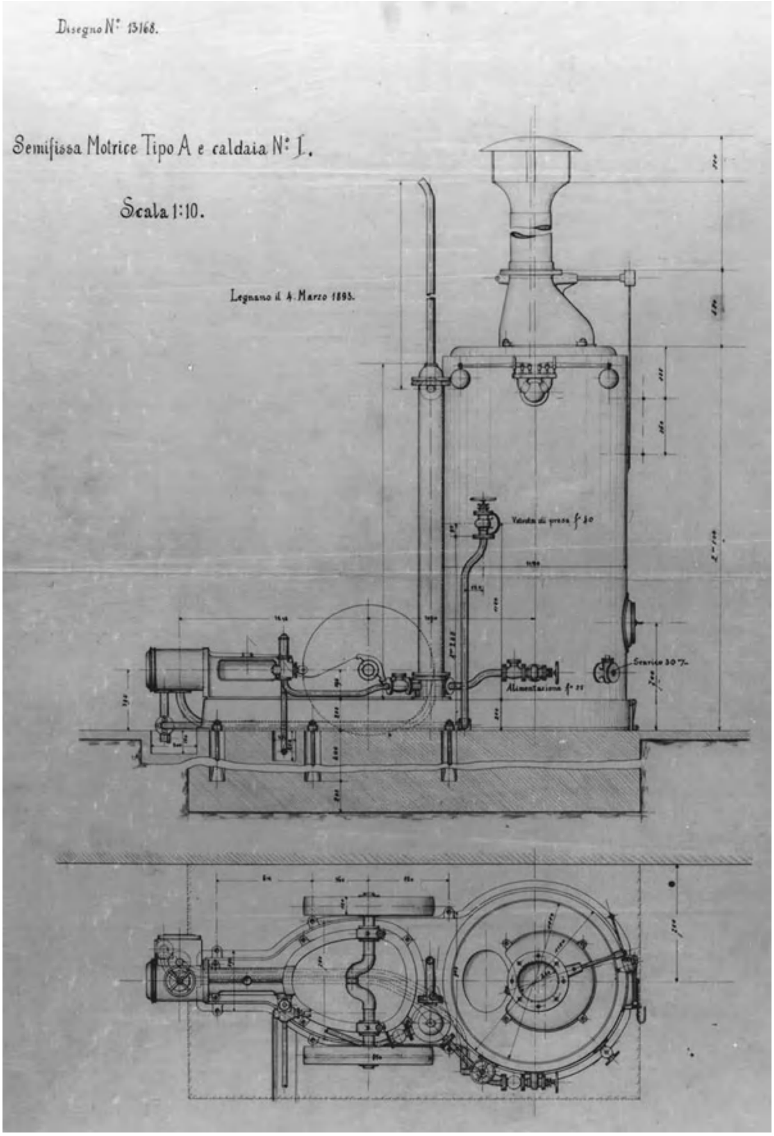


Fig. 6.9 Steam machine (by Franco Tosi 1893)

The importance of artistic drawing is confirmed by Camillo Boito, brother of the well-known musician Arrigo, in a book written as a letter to an imaginary friend.

The principles of axonometric projections are included for the first time in a book by Farish (Farish 1796–1821), an English professor who developed a drawing technique which he called "Isometric Perspective" , as reported by Dalla Rosa (1876), Meyer-Meyer (1863) and Schmidt (1859) and introduced in Italy by

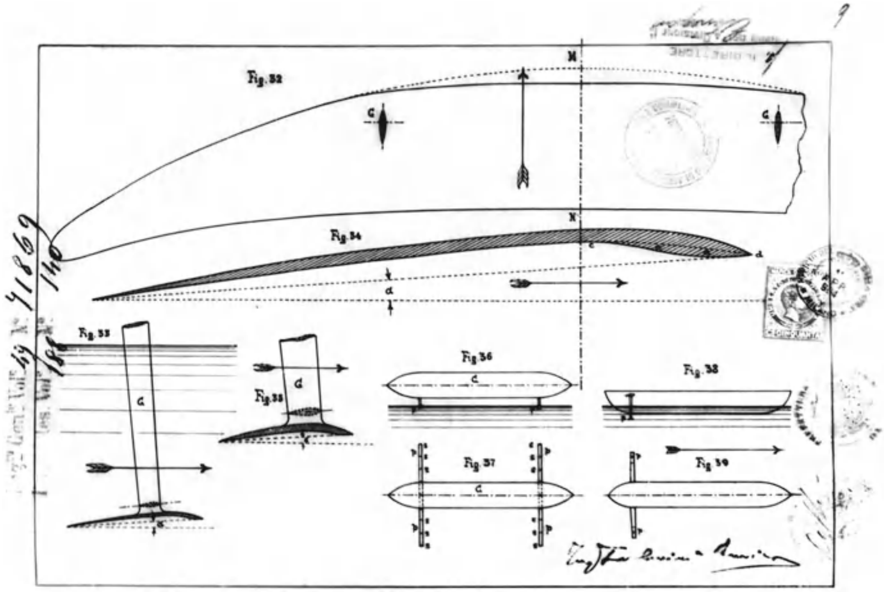


Fig. 6.10 From the patent "Apparecchi idrovolanti o volanti sull'acqua e nell'aria" (Seaplanes, or flying machines in the air and water) by Enrico Forlanini, April, 11, 1904

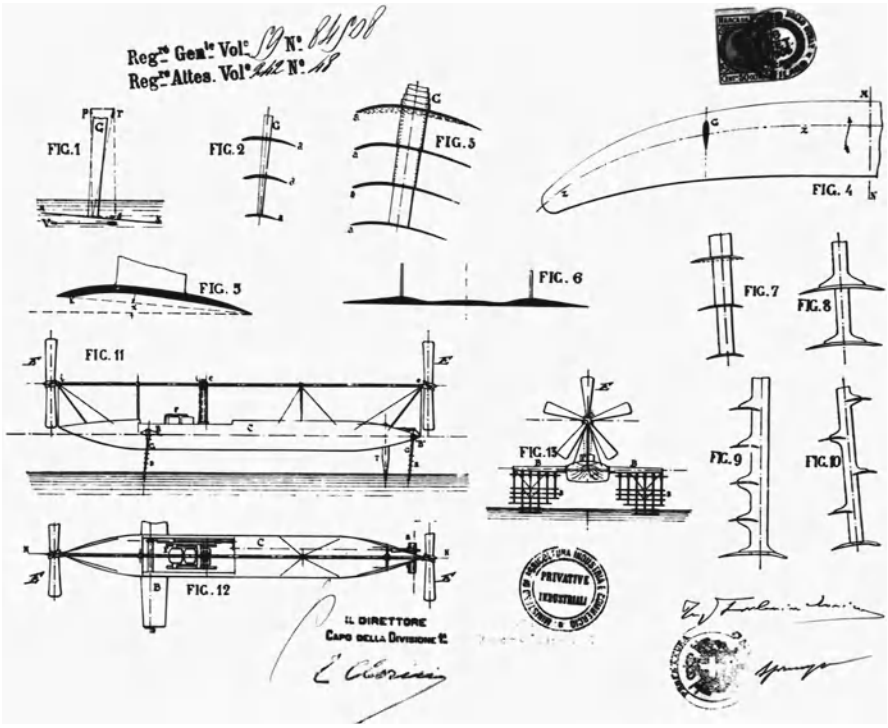


Fig. 6.11 From the patent "Apparecchio per navigare sull'acqua e nell'aria detto "Idrovolante"" (Machine to voyage in the air and water, called "Seaplane") by Enrico Forlanini, September, 6, 1906

Table 6.2 Year of foundation of some technical universities and schools

Year	Universities
1794	Conservatoire National des Arts e Metiers (since 1819, courses for technicians)
1811	First Italian Engineering Faculty in Naples
1821	Technical University of Berlin
1825	Technical University of Karlsruhe
1829	Technical University of Munich
	Technical University of Stuttgart
1831	Technical University of Hannover
1831	Società di Incoraggiamento Arti e Mestieri (Society for the Encouragement of Arts and Crafts) in Milan (Lacaita 1990)
1857	University of Pavia: "Science of machine construction"
1863	Politecnico di Milano (Technical University of Milan) (Lori 1941; aa.vv. 1964, 1981; Rovida et al. 1988)
1871	School of machine drawing by the Società di Incoraggiamento Arti e Mestieri (Society for the Encouragement of Arts and Crafts) in Milan

Quintino Sella (1861). The texts of this time contain very deep principles of descriptive geometry with some, not particularly numerous, applications to the elements of machines. The texts of this period are very numerous, because industry increasingly requires the technical capacity of representation.

Drawing is a mandatory subject in schools in France (since 1833), in England (since 1851) and Italy (since 1862–1863).

Some interesting didactic books for drawing are as follows: in Germany (Schmidt 1859), in Italy (Astolfi 1825; Codazza 1842; Cavallero 1861; Boito 1882, 1895), in France (Marie 1836; Armengaud and Moroux 1848; Leblanc 1860; De la Gournerie 1860).

As examples of didactic books about technical drawing, the figures below are relative to certain cases. In particular Fig. 6.12 represents the cover of the book of Giovanni Astolfi about linear perspective, edited in 1825. Such a book was mainly utilized in Italian schools as a textbook for drawing courses. The book is relative to perspective and this fact confirms that artistic drawing and perpective are considered very important and formative items for the drawing of machines.

Figure 6.13 represents the cover of an interesting French book (1835), about polyhedrons. This book has very good didactic value, because the sheets allow the constructions of polyhedrons, by cuts and folds of the paper (Fig. 6.14).

The following figures are relative to some exercises of students of the nineteenth century. They illustrate the great amount of work relative to geometric and artistic drawing, that is considered as an important preliminary exercise in drawing, successively, the elements of machines.

Figure 6.15 from the book (Astolfi 1825) is relative to geometric constructions and perspectives.

Such a book is interesting from the didactic point of view: the layout is realized as "observations" (presentation of theoretic principles and rules) and "problems" (with the application of the abovementioned principles and rules to practical situation, with guided solutions).

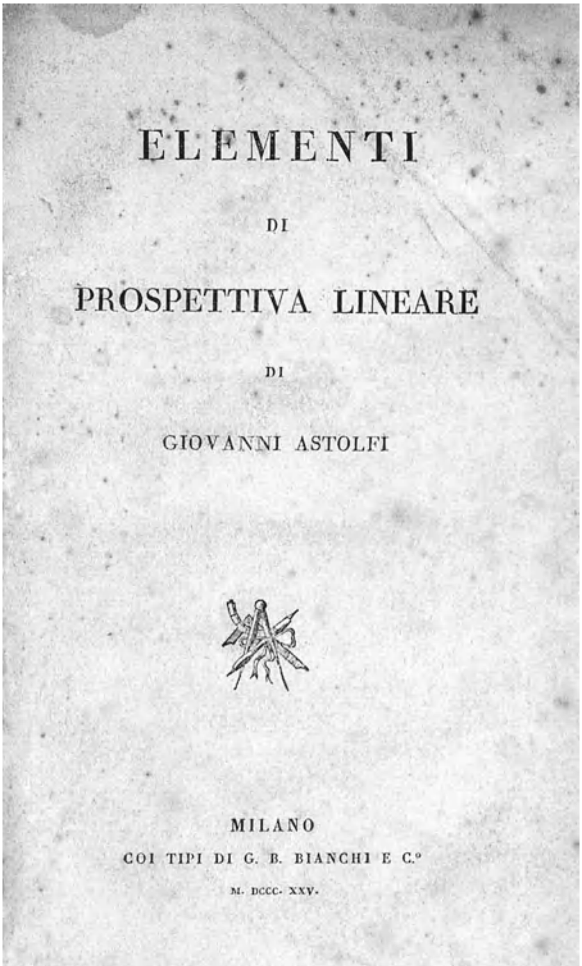
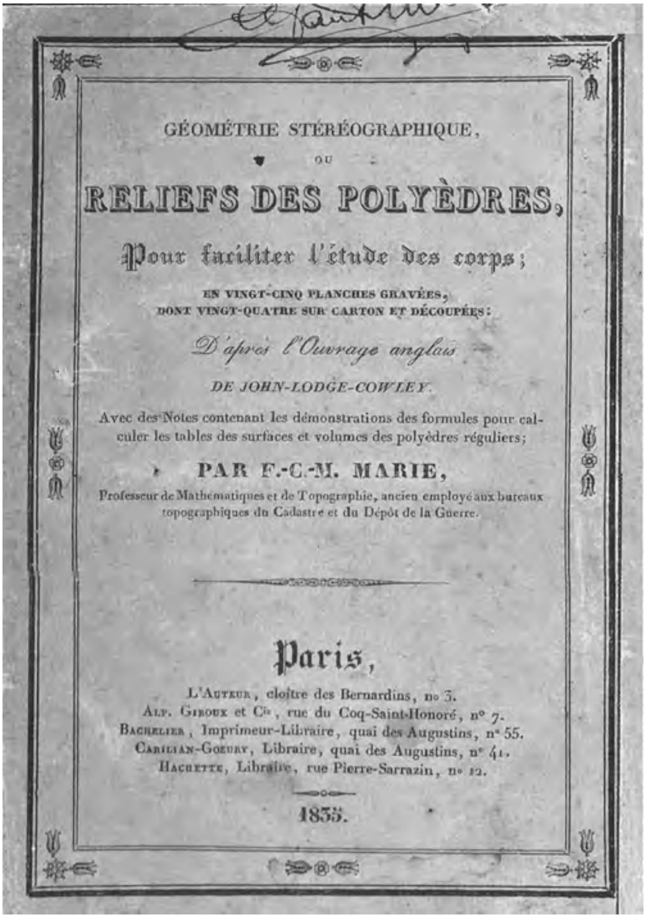


Fig. 6.12 The book of Giovanni Astolfi about linear perspective edited in 1825

In addition, the layout of the book is interesting because all figures are at the end and readable with the opened book.

In Fig. 6.16 there is an example of an exercise in artistic drawing in an Italian technical school.

After an important activity and many hours spent in exercises about artistic and geometric drawing, the students of technical courses, finally, can draw the parts of machines. Figure 6.17 represents an exercise about a crank mechanism: this figure confirms the great integration between the graphical aspect and calculations, necessary for a good proportioning of the represented machines. The drawing is a sketch and represents the abovementioned mechanical components through orthographic projections. Figures 6.18 and 6.19 are relative to other mechanical components.



GÉOMÉTRIE STÉRÉOGRAPHIQUE,

OU

RELIEFS DES POLYÈDRES,

Pour faciliter l'étude des corps;

EN VINGT-CINQ PLANCHES GRAVÉES,
DONT VINGT-QUATRE SUR CARTON ET DÉCOUPÉES:

D'après l'Ouvrage anglais

DE JOHN-LODGE-COWLEY.

Avec des Notes contenant les démonstrations des formules pour calculer les tables des surfaces et volumes des polyèdres réguliers;

PAR F.-C.-M. MARIE,

Professeur de Mathématiques et de Topographie, ancien employé aux bureaux topographiques du Cadastre et du Dépôt de la Guerre.

Paris,

L'Auteur, cloître des Bernardins, n° 3.
Alf. Giroux et Cie, rue du Coq-Saint-Honoré, n° 7.
Bachelier, Imprimeur-Libraire, quai des Augustins, n° 55.
Carilian-Goeury, Libraire, quai des Augustins, n° 41.
Hachette, Libraire, rue Pierre-Sarrazin, n° 12.

1835.

Fig. 6.13 Cover of a French book (1835), with the possibility to realize polyhedrons by cuts and folds of papers, as indicated in the figure

Figure 6.20 is a sketch of bearings, while Fig. 6.21 is a geometric construction relative to the contact line between two teeth of a gear.

The above-mentioned figures are relative to some preparatory sketches. Students of the nineteenth century also had very good manual ability and definitive drawings reach a very high aesthetic level.

6.4 The Drawing as Documentation Tool for Scientists

An important characteristic of the nineteenth century was the great development in all fields of science: many scientific discoveries were made in this period of time and the relative applications gave a strong impulse to technological progress.

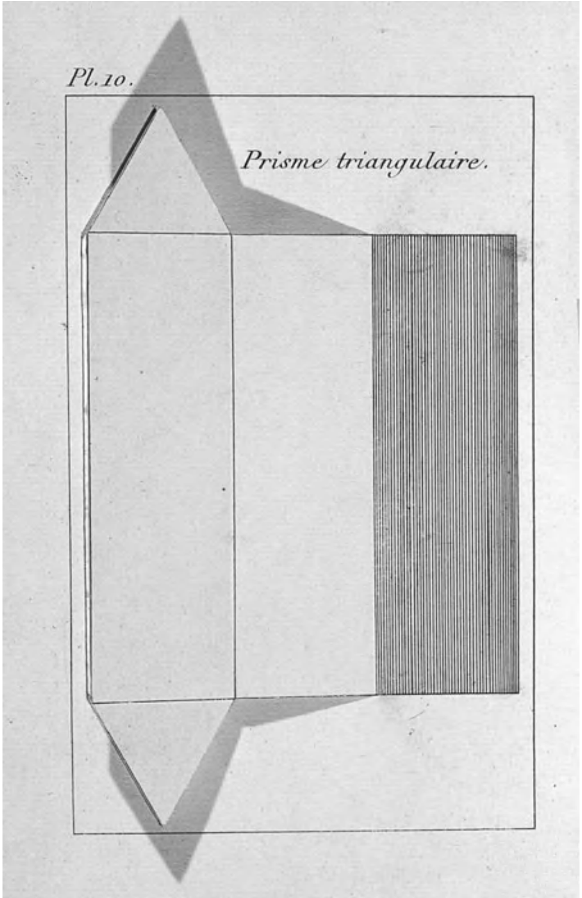


Fig. 6.14 Example of polyhedron construction.(From the book of Fig. 6.13)

Therefore, it became very important to attain great efficiency in scientific-technical communication, particularly in contacts among scientists and in transmission of reciprocal results and, consequently, in the development of all technology.

Drawings, as immediate means of transmission of ideas, are very important for communication among scientists. In the chapter relative to the eighteenth century, some examples of drawings of Alessandro Volta were presented and illustrated. In the nineteenth century, as an example, some scientific drawings of Giuseppe Belli (1792–1860) were presented. Giuseppe Belli was a physicist born in Italy, near Novara (Piemont) and professor of physics at Pavia University. He was active particularly, but not only, in the electrical field and realized many electrical devices as well as their drawings (Bellodi and Rovida 1994).

In Fig. 6.22 an electric device designed and realized by Giuseppe Belli is represented (Belli 1831): such a device, the electrostatic generator, is represented by four

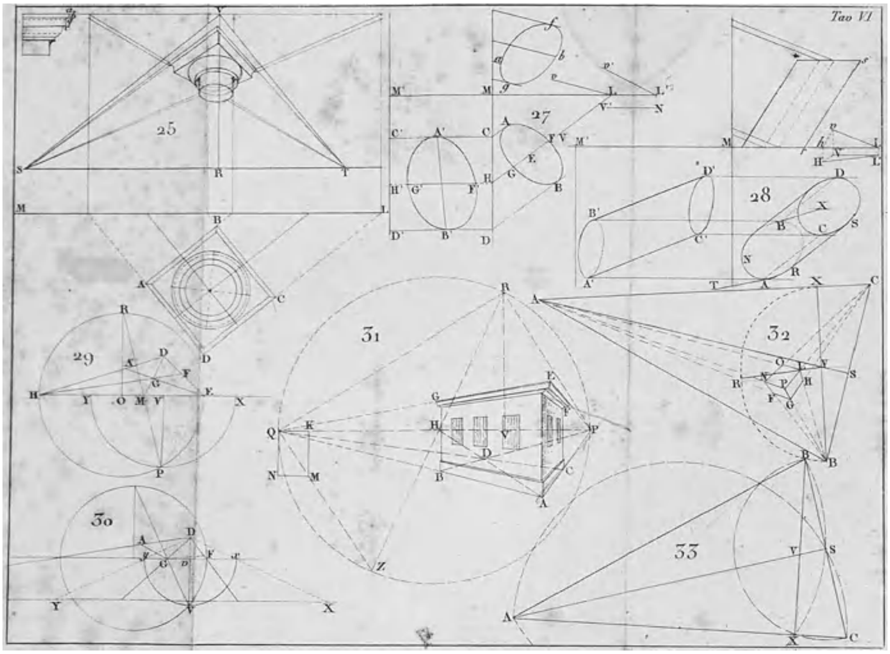


Fig. 6.15 Example of didactic drawings from the book (Astolfi 1825)

views. Three views are orthographic and the fourth is axonometric. Modern drawing standards establish that the orthographic views must be positioned in reciprocal fixed positions, with the aim of avoiding ambiguity. In relation to the reciprocal positions, the projection methods are called method of the first dihedral and, respectively, method of the third dihedral: some people call such methods, respectively, European and American methods.

In the drawing of the device of Giuseppe Belli, the three views are in positions not corresponding with the above mentioned methods, but in general positions, easily understandable. This application could be considered an anticipation of the "arrow method", included in the modern international drawing standard.

The "cabinet" axonometric projection is characterized by the front face represented as an orthographic projection, while the other faces are represented as foreshortened.

The orthographic projection, as it is easy to recognize, describes completely and "analytically" the represented object: of such an object, the above mentioned projection, by using many views from different directions of observation, give all particulars. The axonometric projections, however, give of the represented object only a "synthetic" view: i.e., it represents the volumetric complex of the object, generally with only one view, but without description of all particulars.

Giuseppe Belli represents some parts of the electric device in a cut: such parts are highlighted by hachures, corresponding to the sectioned surfaces. Such hachures are graphically different in relation to the different materials of the parts.

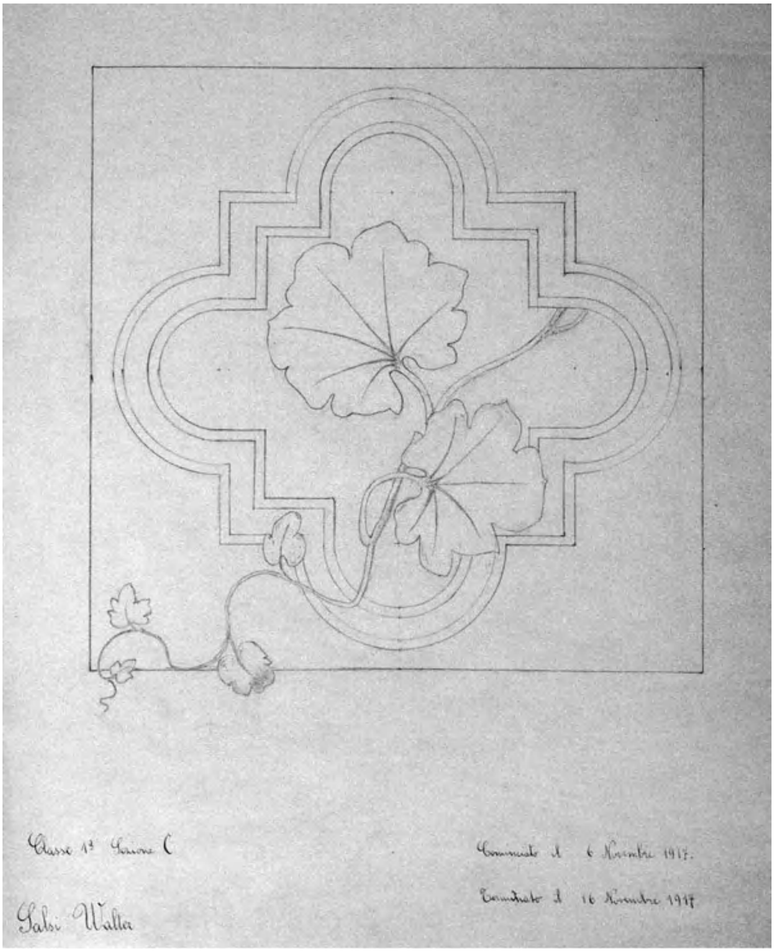


Fig. 6.16 Example of geometric and artistic drawing

The dimensions are indicated not directly on the drawing, but by a graphical scale.

The drawing is very carefully realized and the aesthetic value is interesting. The precision of the execution is very good and the dimensioning by the graphical scale give to the drawing a good constructive character.

Figure 6.23 is relative to another electric device, the "duplicator" (Belli 1838): such a device is represented by an axonometric view and two orthographic projections, obtained by observing the axonometry in horizontal and vertical directions. The two orthographic projections are in generic positions, not corresponding to the

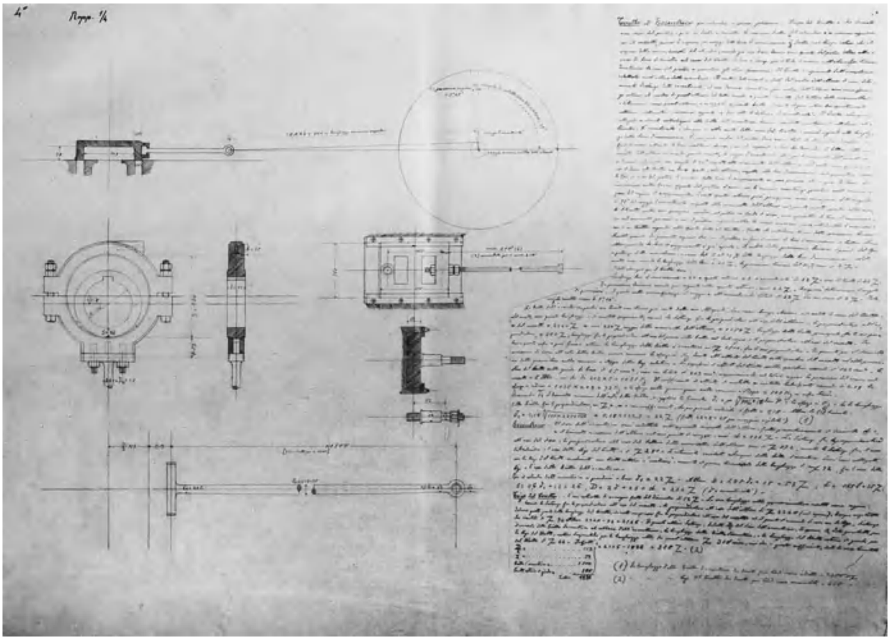


Fig. 6.17 Drawings and calculations relative to a crank mechanism (end of Nineteenth Century)

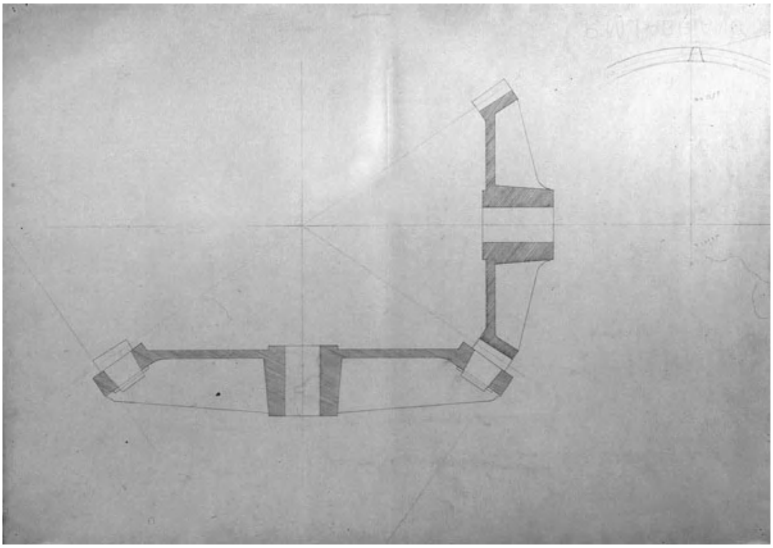


Fig. 6.18 Didactic drawing of a gear mechanism

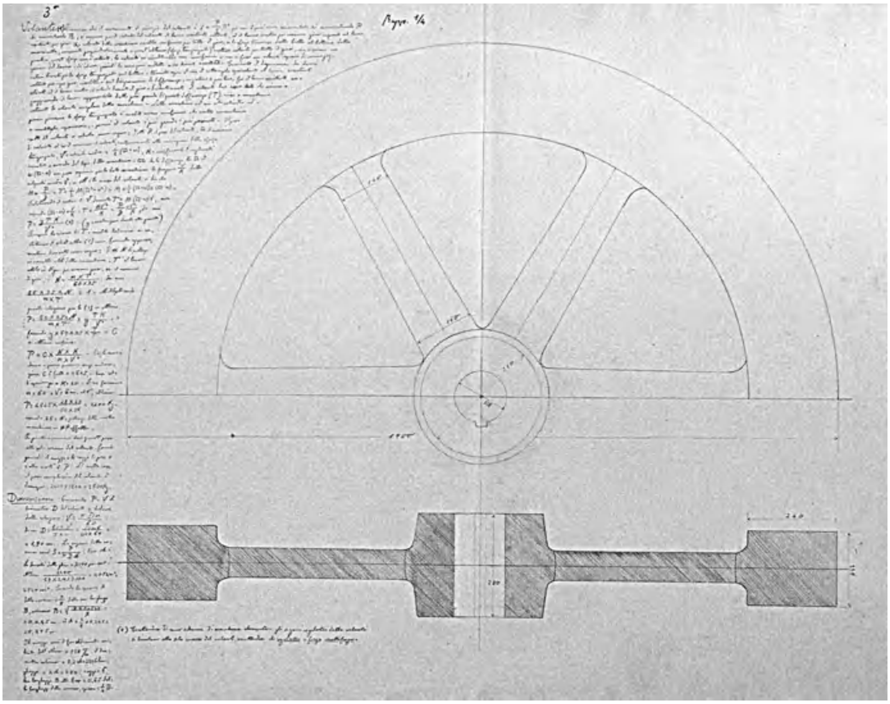


Fig. 6.19 Didactic drawing of a flywheel, with some notes by the student

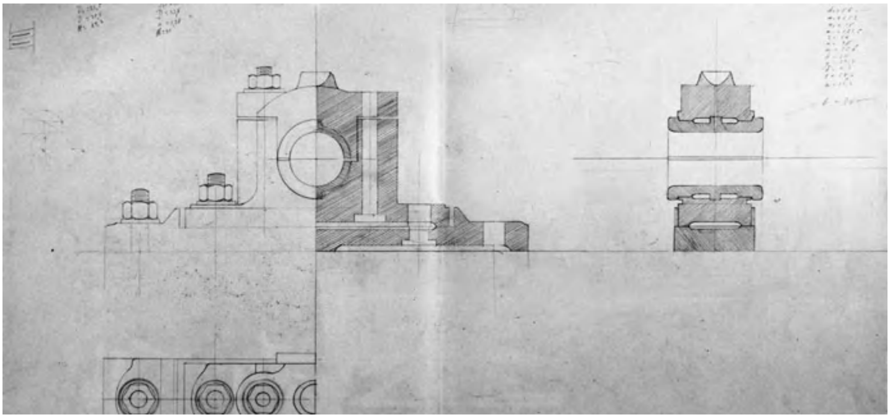


Fig. 6.20 Sketch of bearings

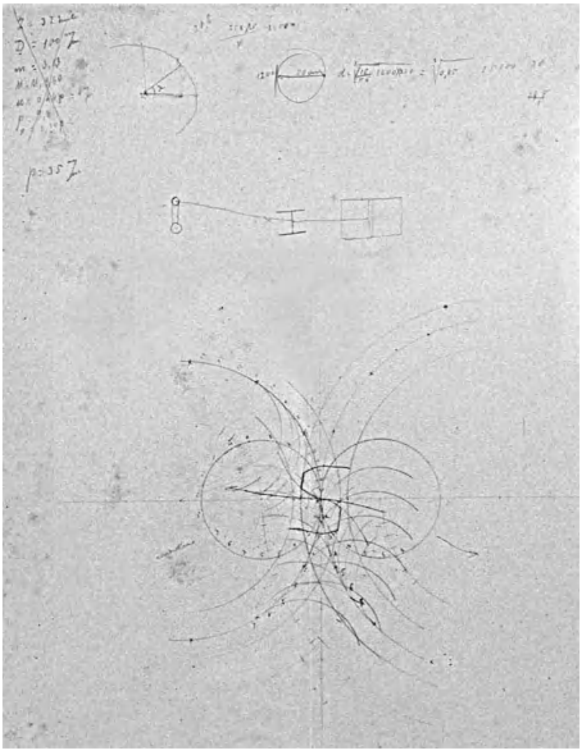


Fig. 6.21 Geometric construction relative to the contact line between two teeth of a gear

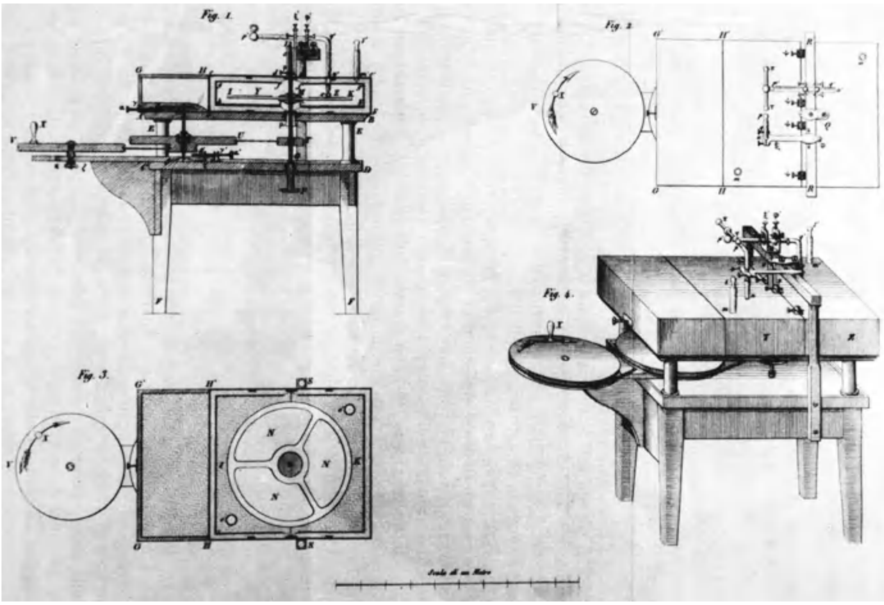


Fig. 6.22 Electrostatic generator by an Italian physicist, Giuseppe Belli (1831): the drawing represents an anticipation of the "arrow projection method" and of the individuation of the materials of sectioned parts (Bellodi and Rovida 1994)

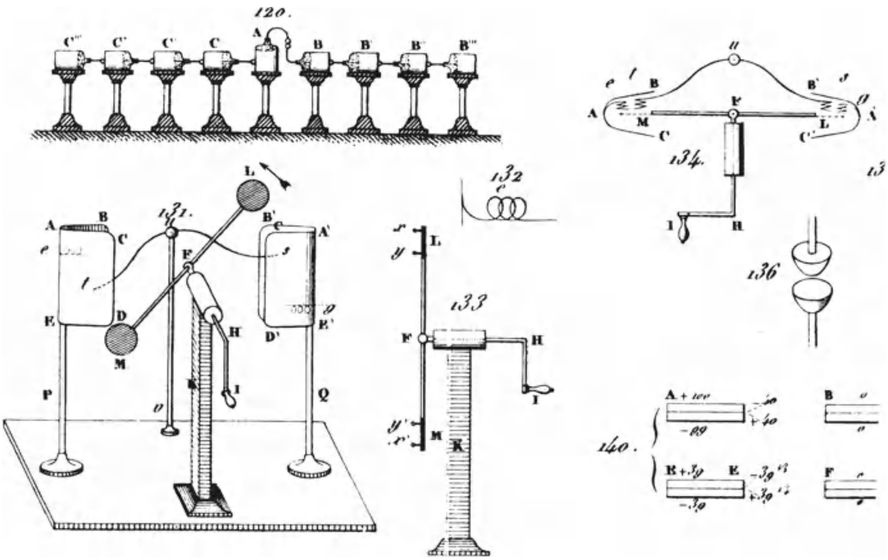


Fig. 6.23 Device of Belli ("duplicator") (1838) (Bellodi and Rovida 1994)

position fixed by the modern methods of the first dihedral and of the third dihedral.

The represented object is very simple: therefore, it is easy to recognize the direction of observation of each view and there is no problem of ambiguity. The drawing is realized with pictorial and aesthetic care: e.g.. the shadows give to the representation a good three-dimensional impression. The aim of this representation is to express the general configuration of the device: the simplicity of the device allows a constructive character.

In Fig. 6.24 is represented a device for experiences on Voltaic electricity (Belli 1841). The device is constituted by two metallic overlapping disks and is represented by four orthographic views. Also in this drawing, the position of the views are generic, but the interpretation is easy. The drawing could be considered another anticipation of the "arrow method", present in modern international drawing standards. Some parts are sectioned and the hachure is used to identify the sectioned parts. It is interesting to observe that some parts, such as threads, are realistically represented: modern drawing standards recommend a simplified representation.

Another electric device is the object of Fig. 6.25 (Belli 1838). In this drawing, one should observe the high level of schematization. Another characteristic of this drawing is the representation partially in axonometric (the forks) and partially in orthographic projection (the pedestals, also represented as sectioned): in this way, only one view allows a complete representation of the device.

