THE ART OF MAKING WATCH MAINSPRINGS, REPEATER SPRINGS AND BALANCE SPRINGS

By

Mr W. BLAKEY

Hydraulic Engineer Etc.

AMSTERDAM
MARC-MICHEL REY
1780

www.watkinsr.id.au

Translated from William Blakey *L'Art de Faire les Ressorts de Montres*, 1780, Amsterdam: Marc-Michel Rey: http://gallica.bnf.fr/ark:/12148/bpt6k61161354

Contents

Translator's Notes

Biography of William Blakey

William Blakey was the son of an English watchmaker of the same name.

Blakey senior was born about 1688. He was apprenticed as a watchmaker in 1701 and died in 1748 aged 60. In 1718 he went to France where he was in charge of a steelworks in Normandy which provided springs and pinion wire for the watchmaking factory in Versailles, set up by John Law and run by Henry Sully. He was a described as a *horloger en ressorts*, a spring maker.

Blakey senior and Sully were involved in the creation of the Paris Society of Arts circa 1718, which originated from the academic project of a *Description des Arts et Métiers*.

Blakey senior had at least two children, but the information on them is contradictory.

Nicholas Blakey is said to have been born in Ireland, probably shortly after 1711. He was an artist and book illustrator.

William Blakey junior was apparently born in London in 1711 and went to France with his parents. It is clear that he followed his father into the steel making business and they probably worked together. Then, before 1744, he established (or took over) a mill for drawing pinion wire. This was regarded as an invention by the Paris Academy of Science, and in 1744 Blakey received exclusive rights for his process, promising to sell at one-third less than English steel.

About the same time, in 1742, he entered the Parisian Guild of Surgeons as a *chirurgiens bandagistes*, a truss maker, producing "elastic steel trusses" with steel springs.

In 1750 he joined the guild of watchmakers. However, there is no evidence that he had trained in watchmaking, and acceptance into the guild was probably because he was, like his father, a *horloger en ressorts*. However, his article *On Horlogery* indicates some knowledge of watchmaking.

In 1759 Blakey was involved in creating an iron rolling mill and machines for making files at Essonnes near Paris. This establishment also made trusses. And in 1761 he was granted a privilege to manufacture files.

In 1765, Blakely was awarded an exclusive contract with Benjamin Huntsman to use Huntsman's steel in France.

About 1777, Blakey moved to Liège, presumably to retire. On 9 January 1778 he wrote a letter to Benjamin Franklin that contains the following strange remarks:

> *I shall soon have my Art of watch and Clock spring making in Print. I send you the preface to give you an idea of it. I shall send it you when finishd as a thing of some use to those brave defender of Liberty, who have saved England from the Yoke a Tyrant was aworking under the name of his servants as I have said in my letter on the times.*

The date of William Blakey's death is not known.

Dating the Technology

Although *L'Art de Faire les Ressorts de Montres* was published in 1780, it is clear that most of it is based on methods used much earlier.

The report of the *Académie royale des sciences* indicates that only Sections 1 to 69 (describing watch mainspring making) were supplied to the Academy in 1772, and it is possible that the remaining sections (70 to 97 on repeater springs and balance springs) were written after that date. However, in the Prospectus Blakey states that he had the 12 plates engraved about 1772, suggesting he had at least planned the text for the later sections. And although clock springs are mentioned, it seems Blakey never wrote about them.

The most important dating evidence comes from the book. In it, Blakey repeatedly refers to the inventions and improvements made by his father, who died in 1748, and what appears to be his only invention in this field (the *large leads* tool, page 16) was designed when he was young and his father was alive, about 1730 or a little later.

To this we can add that in Section 14 (page 4) Blakey states that "Forty years ago we found tools that give such perfect equality, that it could be done without drawn wire". That is, about 1740. And in Section 26 (page 10) he states that he had seen "about 50 years ago, springs hardened by folding them in small circles about three inches in diameter"; a method which had been superseded by his father. Although not certain, this remark probably refers to 1722.

As a consequence, we can be confident that the first part of the book, on watch mainsprings, is based on methods circa 1740 or earlier.