The drawing of Fig. 6.26 represents a pneumatic machine and is very schematic (Belli 1827). The machine consists of two cylinders and pistons: with this motion

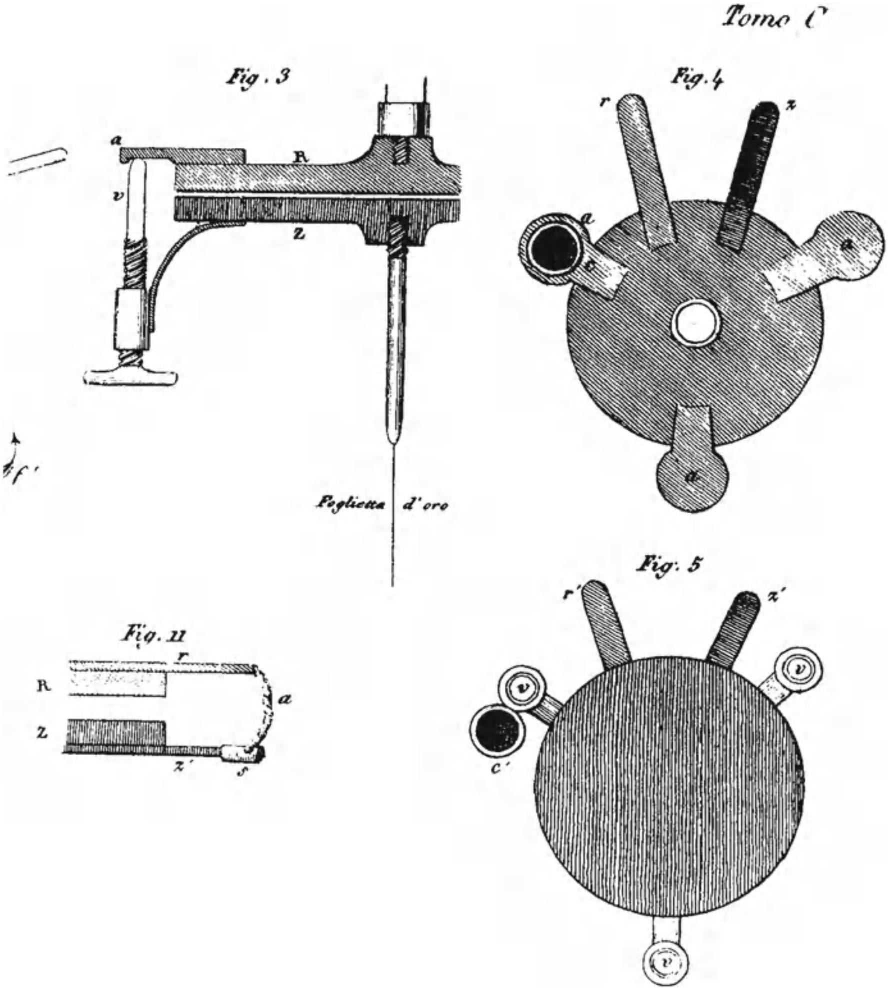


Fig. 6.24 Device of Belli for experiments with Voltaic electricity (1841) (Bellodi and Rovida 1994)

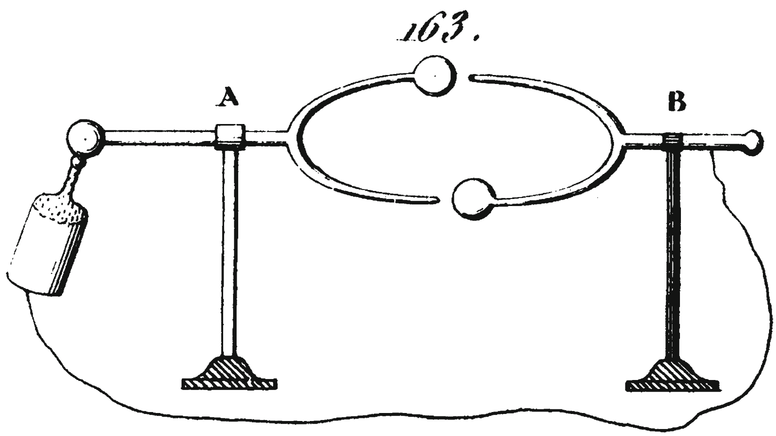


Fig. 6.25 Another electric device of Belli (1838) (Bellodi and Rovida 1994)

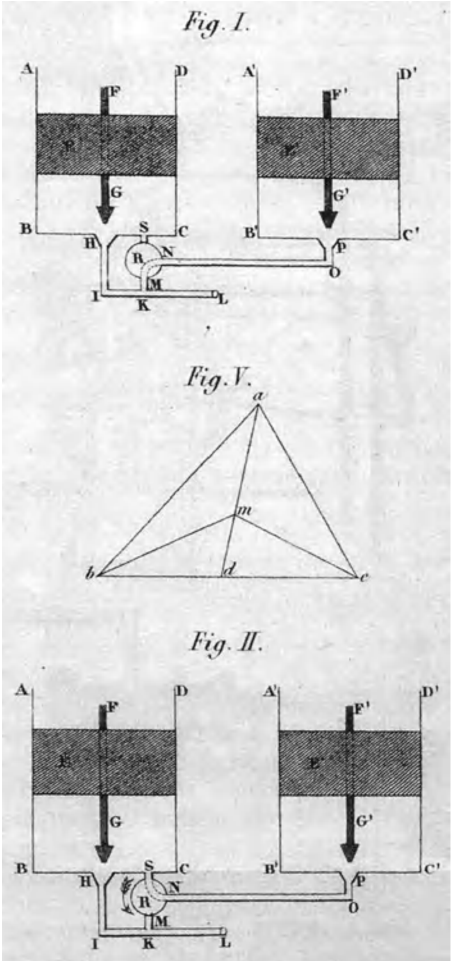


Fig. 6.26 Pneumatic machine of Belli (1827), represented by schematic drawings (Bellodi and Rovida 1994)

and a pipe system, the machine realizes the vacuum. The drawing is interesting because it is an attempt to propose a schematization of the drawing, by representing only the performed function, without constructive particulars: these trends, will by codified, 100 years later, by modern drawing standards.

The electroscope of Bohnenberg represents in axonometric projection and with some schematization an electrical device (Belli 1838). The aesthetic of the representation is good, with shadows to highlight the three-dimensional effect (Fig. 6.27).

Figure 6.28 represents the electrostatic generator of Ramsden (Belli 1838). The drawing is realized with great graphical care and the efficiency of the representation, in axonometric projection is very good. The three-dimensional effect is highlighted by shadows on the lateral face. The aim of this drawing is, of course,

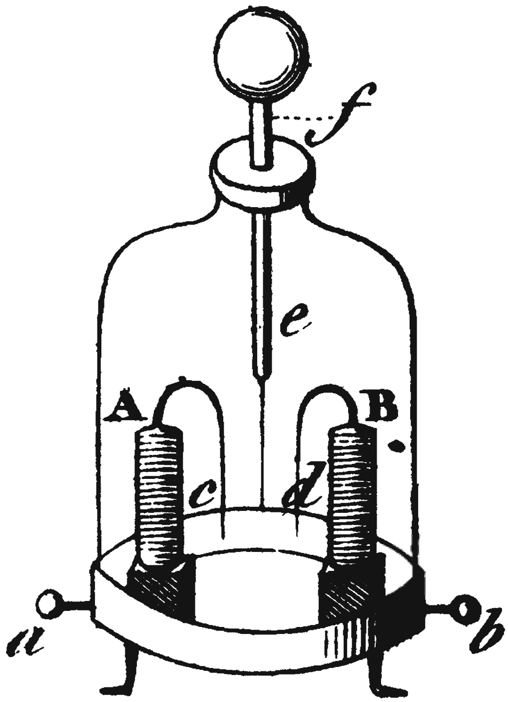


Fig. 6.27 Electroscope of Bohnenberger, represented by Belli (1838) (Bellodi and Rovida 1994)

functional, to describe structure and behavior of the device. The drawing of an object characterized by this complexity makes it difficult to include all constructive information, useful for a manufacturer.

Figure 6.29 represents a steam machine in axonometry (Belli 1838). The aesthetic effect is very good and the illustrative validity is also interesting. The aim of this drawing is fundamentally didactic.

Figure 6.30 forms a great idea of Belli relative to a general book about physics, never completed; it is illustrative of several experiments, particularly of thermology and optics (Belli 1838). The illustration has particular didactic character. From the representation point of view, it is interesting to note the attempt to search for some rules of drawing's. For example, the hidden edges are represented by dotted lines and the hachures to indicate the sectioned parts. Some specific hachures are used to indicate "sectioned" liquids and gaseous substances.

Figure 6.31, also from the never-completed text of physics (Belli 1838), is relative to the properties of bodies: observe the careful three-dimensional representation with shadows.

Figure 6.32 represents an innovative device designed and proposed by Giuseppe Belli (Belli 1841). Such an instrument is represented by a longitudinal cut (observe the text "longitudinale" on the drawing). From the representation point of view

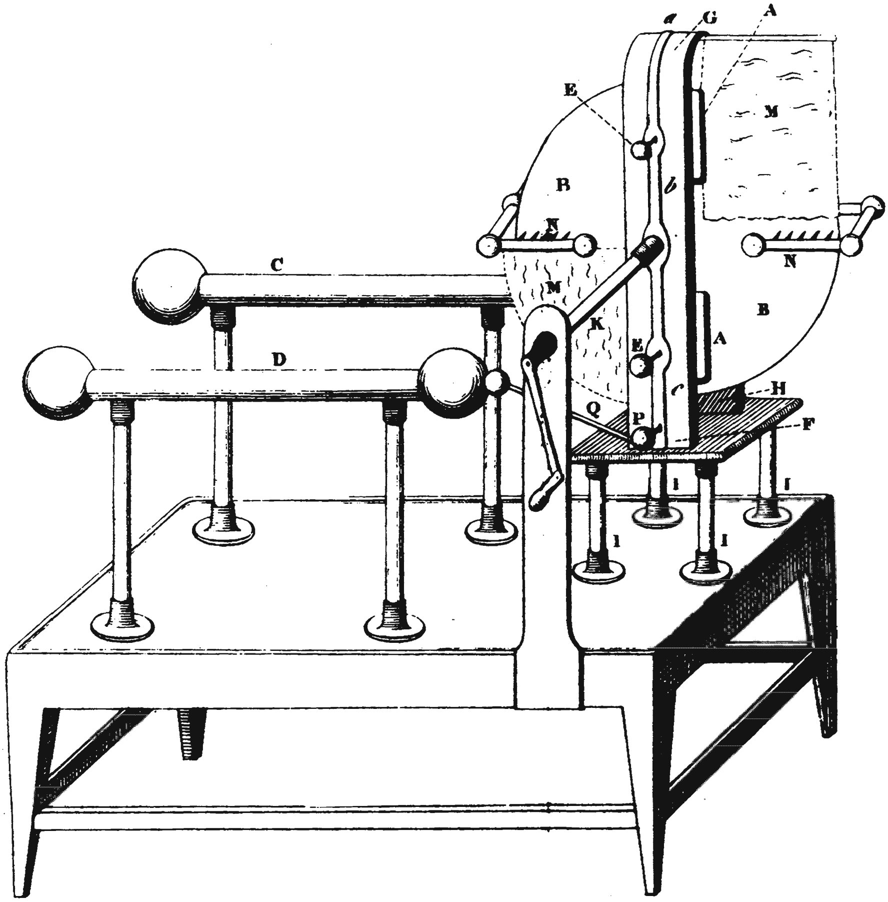


Fig. 6.28 Electrostatic generator of Ramsden, represented by Giuseppe Belli (1838) (Bellodi and Rovida 1994)

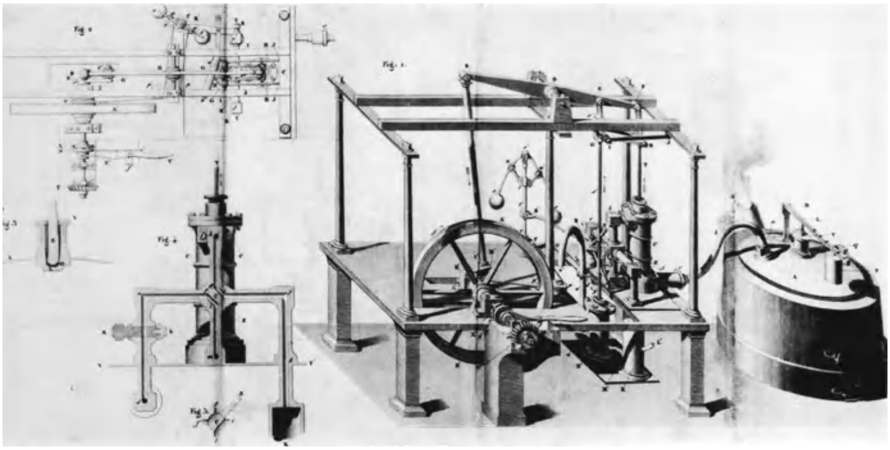


Fig. 6.29 Steam machine by Belli (1838) (Bellodi and Rovida 1994)

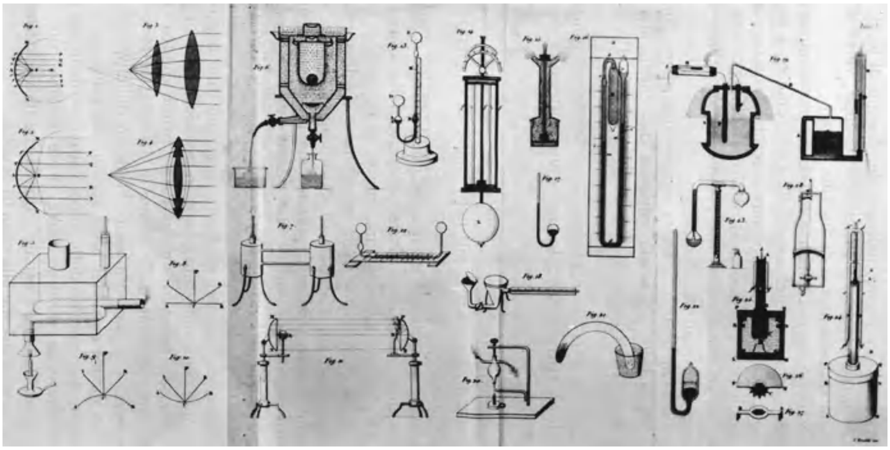


Fig. 6.30 Didactic representation of physical experiments by Belli (1838) (Bellodi and Rovida 1994)

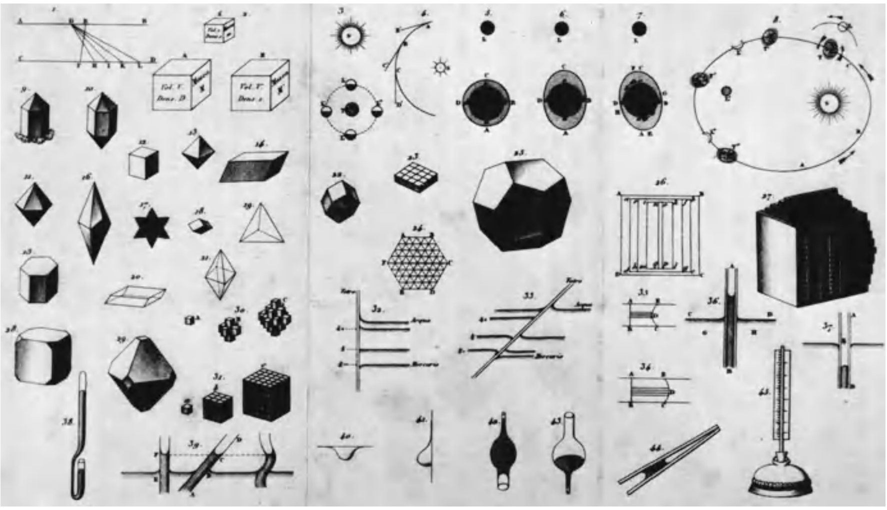


Fig. 6.31 Properties of corps: didactic representation by Belli (1838) (Bellodi and Rovida 1994)

the drawing is an interesting attempt of schematization that anticipates schematic drawing, very often applied in modern standards.

Figure 6.33 is a sketch representing an electrical generator, made by Michael Faraday (1791–1867), a well-known English chemist and physicist, who contributed to the fields of electromagnetism and electrochemistry. From the graphic point of view, the drawing is an axonometric representation, very simple and schematic and is an interesting document of the history of science.

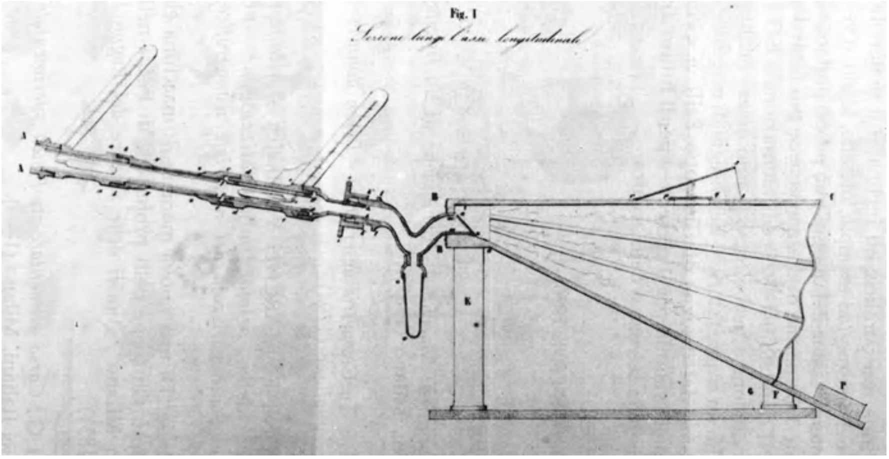


Fig. 6.32 Device designed by Belli (1847) and represented with a high degree of schematization (Bellodi and Rovida 1994)

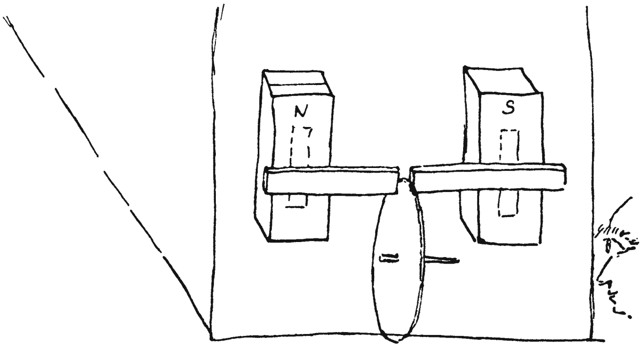
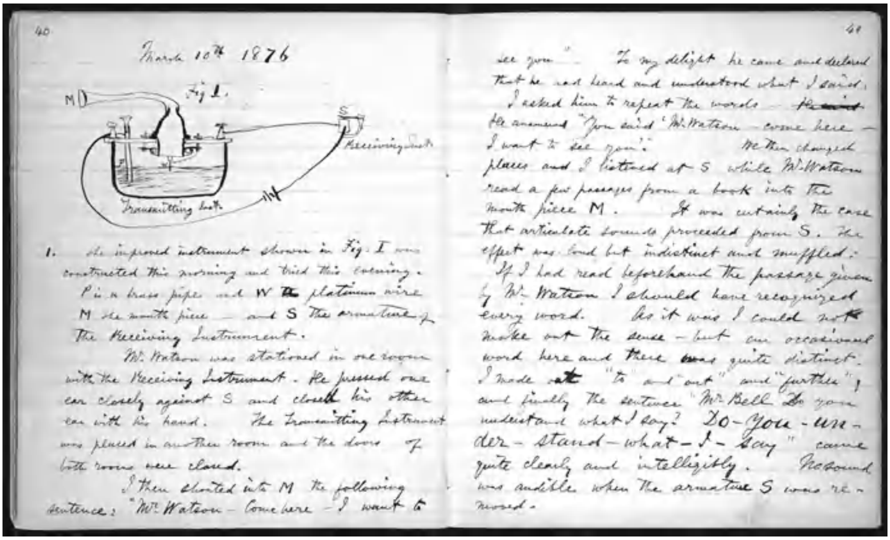


Fig. 6.33 Electrical generator by Michael Faraday

Very interesting are the sketches of Figs. 6.34, 6.35 and 6.36: they are sketches and manuscripts of Alexander Graham Bell (1847–1922) and are relative to the invention of the telephone. Figure 6.34, particularly, represents a schema of an experience of transmission between Mr. Bell and Mr. Watson, in two different rooms with communication doors closed. Mr. Bell shouted the following sentence "Mr. Watson come here. I want to see You".

Figure 6.35 is relative to another schema of experiments, with the signature of Bell (Boston, May 1876). There is written "As far I can remember, these are the first experiments made of my telephone."

Very interesting, from the personal point of view, is the document in Fig. 6.36: it is a communication of Bell to his parents Alexandre Melville Bell and Eliza Bell (May, 5, 1876).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March 10th 1876

Fig. 1.

M

S

Receiving Inst.

Transmitting Inst.

1. The improved instrument shown in Fig. I was constructed this morning and tried this evening.
P is a brass pipe and W the platinum wire M the mouth piece and S the armature of the Receiving Instrument.
Mr. Watson was stationed in one room with the Receiving Instrument. He pressed one ear closely against S and closed his other ear with his hand. The Transmitting Instrument was placed in another room and the doors of both rooms were closed.
I then shouted into M the following sentence: "Mr. Watson – Come here – I want to

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see you." To my delight he came and declared that he had heard and understood what I said.
I asked him to repeat the words – He answered "You said 'Mr. Watson – come here – I want to see you.'" We then changed places and I listened at S while Mr. Watson read a few passages from a book into the mouth piece M. It was certainly the case that articulate sounds proceeded from S. The effect was loud but indistinct and muffled.
If I had read beforehand the passage given by Mr. Watson I should have recognized every word. As it was I could not make out the sense – but an occasional word here and there was quite distinct. I made out "to" and "out" and "further"; and finally the sentence "Mr. Bell Do you understand what I say? Do – you – un-der – stand – what – I – say" came quite clearly and intelligibly. No sound was audible when the armature S was removed.

Fig. 6.34 Schema of an experiment of transmission by Bell. P is the brass pipe and W the platinum wire, M the mouth piece and S the armature of the receiving instruments

"Dear Papa and Mama" begins the text which informs them that the experiments at Harvard College went off "splendidly".

As conclusions about the application of drawing to scientific documentation, it is possible to observe the general great care in the representation and, consequently, the great communicative efficacy, obtained with three-dimensional effect, such as shadows.

Another consideration could be that some of the above mentioned drawings can be an anticipation of some modern drawing standards. Some example are as follows:

- "Arrows" method;
- Hachures to indicate sectioned parts;
- Differentiation of materials by different hachures;
- Simplified and schematic representation.

Such historical drawings was a prime source for new drawing standards.

Figure 6.37, probably from an illustrative book, represents a complex machine. From the graphical point of view, it is interesting to observe that some dimensions are present and some enlarged details are represented. The dimensioning of the machine, in addition to the dimensions directly assigned on the assembly drawing, is completed by a graphical scale.

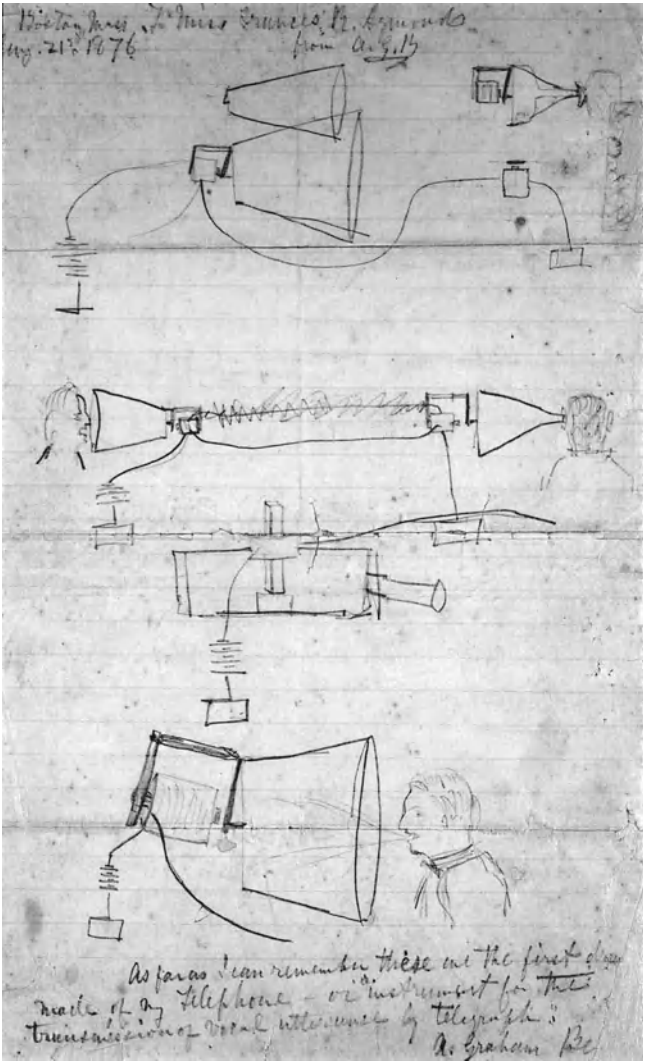
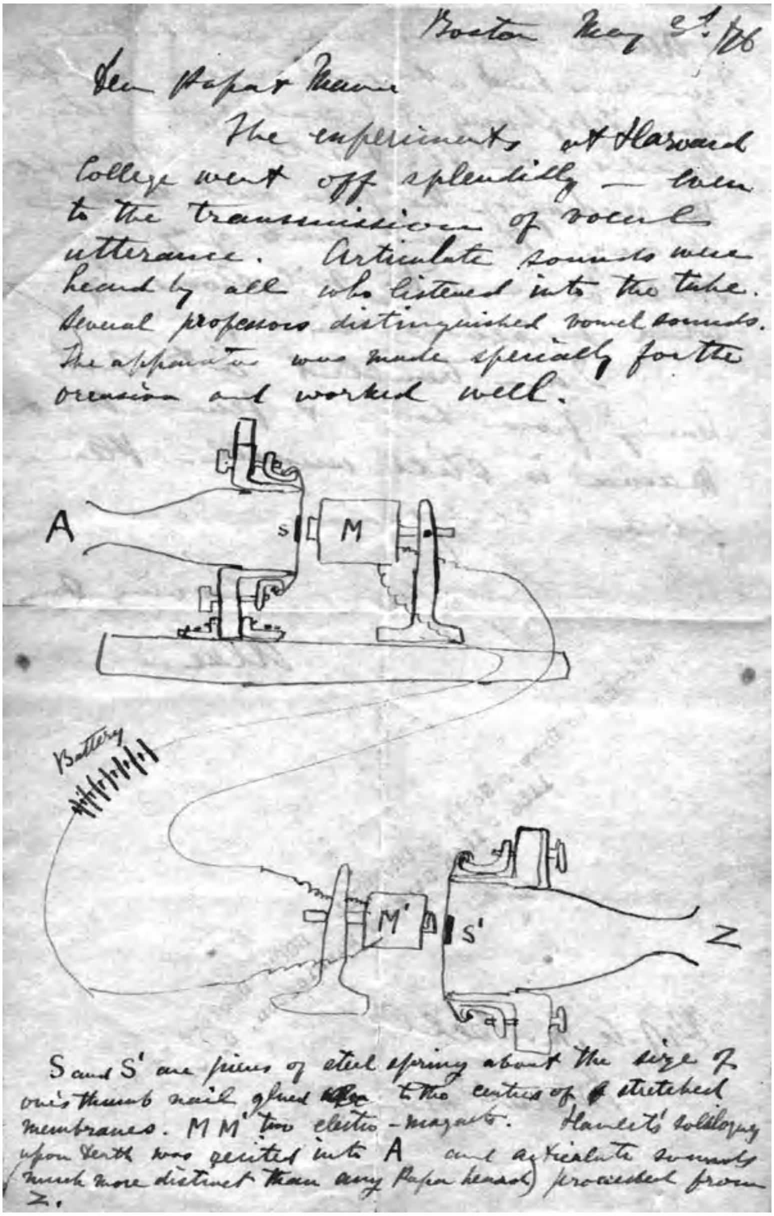


Fig. 6.35 Another schema of experiments, with signature of Bell (1876)

6.5 The Drawing as a Tool for Scientific-Technical Divulgation

The nineteenth century was characterized by a very great development of science and technology: drawing was largely utilized for the divulgation of development in many fields; drawing, therefore, reached great importance in upgrading the diffusion of knowledge and, consequently, interest in new scientific-technical achievements. Very skillful designers realized representations of machines, instruments, devices and so



Boston May 21/76

Dear Papa & Mama

The experiments at Harvard College went off splendidly — even to the transmission of vocal utterance. Articulate sounds were heard by all who listened into the tube. Several professors distinguished vowel sounds. The apparatus was made specially for the occasion and worked well.

S and S' are pieces of steel spring about the size of one's thumb nail glued to the centres of stretched membranes. MM' two electro-magnets. Hamlet's soliloquy upon Death was recited into A and articulate sounds (much more distinct than any Papa heard) proceeded from Z.

Fig. 6.36 Communication of Bell to his parents about his successful experiments

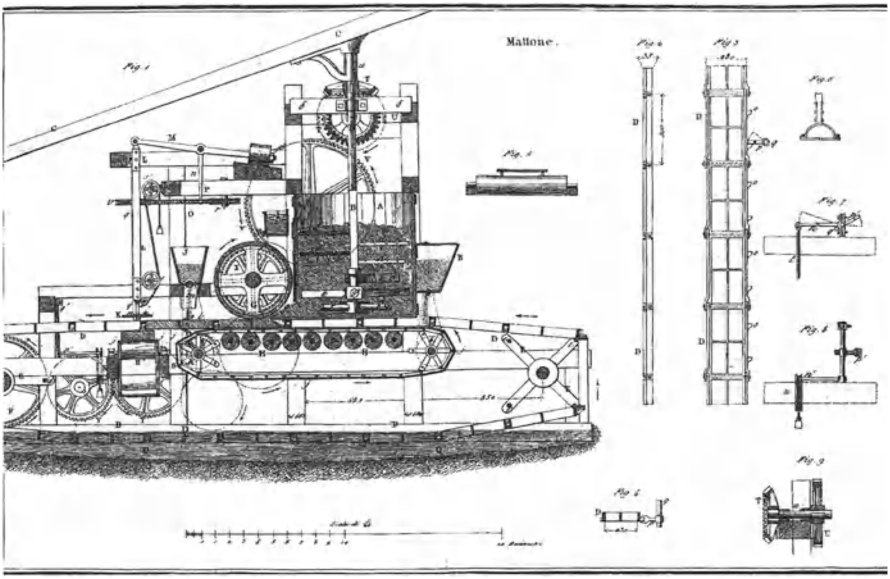


Fig. 6.37 Drawing of a complex machine, from, probably, an illustrative book of the Nineteenth Century

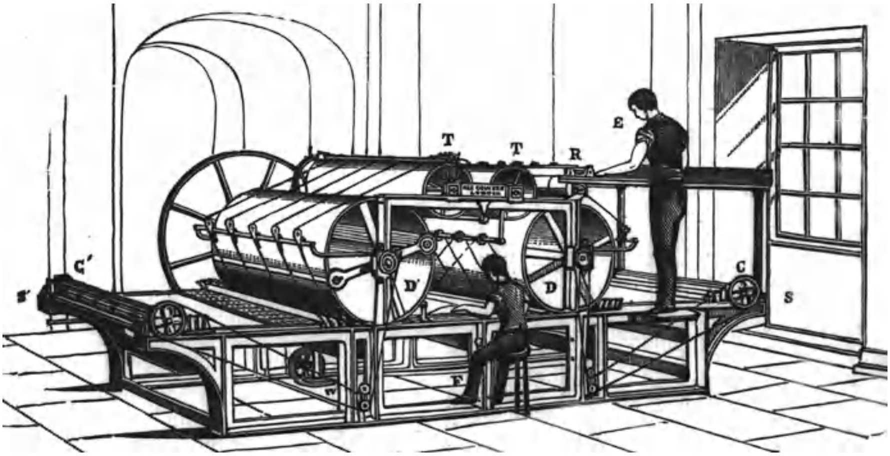


Fig. 6.38 Printing machine (1860) (The Applgate & Cowper Royal 1860), capable of printing papers on both sides simultaneously with the speed of 1,000 copies/h

on, by utilizing many graphical criteria, such as axonometric projections, chiaroscuro, colors, shadows, surrounding of represented objects e.g. with men or trees: in this way, technical drawings with a divulgation role reached great communicative efficiency. This is another, not secondary, importance of technical drawing.

Some examples are here presented in the Figs. 6.38, 6.39, 6.40, 6.41 and 6.42.

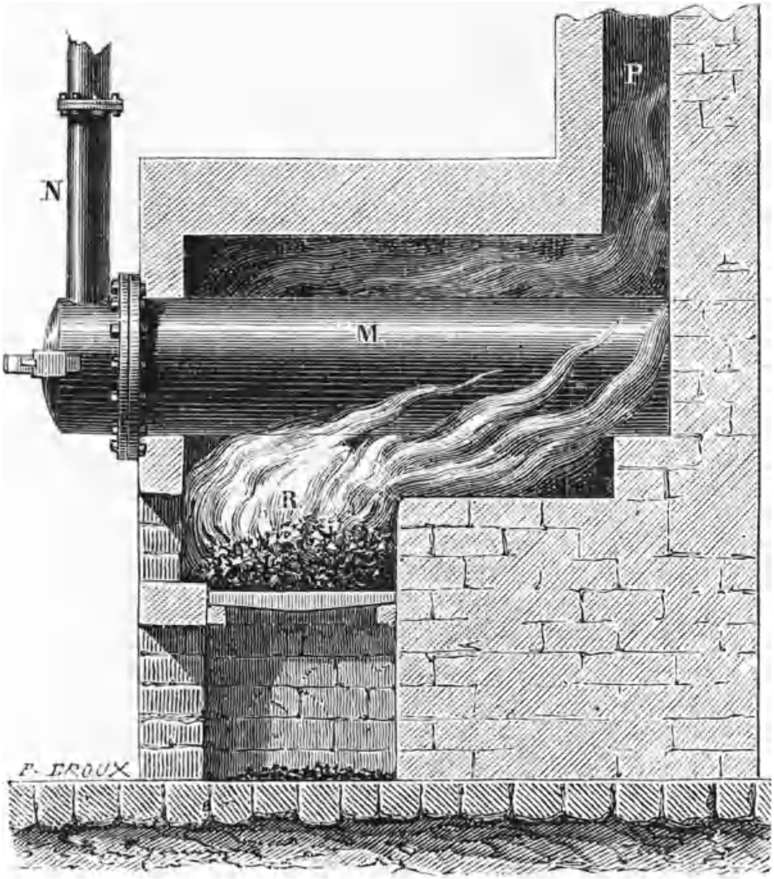


Fig. 6.39 Device for the distillation of coal

6.6 Drawing Instruments

The development of drawing in industries and schools involved a great development of drawing instruments.

Figures 6.43, 6.44, 6.45, 6.46, 6.47, 6.48 and 6.49 show examples of such instruments that are a testimony to the professional ability and aesthetic care, which was profuse in the execution of every item that, even though technical, became in a sense, a "work of art". Such instruments are a very important tool to realize the abovementioned drawings, by students in schools and by technicians in industry (Brunetti and Rovida 2006).

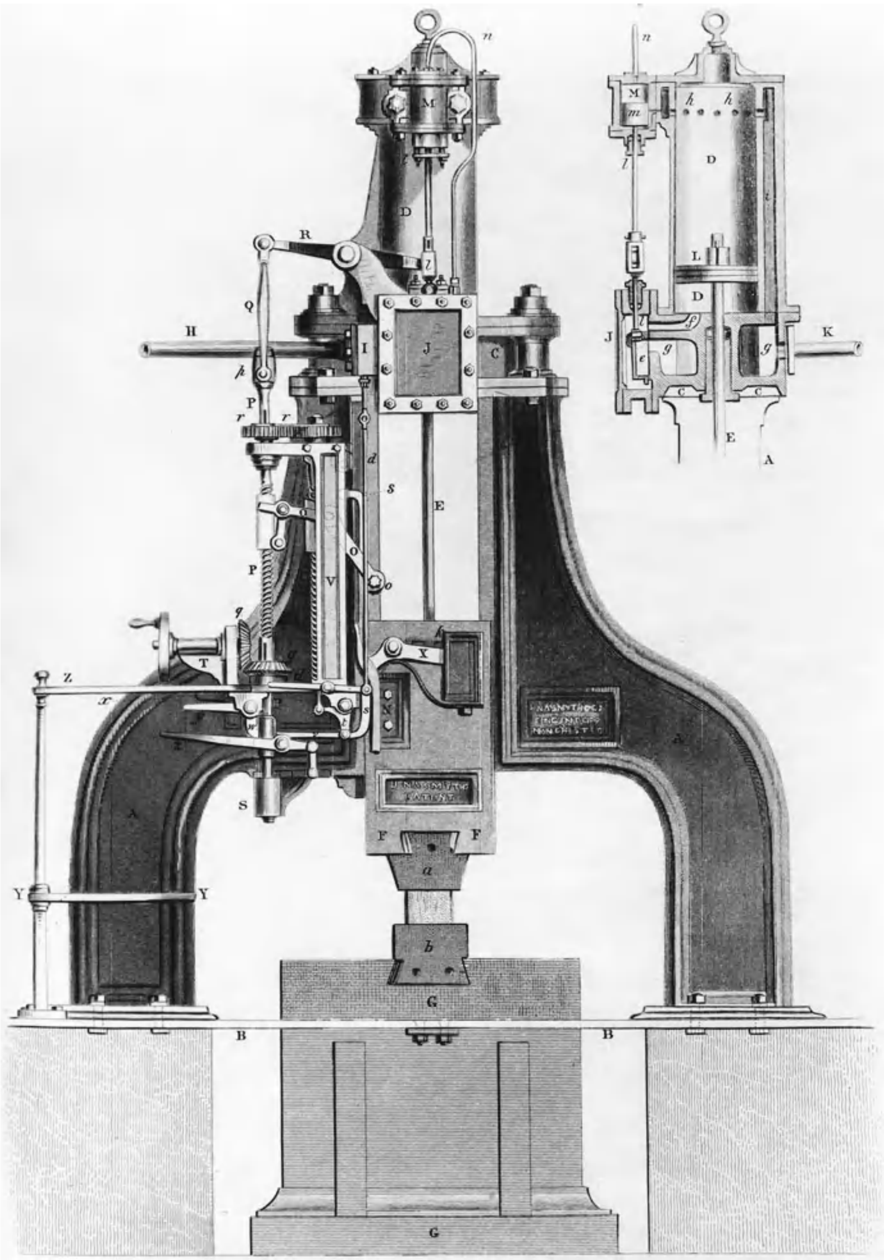


Fig. 6.40 Steam hammer, from the Nasmyth patent (1854)

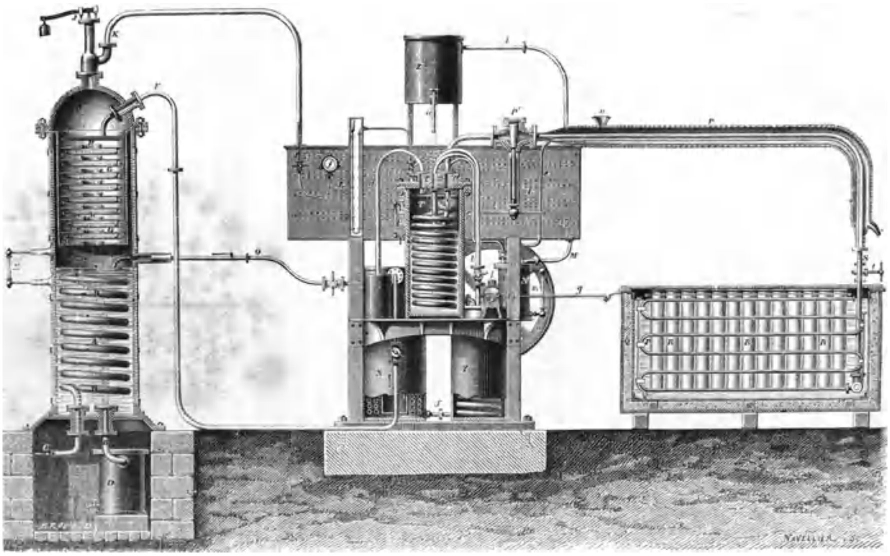


Fig. 6.41 Ice making device by Ferdinand Carré patented in France in 1859 and in USA in 1860. In 1862, the machine was exhibited at the Universal London Exhibition

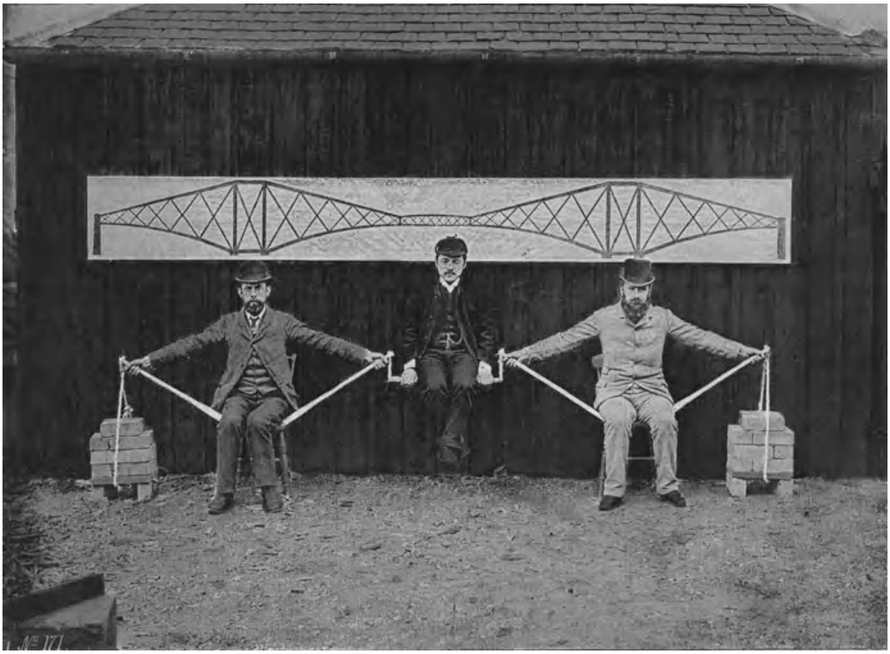


Fig. 6.42 "The human cantilever", living model illustrating the principle of the Forth Rail Bridge. (From the book "The Forth Bridge"(1890) by Westhofen)

Fig. 6.43 Pencil of the Nineteenth Century with the tip telescopically sliding

Fig. 6.44 Pencil in the Nineteenth Century, with the tip telescopically sliding, signed by Robert Linzeler

Fig. 6.45 Pencil of the Nineteenth Century

Fig. 6.46 French compasses of the Nineteenth Century

Fig. 6.47 Compass to draw circles of very small radius

Fig. 6.48 Italian compasses of the nineteenth century. The case is realized with high accuracy and elegance

Fig. 6.49 Drawing complete that contains 11 pieces, among them, drawing pens, compasses, ruler and geometric compass. The case is covered with fish skin (a very common feature in the Nineteenth Century)

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Chapter 7
The Twentieth Century

7.1 Introduction

The twentieth century is characterized by several events relative to technical drawing. The most important correspond to the paragraphs of the present chapter as follows.

- Foundation of Standardization Institutions that publish standards with the aim of giving rules and criteria in all fields of activity and, consequently, in technical drawing.
- Development of industry: the industries born in the nineteenth century reach a great development and many new industries are born. All the above mentioned industries need technical drawing as an indispensable communication tool among technicians.
- Development of teaching: the needs of industry, relative to professional ability of technicians, find an answer in the development of technical schools. Among such abilities, an important role is represented by the technical drawing, which is a fundamental argument to be transmitted
- Diffusion of the computer, particularly in the 1980s and 1990s, that represent a great revolution in the realization and management of representation.

7.2 Drawing Standards

Standards could be defined as the rules necessary to organize human activities in all fields. In the present text, the considered activity is, of course, technical and, particularly, related to technical drawing.

E. Rovida, *Machines and Signs*, History of Mechanism and Machine Science 17,
DOI 10.1007/978-94-007-5407-2_7,

7.2.1 Historical Background

Standardization is a very ancient activity. The ancient Romans were very active in standardization. As an example, all Roman building was realized utilizing only two formats of bricks: the *bipedalis* (59.2 cm × 59.2 cm × 59.2 cm) and the *sesquipedalis* (44.4 cm × 44.4 cm × 44.4 cm). Another example was the diameters of pipes (*fistulae*) for the distribution of water.

A very important standardization was applied in the eighteenth century with the introduction of the metric system that deleted all local units of measurement and allowed a unified system of measurement.

Other, more modern examples are the Whitworth threads, the dimensions of roll bearings, the diameters of ropes and pipes.

Very important for this work are the standards relative to technical drawing: such rules were initially born by instinct and successively codified by official documents, the standards.

7.2.2 Standardization Institutions

Standardization institutions are officially recognized institutes, founded often by scientific-technical associations, with the aim of realizing standards in all fields of human activity. The first country to found a standard institution was Great Britain (1901), then Nederland (1916), Switzerland and Canada (1917), USA and France (1918), Belgium and Sweden (1919). The Italian standard institution (UNI, Ente Nazionale Italiano di Unificazione) was founded in 1921.

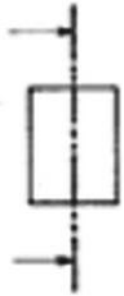
Nowadays, practically all countries have a national Standardization Institute. All such national institutions publish standards valid only in the respective country. The drawing standards are often very different, in the different countries. As an example, Table 7.1 represents the different indications of a cut plan (Biggioggero and Rovida 1980).

With increasing international contacts and cooperations, particularly important in the scientific-technical fields, the need was very strong at an international level, to publish standards valid in all countries. The first international Standardization Institution was born in 1926, with the name of ISA (International Federation of the National Standardizing Associations) and with the participation of 27 Countries. The activity of ISA ceased in 1942, because of the second world war.

In 1946, after the war, in London, the International Standardizing Institution was refounded, with the name of ISO (International Organization for Standardization).

Today, national standards, particularly in the field of drawing, are first published as international standards by ISO and then translated into the languages of the ISO Member Countries.

Table 7.1 Indications of cut plan in different countries

						
Belgium Korea Cuba Denmark France Germany India Italy Norway Nederland Portugal Romania Sweden Switzerland	Argentina India USA	Australia Austria Chile Germany Great Britain Israel Spain	Belgium Bulgaria URSS	Sweden	USA	Canada

In this way, all countries have only one graphical language and the drawings in all countries are executed with the same rules. It is easy to recognize the great advantage represented by the abovementioned uniformity.

7.2.3 Drawing Standards

Of course, the first standards published were in mechanical fields, and particularly in the technical drawing. Figures 7.1 and 7.2 represent two among the first standards published by the Italian Standardization Institute, called UNI (Ente Nazionale Italiano di Unificazione) (Italian National Standardization Institute). Such standards were published in 1922 and respectively, in 1924. In Fig. 7.2 is represented another Italian "historical" standard, about orthographic projections, from an Italian didactic book (Gilardi 1926).

In Fig. 7.3 is represented an example of a sketch (wrong to the left, correct to the right), from the book (Gilardi 1926), executed by following the first drawing standards.

The evolution of standards was very fast, with the aim to follow the industrial evolution and to reach clarity and simplicity. As an example, Fig. 7.4 (Gilardi 1926) represents the evolution of standardized representation of threads. The first is very realistic, the second one is a first step of simplification, while the third is more simplified and now applied.

As examples, in the following figures, some standards of different times and countries are represented. Figure 7.5 is a Swiss standard (1939) relative to the indication of materials in cuts. It is interesting that individuation of material is expressed by using hachures or colors.

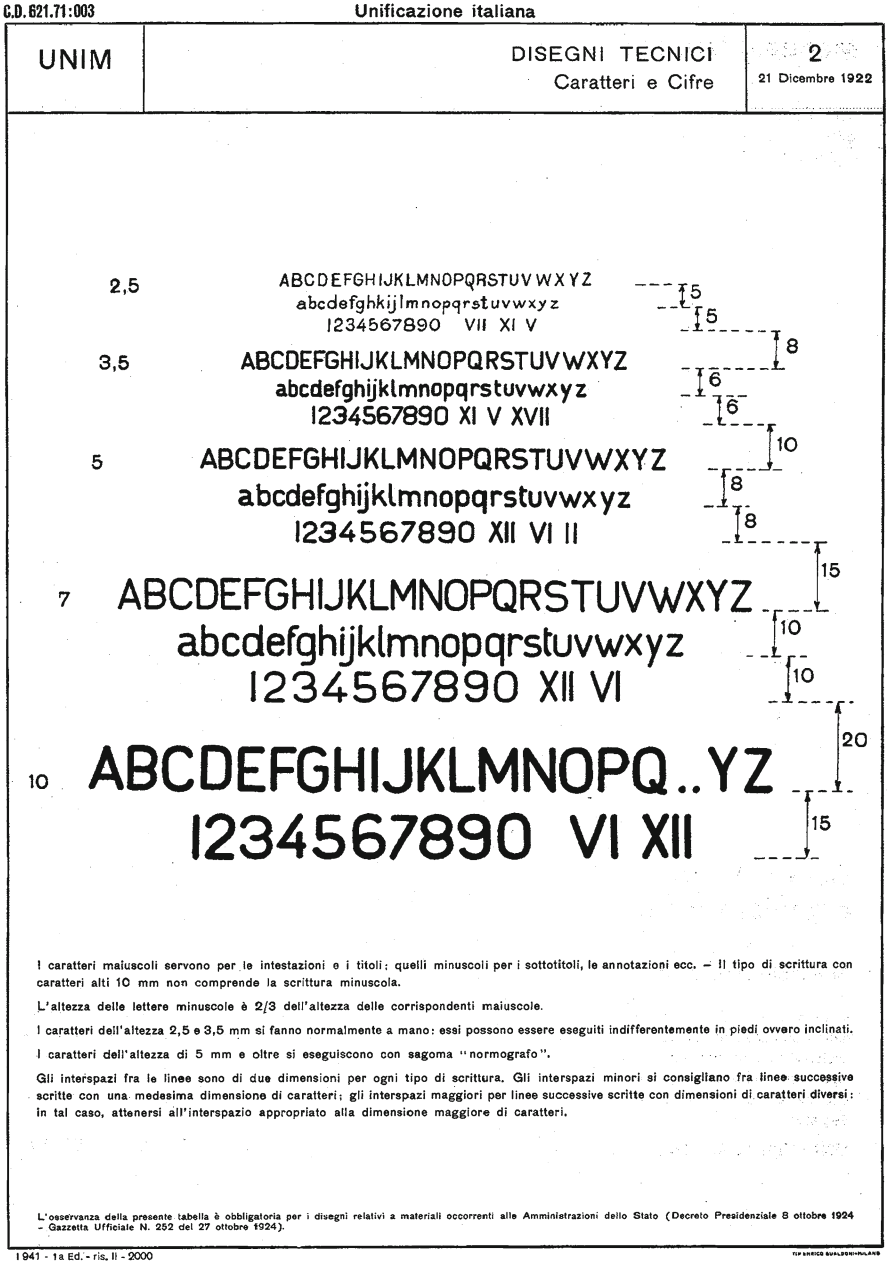
Figure 7.6 represents an Israeli standard (1956) relative to dimensioning.

As further example, Fig. 7.7 represents an example of the drawing standard of South Vietnam and is from a didactic book of that country.

7.2.4 Effect of Drawing Standards

Application of the standards has many significant effects on technical drawings:

- The drawings are progressively less beautiful and very different from the drawings of the nineteenth century, with colors and realistic representations;
- The drawings are progressively less different and reaches more uniformity, consequent to the application of drawing standards;
- The standards allows criteria to facilitate the execution of drawings, e.g. with particular indications, such as diameters, radii, chamfers (Fig. 7.8) (Biggioggero and Giannattasio 1988).
- Indication of roughness. The state of the surfaces is indicated, until 1970, with triangles that give a qualitative indication: the surfaces are more finished, with



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1234567890 XI V XVII

6 6 10

5 ABCDEFGHIJKLMNOPQRSTUVWXYZ
abcdefghijklmnopqrstuvwxyz
1234567890 XII VI II

8 8 15

7 ABCDEFGHIJKLMNOPQRSTUVWXYZ
abcdefghijklmnopqrstuvwxyz
1234567890 XII VI

10 10 20

10 ABCDEFGHIJKLMNOPQ..YZ
1234567890 VI XII

15

I caratteri maiuscoli servono per le intestazioni e i titoli; quelli minuscoli per i sottotitoli, le annotazioni ecc. – Il tipo di scrittura con caratteri alti 10 mm non comprende la scrittura minuscola.

L'altezza delle lettere minuscole è 2/3 dell'altezza delle corrispondenti maiuscole.

I caratteri dell'altezza 2,5 e 3,5 mm si fanno normalmente a mano: essi possono essere eseguiti indifferentemente in piedi ovvero inclinati.

I caratteri dell'altezza di 5 mm e oltre si eseguiscono con sagoma "normografo".

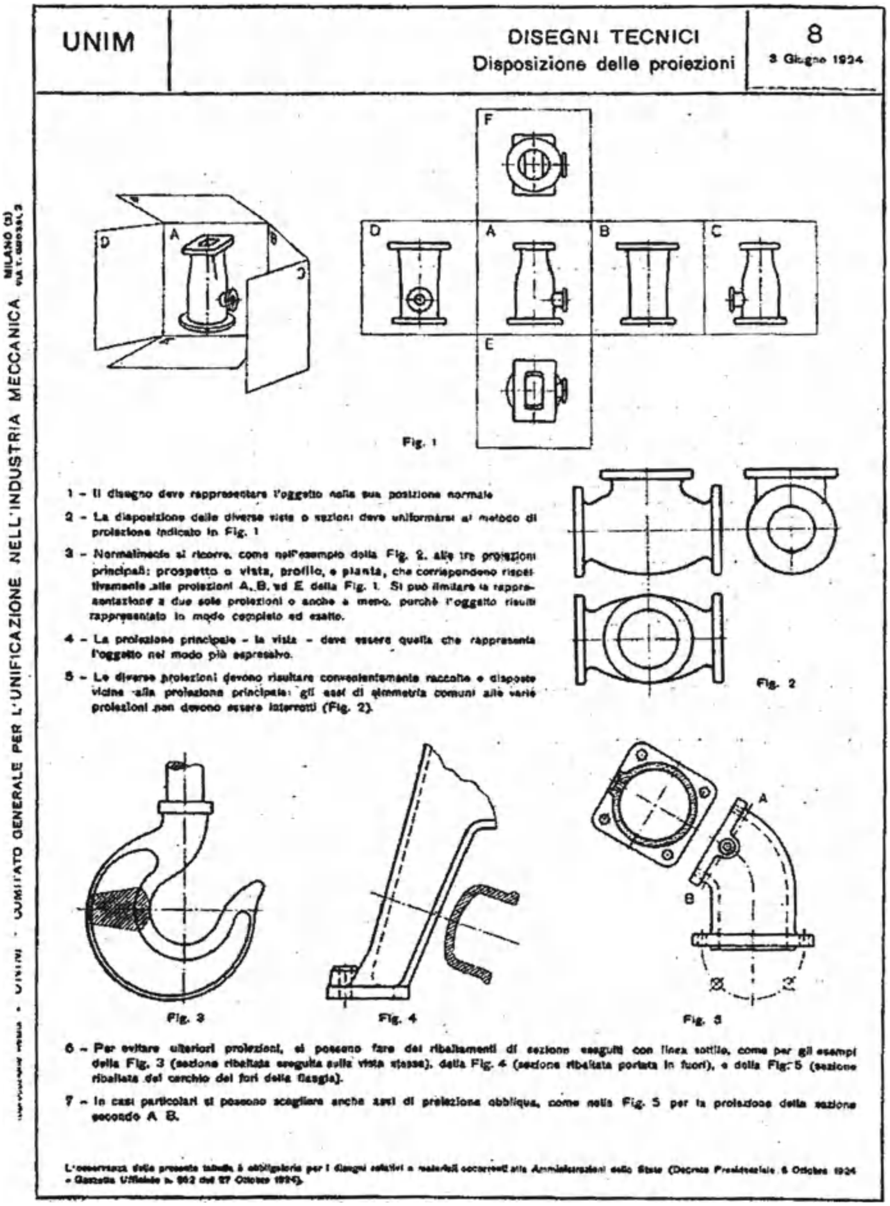
Gli interspazi fra le linee sono di due dimensioni per ogni tipo di scrittura. Gli interspazi minori si consigliano fra linee successive scritte con una medesima dimensione di caratteri; gli interspazi maggiori per linee successive scritte con dimensioni di caratteri diversi: in tal caso, attenersi all'interspazio appropriato alla dimensione maggiore di caratteri.

L'osservanza della presente tabella è obbligatoria per i disegni relativi a materiali occorrenti alle Amministrazioni dello Stato (Decreto Presidenziale 8 ottobre 1924 – Gazzetta Ufficiale N. 252 del 27 ottobre 1924).

1941 - 1a Ed. - ris. II - 2000

TIP. ENRICO GUALDONI - MILANO

Fig. 7.1 Italian standard of lettering (1922)



UNIM

DISEGNI TECNICI
Disposizione delle proiezioni

8
3 Giugno 1924

Fig. 1

1 – Il disegno deve rappresentare l'oggetto nella sua posizione normale

2 – La disposizione delle diverse viste o sezioni deve uniformarsi al metodo di proiezione indicato in Fig. 1

3 – Normalmente si ricorre, come nell'esempio della Fig. 2, alle tre proiezioni principali: prospetto o vista, profilo, e pianta, che corrispondono rispettivamente alle proiezioni A, B, ed E della Fig. 1. Si può limitare la rappresentazione a due sole proiezioni o anche a meno, purchè l'oggetto risulti rappresentato in modo completo ed esatto.

4 – La proiezione principale – la vista – deve essere quella che rappresenta l'oggetto nel modo più espressivo.

5 – Le diverse proiezioni devono risultare convenientemente raccolte e disposte vicine alla proiezione principale: gli assi di simmetria comuni alle varie proiezioni non devono essere interrotti (Fig. 2).

Fig. 2

Fig. 3 Fig. 4 Fig. 5

6 – Per evitare ulteriori proiezioni, si possono fare dei ribaltamenti di sezione eseguiti con linea sottile, come per gli esempi della Fig. 3 (sezione ribaltata eseguita sulla vista stessa), della Fig. 4 (sezione ribaltata portata in fuori), e della Fig. 5 (sezione ribaltata del cerchio dei fori della flangia).

7 – In casi particolari si possono scegliere anche assi di proiezione obbliqua, come nella Fig. 5 per la proiezione della sezione secondo A B.

L'osservanza della presente tabella è obbligatoria per i disegni relativi a materiali occorrenti alle Amministrazioni dello Stato (Decreto Presidenziale 6 Ottobre 1924 – Gazzetta Ufficiale n. 262 del 27 Ottobre 1924).

UNIM · COMITATO GENERALE PER L'UNIFICAZIONE NELL'INDUSTRIA MECCANICA MILANO (3)

Fig. 7.2 Italian standard of orthographic projections and cuts (1924), from an Italian didactic book (Gilardi 1926)

the increasing number of triangles (Fig 7.9 left) (Biggioggero and Giannattasio 1988). Since 1980, the surface indication is expressed with the numerical value of the roughness (Fig. 7.9 right) (Biggioggero and Giannattasio 1988).

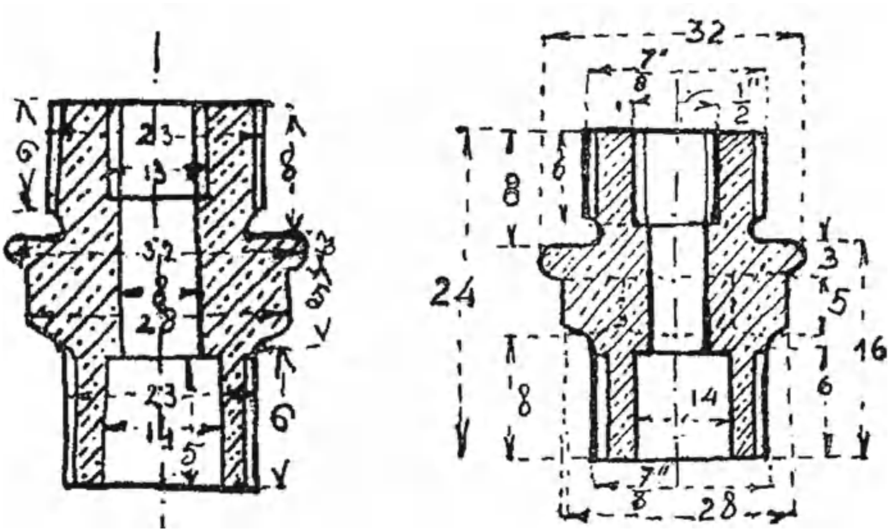


Fig. 7.3 Example of sketches (wrong to the *lef* , correct to the *right*), from the book (Gilardi 1926)

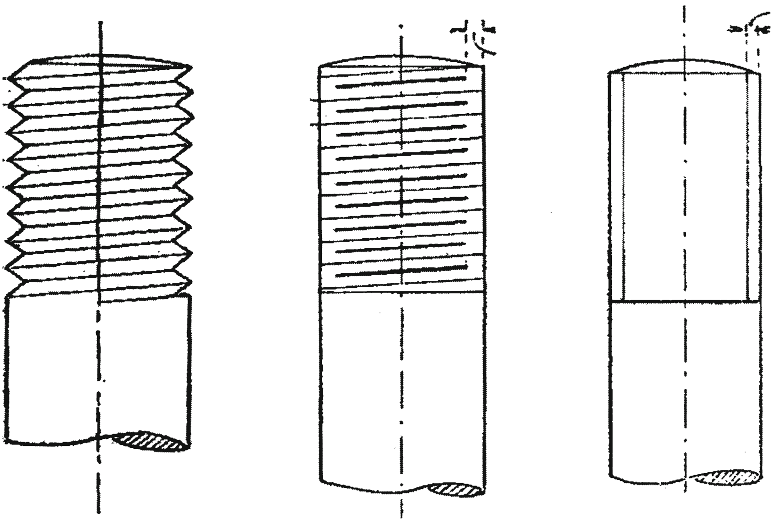
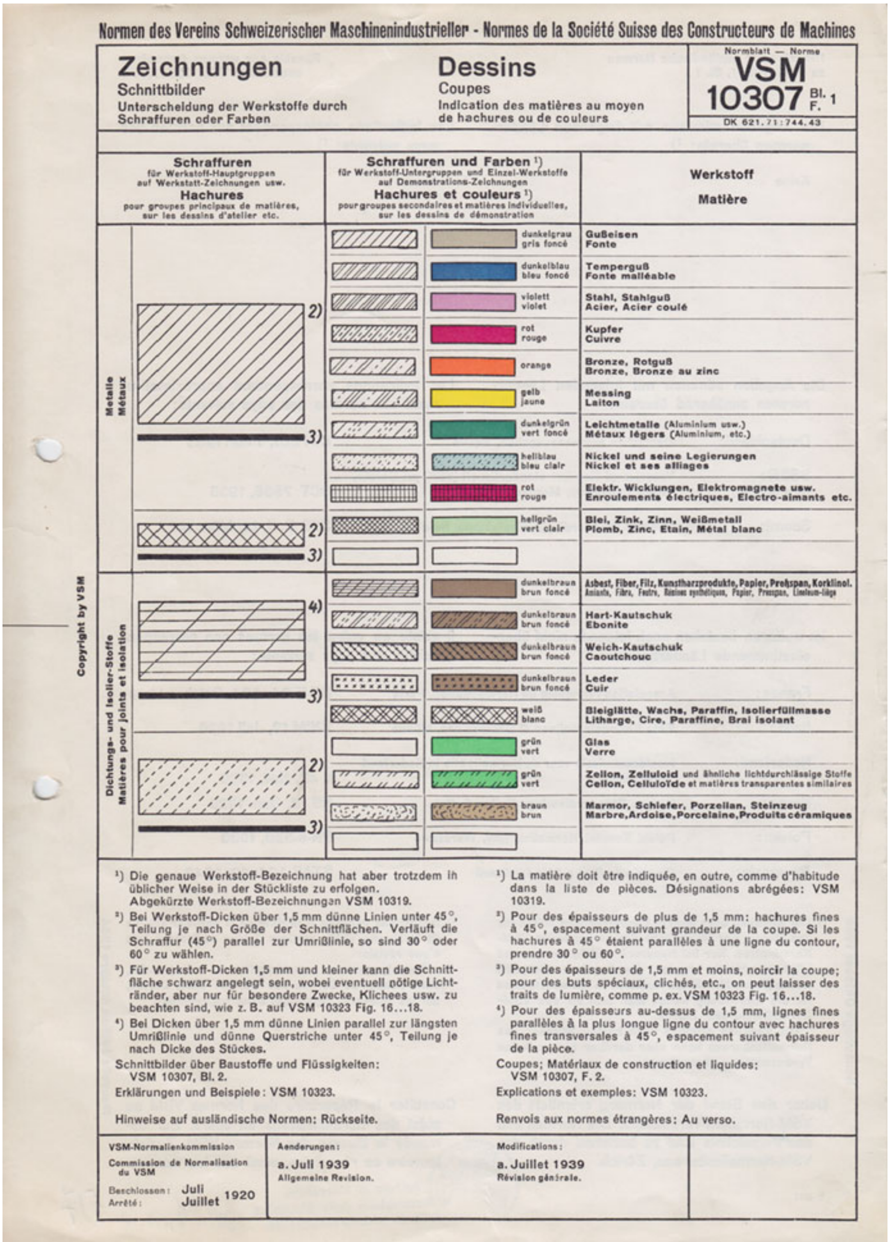


Fig. 7.4 Evolution of standardized representation of threads, with an evident increase of schematization and, consequently, of simplicity (Gilardi 1926)

- Indication of tolerances, with quantitative information. Figure 7.10 shows two examples of indication of geometric tolerances: straightness to the left and perpendicularity to the right
- Precise indication of materials.

The trend in this century was to indicate with precision the materials used: instead of a qualitative indication, such as "steel", the indication will be with an abbreviation



Normen des Vereins Schweizerischer Maschinenindustrieller - Normes de la Société Suisse des Constructeurs de Machines

Zeichnungen
Schnittbilder
Unterscheidung der Werkstoffe durch Schraffuren oder Farben

Dessins
Coupes
Indication des matières au moyen de hachures ou de couleurs

Normblatt — Norme
VSM 10307 Bl. F. 1
DK 621.71:744.43

Schraffuren für Werkstoff-Hauptgruppen auf Werkstatt-Zeichnungen usw. / **Hachures** pour groupes principaux de matières, sur les dessins d'atelier etc.

Schraffuren und Farben [1] für Werkstoff-Untergruppen und Einzel-Werkstoffe auf Demonstrations-Zeichnungen / **Hachures et couleurs** [1] pour groupes secondaires et matières individuelles, sur les dessins de démonstration

Metalle / Métaux: 2) 3) 2) 3)

Dichtungs- und Isolier-Stoffe / Matières pour joints et isolation: 4) 3) 2) 3)

Farbe / Couleur	Werkstoff / Matière
dunkelgrau / gris foncé	Gußeisen / Fonte
dunkelblau / bleu foncé	Temperguß / Fonte malléable
violett / violet	Stahl, Stahlguß / Acier, Acier coulé
rot / rouge	Kupfer / Cuivre
orange	Bronze, Rotguß / Bronze, Bronze au zinc
gelb / jaune	Messing / Laiton
dunkelgrün / vert foncé	Leichtmetalle (Aluminium usw.) / Métaux légers (Aluminium, etc.)
hellblau / bleu clair	Nickel und seine Legierungen / Nickel et ses alliages
rot / rouge	Elektr. Wicklungen, Elektromagnete usw. / Enroulements électriques, Electro-aimants etc.
hellgrün / vert clair	Blei, Zink, Zinn, Weißmetall / Plomb, Zinc, Etain, Métal blanc
dunkelbraun / brun foncé	Asbest, Fiber, Filz, Kunstharzprodukte, Papier, Preßspan, Korklinol. / Amiante, Fibre, Feutre, Résines synthétiques, Papier, Presspan, Linoleum-liège
dunkelbraun / brun foncé	Hart-Kautschuk / Ebonite
dunkelbraun / brun foncé	Weich-Kautschuk / Caoutchouc
dunkelbraun / brun foncé	Leder / Cuir
weiß / blanc	Bleiglätte, Wachs, Paraffin, Isolierfüllmasse / Litharge, Cire, Paraffine, Brai isolant
grün / vert	Glas / Verre
grün / vert	Zellon, Zelluloid und ähnliche lichtdurchlässige Stoffe / Cellon, Celluloïde et matières transparentes similaires
braun / brun	Marmor, Schiefer, Porzellan, Steinzeug / Marbre, Ardoise, Porcelaine, Produits céramiques

1) Die genaue Werkstoff-Bezeichnung hat aber trotzdem in üblicher Weise in der Stückliste zu erfolgen. Abgekürzte Werkstoff-Bezeichnungen VSM 10319.

2) Bei Werkstoff-Dicken über 1,5 mm dünne Linien unter 45°, Teilung je nach Größe der Schnittflächen. Verläuft die Schraffur (45°) parallel zur Umrißlinie, so sind 30° oder 60° zu wählen.

3) Für Werkstoff-Dicken 1,5 mm und kleiner kann die Schnittfläche schwarz angelegt sein, wobei eventuell nötige Lichtränder, aber nur für besondere Zwecke, Klichees usw. zu beachten sind, wie z. B. auf VSM 10323 Fig. 16...18.

4) Bei Dicken über 1,5 mm dünne Linien parallel zur längsten Umrißlinie und dünne Querstriche unter 45°, Teilung je nach Dicke des Stückes.

Schnittbilder über Baustoffe und Flüssigkeiten: VSM 10307, Bl. 2.

Erklärungen und Beispiele: VSM 10323.

Hinweise auf ausländische Normen: Rückseite.

1) La matière doit être indiquée, en outre, comme d'habitude dans la liste de pièces. Désignations abrégées: VSM 10319.

2) Pour des épaisseurs de plus de 1,5 mm: hachures fines à 45°, espacement suivant grandeur de la coupe. Si les hachures à 45° étaient parallèles à une ligne du contour, prendre 30° ou 60°.

3) Pour des épaisseurs de 1,5 mm et moins, noircir la coupe; pour des buts spéciaux, clichés, etc., on peut laisser des traits de lumière, comme p. ex. VSM 10323 Fig. 16...18.

4) Pour des épaisseurs au-dessus de 1,5 mm, lignes fines parallèles à la plus longue ligne du contour avec hachures fines transversales à 45°, espacement suivant épaisseur de la pièce.

Coupes; Matériaux de construction et liquides: VSM 10307, F. 2.

Explications et exemples: VSM 10323.

Renvois aux normes étrangères: Au verso.

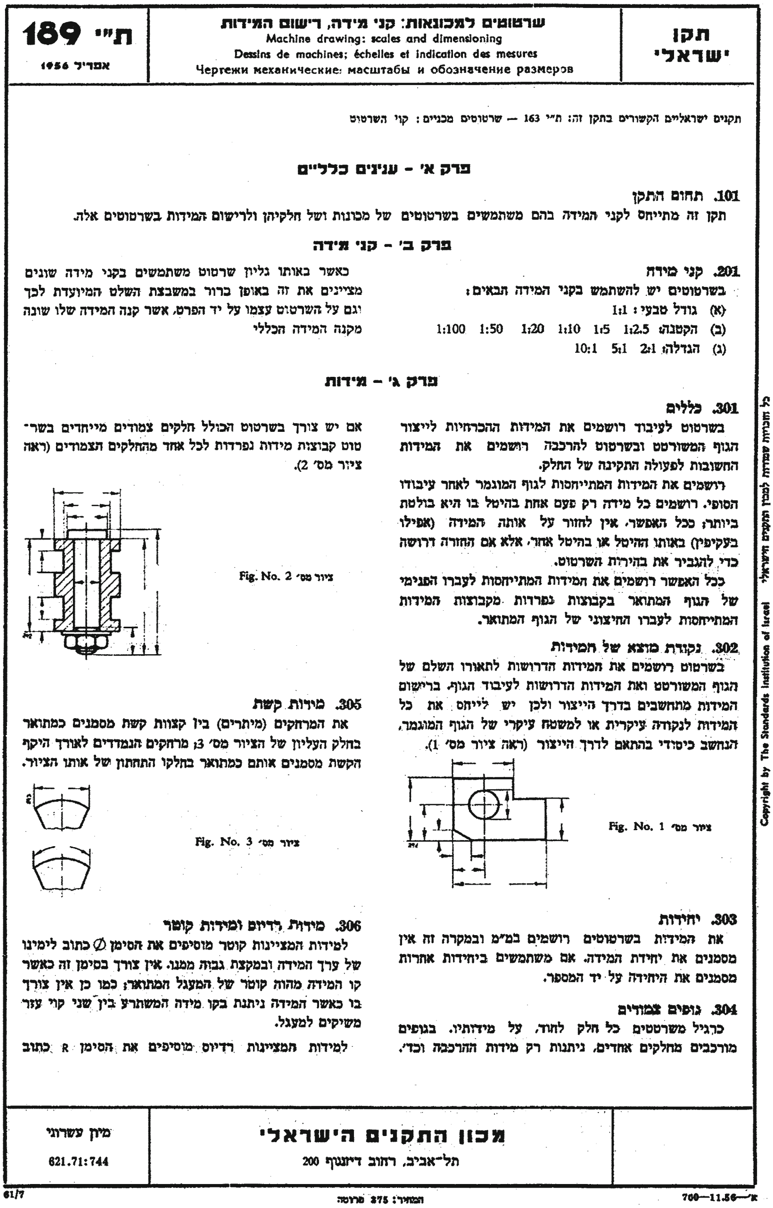
VSM-Normalienkommission / Commission de Normalisation du VSM
Beschlossen: / Arrêté: Juli / Juillet 1920

Aenderungen: a. Juli 1939 Allgemeine Revision.

Modifications: a. Juillet 1939 Révision générale.

Copyright by VSM

Fig. 7.5 Swiss standard (1939) relative to the indication of materials in cuts with colors and hatchings



תקן ישראלי

שרטוטים למכונאות: קני מידה, רישום המידות
Machine drawing: scales and dimensioning
Dessins de machines; échelles et indication des mesures
Чертежи механические: масштабы и обозначение размеров

ת"י 189
אפריל 1956

תקנים ישראליים הקשורים בתקן זה: ת"י 163 — שרטוטים מכניים : קוי השרטוט

פרק א' - ענינים כלליים

101. תחום התקן

תקן זה מתייחס לקני המידה בהם משתמשים בשרטוטים של מכונות ושל חלקיהן ולרישום המידות בשרטוטים אלה.

פרק ב' - קני מידה

201. קני מידה

בשרטוטים יש להשתמש בקני המידה הבאים:

(א) גודל טבעי: 1:1

(ב) הקטנה: 1:2.5 1:5 1:10 1:20 1:50 1:100

(ג) הגדלה: 2:1 5:1 10:1

כאשר באותו גליון שרטוט משתמשים בקני מידה שונים מציינים את זה באופן ברור במשבצת השלט המיועדת לכך וגם על השרטוט עצמו על יד הפרט, אשר קנה המידה שלו שונה מקנה המידה הכללי

פרק ג' - מידות

301. כללים

בשרטוט לעיבוד רושמים את המידות ההכרחיות לייצור הגוף המשורטט ובשרטוט להרכבה רושמים את המידות החשובות לפעולה התקינה של החלק.

רושמים את המידות המתייחסות לגוף המוגמר לאחר עיבודו הסופי. רושמים כל מידה רק פעם אחת בהיטל בו היא בולטת ביותר; ככל האפשר, אין לחזור על אותה המידה (אפילו בעקיפין) באותו ההיטל או בהיטל אחר, אלא אם החזרה דרושה כדי להגביר את בהירות השרטוט.

ככל האפשר רושמים את המידות המתייחסות לעברו הפנימי של הגוף המתואר בקבוצות נפרדות מקבוצות המידות המתייחסות לעברו החיצוני של הגוף המתואר.

אם יש צורך בשרטוט הכולל חלקים צמודים מייחדים בשר־טוט קבוצות מידות נפרדות לכל אחד מהחלקים הצמודים (ראה ציור מס' 2).

Fig. No. 2 ציור מס'

302. נקודת מוצא של המידות

בשרטוט רושמים את המידות הדרושות לתאורו השלם של הגוף המשורטט ואת המידות הדרושות לעיבוד הגוף. ברישום המידות מתחשבים בדרך הייצור ולכן יש לייחס את כל המידות לנקודה עיקרית או למשטח עיקרי של הגוף המוגמר, הנחשב כיסודי בהתאם לדרך הייצור (ראה ציור מס' 1).

Fig. No. 1 ציור מס'

303. יחידות

את המידות בשרטוטים רושמים במ"מ ובמקרה זה אין מסמנים את יחידת המידה. אם משתמשים ביחידות אחרות מסמנים את היחידה על יד המספר.

304. גופים צמודים

כרגיל משרטטים כל חלק לחוד, על מידותיו. בגופים מורכבים מחלקים אחדים, ניתנות רק מידות ההרכבה וכד'.

305. מידות קשת

את המרחקים (מיתרים) בין קצוות קשת מסמנים כמתואר בחלק העליון של הציור מס' 3; מרחקים הנמדדים לאורך היקף הקשת מסמנים אותם כמתואר בחלקו התחתון של אותו הציור.

Fig. No. 3 ציור מס'

306. מידות רדיוס ומידות קוטר

למידות המציינות קוטר מוסיפים את הסימן ∅ כתוב לימינו של ערך המידה ובמקצת גבוה ממנו. אין צורך בסימן זה כאשר קו המידה מהוה קוטר של המעגל המתואר; כמו כן אין צורך בו כאשר המידה ניתנת בקו מידה המשתרע בין שני קוי עזר משיקים למעגל.

למידות המציינות רדיוס מוסיפים את הסימן R כתוב

מכון התקנים הישראלי
תל־אביב, רחוב דיזנגוף 200

מיון עשרוני
621.71:744

61/7 המחיר: 275 פרוטה 700—11.56—א'

Copyright by The Standards Institution of Israel — כל הזכויות שמורות למכון התקנים הישראלי

Fig. 7.6 Example of Israeli standard (1956) about dimensioning

that expresses the category of steel. For example, 38 NCD 4 is an indication utilized, until 70, to indicate a steel with percentage of 0.38% of C, 1% of Ni and smaller amounts of Cr and Mo. The standard number allows one to know all chemical and mechanical characteristics of this steel. After 70, the indication changes and the

CHƯƠNG II

CÁCH VẼ HỌA KỸ-NGHỆ

1 — PHƯƠNG-PHÁP CHIẾU

1.1 — Nguyên-tắc

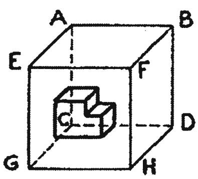
Chúng ta đã thấy ở chương trước cách-thức biểu-diễn một lập-thể bằng cách chiếu trên 2 hay 3 mặt phẳng. Nguyên-tắc này là căn-bản của phương-pháp chiếu.

1.2 — Quy-ước

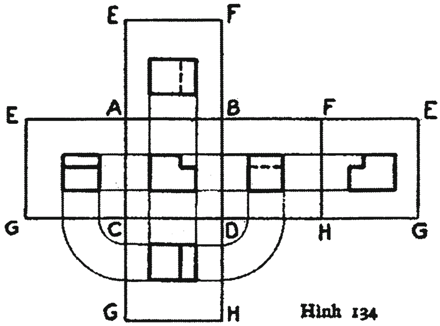
a/ CHỌN MẶT CHIẾU. Thường là sáu mặt của hình lập-phương, còn gọi là lập-phương chiếu; mặt trên và dưới nằm ngang, mặt trước và sau là mặt tiền đầu, mặt hai bên hông là mặt đâm thẳng.

b/ VỊ-TRÍ CỦA LẬP-THỂ. Nó được đặt trong hình lập-phương chiếu như thế nào để các mặt hay mặt đối-xứng được song-song hay thẳng góc với mặt của hình lập-phương.

Lập-thể chiếu



Hình 133



Hình 134

c/ PHƯƠNG-PHÁP TRẬP. Sau khi chiếu lập-thể trên 6 mặt của lập-phương; hình chiếu sẽ được kéo về mặt tiền đầu sau như trên họa-hình, mặt trước theo qui-ước trập sang bên phải của mặt đâm thẳng bên phải (hình 134).

Fig. 7.7 Example of a standard of South Vietnam (1970s) from a didactic book

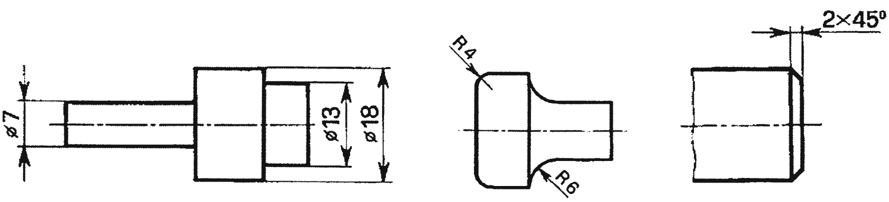


Fig. 7.8 Indication of diameters, radii, chamfers (Biggioggero and Giannattasio 1988)

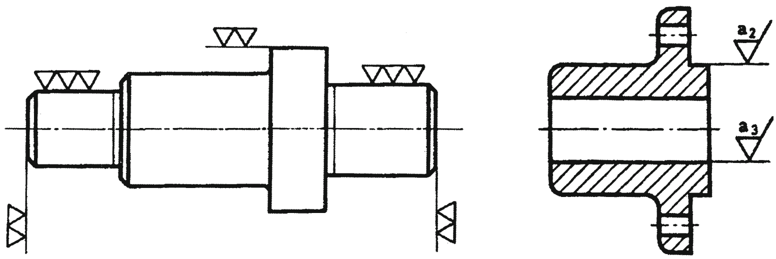


Fig. 7.9 Indication of surfaces (Biggioggero and Giannattasio 1988)

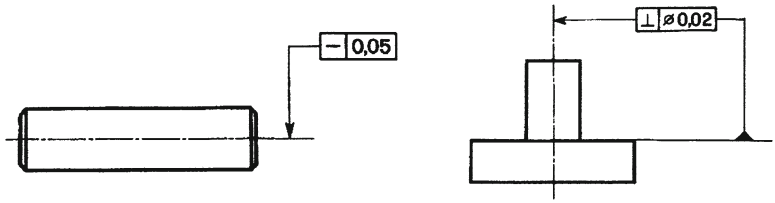


Fig. 7.10 Indication of geometric tolerances (Biggioggero and Giannattasio 1988)

metallurgical symbols of the chemical elements (N, C, D), become chemical symbols, respectively Ni, Cr, Mo. The above mentioned steel is therefore identified as 38 NiCrMo 4 and, successively, as 39 NiCrMo 3.

7.3 Development of Industry

7.3.1 Industries Born in the Twentieth Century

The twentieth century was characterized, from the industrial point of view, by a great development of industry in all fields: in particular, many industries that had been founded in the nineteenth century fulfilled their promise and led to the creation of new products and the birth of numerous new industries around them. The great importance of industrial growth was demonstrated by a number of widely acclaimed international exhibitions: for example, the Exposition Universelle in 1900 in Paris (where many new products were introduced, including the first escalator) and the Esposizione Internazionale in 1906 in Milan (which was devoted to the transportation industry) and, in particular, celebrated the opening of the Simplon tunnel (Milano e l'Esposizione internazionale del 1906, 2008).

Table 7.2 lists some important industries born in the twentieth century.

Table 7.2 Industries founded in the twentieth century

Year of foundation	Industry	Field of activity
1902	Bianchi	Cars, motorcycles, trucks
1902	Mercedes	Cars
1903	Zuest	Machine tools
1903	Ford	Cars
1904	Isotta Fraschini	Cars
1905	Filatura Vogherese Carminati	Webbing
1905	Austin	Cars
1905	Delage	Cars
1905	San Giorgio (Zavadini 1995)	Cars, then precision mechanics
1906	Rolls Royce	Cars
1906	Lancia (Storia della Lancia 1989)	Cars
1906	Falck	Steel
1907	Galdabini	Machine tools
1907	Officine Meccaniche Gallaratesi (aa. vv. 2007)	Pumps
1908	Mercedes	Cars
1909	Bugatti	Cars
1910	A.L.F.A.(will be Alfa Romeo) (Borgeson 1990; Hull and Slata 1970)	Cars
1913	Aeronautica Macchi (Nieuport Macchi 1920)	Airplanes
1911	Ceruti	Machine tools
1913	Aston Martin	Cars
1914	Restellini	Machine tools
1916	DKW	Cars
1917	BMW	Cars
1919	Grazioli	Machine tools
1919	Bentley	Cars
1919	Citroen (Wolgensinger 1991)	Cars
1921	Loro e Parisini	Earthmoving equipment
1922	Jaguar	Cars
1924	Daimler	Cars
1926	Ducati (Cavalieri Ducati 1991; Boni 2007)	Motorcycles
1927	Volvo	Cars
1927	SAME (Di Nola 1987)	Tractors
1928	ALSTOM	Railways
1929	Borgward	Cars
1931	Porsche (Conradt 2008; Boni and Ardizio 2010; Pasini 2011)	Cars
1937	Saab	Cars
1933	Innocenti	Cars
1938	Volkswagen	Cars
1939	Iso Rivolta (Goodfellows 2009)	Cars
1940	Ferrari (Ferrari and Turrini 2007)	Cars
1941	Mori Seiki	Machine tools
1942	Bombardier	Railways
1946	Techint	Mechanical plants

(continued)

Table 7.2 (continued)

Year of foundation	Industry	Field of activity
1955	Goggomobil	Cars
1958	DAF	Cars
1963	Lamborghini (Carugati 2009)	Cars
1968	Leyland	Cars, trucks

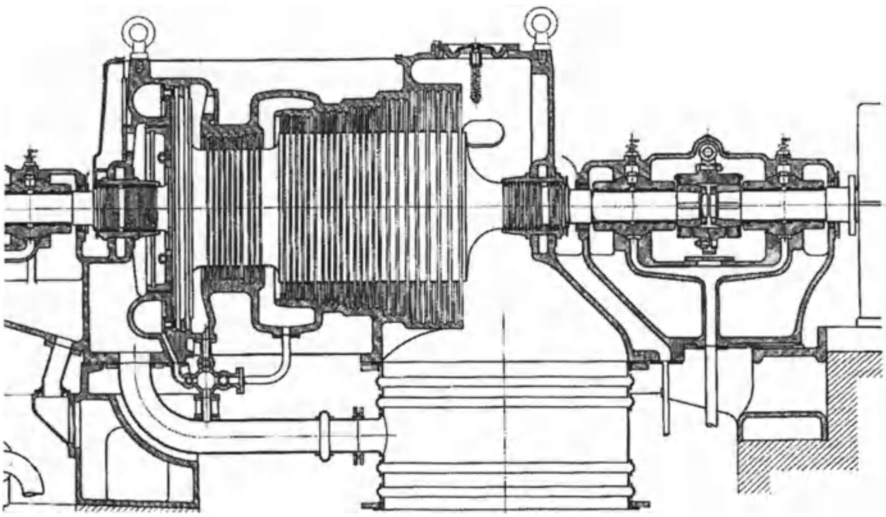


Fig. 7.11 Assembly drawing of a steam turbine (ca 1900)

7.3.2 Examples of Drawings of the Twentieth Century

Here are presented some drawings from industry in chronological order. Figure 7.11 (ca 1900) represents a steam turbine. The drawing is an assembly and represents the machine in complete configuration of functioning (Stodola 1910).

Figure 7.12 represents an example of the bearing of a steam turbine (ca 1900) (Pfarr 1907). Such bearing allows also spherical motion. Its purpose is to observe the representation of all threads. The actual standards allow a simplified representation of threads. This drawing is an assembly drawing, because it represents a complex constituted of many parts, but some indications of dimensions are present: the drawing, therefore, has also a constructive value. A drawing particularity is the representation of the near parts with center lines.

Figure 7.13 represents assembly and constructive drawings of an end of shaft (Pfarr 1907).

Figure 7.14 represents a boiler (1902) through some orthographic views and some enlarged details. The precision of the execution is good, but very inferior to the precision of many drawings of the twentieth century.

It is interesting to observe that these drawings, less beautiful than those of the nineteenth century, are however executed with great care, witness to an admirable

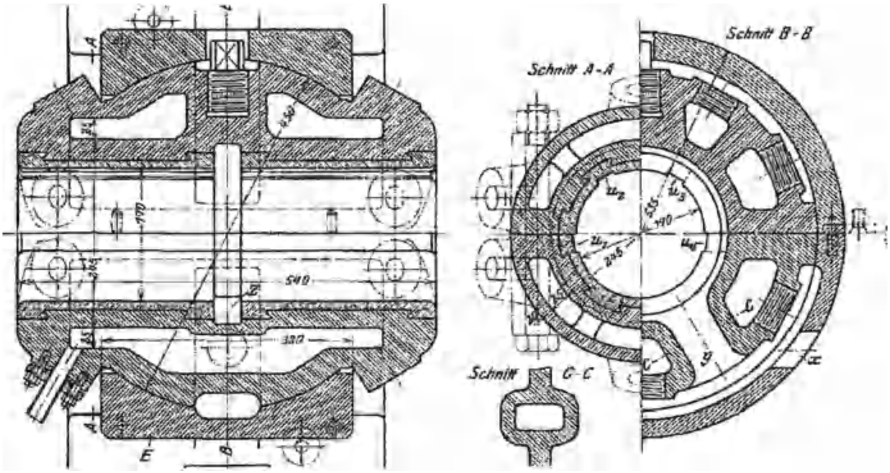


Fig. 7.12 Bearing with possibility of spherical motion (ca 1900)

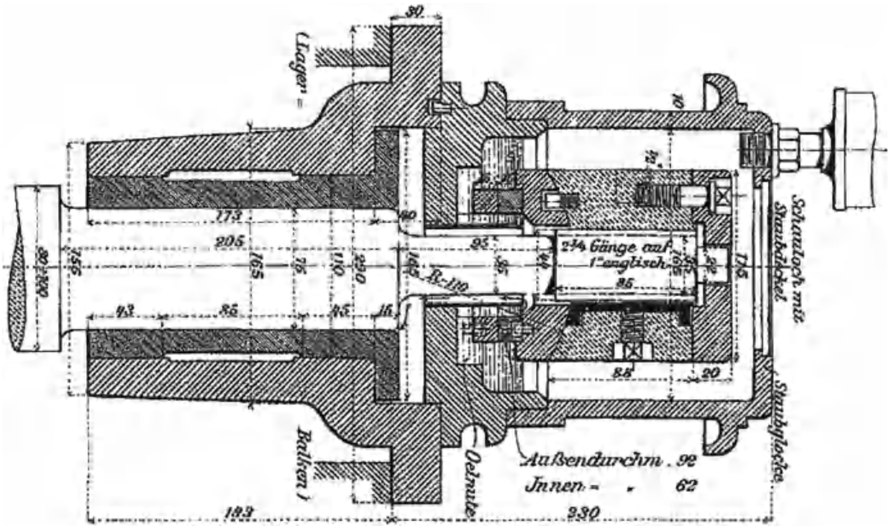


Fig. 7.13 End of shaft: assembly and constructive drawing (ca 1900)

professional ability. As examples, the drawing of Fig. 7.15 (1906) (Tecnomasio Italiano Brown Boveri) represents a schema of electrical windings. The excellence of execution gives to the drawing itself a great aesthetic value.

The drawing of Fig. 7.16 represents a vehicle to transport persons for hotels (Tecnomasio Italiano Brown Boveri) (1910). The vehicle is moved by an electric front axle; the drawing is represented in a scale of 1:10.

Figure 7.17 is relative to an automotive multi-plate clutch, actuated by a central spring. On the drawing it is possible to read "Società Italiana Automobili

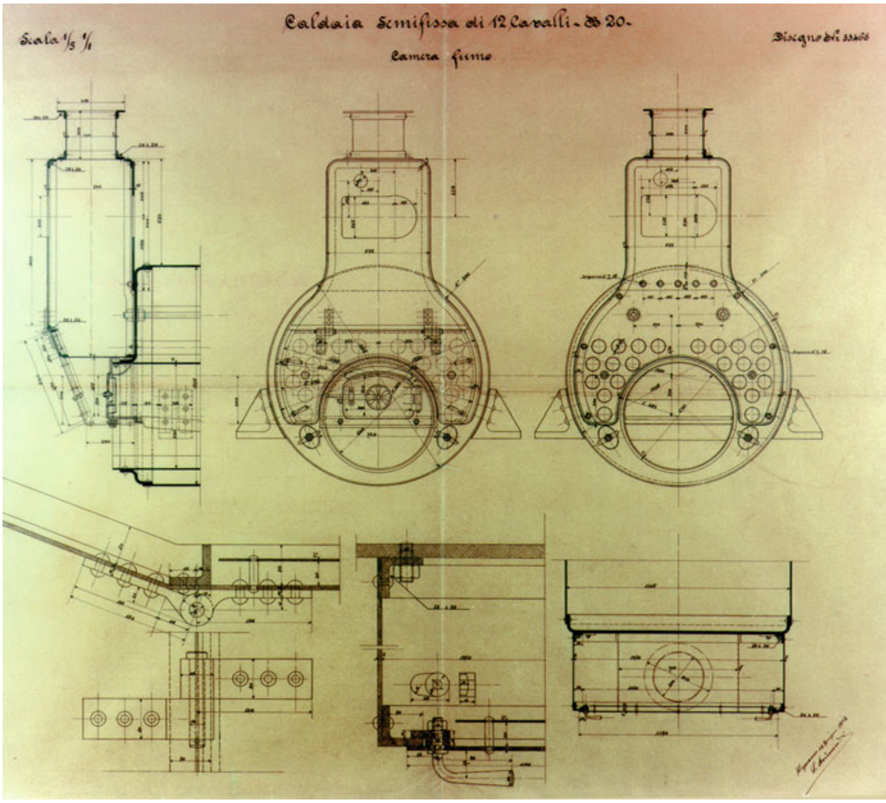


Fig. 7.14 Drawing of Franco Tosi (1902) (Pavan and Sabbatini 1987; Rovida 1999)

Darracq"(Italian Society Automobiles Darracq), the industry "mother" of Alfa Romeo. The author of the drawing is the well-known car designer Merosi. The drawing is an interesting documentation of the automotive constructions of this time.

Figure 7.18 represents an electrical railway vehicle, from Tecnomasio Italiano Brown Boveri (1915). The original drawing has very big dimensions (1,560×1,080 mm). It is interesting to note the great care taken with the drawing and the high precision of all particulars of these very complex objects. The drawing is an important documentation of the railway constructions of this time.

Figure 7.19 represents some electrical winding (Tecnomasio Italiano Brown Boveri, 1923) expressed with a very high degree of schematization.

The drawing of Fig. 7.20 is a constructive representation of a spring (Tecnomasio Italiano Brown Boveri, 1923). It is interesting as an example of anticipation of simplified representations of springs. The simplification is relative to the qualitative (not all coils of the spring are represented) and quantitative aspects (some dimensions are indicated directly on the drawing, while others are indicated in an elementary table).

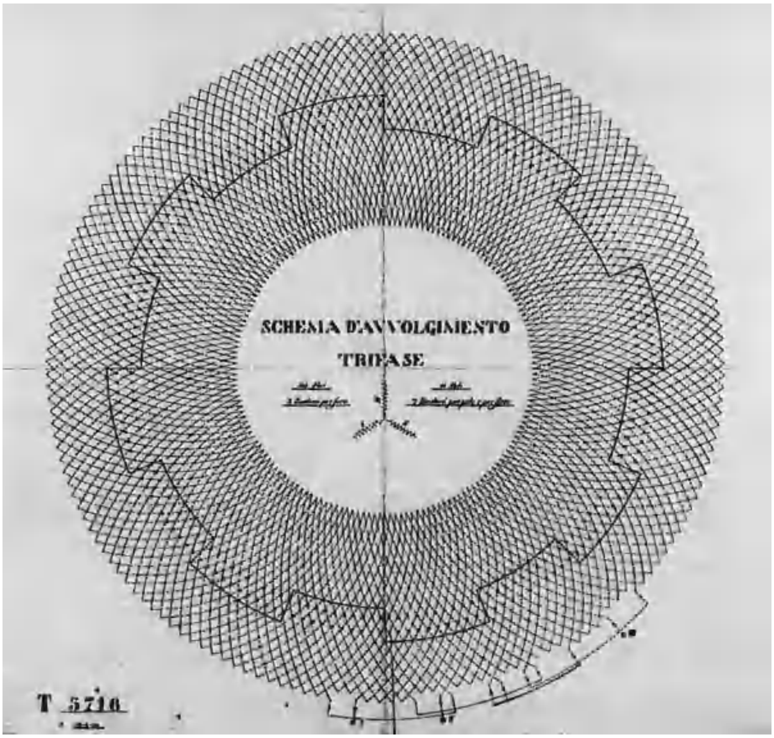


Fig. 7.15 Electrical winding (1906) (Rovida 1999)

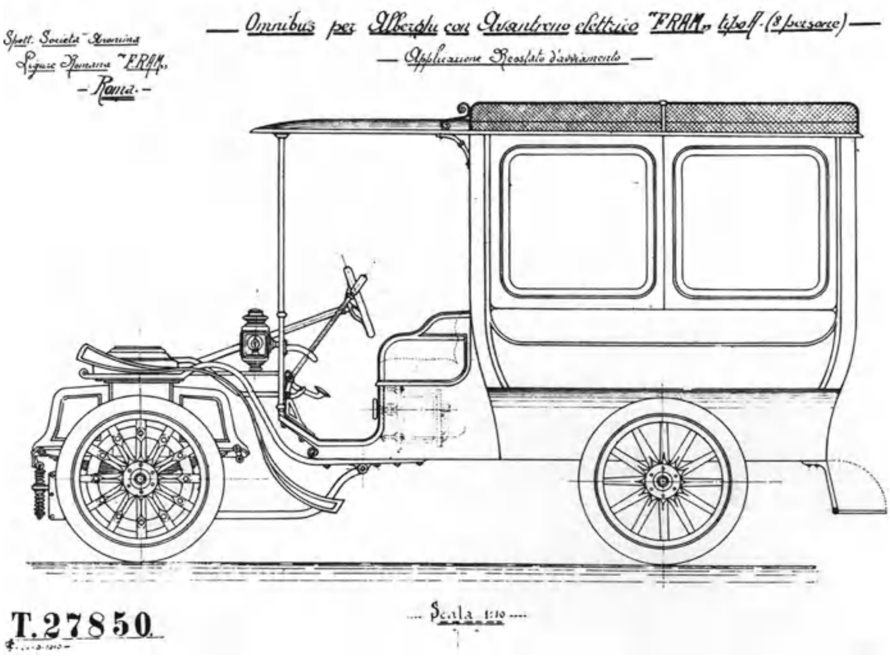


Fig. 7.16 Vehicle to transport persons for hotels (1910) (Rovida 1999)

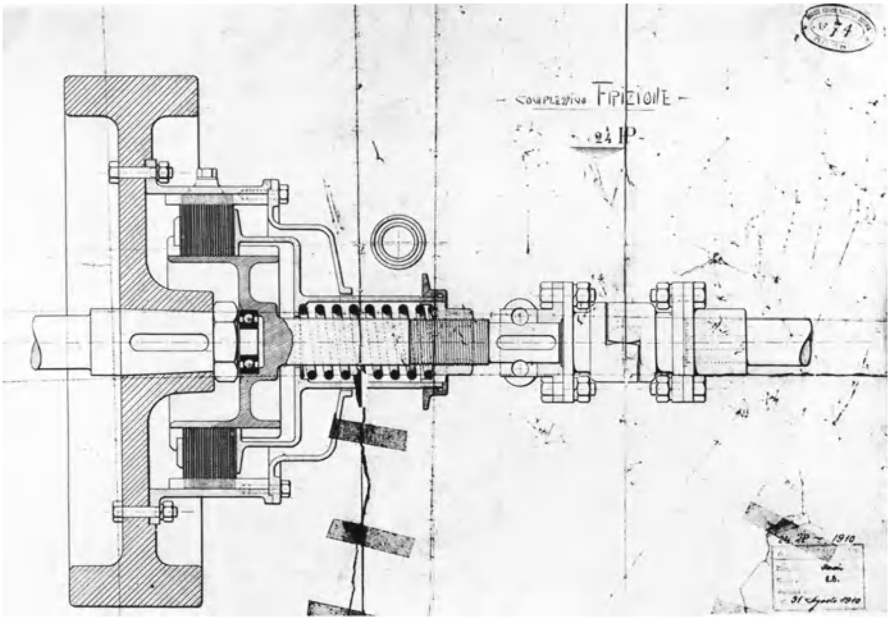


Fig. 7.17 Clutch (1910, Rovida 1999)

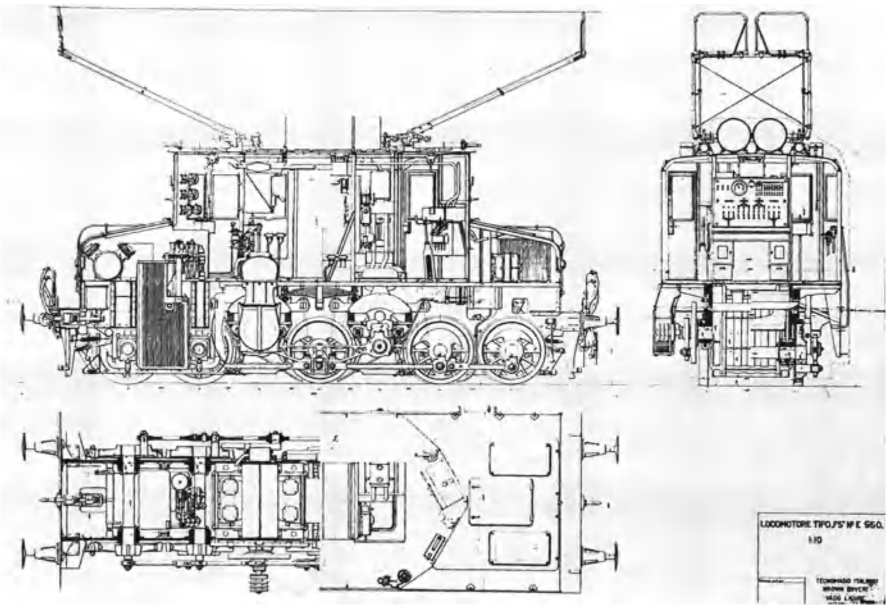


Fig. 7.18 Drawing of an electrical rail vehicle (1915, Rovida 1999)

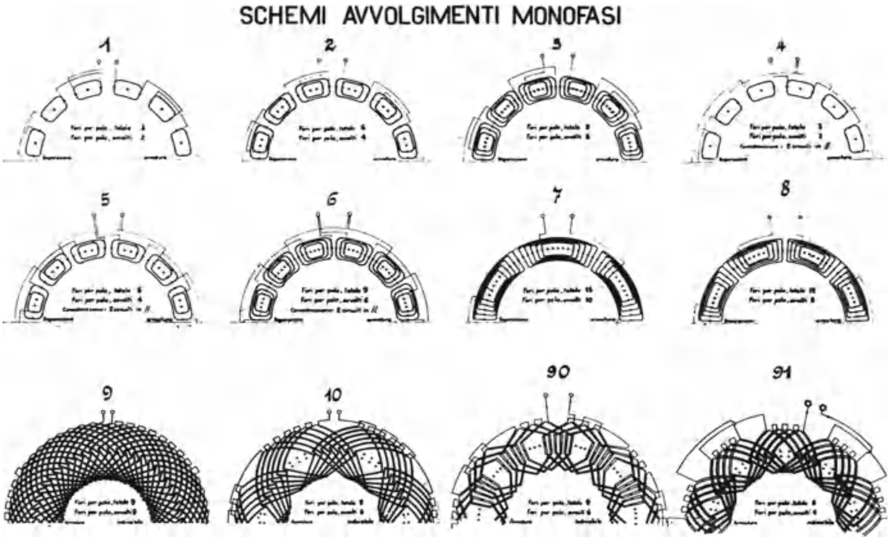


Fig. 7.19 Electrical winding Tecnomasio Italiano Brown Boveri (1923) (Rovida 1999)

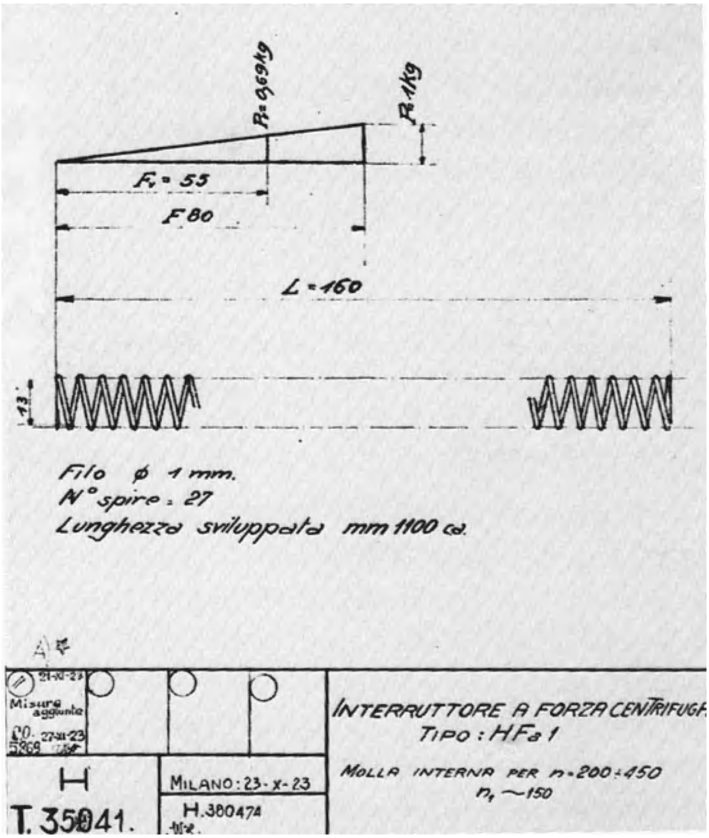


Fig. 7.20 Constructive representation of a spring (1923) (Rovida 1999).

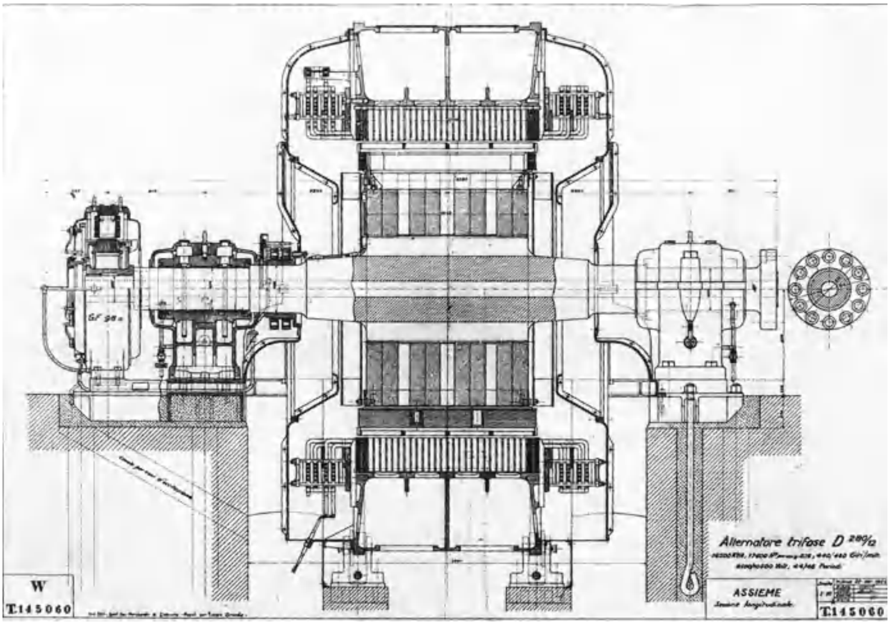


Fig. 7.21 Electrical machine (1925) (Rovida 1999)

Figure 7.21 (Tecnomasio Italiano Brown Boveri, 1925) is relative to a longitudinal cut of an electrical machine and is a valid example of electromechanical constructions.

Figure 7.22 is characterized by very big dimensions (1,300 × 800 mm) and was drawn by Tecnomasio Italiano Brown Boveri, 1939. The drawing represents a railway vehicle. The represented object is very complex and carefully represented. In addition, it is an interesting documentation of railway construction at the end of the 1930s.

The electrical power unit of a railway vehicle (Tecnomasio Italiano Brown Boveri, 1939) is the object of the drawing of Fig. 7.23. The original of this drawing also has very big dimensions (1,040 × 750 mm) and is interesting for the complexity of the represented object and for the extreme care in its execution.

Figure 7.24 is relative to a mechanical device, probably a part of a graphic machine.

The drawing of Fig. 7.25 represents a connecting rod for a motorcycle. The drawing is realized by a frontal view and a longitudinal cut. The configuration of the rod is represented by two transverse sections, in defined positions. The constructive information is completed by material (cementation steel) and dimensional tolerances (assigned by ISO-symbols and deviations).

Figure 7.26 is relative to a constructive part of a textile machine. Interesting is the indication of dimensional tolerances with ISO symbols and graphically highlighted.

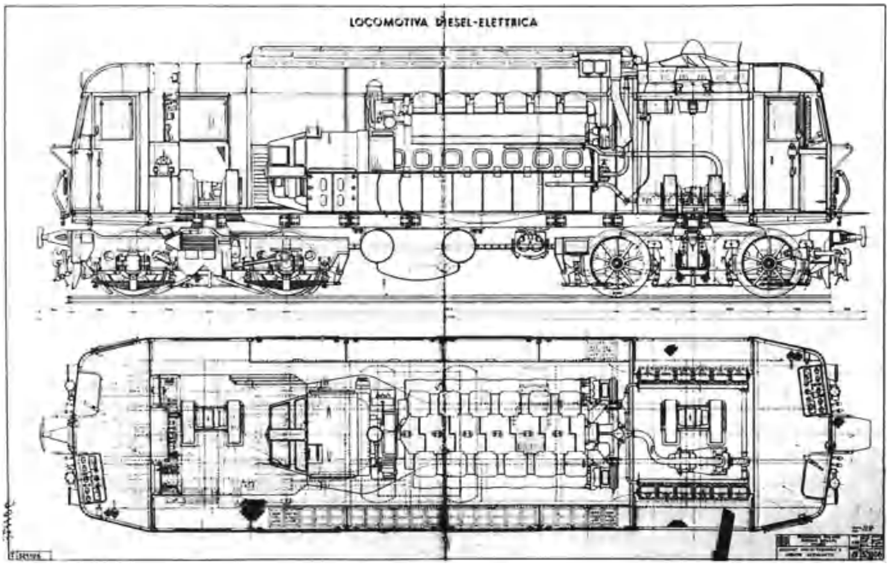


Fig. 7.22 Railway vehicle (1939) (Rovida 1999)

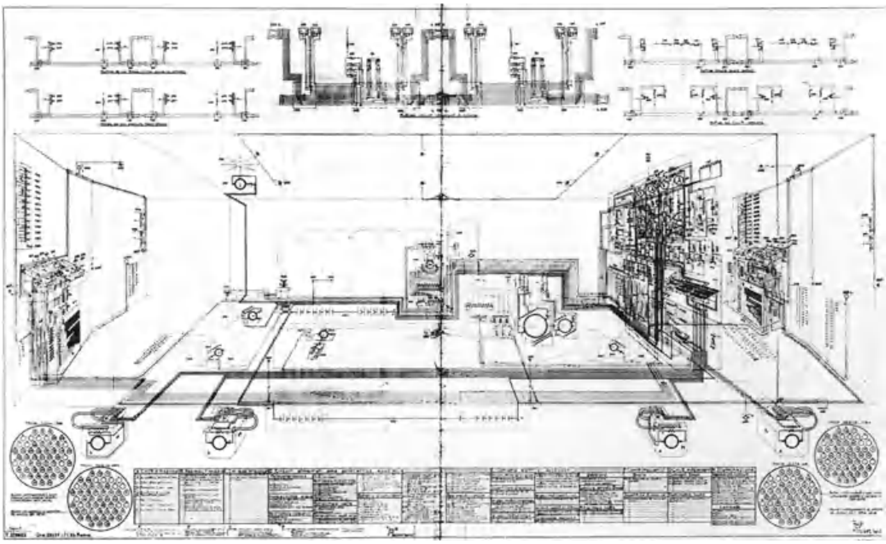


Fig. 7.23 Electrical power unit of a railway vehicle (1939) (Rovida 1999)

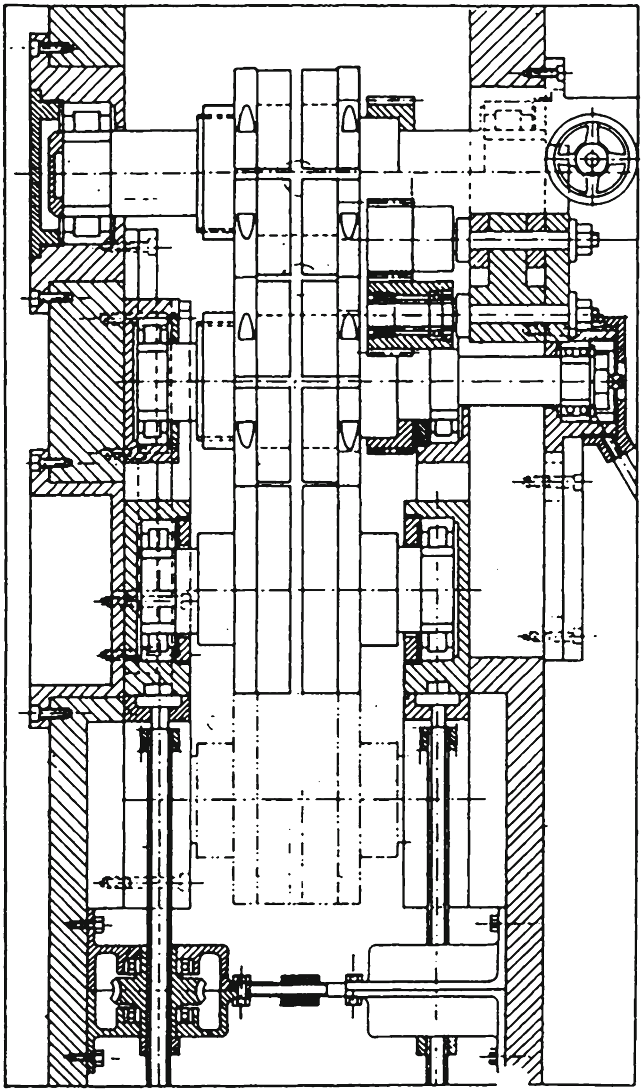


Fig. 7.24 Drawing of a mechanical device (1950)

Figure 7.27 is relative to a drawing of an actuation screw for an elevation machine. The assembly drawing has constructive value, by the indication of dimensions. It is interesting that the drawing is utilized as a basis for a free-hand sketch relative to a different constructive solution of a specific detail.

A drawing by an Italian manufacturer of an elevation machine (and, particularly, the parachute device) is the object of Fig. 7.28. It is an assembly drawing, with two cuts in perpendicular planes to show the details.

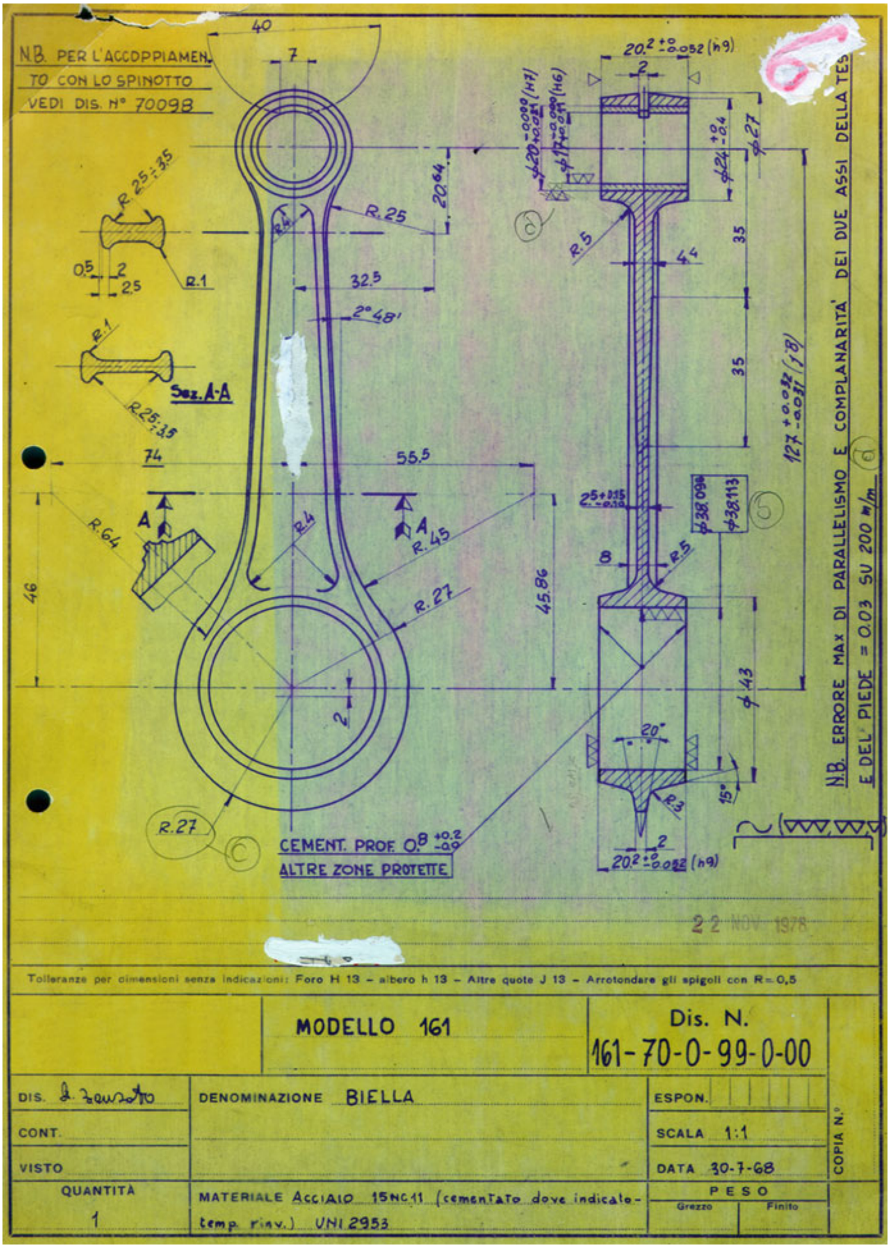


Fig. 7.25 Italian drawing (1968) relative to a connecting rod for a motorcycle (Rovida 1999)

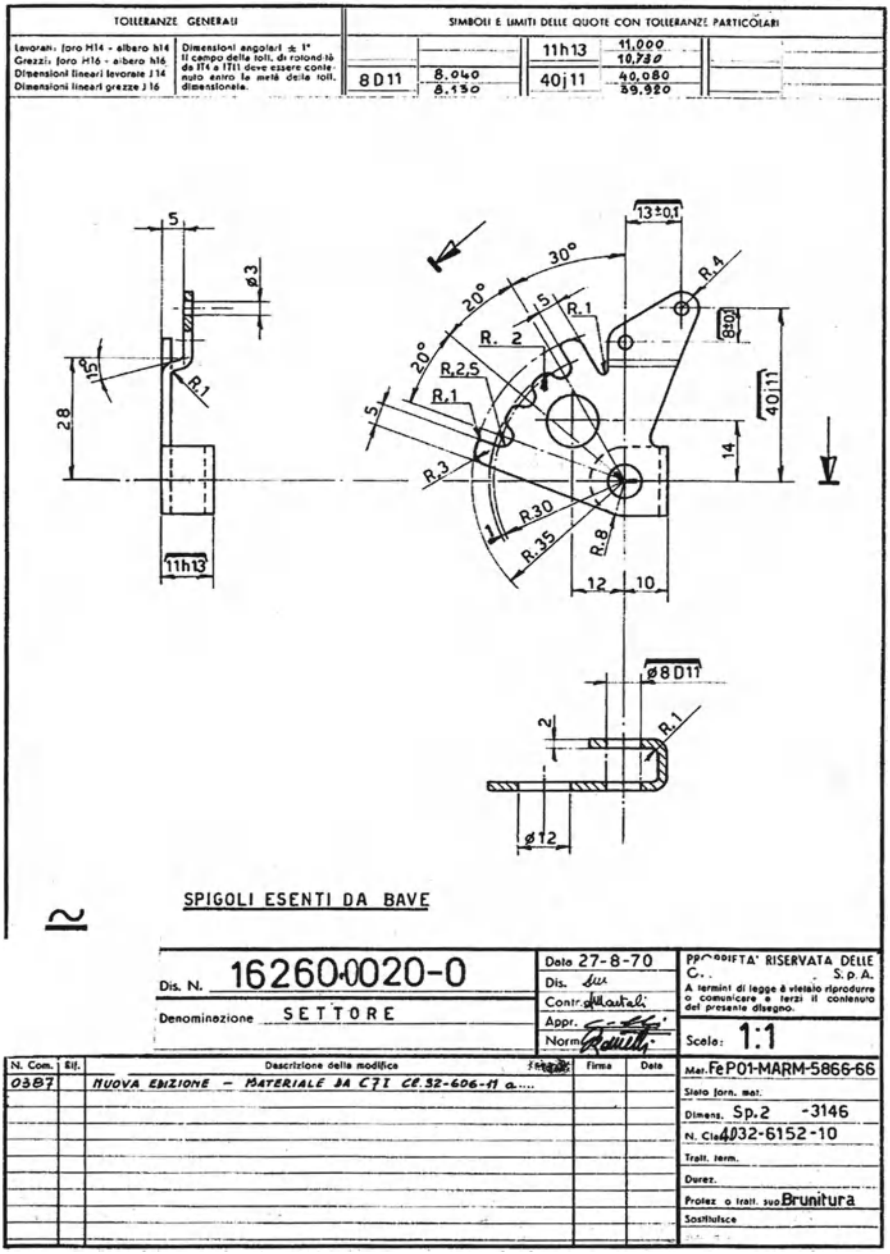


Fig. 7.26 Italian constructive drawing (1970)

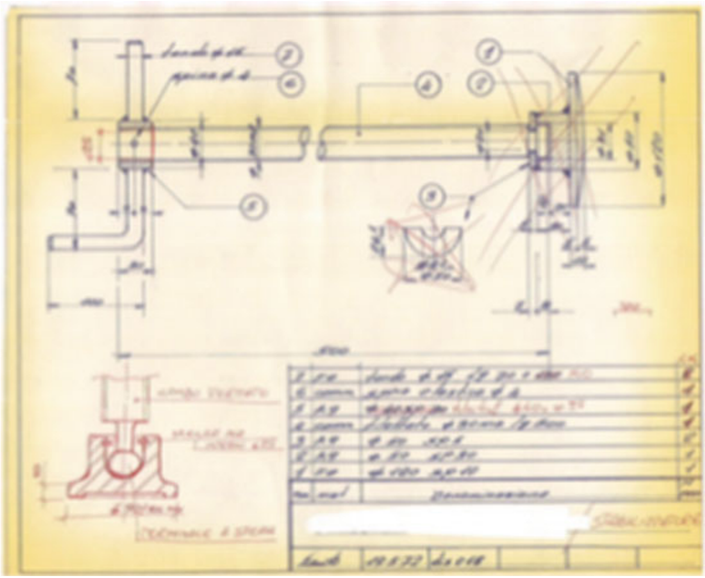


Fig. 7.27 Italian Drawing (1972) relative to an actuation screw for an elevation machine

7.4 Development of Technical Schools

7.4.1 General Characters

The teaching of drawing became more and more complex, with development of the mechanical industry and improvement of drawing standards that, particularly since 1920, were numerous and linked with all aspects of drawings.

Particularly in the second half of the twentieth century, the number of students rapidly increased. In addition, preparation of the students was very often inhomogeneous and their motivation not always very high. In addition, the proliferation of computers and their graphics programs precipitated a great transformation in the teaching of drawing. Another big problem was the available time, always shorter, particularly in relation to the amount of information to be transmitted.

The teaching of technical drawing, therefore, had to take into account all the above mentioned factors: in other words, it became necessary to upgrade the contents to be taught (in relation to the progress of the industry) and the way of teaching (in relation to the number of students, the inhomogeneity of their technical background and the short available time).

7.4.2 Fundamental Steps

The evolution of teaching of technical drawing in the twentieth century could be divided into steps, corresponding to the fundamental periods of time, individuated,

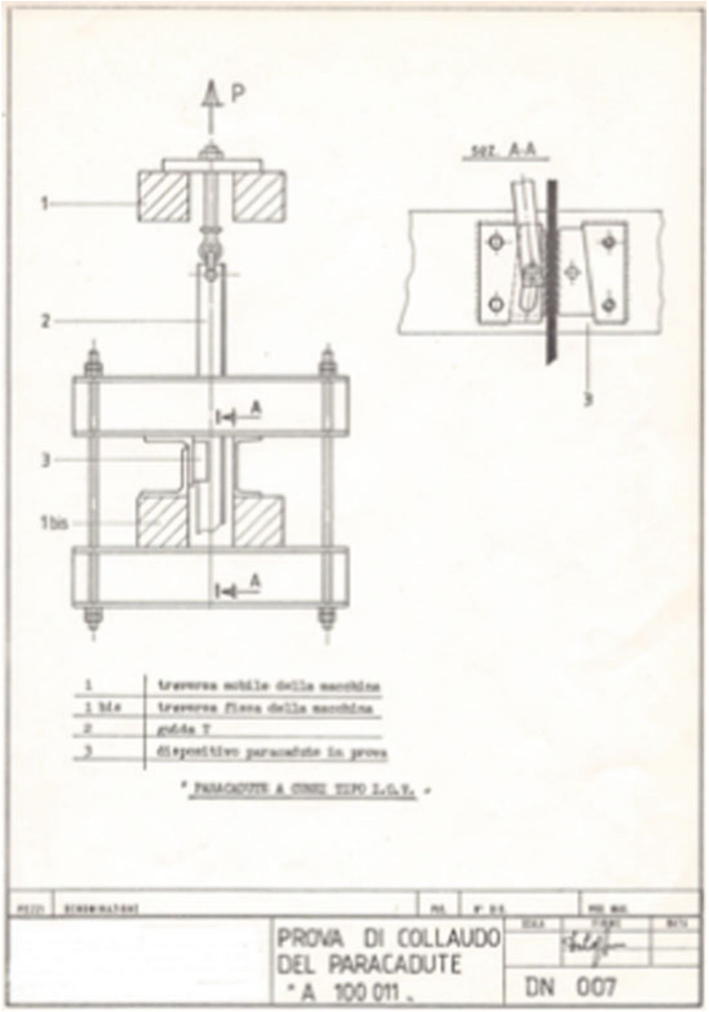


Fig. 7.28 Italian drawing (ca 1988)

respectively, by: introduction of standards (ca 1920), beginning of modern drawing and design (ca 1950), first application of the computer (ca 1970).

7.4.2.1 From 1900 to 1920

The heritage of the nineteenth century in this period became very strong: didactic drawings were characterized by great aesthetic care, e.g. with colors, shadows and consequently realistic representation, even including not really necessary particulars such as in threads, gears, and springs.

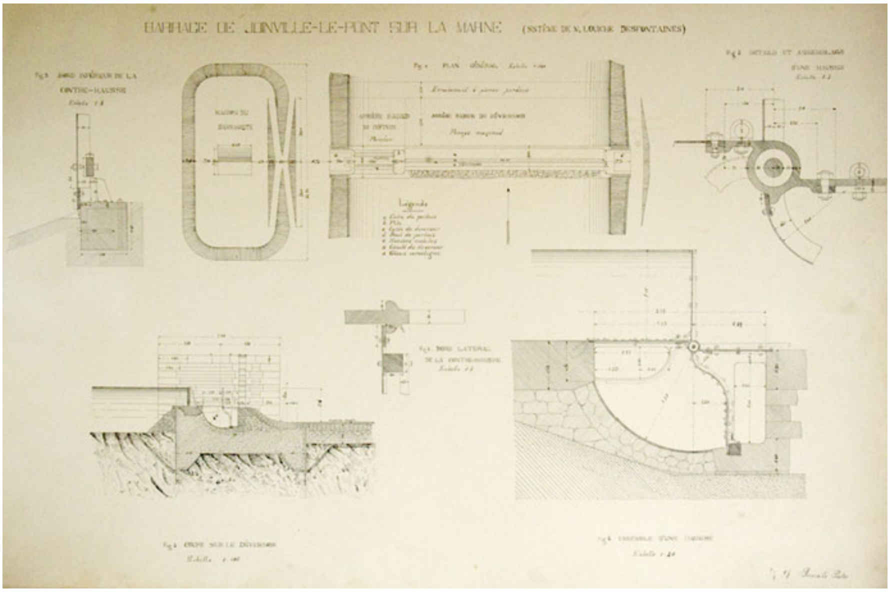


Fig. 7.29 General configuration of a plant, with some constructive details (1901)

The absence, in many countries, of drawing standards in this period produced, as a side effect, a great variety of styles of drawing: each author of drawings had to interpret in a personal way the theory of orthographic projections.

Teaching of drawing, fundamentally, consisted of transmitting the theory of orthographic projections, then demonstrating the application of such theory to the drawing of machine elements.

Figures 7.29, 7.30, 7.31, and 7.32 are exercises of Hydraulics Constructions at Politecnico di Milano and are of the first year of the twentieth century. These drawings are relative to some mechanical particulars of hydraulic plants and, therefore, can be considered examples of mechanical drawings. They are significative examples of the abovementioned heritage of the nineteenth century: the great aesthetic care and the representation of not necessary particulars, without simplification are evident. These drawings are applications of orthographic projections and are witnesses of the abovementioned way to teach technical drawing by the principles of the twentieth century.

Figure 7.29 represents a didactic drawing (1901) with the general configuration of a plant, with some constructive details.

Figure 7.30 represents a general plant, with some dimensions (1902). One should observe the reduction scale 1:250: perhaps, because the scale 1.2 was prohibited because the technicians believe that such a scale could cause some error of evaluation of the proportions: this idea was demonstrated to be wrong (Groutel 1948; Biggioggero and Rovida 1976) and, therefore, since 1980, this scale has been acceptable by ISO standards.

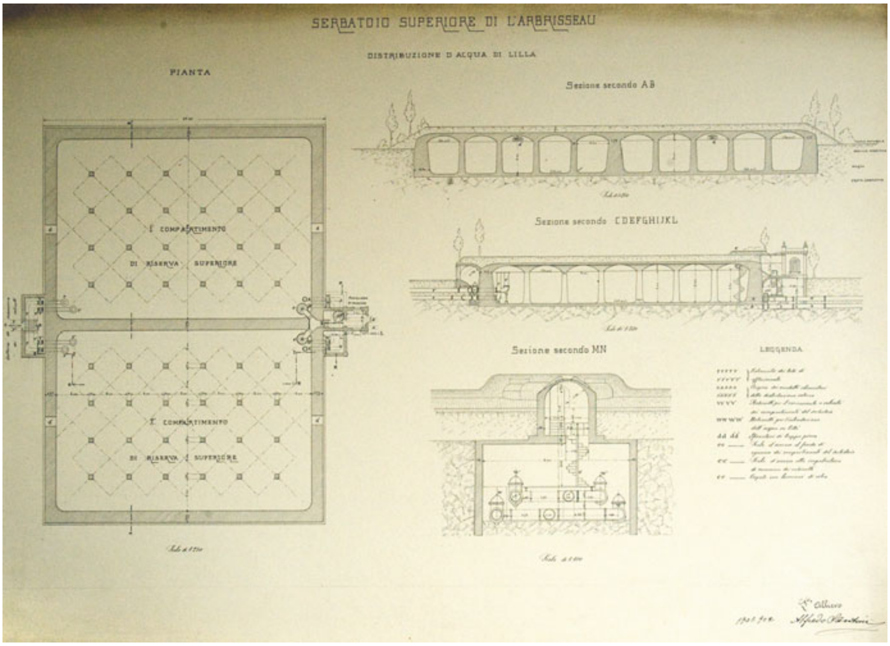


Fig. 7.30 General plant, with some dimensions (1902)

Figure 7.31 represents a steel construction and is a documentation of such constructions (nails and bolts connections) of this time (first years of the twentieth century).

Figure 7.32 is relative to some graphical calculations (1914). Before the use of computers, graphical calculations were very important and widely utilized.

Figure 7.33 represents two gears, drawn with great care and ability. The student drew all the teeth of both gears: simplifications allowed by modern drawing standards were not yet born.

In general, from an analysis of the above mentioned didactic drawings, it is possible to express the following considerations about the use of drawings in the technical schools in this period of time:

Assembly and constructive drawings are very often on the same figure: in other words, assembly (or subassembly) drawings contain constructive information that, in this period, are substantially only the dimensions;

Very often some particulars are represented in an enlarged scale;

Often unusual scales are utilized: as example, 1:40, 3: 200;

The scale 1:200 is not often utilized: this could be an influence of the exclusion of the scale 1:2;

These drawings are interesting examples of how to teach and how to build: the teaching of drawing, substantially, is identified with the teaching of orthographic projections and with the practical and careful application of this theory to the elements of machines and plants. Some examples of didactic books of this period are (Riedler 1923) and (Keiser 1914).

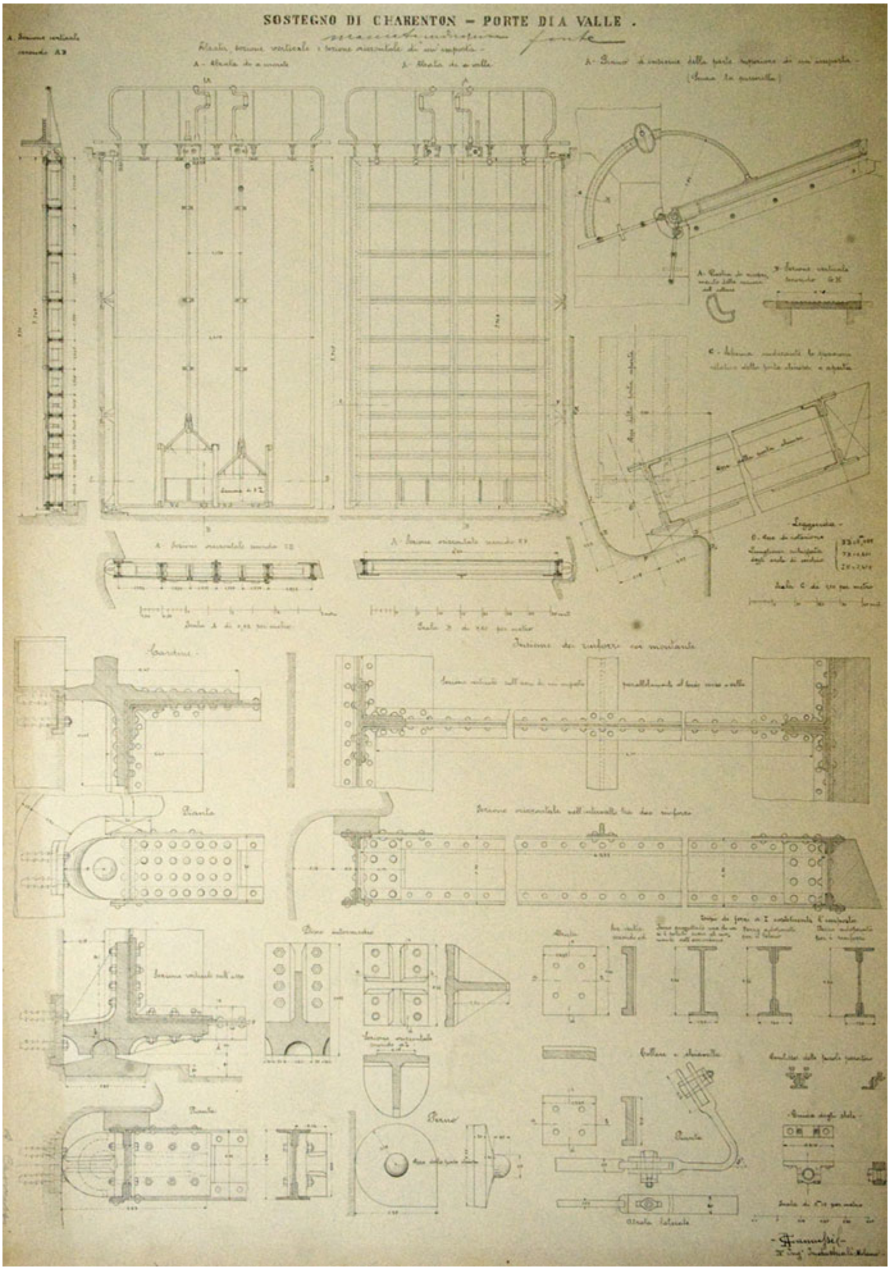


Fig. 7.31 Mechanical particulars of an hydraulic plant (first years of the nineteenth century), with nails and bolts connections

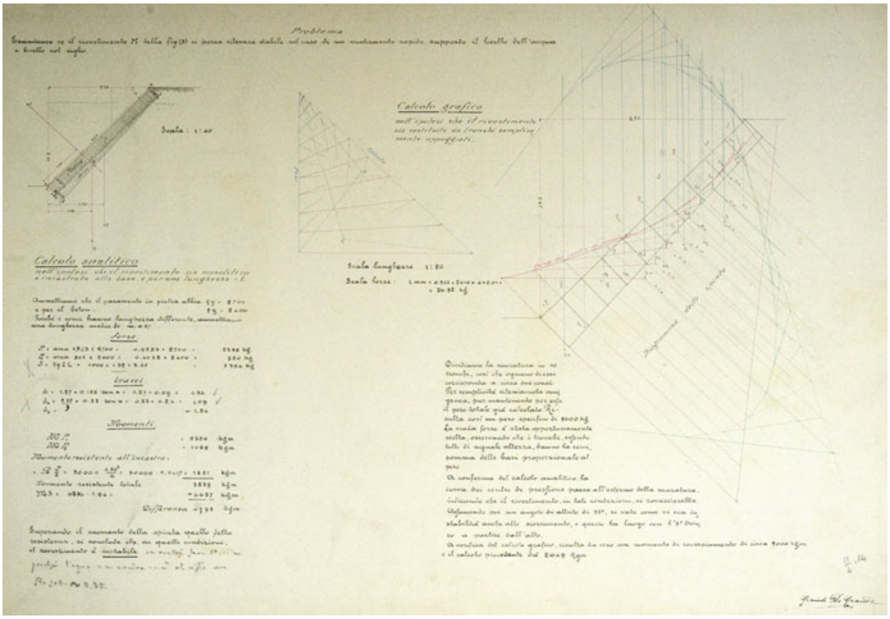


Fig. 7.32 Graphical calculations (1914)

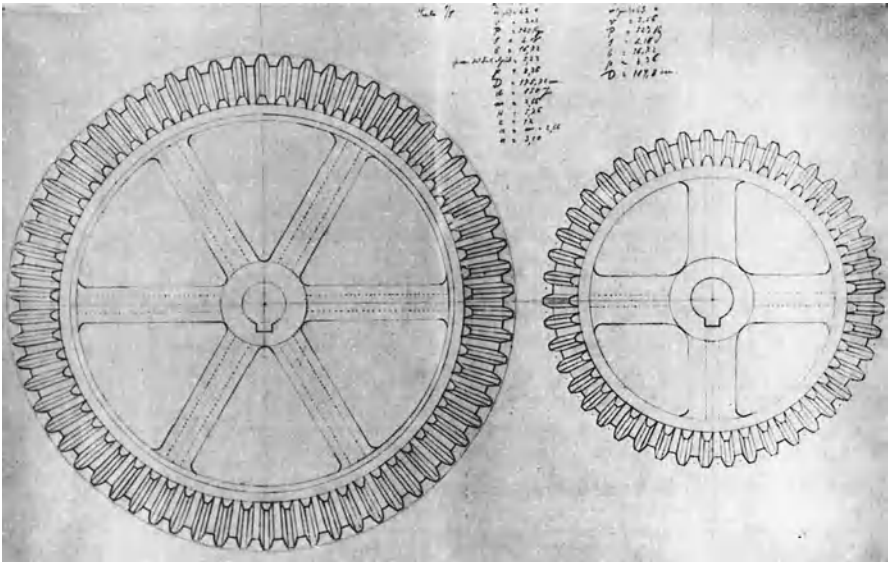


Fig. 7.33 Representation of gears (1915) drawn with care and ability

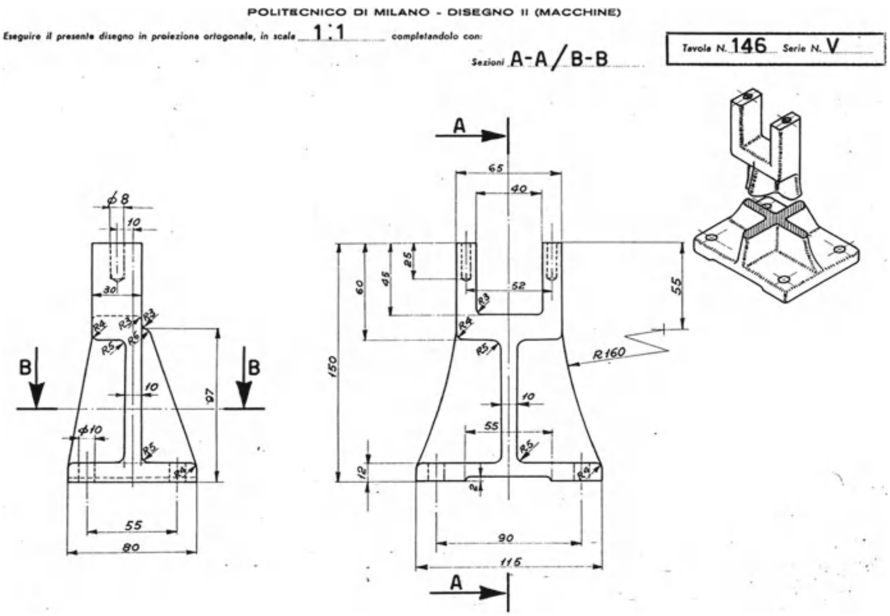


Fig 7.34 Example of a drawing exercise (late 1940s)

7.4.2.2 From 1920 to 1950

The principles of this period were characterized by the birth of drawing standards, which established rules of drawing, i.e. to apply the theory of orthographic projections and, successively, with more specific constructive information, such as the indications of materials, tolerances and roughness. The drawing standards allowed, in addition, the simplification of some mechanical parts and features of parts, such as threads, gears, bolts, nuts, springs. The effect of the application of standards was, in general, more uniformity in styles and ways to draw, and less care to the aesthetics.

The teaching is, substantially, the transmission of the standards and of relative application.

The exercises can be divided in two successive steps:

- Exercise solved starting from a case "on paper" (Fig. 7.34). A mechanical part is assigned with an axonometric view and some orthographic projections/cuts: the exercise consists in drawing other views/sections. With such exercises, the student acquires the ability to utilize orthographic projections.
- Survey and sketching of real mechanical parts: realization of the drawing of the part, starting from the real part (Fig. 7.35). This step can be also an exercise of design. The students realize assembly drawing (Fig. 7.36) and the corresponding constructive drawings (Fig. 7.37), congruent with the function expressed by the assembly.

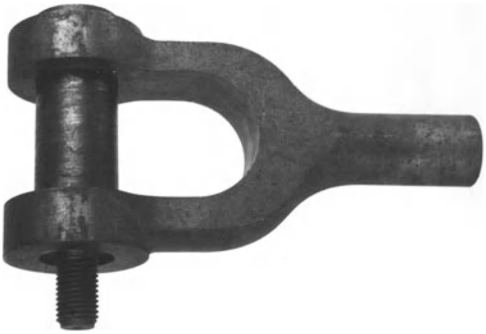


Fig. 7.35 Example of an element of a machine, to be studied by the students

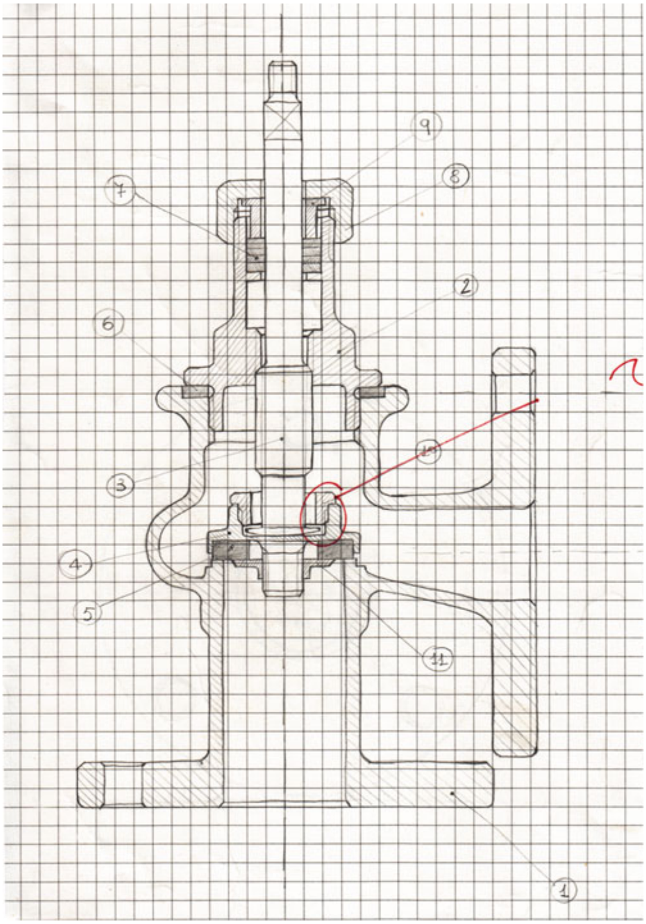


Fig. 7.36 Assembly drawing of a simple machine

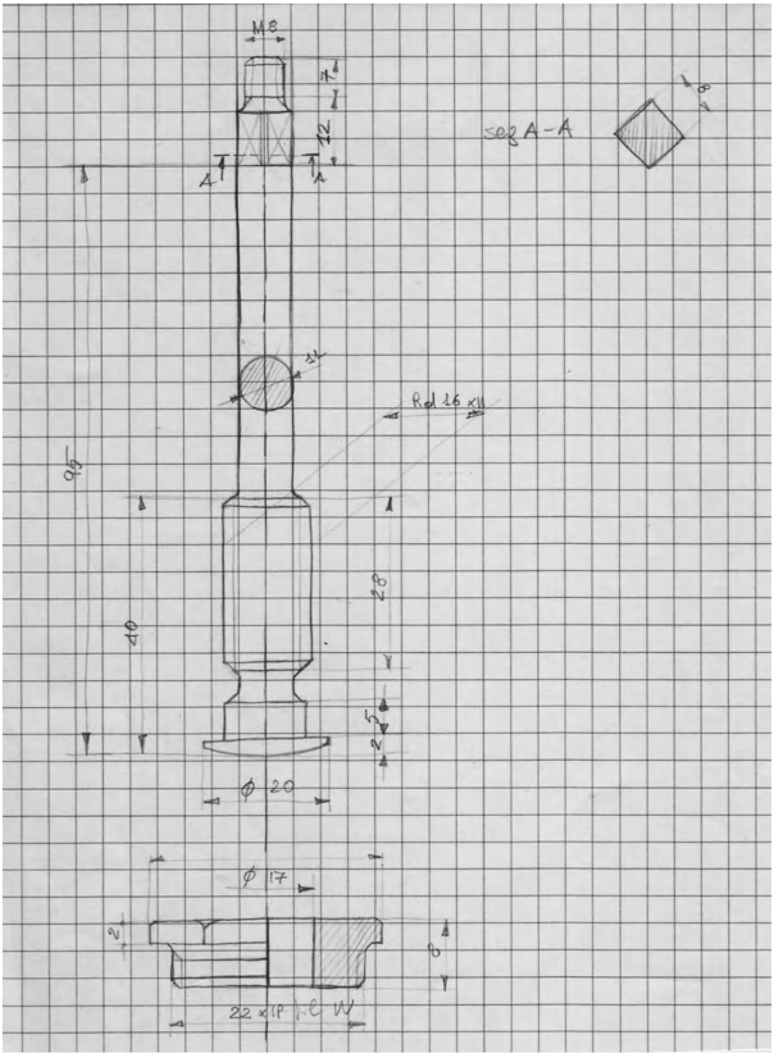


Fig. 7.37 Constructive drawings of some parts of the machine of Fig. 7.36

With these exercises, the students reach the following objectives:

- Good knowledge of drawing standards;
- Ability to draw and to manage drawing instruments;
- Good knowledge of the elements of machines;
- Preliminary approach to design procedures.

Such areas of knowledge are important tools for several successive courses. For example, Fig. 7.38 is relative to constructive drawings of an automotive suspension. This drawing (of late 1940s) is relative to a thesis in Automotive Constructions.

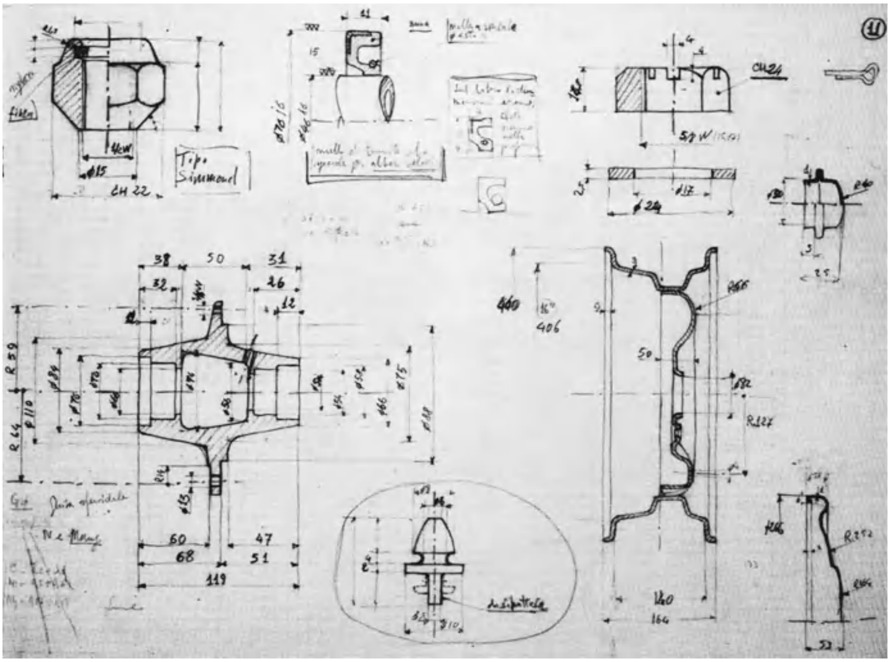


Fig. 7.38 Drawings of automotive components (late 1940s)

Some important didactic books of this period are Volk 1921; Sauer 1923; Apel 1923; Gilardi 1926; Massero 1937; Jones 1941; Spooner 1943; Luzadder 1946; Giesecke et al. 1948; Belvalette 1953.

7.4.2.3 From 1950 to 1970

In this period there were no great differences in comparison with the period 1920–1950: we have observed that there appeared many standards for all aspects of drawing (more specific indication of materials, tolerances, roughness): learning and applying these standards is an important object in the teaching of drawing. We also observe the harmonization of national with international standards. The trend is to first realize a standard at the international level (such as an ISO standard), while at the national level (as, for example, UNI standards in Italy, DIN standards in Germany, AFNOR standards in France, BSI standards in Great Britain, and so on) these standards are realized, in most cases, as simple translation into a national language and, if necessary, particularization, in relation to national requirements.

The survey and sketching of parts of machines by applying the standards is an important part of the teaching of drawing of machines. We also observe that it is the first elementary application of computers in graphics.

Figure 7.39 is an example of didactic drawing of the late 1950s, (very similar to the example of Fig. 7.34) with the aim of teaching drawing standards and affecting

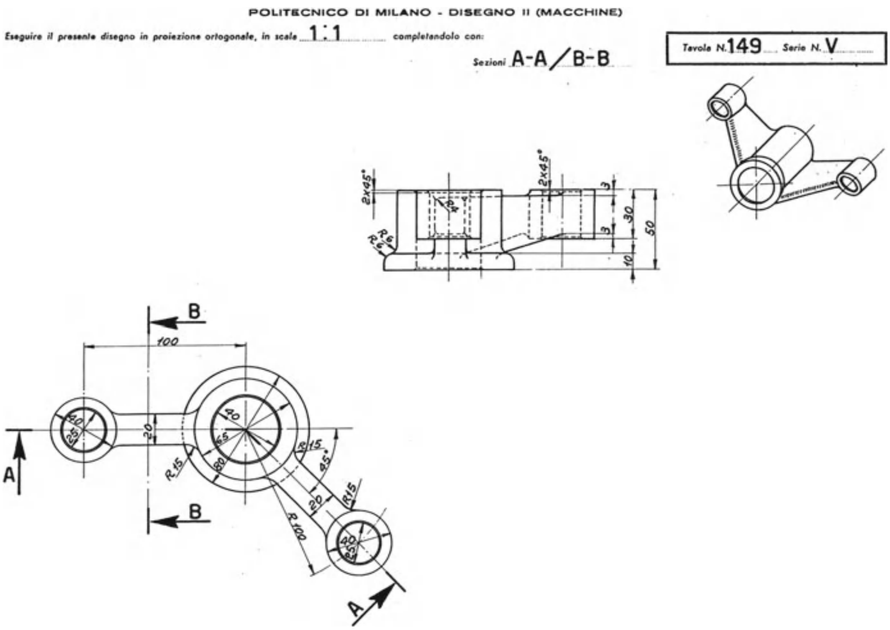


Fig. 7.39 Drawing exercise (late 1950s)

the "translation" of a three-dimensional object into two-dimensional views and vice versa, while Fig. 7.40 is an example of didactic drawing, relative to a welded structure (1962).

Some examples of didactic books of this period are Zozzora 1953; Luzadder 1956; French and Svensen 1957; Bachmann and Forberg 1960; Rabe et al. 1967; Speluzzi and Tessarotto 1968.

7.4.2.4 From 1970 until today

This period was characterized by some recurring problems such as the great number of students, with motivation often not very high and with great inhomogeneity of basic preparation, rapid development of industry and consequent necessity to upgrade didactic programs.

With the aim of solving this problem, many experiments were undertaken. An important initiative was experimentation with automation of teaching and of evaluation: as examples, see the books and the papers from Bristol 1970; Schroeter and Schroeter 1973; Feranndez-Jambrina and Pulido 2003; Holt 1995; Federighi and Clark 2009; Van der Loos and Ostafichuk 2009; Hernandez Abad et al. 2003a, b; Schneiders and Sappert 1971; Biggioggero and Rovida 1986; Biggioggero et al. 1983; Caputo et al. 1983; Santoro and Schiavone 1986; Milanese and Tosetti 1986; Concheri and Guggia 1993; Concheri and Milanese 1993; Bandera and Zonta 1997; Barbero et al. 2003.

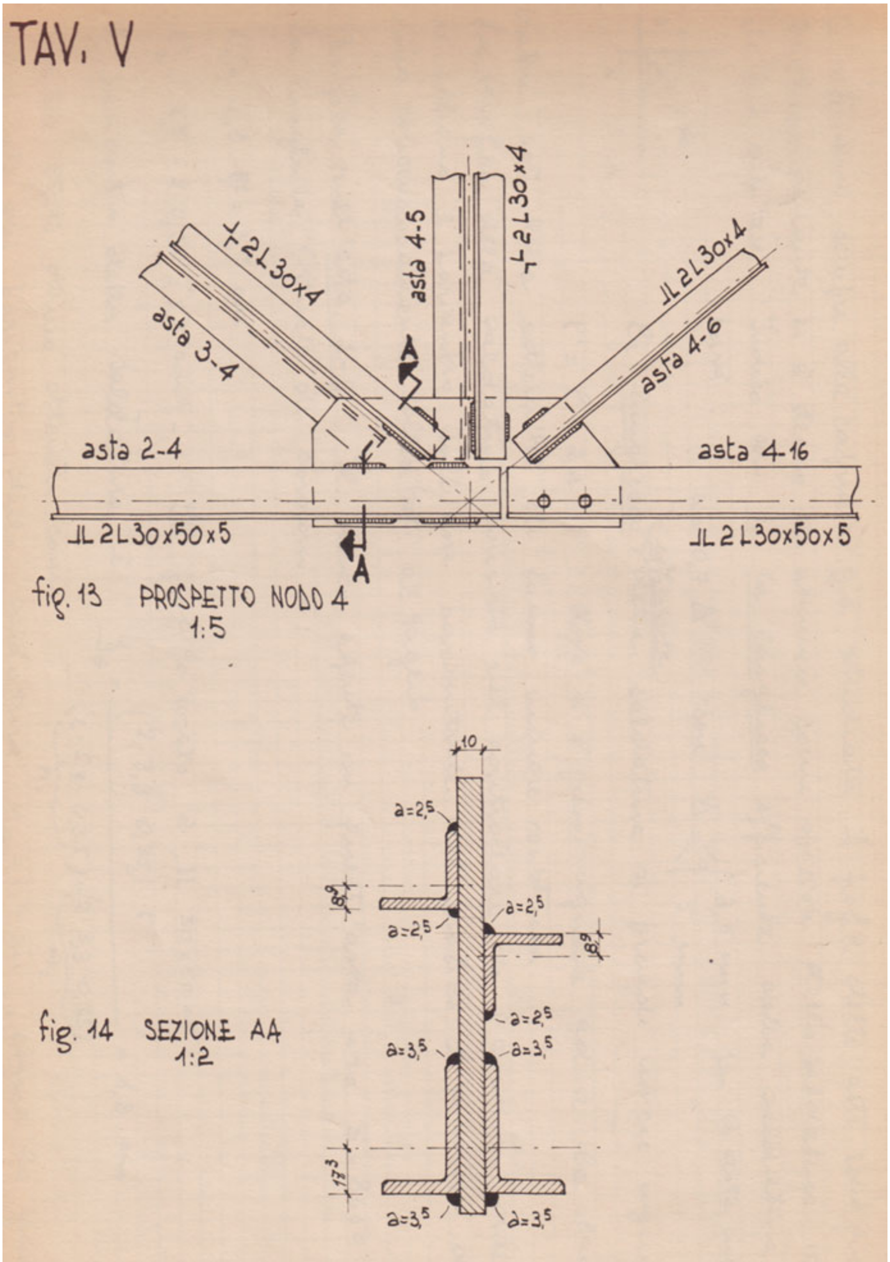


Fig. 7.40 Example of didactic drawing relative to a welded structure (1962)

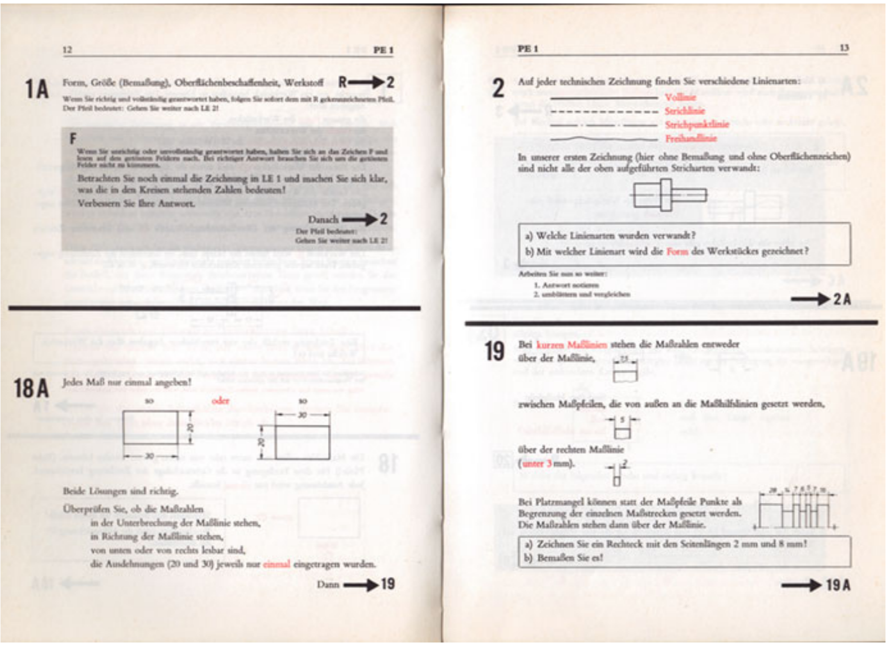
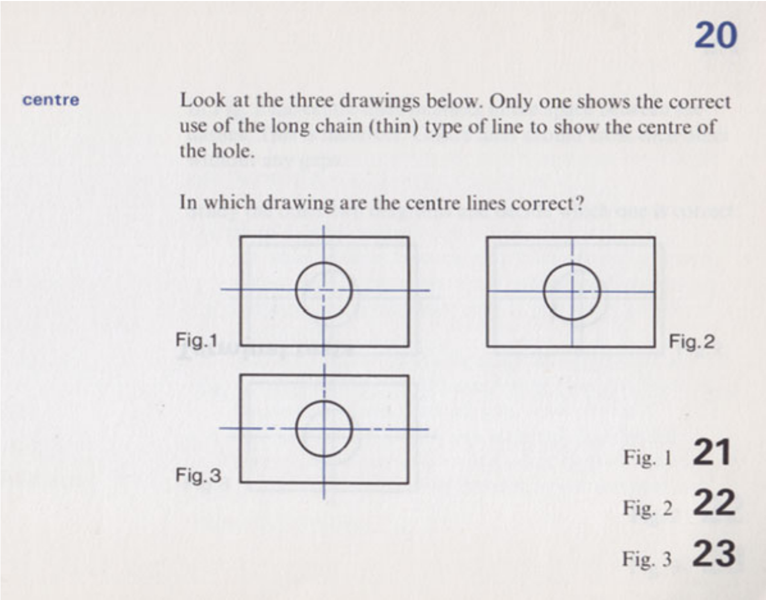


Fig. 7.41 German example of a programmed book

Some means utilized were for example: programmed/individualized learning (Schroeter and Schroeter 1973), e-learning (Fernandez-Jambrina and Pulido 2003), computer-aided instruction, working in groups (Holt 1995; Federighi and Clark 2009; Van der Loos and Ostafichuk 2009), and outline teaching (Hernandez Abad et al. 2003a, b). Figure 7.41 is a German example (Schroeter and Schroeter 1973), Fig. 7.42 an English one (Bristol 1970) of programmed books to teach technical drawing.

Looking at real objects and then sketching them was considered important, until the general application of the computer. Because of the great number of students, some experiments in substitution of real parts with photographs were made (Fig. 7.43) (Rabe et al. 1967; Schneiders and Sappert 1971)

The contents of all courses, and also of courses related to technical drawing, enlarged very quickly. The contents most in demand could be determined through systematic and regular contacts with industries interested in the activity of young industrial engineers. Such contacts were realizable through questionnaires, with the aim of extracting information about what was wanted and how to teach it (Biggioggero and Rovida 1986). An example of such a search is the description of the ability that must be reached at the end of a drawing course. The objective of any technical communication (and a university course is an example of technical communication) could be formalized in terms of "terminal behaviour", i.e. the amount of knowledge that needed to be acquired by the students, which start from some prerequisites that could be called "initial behaviour". The "terminal behaviour" could be described as follows.



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centre

Look at the three drawings below. Only one shows the correct use of the long chain (thin) type of line to show the centre of the hole.

In which drawing are the centre lines correct?

Fig.1 Fig.2

Fig.3

Fig. 1 **21**

Fig. 2 **22**

Fig. 3 **23**

Fig. 7.42 English example of a programmed book

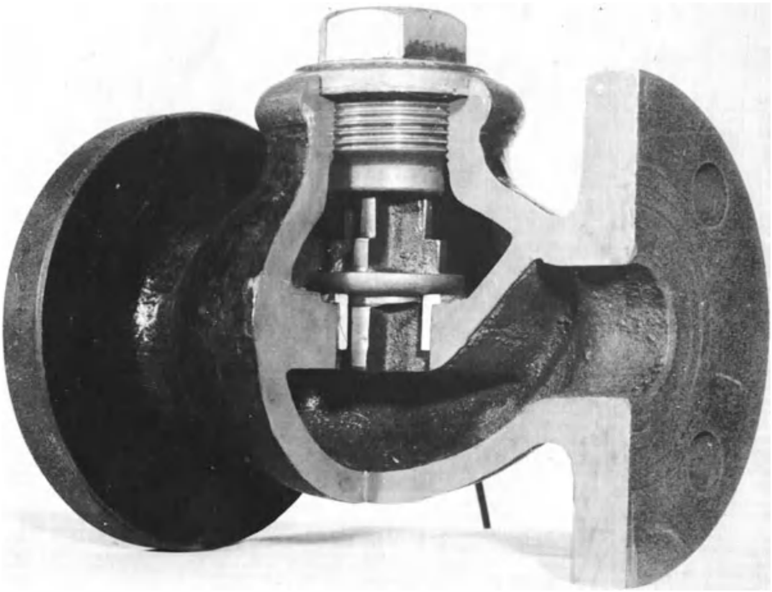

Fig. 7.43 Experiment of substitution of real parts of machines with photographs

The student, after the course, must be able to:

- Express the mechanical function of a simple complex by realizing an assembly drawing;
- Realize the constructive drawings of all parts, i.e. the drawing of each part by the information necessary to the construction, such as forms, dimensions, materials, tolerances, roughness. The parts, if realized by using the above mentioned constructive information, and if assembled, must be able to perform the function mentioned at first point.

The above described abilities must be expressed with freehand sketches and with 3D Modeller Autodesk Inventor.

The contents of drawing courses have tended to involve not only the graphical, but also the design aspects. Some items to be transmitted are as follows:

- drawing standards
- machine elements
- design methods
- technology aspects
- criteria to develop innovative products
- lifecycle analysis
- virtual prototyping

Other aspects to be considered are:

- technical communication (the drawing itself is a communication and the communication is to be considered an integral phase of the design process);
- history of technology (the study of the evolution of technology requires students to read historical drawings and, in addition, as often mentioned in the present book, the historical heritage can be regarded as the basis of modern design);
- tools.

The freehand sketch is still an important drawing tool, while drawing with traditional instruments has virtually disappeared. The most important phenomenon of this period was the diffusion and generalization of applications of the computer, from the first applications with selected students and successively generalized: examples from (Biggioggero et al. 1983; Caputo et al. 1983; Santoro and Schiavone 1986; Milanese and Tosetti 1986; Concheri and Guggia 1993; Concheri and Milanese 1993; Bandera and Zonta 1997) and successive application of hypermedia, virtual reality (Barbero et al. 2003), internet.

The problem of teaching of drawing, taking into account the design aspects, is not easy and can have many solutions. As example, here are mentioned some steps, deduced fundamentally from the experience of the author and some colleagues.

- Learn the drawing standards by realization of a freehand sketch of a simple part and acquisition by the students of the ability to "translate" a three-dimensional object by some two-dimensional views and vice versa (Fig. 7.44).
- Learn the use of a 3D system to model the same parts and self evaluation of the sketch (Fig. 7.45).

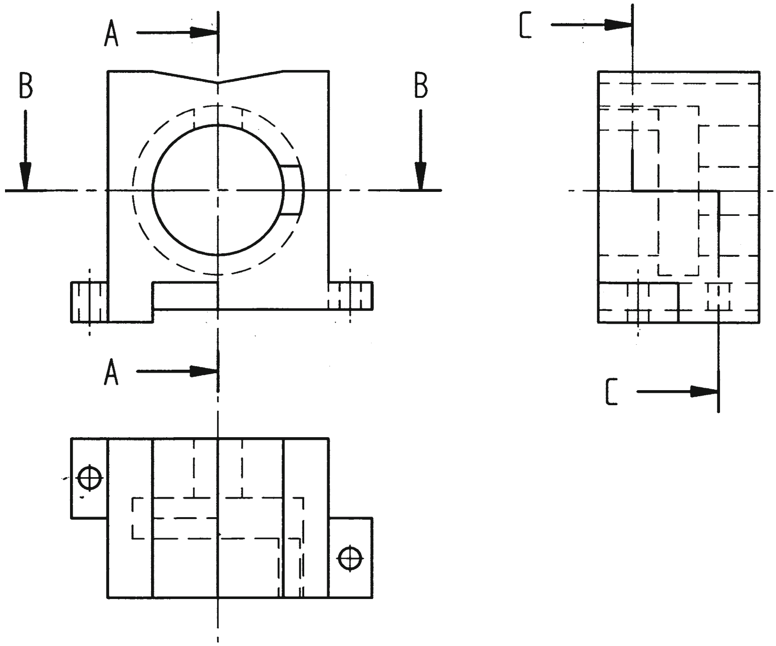

Fig. 7.44 Example of an exercise to learn orthographic projection

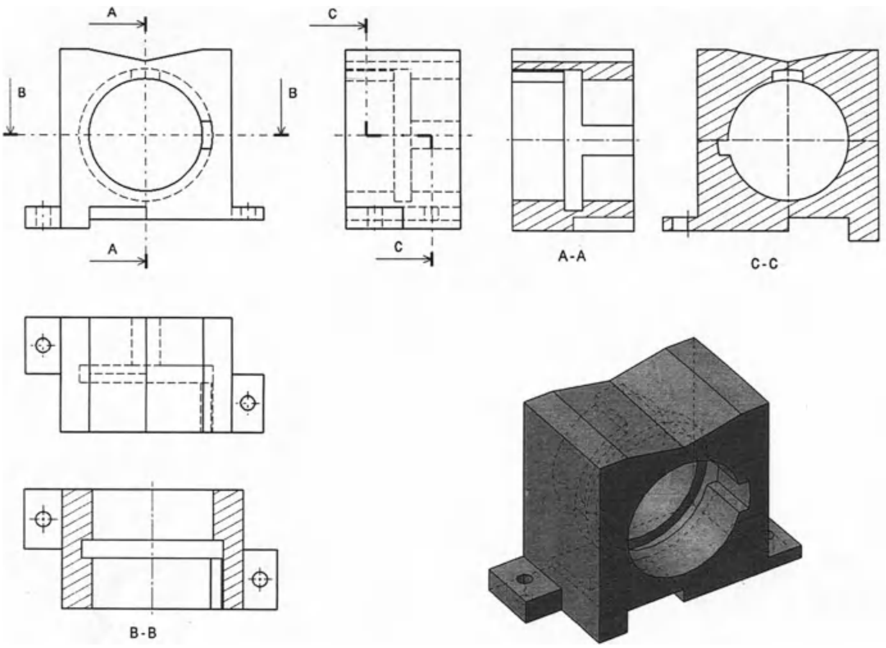

Fig. 7.45 3D modelling and orthographic projections of the same part of Fig. 7.44, to allow self evaluation of the previous exercise

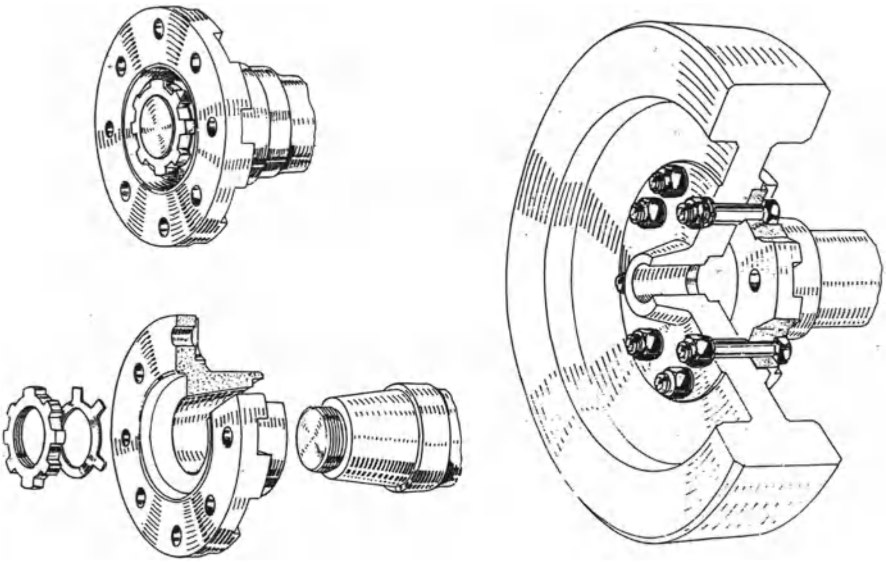

Fig. 7.46 Example of exercises relative to the elements of machines: the two solutions of shaft-hub connections must be represented by assembly drawing and constructive drawings of all parts

- Apply the learned standards, the ability to sketch freehand and to apply a 3D modeller to the critical drawing of some elements of machines.
- Learn the configuration and behaviour of the most common elements of machines: for example, by starting from an axonometric view (eventually exploded), the students must draw the assembly representation and the constructive drawings of all parts, with all constructive information(complete representation with all necessary views and cuts, dimensions, materials, tolerances). In this step, it is interesting to draw again the assembly, by critically changing some constructive solution and evaluating the corresponding changing of the behaviour. In Fig. 7.46 an example relative to two constructive solutions relative to shaft and hub connection. The students must represent, by orthographic projections, the assemblies of the two solutions and, successively, the constructive drawings of the component parts, with the hypothesis that the diameter of a shaft has a value, e.g., of 50 mm and by proportioning the parts.
- General synthesis

These steps correspond to a simulation of a technical office, by considering a real machine. An example is a go-kart considered as a machine. The steps of the work are in Table 7.3 (Galli et al. 2005).

1 Real go-kart
The real go-kart was carefully considered and studied. Some theoretical lessons about automotive engineering (strictly correlated to the go-kart) were recalled. By using methodic design theories, the general function of the go-kart was individuated.

Table 7.3 Steps of the student work

Object	Instruments	Operations
Real go-kart	Methodic design theories	General function
Disassembling of the machine in mechanical groups	Methodic design theories Disassembling devices	General function analysis and component functions individuation
Measuring, machinery survey	Measuring devices (as micrometer) Freehand sketches devices	Freehand sketches and dimensions of all parts of the mechanical group
Modelling	3D-Modeller (Autodesk inventor)	3D-Models of all parts of the mechanical group
Virtual assembling of the mechanical groups	3D-Modeller (Autodesk inventor)	Congruence verifying
Simulation	FEM Software	FEM-Analysis of some parts and proposal of variations
Virtual assembling of the go-kart	3D-Modeller (Autodesk inventor)	Virtual prototype
Real assembling of the go-kart	Assembling devices	Real machine verifying of correct assembling

2 Disassembling of the machine into mechanical groups

The mechanical groups of the machine (recognized in 1) were disassembled, by using disassembling devices. The general function was analyzed as component functions and each of them was linked to the corresponding mechanical group.

3 Measuring and machinery survey

Each student group has studied a specific mechanical group of the go-kart.
The first step of the study is the freehand sketches of all parts of the group, including the fundamental dimensions, determined by direct measurement with a micrometer.

4 Modelling

Each group of students, starting from freehand sketches, has realized the modelling of all parts of the mechanical group. Such operations were realized by using the 3D-Modeller Autodesk Inventor.

5 Virtual prototyping

In this step, the models of all parts of the mechanical group are assembled, with the aim to reach a virtual prototype of the specific mechanical group.

6 Simulation

In this step, starting from the virtual prototype of the mechanical group, a CAE approach was made, by using the FEM Module included in the Autodesk Inventor, with the aim to reach a stress and strain analysis of some significant parts of the assembly.

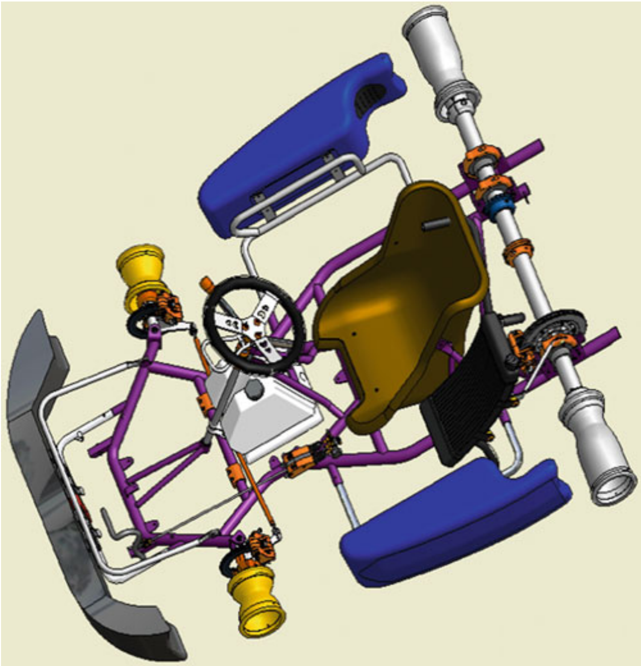

Fig. 7.47 Virtual prototype of go-kart

After critical considerations of stress and strain levels, a proposal of variations was made.

Such variations can regard forms and dimensions.

7 Virtual assembling of the go-kart
By using the same 3D Modeller Autodesk Inventor, the students realize the virtual assembly of all mechanical groups, i.e. the virtual prototype of the complete go-kart. Of course, in these steps, all necessary modifications were made, to reach the congruence of all parts and dimensions.

8 Real assembling of the go-kart
In this last step of the course, the students, by using mechanical assembling devices, realizes the real assembling of the go-kart.

The output of this step is the real machine, in the same initial conditions.

The correct functioning of the go-kart was verified.

Figure 7.47, shows the virtual prototype of the go-kart. The exercise of virtual prototyping can be upgraded by simulating the behaviour of the machine in real use (Fig. 7.48).

Very important is the "real" exercise too: the students have really worked with the machine, with mechanical devices, and have learnt many mechanical operations that can be considered important for an engineer.

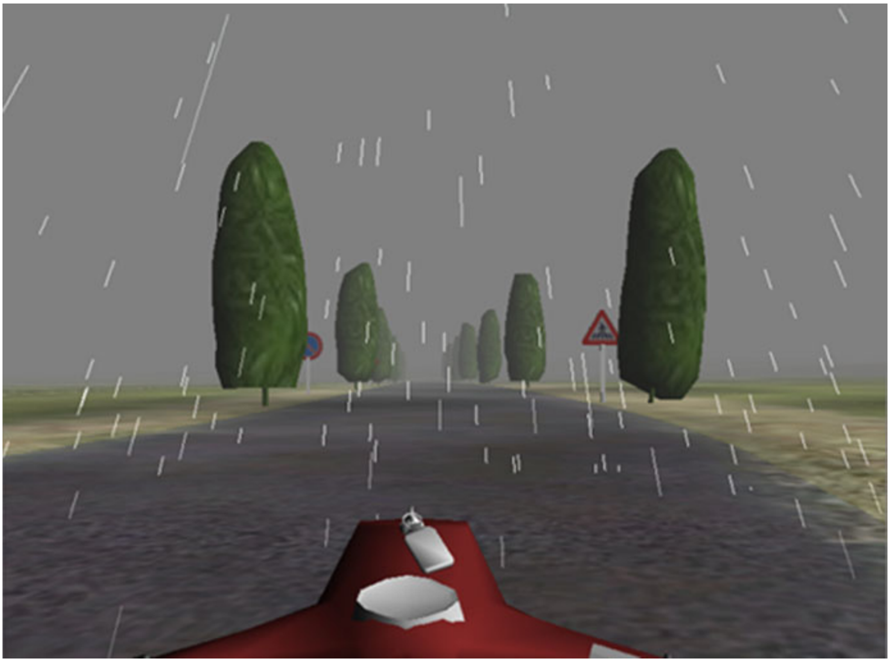

Fig. 7.48 Simulation of the real utilization of a machine

The amount of knowledge acquired by the students encompasses, in this way, many fields that are very important for a mechanical engineer, such as functional analysis, study of real machines and mechanical operations about such machines, freehand sketching, mechanical measurement of dimensions of parts, and use of 3D-Modeler.

The assumed terminal behaviour can, in this way, be considered in very large measure reached.

If wanted and possible, it would be interesting to upgrade the exercise with an application of virtual reality (Viganò et al. 2010).

7.5 Computer Graphics

The creation of computer graphics had a great influence on technical drawing and the manner of teaching it. It became a part of the "informatics revolution". Some fundamental landmarks along the way were:

(a) 1950s : first graphic applications in the military field;
(b) 1962: thesis of Ivan Sutherland "Sketchpad: A man–machine graphical communication system";

Fig. 7.49 Example of deck of cards (1968)

(c) 1968: the first CAD systems;
(d) 1970 Pierre Bezier develops a notation to produce smooth curves;
(e) 1976: Steve Wozniac and Steve Jobs build the first Apple;
(f) 1976: Bill Gates and Paul Allen found Microsoft;
(g) 1981: IBM introduces the PC;
(h) 1983: Autodesk introduces the first P C-based CAD software;
(i) 1984: Apple introduces the Macintosh;
(j) 1980s: the first graphical standards are established;
(k) 1990s: Virtual Reality is invented.

Some publications about first sources and references are Coons 1967; Bézier 1968; Forrest 1968; Armit 1968; Braid 1974; Laning et al. 1973; Riesenfeld 1973; Requicha and Voelcher 1974.

Initially the computer was utilized as a substitute for the pencil but, step by step, the computer assumed complete involvement in all phases of drawing and also of design. Some fundamental creations were:

(a) C G: Graphic created by the computer;
(b) CAD: digital model;
(c) RP: from digital to physical model;
(d) RE: from physical to digital model;
(e) CAM: tools managed by computer;
(f) CAE: simulation from a digital model;
(g) VR: evolution of simulation to interactivity.

Figure 7.49 shows an example of a deck of cards (1968). Figures 7.50, 7.51, 7.52, 7.53, 7.54, 7.55, 7.56, and 7.57, show in chronological order some computer applications to drawing.

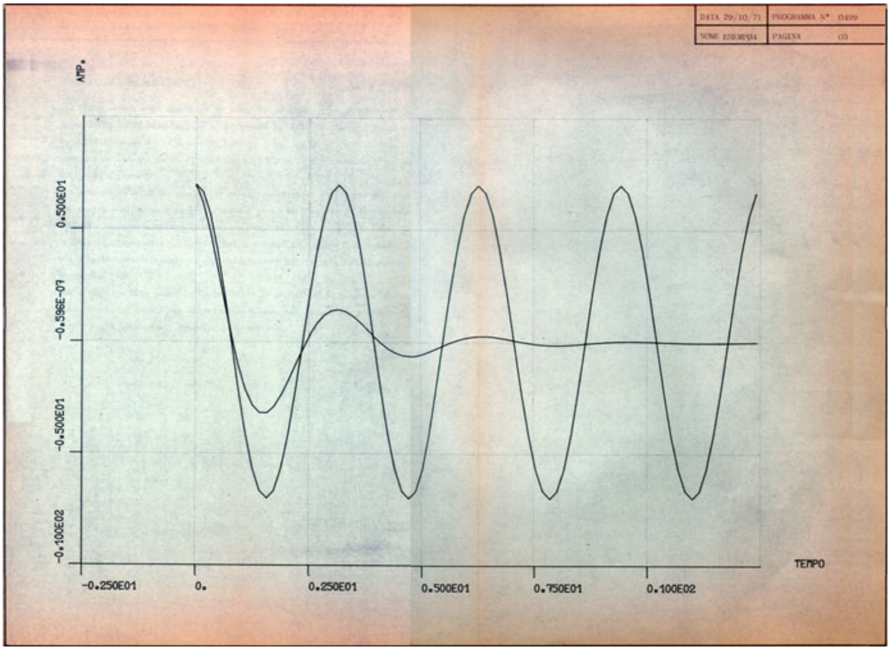

Fig. 7.50 Automatic drawing of curves (1971) (Rovida 1999)

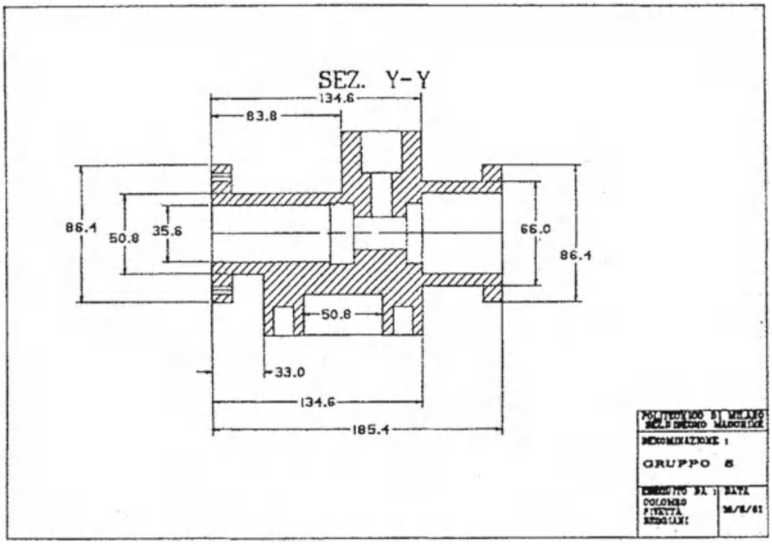

Fig. 7.51 Drawing of mechanical parts (1981) (Rovida 1999)

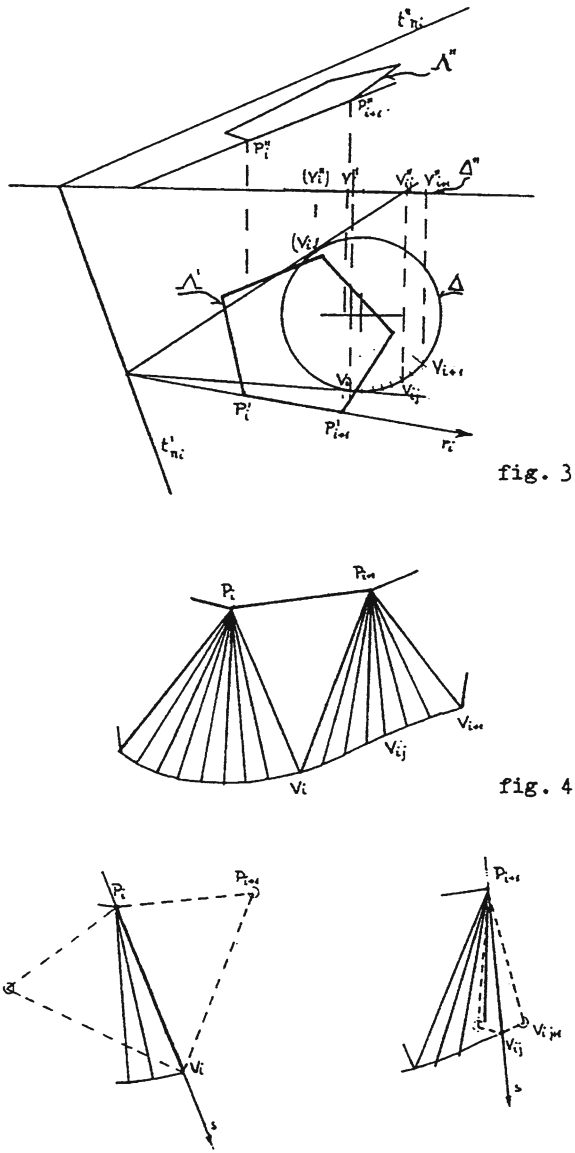

Fig. 7.52 Development of surfaces (1983) (Rovida 1999), (Biggioggero et al. 1983)

7.6 Drawing Instruments

The exposed instruments are represented in the paragraphs and in addition in the Figs. 7.58, 7.59, 7.60, and 7.61 (Brunetti and Rovida 1974).

Some traditional drawing instruments are represented in figs. 7.58, 7.59, 7.60, and 7.61.

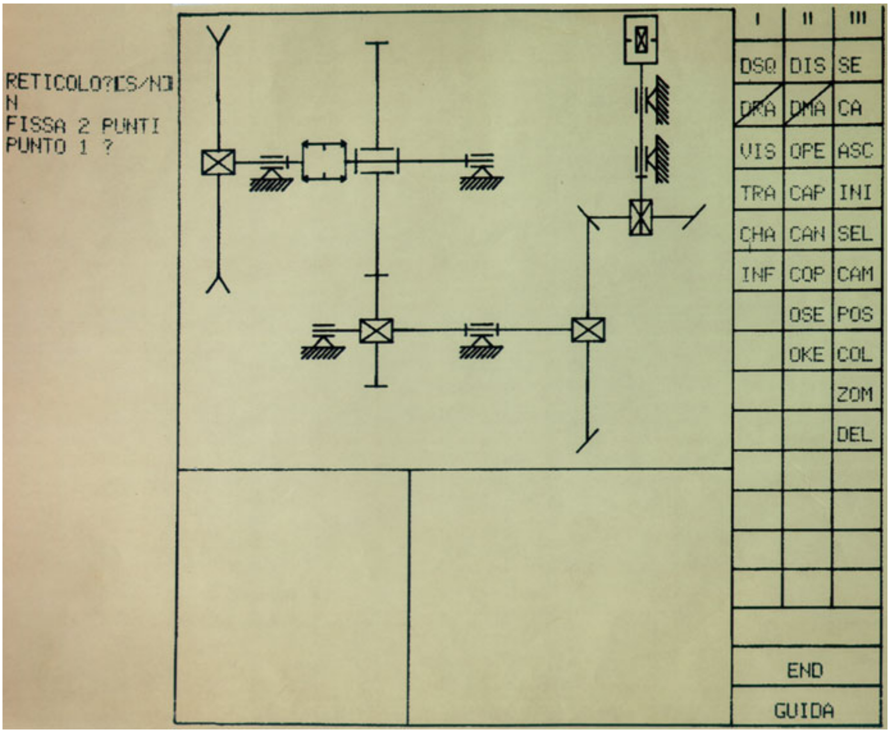

Fig. 7.53 Schematic representation of mechanisms (1985) (Rovida 1999)

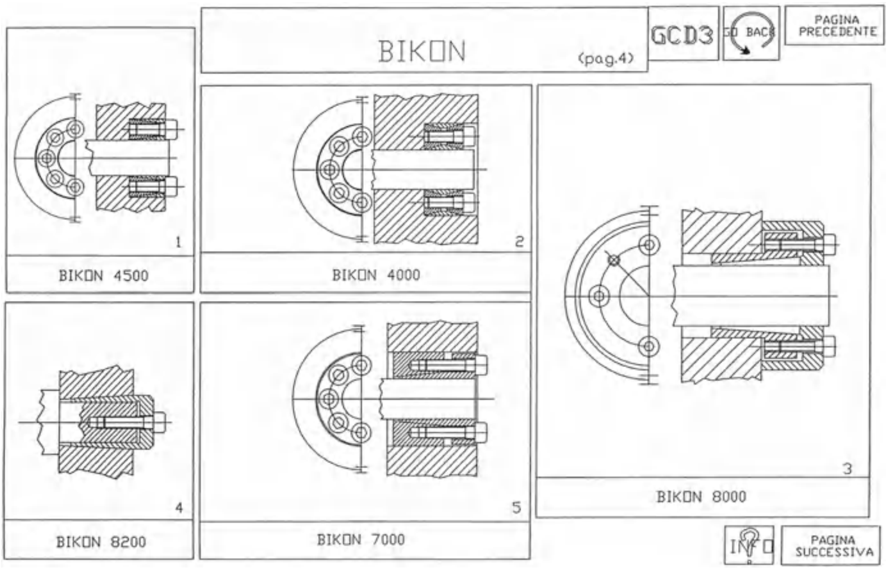

Fig. 7.54 Data-base of mechanical elements (shaft-hub connections) (1994) (Rovida 1999)

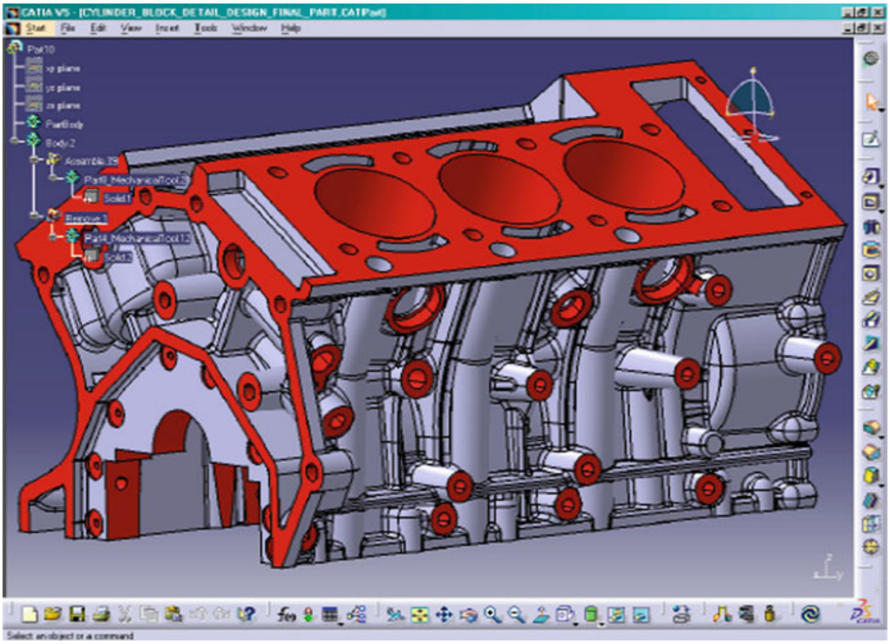

Fig. 7.55 3D model of an engine (2000)

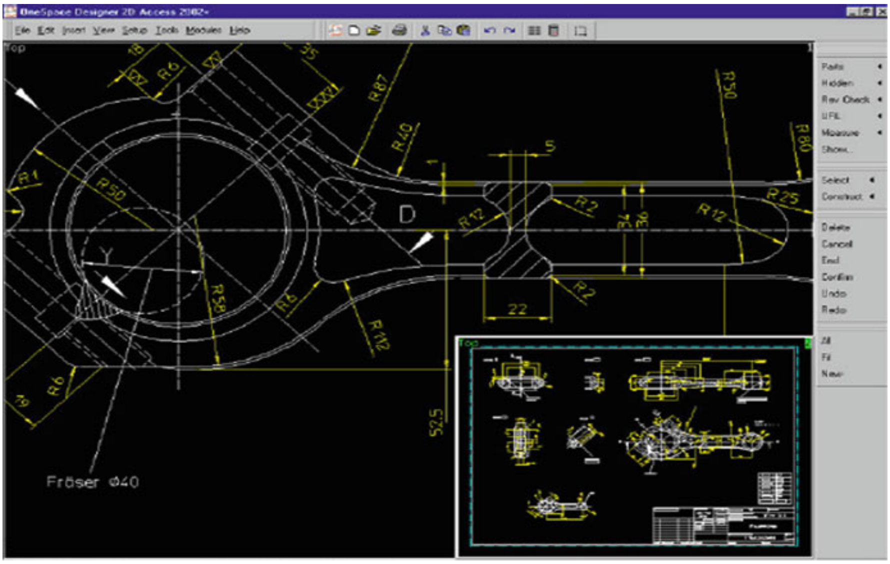

Fig. 7.56 Constructive drawing of connecting rod, realized from a 3D model (2000)

Fig. 7.57 Example of virtual reality, relative to a driving simulator (Viganò et al. 2010)

Fig. 7.58 Drawing pen (1920)

Fig. 7.59 Compass to draw circles with very small radius (principle of the Twentieth Century)

Fig. 7.60 Compass with fixed tips (1920)

Fig. 7.61 Adjustable compass (1940)

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Chapter 8
Archives of Historical Drawings

8.1 Role of Archives of Historical Drawings

Historical drawings, as mentioned in many previous chapters, are one of the most important witnesses of technical realization in past times. Therefore, archives of ancient drawings are the best "photography" of technical development in all times. With an organic collection of historical drawings it is possible to reconstruct the historical evolution of a machine, a mechanism, a device. People in many professional categories would benefit from knowledge of these historical evolutions:

(a) Technicians, engineers and designers, who, through a critical analysis of historical drawings, could search for a source of inspiration for "innovative" solutions;
(b) Technicians operating in standardizations institutions: the old drawings are interesting not only for "what" they are representing, but also for "how" the objects are represented. Some historical drawings could suggest new drawing standards;
(c) Teachers and students: through the critical analysis of historical archives, it is possible to create an historical *forma mentis*, important to recognize origins and to correctly evaluate modern technology;
(d) Historians: the *forma mentis* of historians who are particularly devoted to the evolution of industry can be enriched by studying engineering tools and procedures.

The role of this history has been recognized by such publications as (Dowlen 1997, 2011). In the following paragraphs, some criteria for such studies are proposed, with particular reference to the experience of the author.

E. Rovida, *Machines and Signs*, History of Mechanism and Machine Science 17,
DOI 10.1007/978-94-007-5407-2_8, © Springer Science+Business Media Dordrecht 2013

8.2 Steps to Realize an Historical Archive

The author has previously conducted research on important archives of technical-scientific passenger car drawings (Calabrò et al. 1997a, b, c, 1999; Biggioggero et al. 2003). Past experience has created for design engineers the guidelines of a general methodology to systematically study the historical evolution of specific mechanical constructions.

The choice of a research topic can be made by using one or more selection criteria, such as, e.g. the type of design required, the country of origin, the factory where the mechanism was constructed, a specific period of time, etc.

The usual sources are institutions such as museums, libraries, public or private archives. One key issue is the appropriate choice of relevant sources.

The choice of methodology to classify the materials and the design of the form that will be used is the next step in the research. The general classification form, although designed to satisfy the needs of the specific research that will be conducted, has to comply with the general guidelines adopting in classifying materials in other fields of research. In so doing, it will be possible to input the data to be collected into an integrated database and to manage them accordingly.

The form will include all information useful to describe in detail an historic drawing, i.e. the following elements: author, date, drawing number and title, represented object, types and instruments and accessories used to make it, use of color.

The condition of the drawing at the time it is studied needs also to be documented. Has it been well preserved? Is it complete and readable? What type of damage has occurred and have previous restorations been made? Other information to be added include the name of the company that owned the drawing, its acquisition – if any – by an institution, the marks applied by that institution. Finally, a space has to be provided on the form for the notes that the person who will classify the drawing will deem necessary.

The classification system should be able to differentiate between objects, models, documents, drawings, pictures and patents. Table 8.1 shows a form that includes the most common entries used to classify drawings.

The software programs for managing the classification system should be able to:

(a) Sequentially access data ordering them by form, lists, catalogues, images;
(b) Order the data along content criteria of one or more fields (bottom-up, top-down or personalized order following a list of freely defined values);
(c) Make researches of any kind (linear, correlated, multiple, with operators and omissions) inputting data in any descriptive field;
(d) Visualize the images transferred to a catalogue from which it would be possible to make selections and create sub-catalogues;
(e) Visualize the scaled down image of the technical drawing inside the classification form;
(f) Visualize the technical drawing in full screen, starting either from the catalogue or from the classification form;

Table 8.1 Form with the most common entries to classify historical drawings

General data	1 Number
	2 Date of compilation
	3 Title
	4 Date of execution
	5 Company/author
Formal data	1 Original/copy
	2 Support material
	3 Execution type
	3.1 Free hand/instruments/computer
	3.2 Pencil, ink, print
	4 Dimensions of the drawing
	5 Type of rendering
	5.1 Assembly drawing, detail drawing
	5.2 Rendering (complete, simplified, schematic)
	5.3 Projections (orthographic, axonometric, perspective)
	5.4 Color (yes/no)
	5.5 Scale (1:1, 1:2, 1:2, 5, 1:5, 1:10…)
	5.6 Conditions of the drawing
	5.6.1 No damages
	5.6.2 Limited damages
	5.6.3 Relevant damages
	6 Previous restorations
Key data	1 Object(s) represented
	2 Function(s) performed
Notes	

(g) Print the classification form or part of it;
(h) Print lists based on the research or on the chosen order of data;
(i) Print the technical drawing together with its main data;
(j) Modify, through a password, the existing forms or add new forms;
(k) Import images into new forms;
(l) Export the classification data to other databases or to word processors;
(m) Publish the database, or parts of it, on Internet or on LANs.

The images have to be acquired using the most appropriate technology, to be defined according to the properties of an original document and of the accessibility of the archive in which it is stored. In choosing the reproduction technology, it's to be considered that nowadays the cost of photography is very similar to the digital acquisition of the same image and the final result is more or less the same.

Digital images of very damaged or of barely readable drawings have to be digitally restored. Such techniques "clean" flaws like humidity stains or marks left from workshop use and can rebuild missing parts of the drawing, when those parts are known for sure. The support of technical historians is needed to perform the last activity.

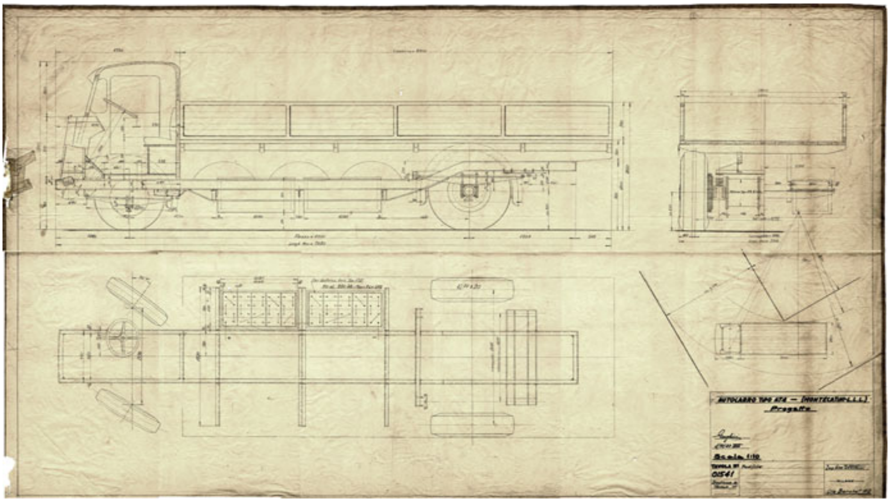


Fig. 8.1 Drawing of the chassis of the truck AT4 –Montecatini L.L.L. constructed by the Italian factory Turrinelli (1940), now conserved in "Fondo Turrinelli" ("Turrinelli Foundation") in Istituto Lombardo Accademia di Scienze e Lettere (Lombard Institute of Science and Literature) in Milan. The drawing has some evident damages

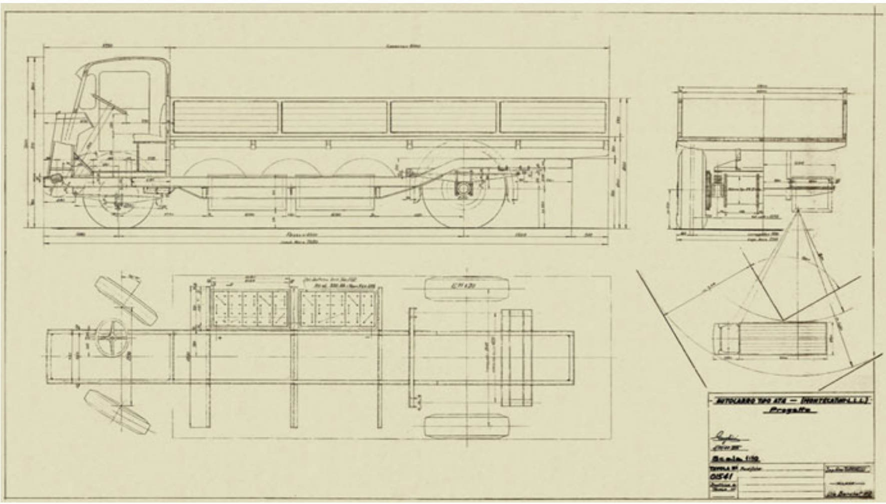


Fig. 8.2 The drawing of Fig. 8.1 after informatics restoration

Figure 8.1 represents a truck chassis from the "Fondo Turrinelli" ("Turrinelli Foundation") in Istituto Lombardo Accademia di Scienze e Lettere (Lombard Institute Academy of Science and Literature) in Milan with some damages. At this Institution, founded by Napoleon in 1797, the author has organized an archive of drawings, documents and books relative to the history of the automobile (Gatti and Robbiati Bianchi 2008).

In Fig. 8.2, however, is the same drawing after informatics restoration.

8.3 Examples Applied to Car Suspensions

8.3.1 General Considerations

The steps described above are very general and could be applied to any technical field. The author, in cooperation with some colleagues, has applied the general method to realize an archive of images (drawings or photographs) of car suspensions. This archive will be described and the possibilities of use by engineering designers will be presented.

8.3.2 Structure of the Database

The general function F of a passenger car can be described as "allowing the wheels to move vertically, while keeping unchanged the vertical position of the bodywork".

Several component functions derive from the general one:

F1 = wheels-body kinematic link
F2 = elastic reaction
F3 = dampening of the oscillations
F4 = body roll control
F5 = pitch control
F6 = set- up of vertical position

Any suspension design S can be considered as the sum of the design solutions Si in relation to the various component functions Fi:

S1 = transverse double wishbone
S2 = cylinder helical spring
S3 = telescopic hydraulic damper
S4 = 0
S5 = 0
S6 = 0

Figure 8.3 represents an example of this approach, applied to a front suspension of an Italian car of 1950.

The idea of applying the general methodology that was just described to the historical evolution of passenger car suspensions derives from the author's personal interest in this subject and from the large availability and accessibility of drawings, images and documents. The suspensions that were studied cover the full history of automobile design, from the early development of the passenger car to the present time, as well as all manufacturers and countries of origin.

The sources are public and private archives (belonging to Institutions and to car manufacturers), books, technical magazines, museums and archives and company documents. Among those archives are the Alfa Romeo Historical Archive, the Istituto

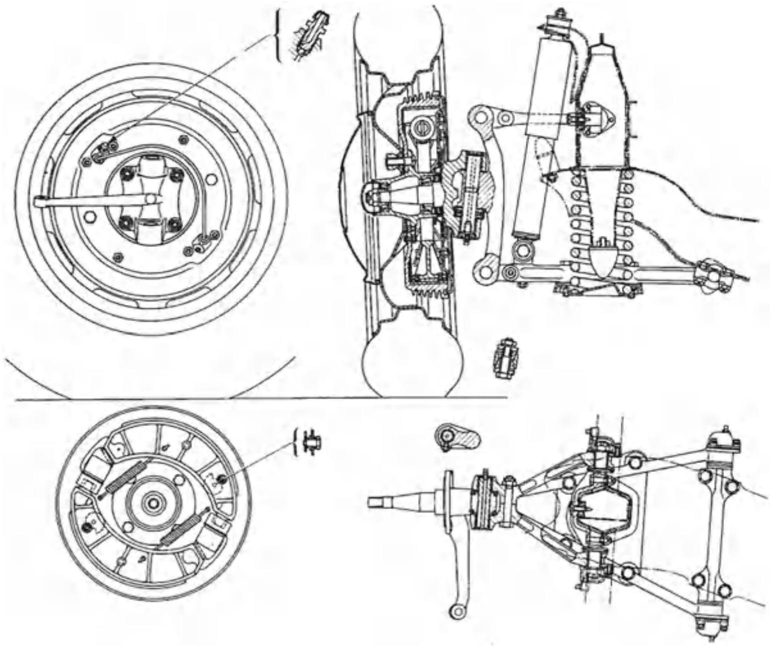


Fig. 8.3 The component functions of a suspension highlighted on an Italian car suspension of 1950

Lombardo Accademia di Scienze e Lettere (Lombard Institute of Sciences and Literature), and the Library of the Mechanical Departement of Politecnico di Milano, which owns full collections of the most important mechanics magazines.

After having defined the logical process of classification and the software support prototype, the collection of suspension cases started; each was digitally classified and acquired.

The archive contains about 500 passenger car suspension schemes; the historic ones were collected from Institutions and libraries, the modern and contemporary ones from car manufacturers.

The images in the archive show suspensions adopted in production cars, in racing cars, in prototypes that were never produced or in patents, from 1900 to 2002.

This database is the largest digital collection of suspension schemes ever made. The schemes were chosen for their significance in the evolution of suspension design, for their innovativeness, and for their use in passenger car production.

The database development started with the choice of its structure and contents. Elements useful for classifying the images were acquired with a preliminary study. Fields were created by selecting the elements that had been identified. A field is the basic unit for inputting a specific type of data or for visualizing the results of calculations made in other fields.

The input of actual data allowed verification of the usefulness of the form.

Table 8.2 presents the data for inputting and retrieving.

Table 8.2 Suspension's data for inputting and retrieving

1 General car data
1.1 Make
1.2 Type
1.3 Year
1.4 Country
2 General suspension data
2.1 Position
2.1.1 Front
2.1.2 Rear
2.2 Wheels
2.2.1 Driving
2.2.2 Idle
3 Linkage elements
3.1 Live axle
3.1.1 Linked with leaf spring
3.1.2 With two radius arms and two transverse arms
3.1.3 With two radius arms and Panhard rod
3.1.4 With two radius arms and upper triangle
3.1.5 With two radius arms and Watt linkage
3.1.6 With two radius arms and Scott-Russell mechanism
3.2 Independent wheels
3.2.1 Sliding pillar
3.2.2 Transverse links
3.2.2.1 Simple
3.2.2.2 Double
3.2.3 Radius arms
3.2.3.1 Simple
3.2.3.1.1 Pushed
3.2.3.1.2 Pulled
3.2.3.2 Double
3.2.3.2.1 Pushed
3.2.3.2.2 Pulled
3.2.3.2.3 One and one
3.2.4 Semi-trailing links
3.2.4.1 Simple
3.2.4.2 Double
3.2.5 McPherson
3.2.6 Multilink
4 Semi-independent wheels
4.1 U-shaped
4.2 H-shaped
4 Elastic elements
4.1 Helical springs
4.1.1 Shape of helix
4.1.1.1 Cylinder
4.1.1.2 Cone

(continued)

Table 8.2 (continued)

4.1.2 Wire section
4.1.2.1 Round
4.1.2.2 Rectangular
4.1.3 Position
4.1.3.1 Single link
4.1.3.2 Upper link
4.1.3.3 Lower link
4.1.3.4 Upright
4.1.4 Direction
4.1.4.1 Vertical
4.1.4.2 Canted
4.1.4.3 Horizontal, fore-aft
4.1.4.4 Horizontal, transverse
4.2 Torsion bars
4.2.1 Section
4.2.1.1 Round
4.2.1.2 Rectangular
4.2.2 Direction
4.2.2.1 Fore-aft
4.2.2.2 Transverse
4.2.3 Position
4.2.3.1 Single link
4.2.3.2 Upper link
4.2.3.3 Lower link
4.3 Leaf spring
4.3.1 Number of leaves
4.3.1.1 One
4.3.1.2 Several
4.3.2 Direction
4.3.2.1 Fore-aft
4.3.2.2 Transverse
4.3.3 Function
4.3.3.1 Only elastic function
4.3.3.2 Elastic and link function
4.3.4 Set-up
4.3.4.1 Upper main leaf
4.3.4.2 Lower main leaf
4.3.5 Shape
4.3.5.1 Semi-elliptic
4.3.5.2 Elliptic
4.3.5.3 ¾ of ellipse
4.3.5.6 ¼ of ellipse
4.3.6 Link to mainframe
4.3.6.1 Hinge/hinge
4.3.6.2 Hinge/rod
4.3.6.3 Hinge shoe

(continued)

Table 8.2 (continued)

4.4 Other metallic springs
4.4.1 Type
4.4.2 Shape
44.3 Position
4.5 Pneumatic springs
4.5.1 Type
4.5.2 Shape
4.5.3 Position
5 Dampers
5.1 Type
5.1.1 Mechanical
5.1.2 Telescopic, hydraulic
5.1.3 Rotating, hydraulic
5.2 Direction
5.2.1 Vertical
5.2.2 Canted
5.2.3 Horizontal fore-aft
5.2.4 horizontal, transverse
6 Anti-roll elements
6.1 Type
6.1.1 Mechanical
6.1.2 Hydraulic
6.2 Notes
7 Anti-pitch elements
7.1 Type
7.1.1 Through the shape and position of the links
7.1.2 Specific, mechanical
7.1.3 Specific, hydraulic
8 Levelling elements
8.1 Type
8.1.1 Hydraulic
8.1.2 Pneumatic
8.1.3 Mechanical
8.2 Notes
9 Control elements
9.1 Type
9.1.1 Level control
9.1.2 Damping control
9.1.3 Roll control
9.1.4 Stiffness control
9.1.5 Pitch control
9.1.6 Rear steering control
9.2 Type of regulation
9.2.1 Step-by-step
9.2.2 Continuous
9.3 Action
9.3.1 Direct
9.3.2 Automatic

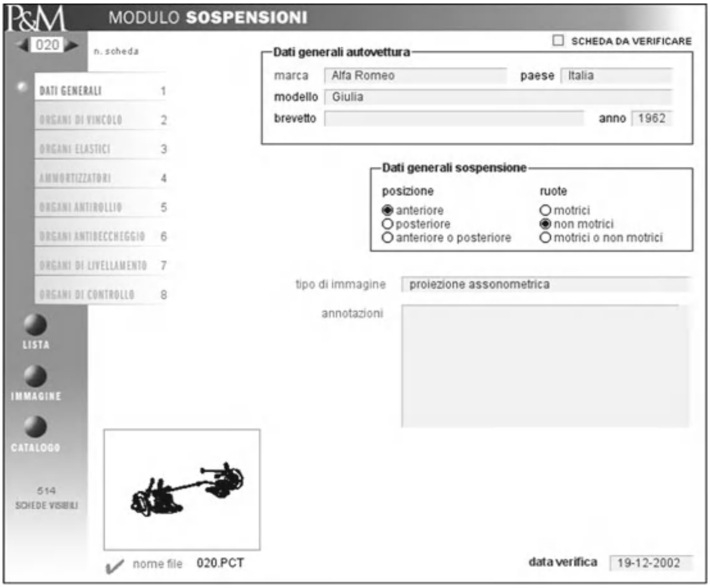


Fig. 8.4 Form for inputting and retrieving the suspension's data

The database, which is accessible and upgradable, is based on a multiplatform software that manages data and can visualize images with powerful research tools. The software has modules for inputting (Fig. 8.4) and for visualizing the images (Fig. 8.5).

These modules allow us to input, retrieve and visualize:

(a) General data on the suspension (when it was designed, built, manufacturer, general car data, general suspension data);
(b) Formal data on the original or the copy of the drawing that is classified (orthogonal projections, axonometric projections, cutaway drawing, photography or drawing);
(c) Specific data that describe the design solution (linkage elements, elastic elements, dampers, and so on);
(d) Data on the condition of the drawing;
(e) Images of the design solutions, scaled-down inside the classification form and in the catalogue, and scaled up.

The modules for inputting and retrieving the data are linked, to make easier the input and visualization of data, which can be done with several criteria and levels of analysis.

The database can be updated by adding new forms that describe suspensions, with their image.

The above described archive is also available in (Conferenza Presidi della Facoltà di Ingegneria).

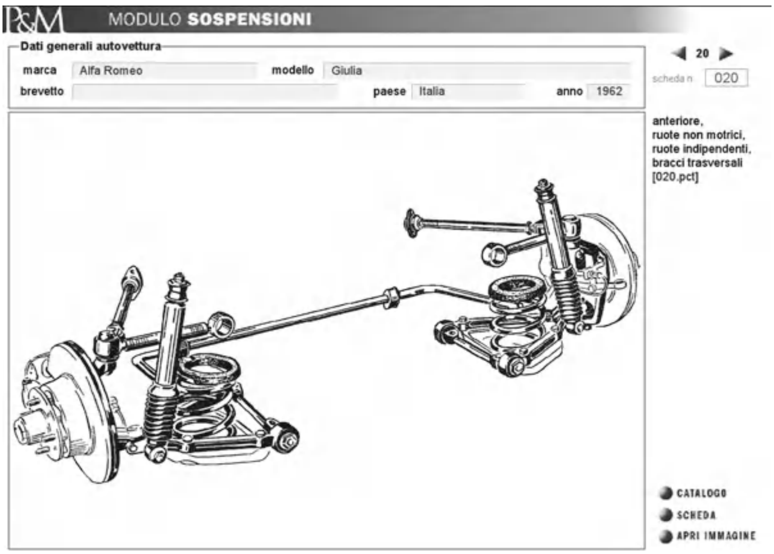


Fig. 8.5 Module for visualizing the scaled-up image

The above described criteria for realizing archives contains a certain difficulty. The author and some colleagues are starting to realize a more simple database organized with a set of Excel sheets.

The aim of such a database is the realization of a catalogue of functions and of constructive solutions to perform each function. The inspiration of this database is the well-known catalogue CREAX (creativity for innovation). The following function representation schema has been derived:

<VERB><NOUN><PREDICATE>

where the Predicate is composed by two elements:

<PREDICATE> = <PREPOSITION> + <NOUN>

and its main aim is to represent the functional environment, so as to say where the solution has to accomplish the action described by the <Verb> + <Noun> part of the construct.

This additional information could be regarded as a non-mandatory element to describe a generic function, since it was developed as a tool to help designers to overcome their “psychological inertia” and therefore to find innovative solutions even in the very first stages of the design process. In other words, in order to guarantee them as much freedom as possible and make this approach more flexible, the possibility is included to search for all the solutions that accomplish the function described by a given <Verb><Noun> pair, independently from the environment.

Verb		Object		Environment		Characteristics
Move	→	Solid	→	In Liquid	→	
			→	On Liquid	→	

Fig. 8.6 Function catalogue

Picture	Name	Date	Author	Historical Comments	Structure	Behavior	Keywords	Input flows			Output flows		
								E	M	S	E	M	S

Fig. 8.7 Constructive solutions catalogue

To better illustrate this, let us consider a public transportation system as an example. The more general and abstract representation of the main function can be formulated as <move><solid>. A designer (who usually operates in that field) would automatically add (maybe implicitly) the <on><solid> specification, since he/she has already in mind the more common solutions such as ground vehicles (trains, subways, buses …). In this way, several other possible solutions are discarded a priori. This limitation can be overcome following the above introduced procedure, in which a designer searching for a solution becomes at least aware of other possible solutions.

Figure 8.6 shows a sample catalogue of functions with the following items:

(a) List of verbs
(b) Object of the verb
(c) The environment where the verb action takes place
(d) Other specific characteristics, like constructive aspects, involved physical phenomena, …

The starting point of the proposed database is a menu with a list of functions stored by means of the above introduced syntax (Fig. 8.6). Each of these functions has then been linked to all the corresponding solutions. Besides picture, structure and behavior, several other fields have been added. In particular, two additional fields have been introduced to store input and output flows of each solution. Each of these two fields has been subdivided in three sub-fields, according to their classical subdivision in material, energy and signal.

The structure of the archive of solutions is depicted in Fig. 8.7: the solutions are collected with Picture, Name, Date, Author (and/or manufacturer), some Historical

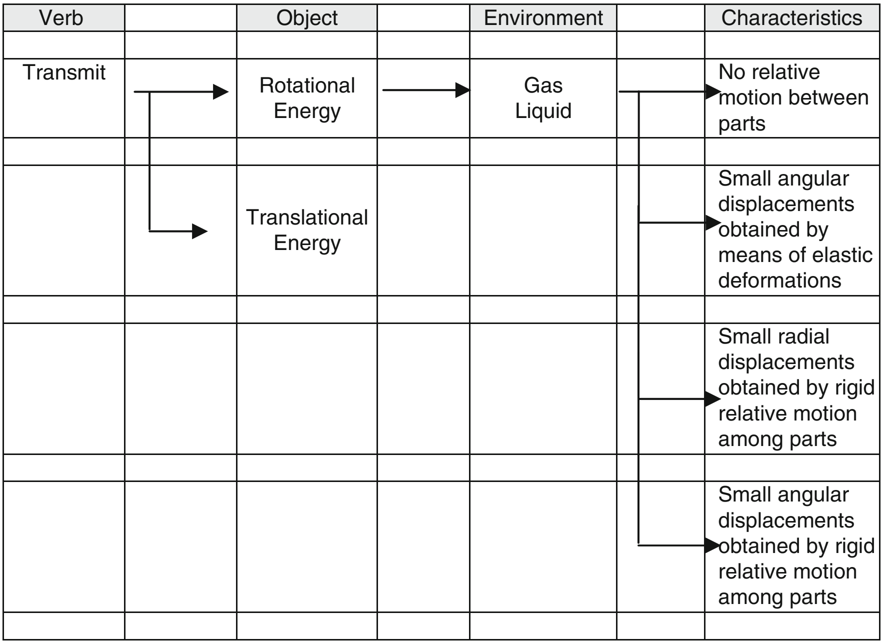


Fig. 8.8 Sample function representation in the function catalogue

Comments, Description of Structure (how the solution is realized and configured), description of Behavior (how the solution behaves to perform the function), some key-words and Input and Output flows (Energy, Material and Signal).

The function <Transmit><Rotational Energy> is used as an example (Fig. 8.8).

According to the above introduced function representation schema, an environment can be specified. Roughly speaking, three main environments can be considered: solid, liquid and gas. Obviously, this definition can be greatly improved and enriched by considering also some characteristics (temperature …) of the environment itself. In the following, gas and (non-corrosive) liquid environments will be considered.

Figure 8.9 shows some of the retrieved solutions querying the database for this function.

The columns containing input and output flows of the solutions of Fig. 8.7 have been omitted, since in these solutions the only flow is rotational energy (power loss due to relative sliding between couplings parts are assumed to be negligible).

Other solutions may have other flows; a hydraulic clutch, for example, has also an input flow of hydraulic energy, and an output flow of thermal energy (power loss is not negligible).

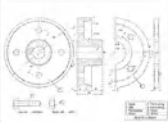
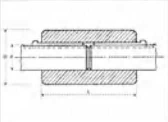
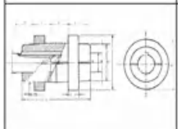
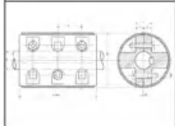
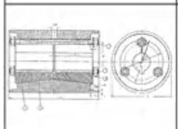
Drawing	Name	Inventor	Year	Country	Historical notes	Description	Operation
Rigid couplings		Rigid couplings are mechanical components, usually made of cast iron with a relatively simple design, aimed at connecting the ends of two rotating shafts (coaxial and perfectly aligned) in order to transmit a torque from a shaft to the other.					
	Flanged coupling					The coupling between each disk and its shaft is made using a key or by mean of a forced coupling, generally H7r6. The number of bolts (generally 4 to 8) is defined upon the size of the disks.	The force transmission between the two disks is achieved by mean of the friction between the two contacting surfaces, kept togheter by a series of bolts.
	Sleeve coupling					This kind of coupling is based on a cast iron cylinder, coaxial with both shafts and fit to them using a key, slightly oblique. Hammering the head of the key it is possible to force the coupling thus trasmitting torque by mean of the friction between the cylinder and the shafts. The coupling is generally protected by a steel laminate.	Torque is transmitted from the primary shaft to the cylinder and then to the secondary shaft.
	Ring sleeve coupling		First half XIX century		It is very difficult to indentify the inventor and the first usage of this type of coupling, due to its very simple behaviour. The first wide-scale usage of them took place in the first half of the XIX century, during the first industrial revolution, when the necessity to connect the various shafts of complex machines brought to their adoption	In this case the sleeve is composed by two semi-cylindrical shells with conical external surfaces with a slope of 1:40 to 1:25. The shells are clamped on the two shafts to be connected by two steel rings (plus, in general, fitting keys). The internal surfaces of the rings are conical with the same slope of the outer surfaces of the shells.	Torque is transmitted from the primary shaft to the cylinder and then to the secondary shaft.
	Shell coupling					The coupling consists of two shells, usually made of cast iron, which are tightened on the shaft by bolts, adding keys for high torques. The cylindrical shells are hollow to host the heads of bolts and nuts. The joint is protected by a steel laminate.	Torque is transmitted from the primary shaft to the cylinder and then to the secondary shaft.
	Sellers coupling					The Sellers coupling summarizes the advantages of the rigid joints previously reported. It consists of a cast iron sleeve having a bi-conical inner surface with a slope of about 12°. Inside the sleeve there are two cast iron cones (compasses), cut along an axial plane and fit onto the shafts by mean of keys.	The torque is transmitted from the shaft to the compass, from this to the sleeve, then to the second compass and finally to the second shaft, by mean of the friction between the contacting surfaces, enhanced by the tightening of bolts.

Fig. 8.9 Solution archive example (some columns have been omitted) [Rosa et al. 2011]

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Chapter 9
The Critical Observation of Historical Drawings

The archives of historical drawings represent the complex of all realized constructive solutions in all technical fields. Therefore, the complex of all historical drawings represents the database of all human constructions and can be utilized to know and to study, from several points of view, the evolution of technology that is the basis of applied scientific research as we know it today.

On the basis of these facts, some general conclusions can be made, that are hereafter presented and organized according to the relevant professional categories.

9.1 Technicians, Engineers and Designers

Technicians, engineers and designers can benefit from a critical observation of our historical heritage. In Chap. 2 it was described how, sometimes, a historical heritage can be considered as an anticipation of innovation. Starting from this observation, a critical observation of historical solutions to scientific problems can be considered as a heuristic method. The author, together with some colleagues, has developed several heuristic design methods based on a critical analysis of databases in which our historical heritage is stored; the main ones are summarized in this section.

9.1.1 Abstraction

The logical schema of this procedure has been derived from the TRIZ general schema (Fig. 9.1) (Michalewicz and Fogel 2000; Altshuller 1996; Orloff 2002).

One of the TRIZ problem-solving strategies consists in generalizing a given problem, and in finding a general solution to a more general problem (instead of searching for a specific solution for a specific problem). Only after these two steps have been completed can the general solution be "adapted" to the specific problem.

E. Rovida, *Machines and Signs*, History of Mechanism and Machine Science 17,
DOI 10.1007/978-94-007-5407-2_9, © Springer Science+Business Media Dordrecht 2013

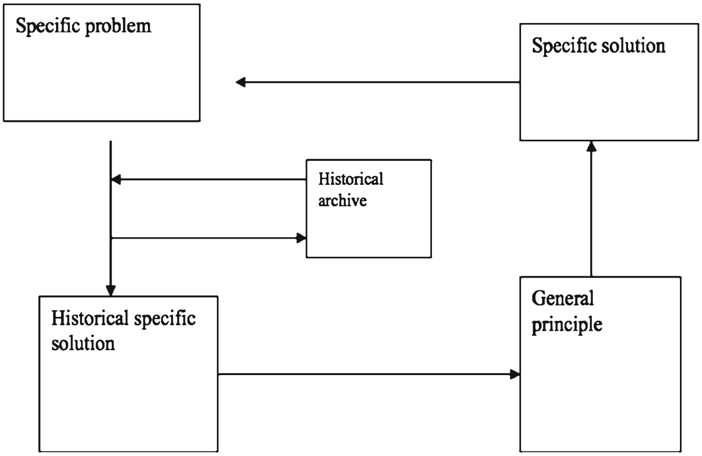


Fig. 9.1 General schema of the "abstraction method" to develop "new" solutions from the historical heritage

In this way, the designer can more easily overcome the psychological barrier of his experience. The problem-solving approach based on a designer's personal experience is often followed, but it will can easily lead to "ancient" solutions, without innovation. An archive of historical solutions can help the designer to formalize and generalize a specific problem: a search in this archive can guide the designer to the individuation of many past specific solutions and make easier the individuation of the underlying general principles, and the related generalization of the problem.

As an example, it is possible to consider the following function: change the height of a car body with suspension with torsion bars, by using only mechanical devices. This can be considered as the specific problem. Instead of immediately searching for a principle (or a constructive solution) able to perform such a function (i.e. to solve such a problem), it is possible to explore the archive of historical solutions. In this case, the considered archive is the collection (Biggioggero et al. 2003) of historical suspensions, realized by the author in cooperation with some colleagues. In this archive was found the German patent (1940) represented in Fig. 9.2. This patent is relative to a mechanism constituted by a quarter leaf spring 37, acting on the upper arm 20 of the suspension. The fixed point of the leaf spring to the frame can be moved, by lever 38 actuated by the nut 39, displaced by the rotation of screw 40. This device, in this way, through a rotation of the wheel 25 can move symmetrically the two nuts 39 and realize a variation of the height of the car body.

Starting from the above described analysis of the historical specific solution, a general principle can be derived: vary the connecting point of the spring to the frame.

According to the general problem, the displacement of this point has to be obtained by means of simple mechanical systems.

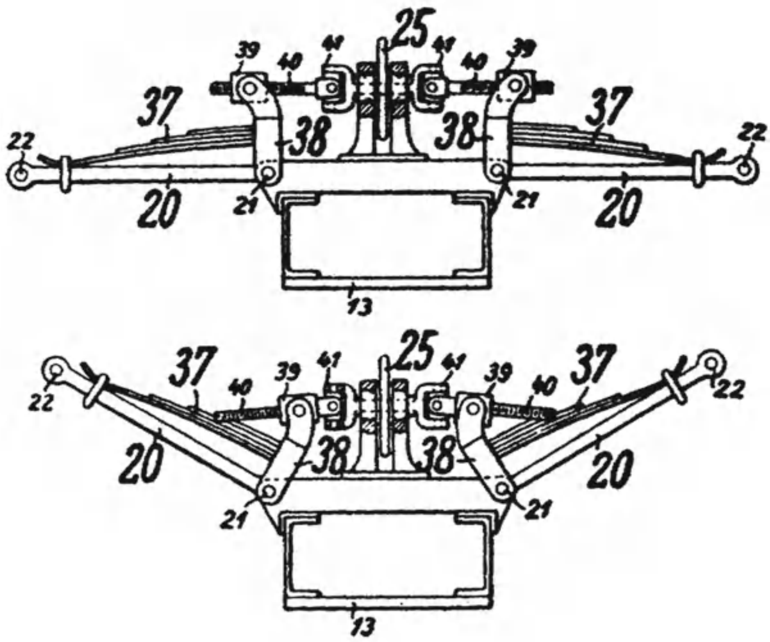


Fig. 9.2 German patent (1940) relative to a mechanical device able to change the height of a car body

In order to find this kind of solutions, the historical archive of car suspension was explored, analyzing the archive's structure: the factory, the year and the constructive solutions are the keys to access to the archive

Figure 9.3 represents the three ways to realize the general principle in the cases of suspension with leaf spring, torsion bar, or helical spring.

The abovementioned archive of suspensions can be considered as search-space factory-year-constructive solutions; such a space can be sectioned by planes corresponding to the given constructive solutions (Fig. 9.4).

In the present case, the archive was sectioned with planes corresponding to the solution *longitudinal torsion bars, transversal arms*. In Figs. 9.5, 9.6, 9.7, 9.8, 9.9, 9.10, 9.11, 9.12 and 9.13, some found examples are shown: such cases can be utilized as an inspiration source to apply the general principle and to propose the wanted specific solution.

Some of the above mentioned cases are not very clear and are difficult to understand, but others can be sources of interesting ideas for the solution of the starting point, i.e. the specific problem. Particularly, the drawing of the suspension in Fig. 9.13 clearly shows the little arms, actuated by bolts, to rotate the fixed end of bar to the frame. This historical idea can be upgraded, taking into account the modern context, with a system able to permit an adjustment in a very simple and comfortable way. A possible modern solution, derived from the historical heritage is represented in Fig. 9.14 (Arona 2003).

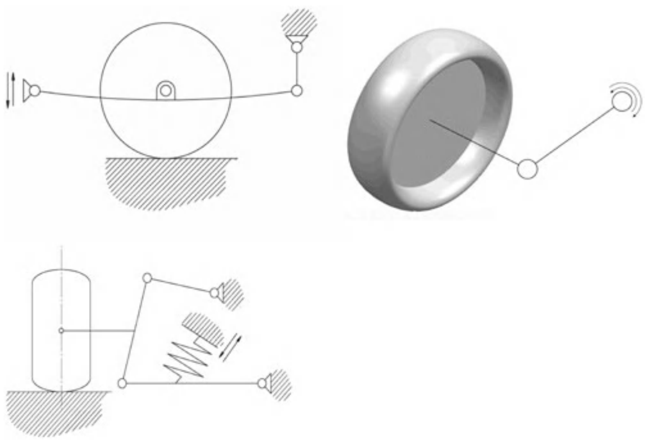


Fig. 9.3 Application of the general principle (i.e. vary the connecting point of the spring to the frame) in the cases of suspensions utilizing, as elastic element a leaf spring, a torsion bar, a helical spring, respectively

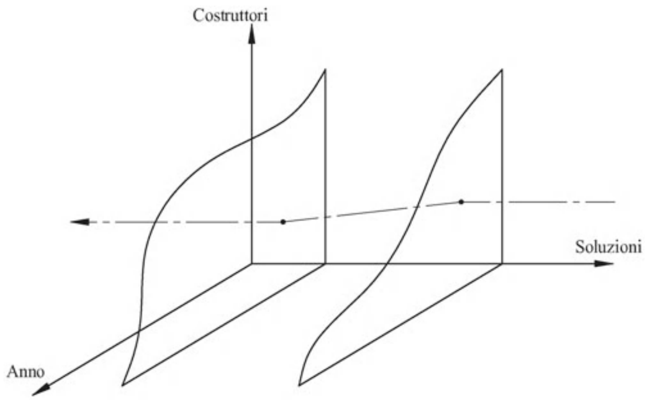


Fig. 9.4 Section of the plane factory-year-constructive solutions, with planes corresponding to the considered solution

The fixed end of the bar can rotate through a crank mechanism, actuated by a screw-nut couple. The rotation of the screw (with opposite threads to the extremities) by an electric motor, realize the symmetrical displacements of the two nuts, that, through the crank mechanisms, realize the wanted rotation and, consequently, the change of set-up of suspension arms and the change of height of car body.

By following a similar logical schema, in the case of suspension with a helical spring, the solution of Fig. 9.15 can be proposed (Junod 2001).

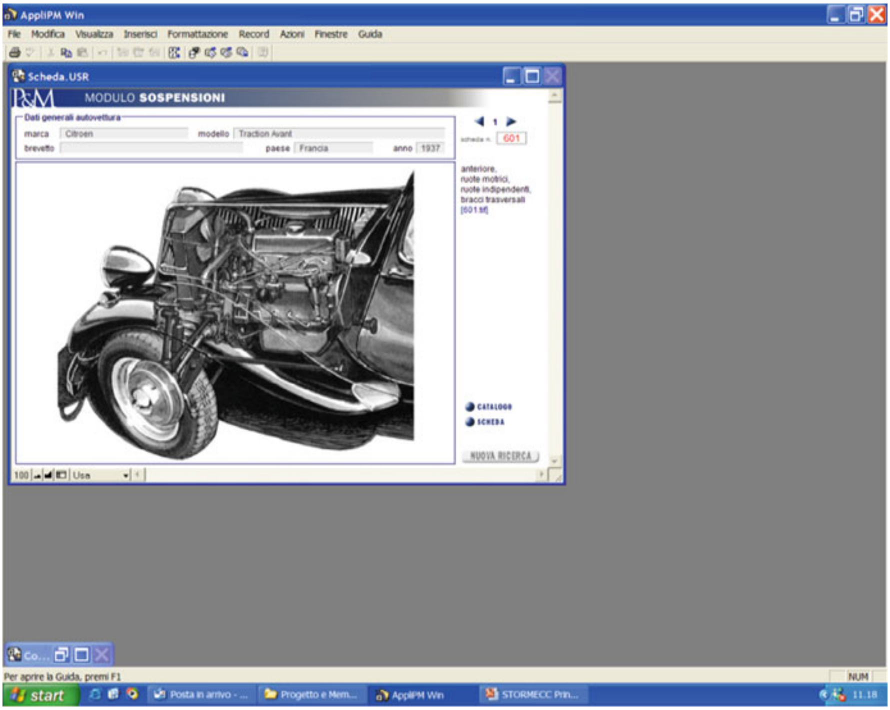


Fig. 9.5 Example of car suspension (1937)

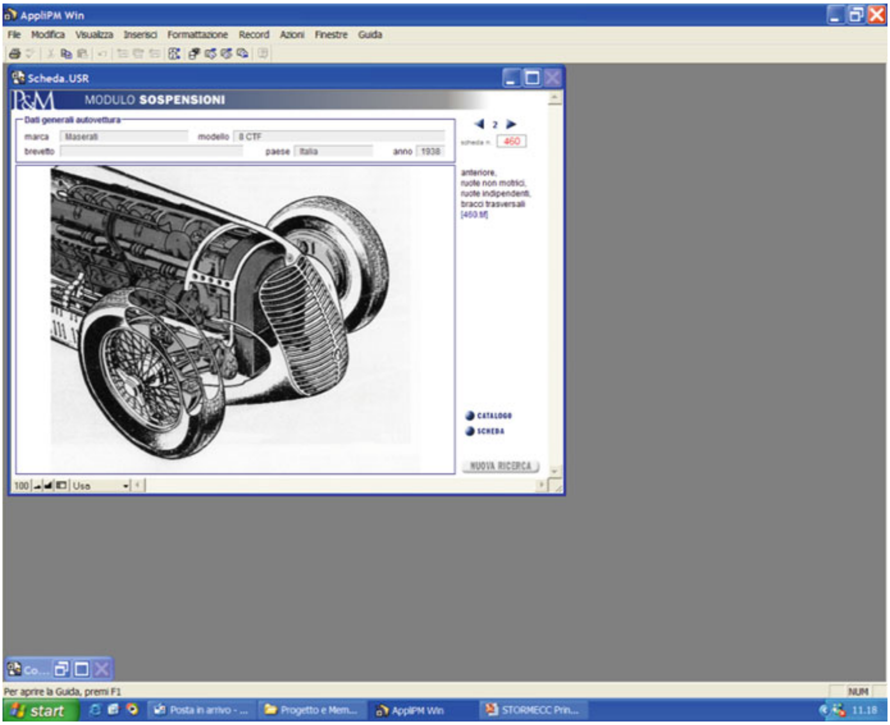


Fig. 9.6 Example of car suspension (1938)

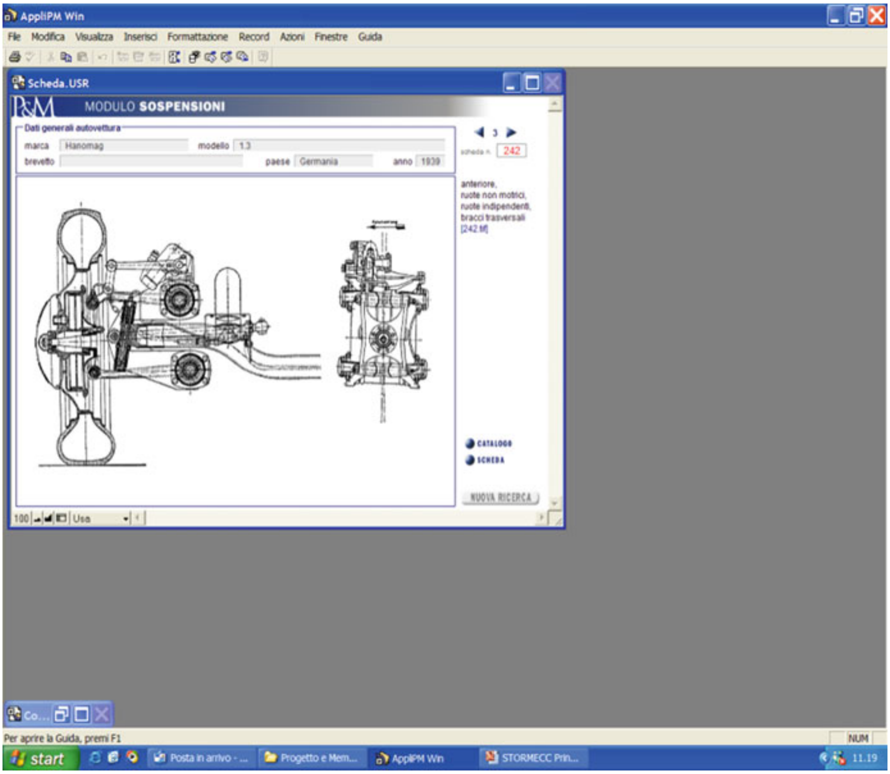


Fig. 9.7 Example of car suspension (1939)

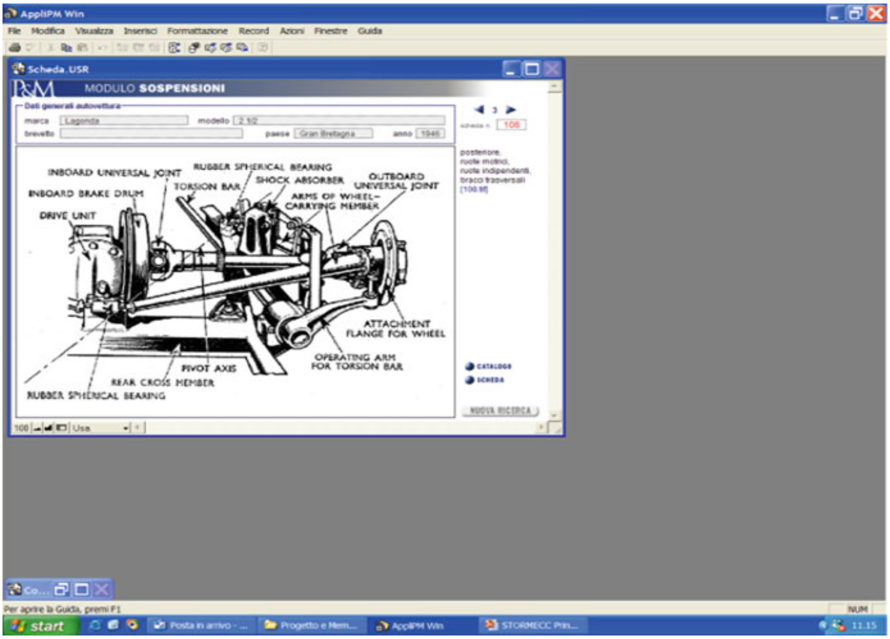


Fig. 9.8 Example of car suspension (1946)

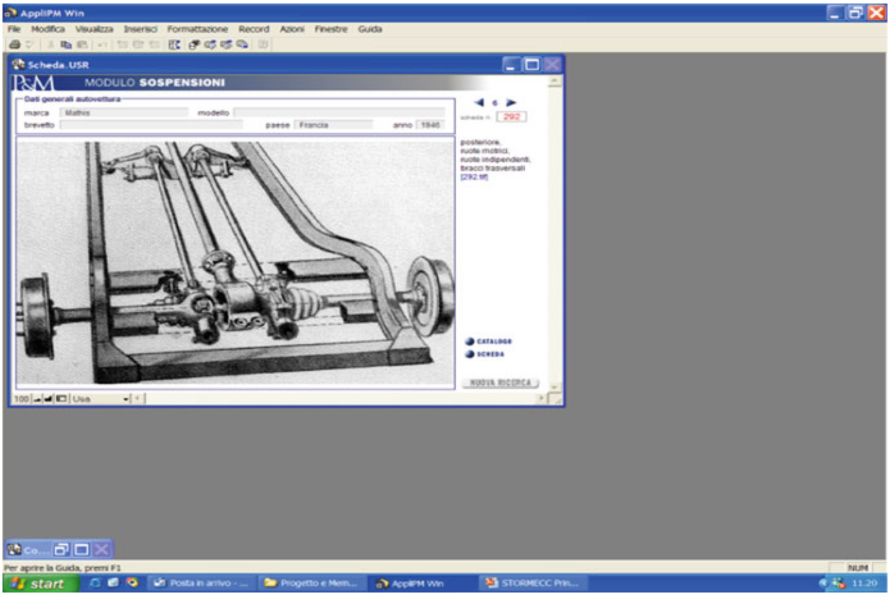


Fig. 9.9 Example of car suspension (1946)

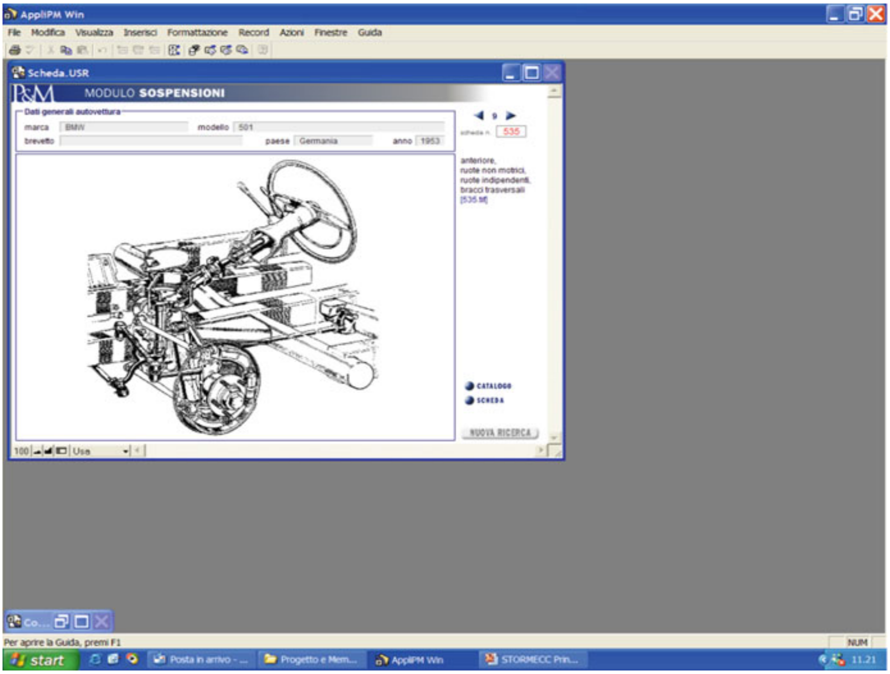


Fig. 9.10 Example of car suspension (1951)

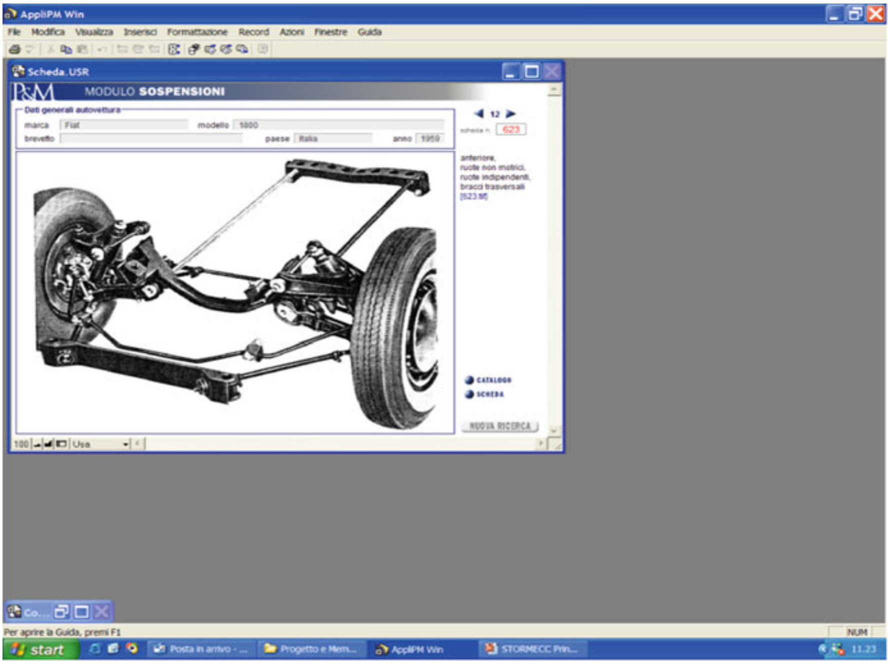


Fig. 9.11 Example of car suspension (1959)

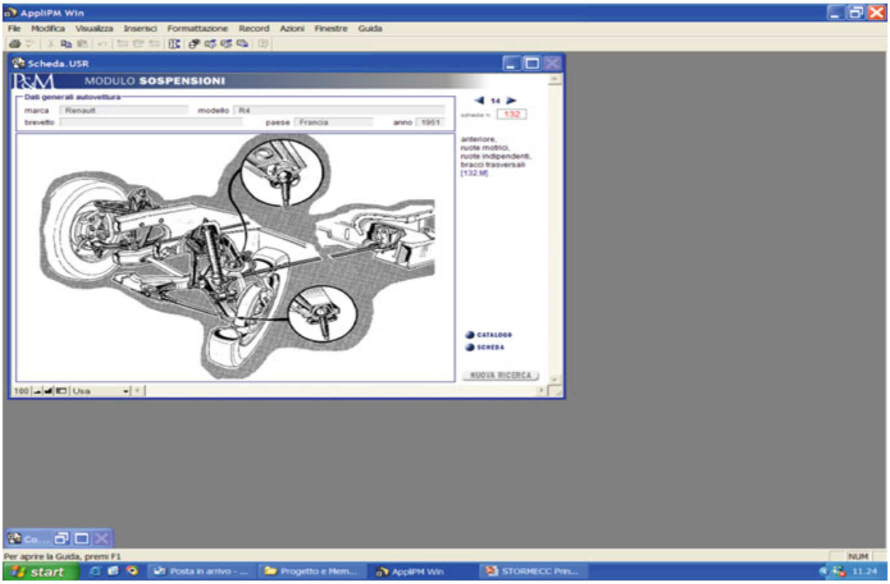


Fig. 9.12 Example of car suspension (1961)

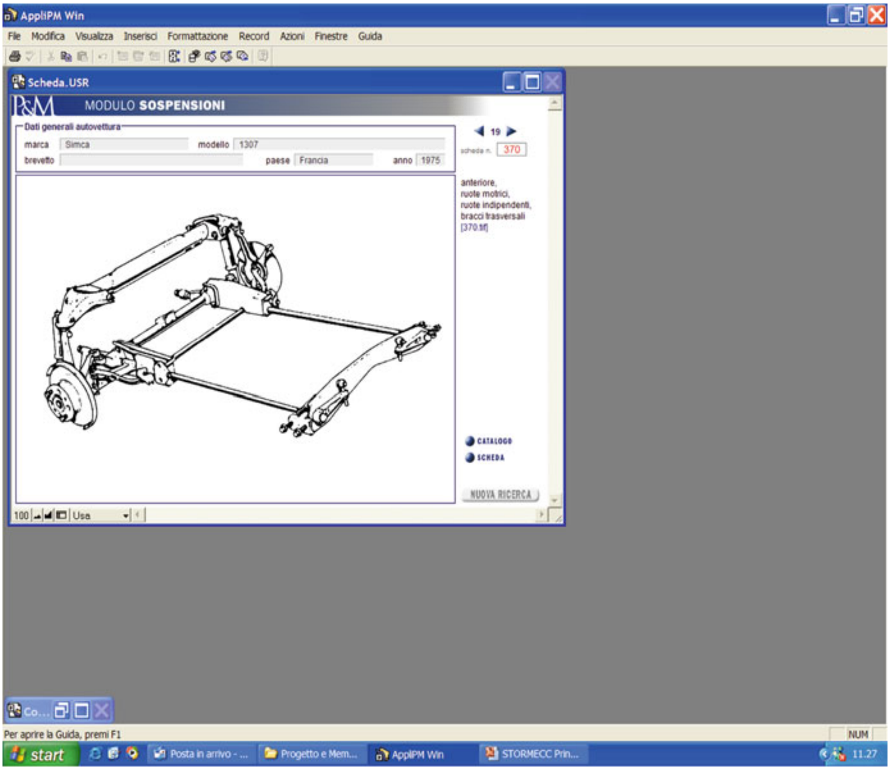


Fig. 9.13 Example of car suspension (1968)

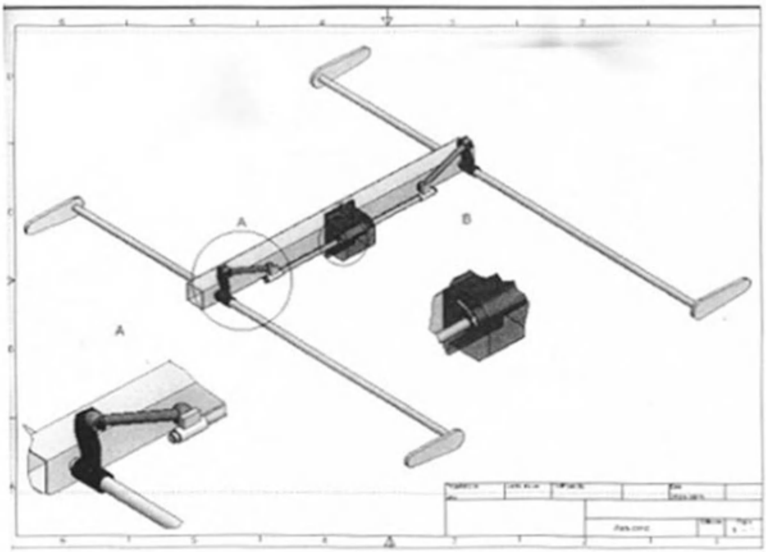


Fig. 9.14 Modern solution derived from the historical heritage

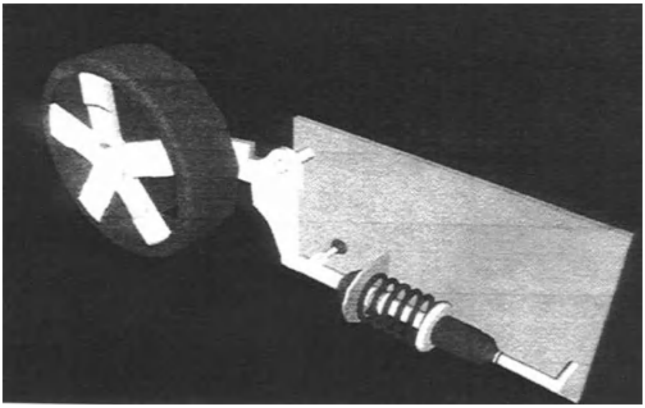


Fig. 9.15 Suspension with helical spring with mechanical device able to change the height of the car body

9.1.2 Evaluation

This method is based on the question determining how the historical solutions of a given archive behave in the life cycle. By comparison with such behavior, it is possible to determine the "best in class": this "best" solution can be critically considered and upgraded. The main steps of this second method are as follows:

1. Individuation of the historical constructive solutions stored in the archive;
2. Evaluation of each solution, considering the performance of each solution in the different phases of the life cycle, by applying methods like DfX (Dubensky 1993; Duffy et al. 1993; Meerkamm 1997; Pighini et al. 2002). The DfX concept means that the designer must take into account that the industrial product must have good behavior in all the phases of the life cycle (Fig. 9.16). In other words, all the design criteria that give to the product good behavior in the X phase of the life cycle, are called Design for X (DfX). Figure 9.16 represents the life cycle (Asimow 1962; Rovida 1997).

This method was applied, for example, to the study of rear suspensions of motorcycles (Morcelli 2005). The historical cases were collected with specific cards: Figure 9.17 shows an example.

The cases, collected with similar cards, are compared, with reference to their behavior in the different phases of the life cycle. By considering the above mentioned phases, some characteristics are deducted, that describe the behavior of the solutions. In Table 9.1 an "evaluation matrix" is presented. The columns are the names of the characteristics deducted from the life cycle, while the rows are called by the names of historical solutions of suspensions.

By giving to each characteristic a weight, in relation to the different importance of the characteristic self in the specific design, it is possible to individuate the "best

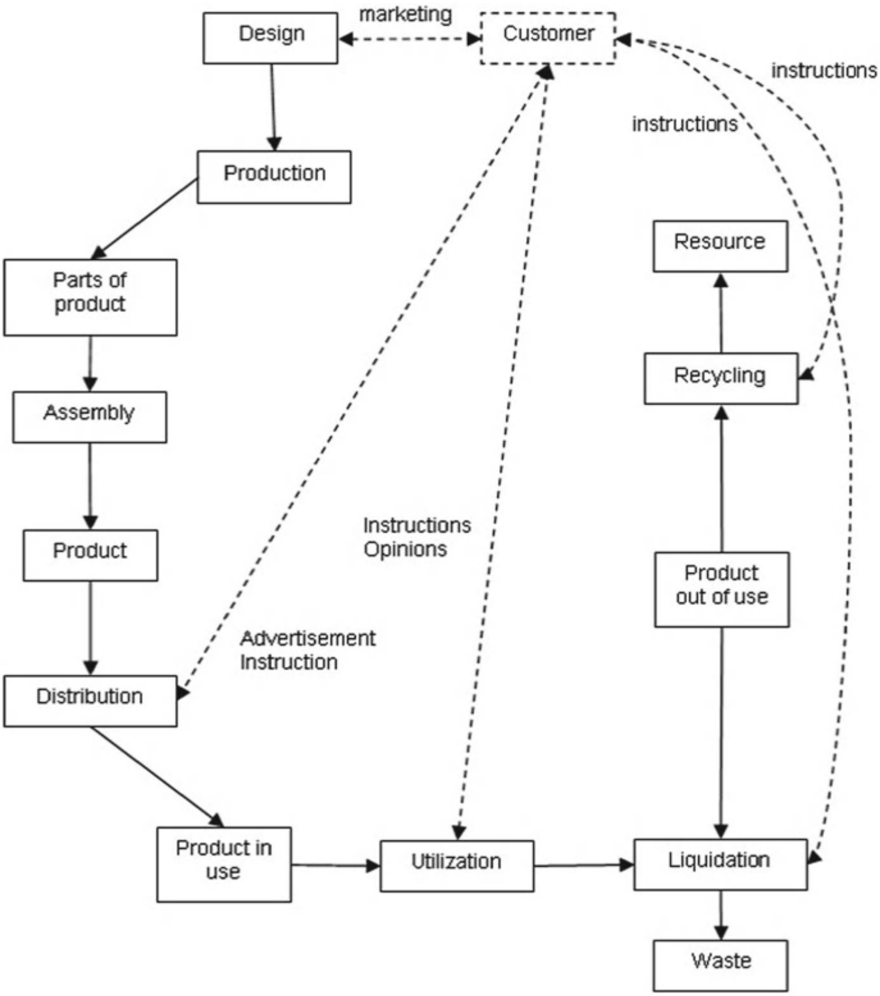


Fig. 9.16 Life cycle of an industrial product

in class" solution. In this example, Fig. 9.18 is the solution from an Italian motorcycle (1928).

Figure 9.19 represents a modern interpretation of this schema.

9.1.3 Progress

This approach is based on the ideas of Descartes, and mainly relies on the supposition that an engineer, after a critical analysis of the historical evolution of a given machine or device, is capable of adding another step to it. It is interesting to observe

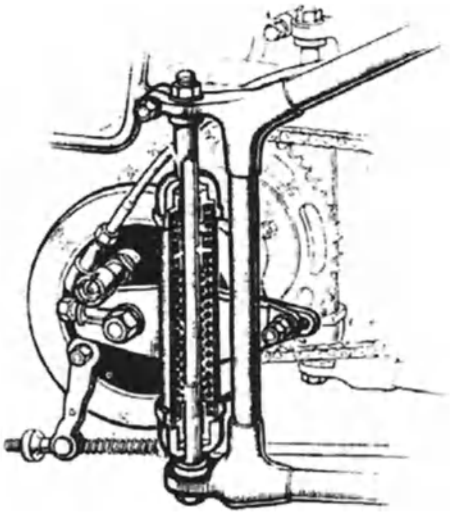
Elastic system with guided wheel	**Motorcycle**
	BMW, Norton, Excelsior
	**Model, year**
	BMW R51 1939
	Elastic organ
	Helical spring
Description	**Damper**
With this solution it is possible to transform a rigid suspension in an elastic one: it is sufficient to insert a helical spring at the connection point of the pipes of the frame, in correspondence to the center of the wheel. In this way, the rear portion of the frame is rigid while the wheel can have a vertical displacement	Telescopic, vertical

Fig. 9.17 Example of card with data about historical case of suspension

that this principle corresponds to a fundamental principle of TRIZ (Michalewicz and Fogel 2000; Altshuller 1996; Orloff 2002), relative to the evolution of technical systems. Figure 9.20 represents an example. The structural evolution represented in this example can be considered in relation to its historical evolution.

9.1.4 Transfer Among Fields

Another possibility consists in transferring a solution from one field to another. As an example, Fig. 9.21 shows a McPherson suspension, typical for car applications, transferred to a sleigh (Zanini 2001).

Table 9.1 Evaluation matrix of suspensions of motorcycles

Type of suspension (in the column, several constructive solutions of suspension are listed)	Weight	Dimensions	Progressiveness	CG height	Symmetrical behaviour	Efficiency	Economy	Maintenence	Constructive simplicity	Assembling
	Utilization of the product manufacturing of the product									
Balestra montata su telaio con forcellino al centro della balestra	1	1	1	2	3	1	2	3	3	2
Ruota guidata	3	3	1	3	2	1	2	1	1	2
Sospensione a barra di torsione	2	2	2	2	2	3	1	1	1	1
Forcellone oscillante con ammortizatore a frizione	3	1	2	2	2	2	2	1	2	2
Forcellone oscillante con molle a nastro verticali	2	2	2	1	1	2	2	2	2	2
Forcellone oscillante con ammortizzatori idraulici ai fianchi della ruota	2	3	2	1	2	2	2	2	3	2
Forcellone oscillante cantilever	3	2	3	3	3	3	3	2	3	2
Forcellone oscillante Unitrack	2	2	3	3	3	3	2	3	2	2
Forcellone oscillante Monocross	3	2	3	3	3	3	2	3	2	2
Forcellone oscillante BASS	2	2	3	3	3	3	2	3	2	2
Forcellone oscillante Pro-link	2	2	3	3	3	3	2	3	2	2
Forcellone oscillante	3	3	2	3	3	3	3	3	2	2

(continued)

Table 9.1 (continued)

Type of suspension (in the column, several constructive solutions of suspension are listed)	Weight	Dimensions	Progressiveness	CG height	Symmetrical behaviour	Efficiency	Economy	Maintenence	Constructive simplicity	Assembling
	Utilization of the product manufacturing of the product									
Infulcrato direttamente al telaio										
Forcellone oscillante bibraccio a banana con monoammortizzatore	2	2	3	3	2	3	2	3	2	2
Forcellone monobraccio monolever	1	2	2	2	2	2	2	2	2	2
Forcellone monobraccio paralever	1	2	3	3	2	3	1	2	1	2
Forcellone monobraccio	1	2	3	2	2	3	1	3	2	3

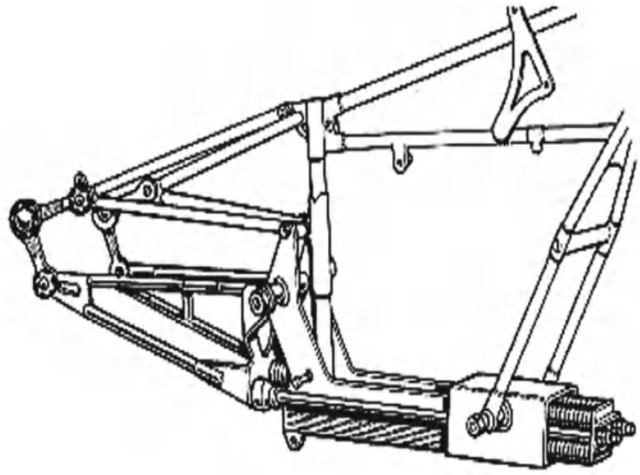


Fig. 9.18 The “best in class” solution in the described example (Italian solution 1928)

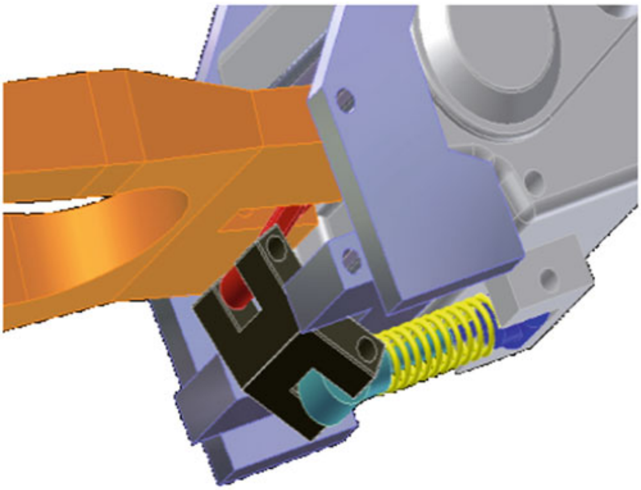


Fig. 9.19 Modern solution inspired from the historical “best in class”

9.2 Standardization Organizations

Some modern drawing standards could be anticipated by a critical observation of historical drawings and of historical drawings. For example, Fig. 9.22 represents an electrical device by Alessandro Volta (see also Chap. 5). This drawing is realized with an anticipation of the “arrow method”, a widely applied method used today in orthographic projections and recommended by ISO standards.

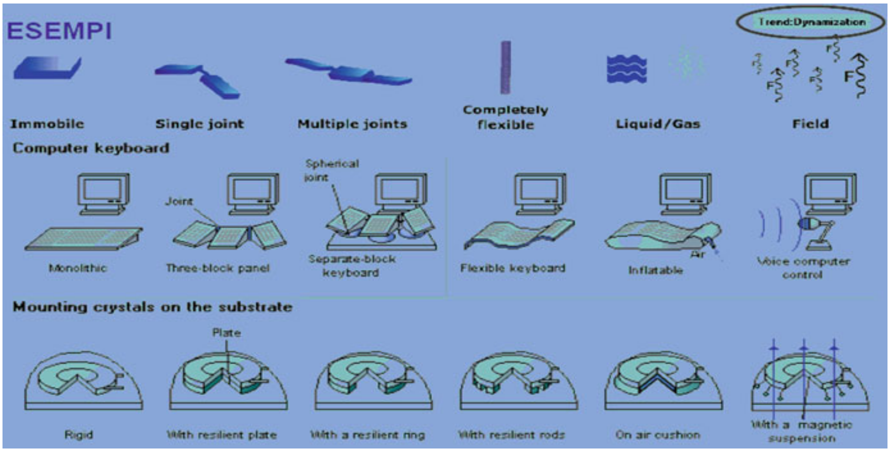


Fig. 9.20 Structural evolution of technical systems according to TRIZ

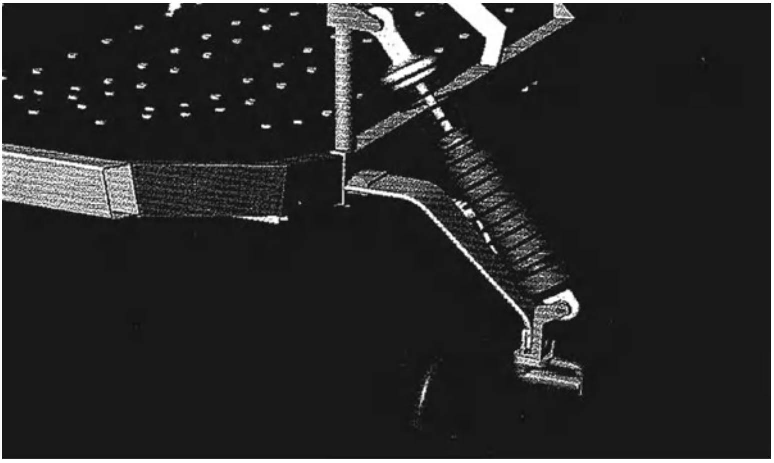


Fig. 9.21 Example of suspension of a sleigh, obtained by transfer of a McPherson car solution

Another example is represented by the reduction scale 1:2. Drawing standards did not allow this scale until ca 1980 because, “it can produce a wrong evaluation of the proportions”. Many historical drawings used the scale 1:2, without problems: for this reason, the reduction scale 1:2 is allowed by the modern ISO drawings standards.

A further example is represented by Fig. 9.23, from a drawing of the physicist Giuseppe Belli (1792–1860) (see also Chap. 6). This drawing is relative to a text-book about “Experimental Physics” and represents optical parts. The simplest

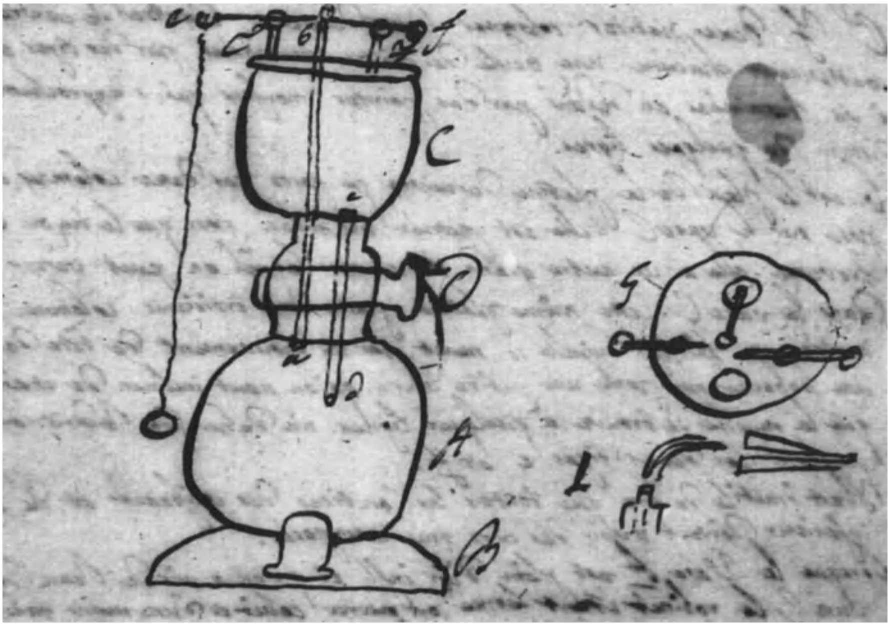


Fig. 9.22 Scientific instrument by Alessandro Volta: the representation can be considered as an anticipation of the "arrows method", today widely applied and recommended by the ISO standards

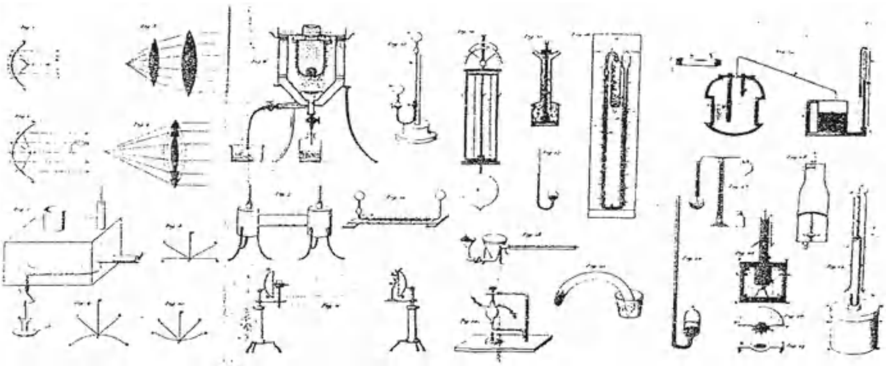


Fig. 9.23 Drawing by the physicist Giuseppe Belli (1792–1860). (see also Chap. 6): the simplest type of hachure is used to indicate the glass of the lenses. This principle is considered by a modern standard, which could be anticipated

hachure type is used to indicate the most frequent material in the drawing: in this case, the simplest type of hachure is used to indicate the glass of the lenses, i.e. the most frequent material in the drawing. This principle is considered by a modern standard, which could be anticipated.

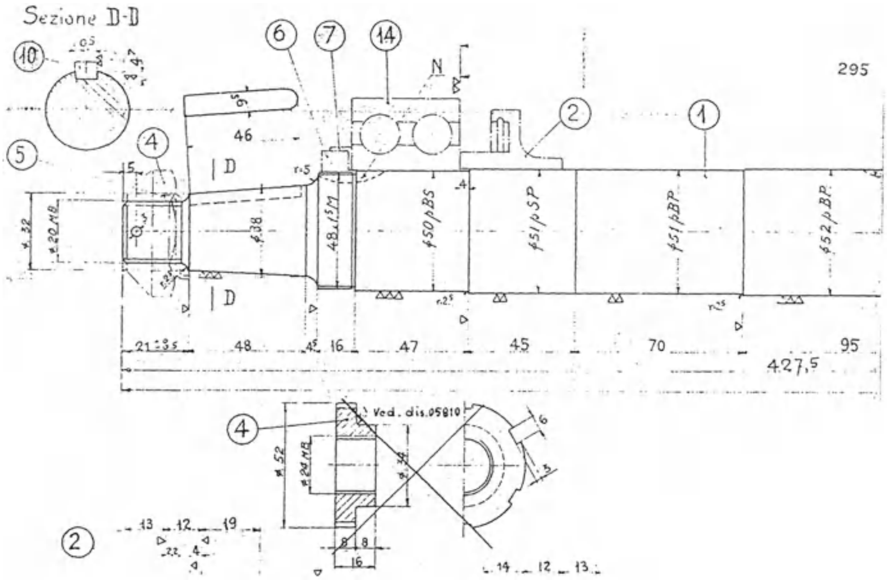


Fig. 9.24 Drawing (1937) of Turrinelli Collection at Istituto Lombardo Accademia di Scienze e Lettere (Lombard Institute of Science and Literature): example of possible representation of details in assembling with principal parts

But, by considering the historical drawings, a proposal of some new standards could be made. An example is represented by the drawing of Fig. 9.24, that is the particular of a drawing (1937) of Turrinelli Collection at Istituto Lombardo Accademia di Scienze e Lettere (Lombard Institute of Science and Literature). This drawing shows a bearing in assembly with a shaft. The use of a dotted line for such an indication would be allowed in a modern standard.

Another aspect is relative to the use of color in technical drawings. As largely demonstrated in the abovementioned examples, colors are widely used, often with specific meaning, in historical drawings. Today, through the use of a computer, colors are again used: perhaps, a new standard with specific rules about the use of color in technical drawings could be proposed.

9.3 Teachers and Students

Historical heritage, critically observed and investigated, can have a positive influence also for didactic purposes.

The archive of suspensions (Biggioggero et al. 2003) is often utilized in exercises for students. Such exercises can be, in general, as follows:

(a) study of innovative suspensions by using the critical observation of historical cases as heuristic method;

Table 9.2 Evaluation by students of a database (Biggioggero et al. 2003)

Aspect	Evaluation (1 = min; 5 = max)
General validity of tool	4.5
Ease of use	2.75
Immediate comprehension of interface	3.75
Uniqueness in information retrieval	3.0
Completeness of the logical schema	4.25
Utility of tool in the design activity	4.75

(b) utilize the given archive as a model to realize similar archives relative to other constructive solutions.
(c) the evaluation of students of such an archive utilized as a tool are as follows (Table 9.2):

The author is responsible for a course in the curriculum of Industrial Engineers, Master degree, called "History of mechanics". In this course, students realize historical evolutions of machines, instruments and devices, by critically evaluating the fundamental steps.

The fundamental results of this course can be summarized as follows:

1. an historical "forma mentis" in engineering students;
2. the basic tools to correctly evaluate the technical events of today that, in a short period of time, will become "historical";
3. avoid evaluating a historical event with the criteria of today (very frequent error);
4. utilize the historical database as a source of "innovative" solutions to technological problems.

9.4 Historians

The database can make it easier to do comprehensive research into historical solutions for technological problems. For example, such a database makes it possible to search all machines with specific technical characteristics, realized in a specific year, or by a given industry, or in a given country.

9.5 The Lesson of Historical Heritage

These results, together with the previously highlighted importance of our historical heritage, Dublin Descriptors (aa. vv. 2004) and the RULEG method (Gavini 1965) are the basis of the following proposals pertaining to historical contents in engineering education.

Table 9.3 Historical contents at bachelor level

Parts	Contents
Informative (RUL)	General ideas about the historical scientific-technical heritage
Critical (EG)	Reflexions about the important role of the historical heritage in modern design
Practical (EG*)	Introduction about historical aspects in the final thesis

Dublin Descriptors, a tool widely used today in engineering education, have been used to study how students can reach the following competencies. These descriptors, in fact, define explicitly the goals that students have to reach during their education:

1. knowledge and understanding;
2. applying knowledge and understanding;
3. making judgments;
4. communication skills.

Dublin Descriptors (DD) can be also directly related to the "RULEG" method (Gavini 1965), used by authors in engineering education. The RULEG method is mainly based on the "communication unit", i.e. the part of communication devoted to the transmission of a specific concept, that is considered as constituted by three components: informative (rule: RUL), critical (complete example: EG) and practical (incomplete example: EG*). This structure makes this method particularly attractive for engineering education, since the definition (RUL) is always followed by some examples (EG), a typical situation in many engineering subjects.

Comparing DD with the RULEG method, the following conclusions can be drawn:

(a) in Dublin Descriptors, knowledge (informative, RUL) and comprehension (critical, EG) are considered together;
(b) "Making judgments" can be considered a part of comprehension ability;
(c) the "Applying knowledge and understanding" ability of DD can be regarded as equivalent to the applicative part (EG*) of the RULEG method;
(d) communication and learning skills, together with knowledge, comprehension and application aspects, can be construed as themes around which to create specific courses or to be selectively chosen as special topics in other courses.

The consequent authors' proposals for the Bachelor and the Master levels are summarized in Tables 9.3 and 9.4.

The capability reached by students to realize a historical evolution of a given machine or device can be a tool and a method to realize a systematic historical database, useful as a basis for modern design.

Table 9.4 Historical contents at master level

Parts	Contents
Informative (RUL)	More depth ideas about historical evolution
Critical (EG)	Ability to critically observe the historical heritage, with the aim to find innovative inputs
Practical (EG*)	Ability to realize a systematic evolution of a given machine or device

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