The second and third parts (on repeater and balance springs) use the same type of methods and probably date from the same period. The only "new" tool, the English method of making balance springs with rolled wire blades (Section 89, page 32) was used, according to Blakey, in the 17th century. If so, none of the book describes "modern" methods, and we must assume that spring makers used the same techniques in 1772 - 1780 as they had used in the 1740s and probably earlier.

This is a little strange. Blakey describes making mainsprings by hand hammering annealed steel rods to produce flat blades. But he notes that the English method for making balance springs, by rolling rods in a mill, was superior. So why was this method not transferred to making mainsprings? After all, Blakey had made hot iron rolling mills to produce plates, and one would think that it would be relatively easy to transfer this experience and his knowledge of the English method of rolling balance spring wire to the making of mainsprings. Blakey answers this question in Section 14 (page 4):

> *Forty years ago we found tools that gave such perfect equality, that it could be done without drawn wire. But routine prevented workers from departing from the method of preparing their steel as round wires and then forging them.*

Although vague, it appears that the English method was well known.

In 1763 Ferdinand Berthoud described how to make clock mainsprings and, allowing for the difference in size, his methods are, in all important respects, identical as those described by Blakey: A shaped (rather than round) rod is annealed, hammered to thickness and sheared to the right width. Then it is placed on the wheel in Plate 4 Figure 4 (page 10) and hardened in oil. The blade is then tempered grey, hammered and filed again, and blued. It is then made into a spiral on a large mainspring winder with cards between the inner turns. Finally, it rewound on the mainspring winder without the cards.

Berthoud does not mention William Blakey.

The Translation

Although translating this book was straightforward, the strange and inconsistent punctuation caused some problems. Also, a few unusual words required a bit of inspiration to understand. To help the reader I have included a few footnotes where I think an explanation is needed.

The translation is in no sense literal. Where the French is clumsy when expressed in English, I have preferred to stray from the original and, hopefully, produced a clearer expression.

Originally the illustrations were on 12 plates at the end of the book, To make this book easier to read, I have placed the illustrations in the text at the appropriate places. And, because some illustrations are referenced in several places, I have duplicated them where necessary. The labels have been replaced, correcting a few minor errors.

Bibliography

Academy of Sciences, 1772, *Procès-verbaux Académie royale des sciences*, volume 91, 1778. (Available from http://gallica.bnf.fr/ark:/12148/bpt6k55767d.r=Proc%C3%A8s-verbaux+Acad%C3%A9mie+royale+des+sciences+1772.langEN)

Baillie, G.H., 1988, *Watchmakers & Clockmakers of the World*, England: N.A.G. Press.

Berthoud, Ferdinand, 1763 and 1786, *Essai sur l'Horlogerie*, Paris: Merigot, Didot, Jombert.

Berthoud, Ferdinand and Auch, Jacob, 2007, *How to Make a Verge Watc*h, Richard Watkins: Tasmania, Australia.

Blakey, Nicholas, http://irishcomics.wikia.com/wiki/Nicholas_Blakey_%28d._1758%29

Blakey, William, 1758, *Instruction pour Prévenir les Descentes ou Hernies*, Paris: G. Desprez

Blakey, William, 1769, "Letter to Mr Ferguson on Blakey's Fire Engine" and "Description of Mr Blakey's Patent Fire Engine", *Gentleman's Magazine*, Volume XXXIX, pages 392-394, 1 plate, London: Sylvanius Urban.

Blakey, William, 1778, "Letter to Benjamin Franklin 9 January 1778", http://founders.archives.gov/documents/Franklin/01-25-02-0358

Blakey, William, 1780, *L'Art de Faire les Ressorts de Montres, 1780, Amsterdam: Marc-Michel Rey*: http://gallica.bnf.fr/ark:/12148/bpt6k61161354

Blakey, William, 1792, *Essay on the Manner of Preserving Children and Grown Persons from Ruptures*, London: The Author.

Blakey, William, 1792, "On Horlogery", *Gentleman's Magazine*, Volume LXII (actually volume 72), pages 328-330 and 403-406, London: Sylvanius Urban. (This is an extract from *Comparisons on the French and the English Arts*, but I have not been able to find that book.)

Blakey, William, 1792, “Blakey’s Standard for an Universal Measure”, *Gentleman’s Magazine*, Volume LXII, pages 606-608, London: Sylvanius Urban.

Blakey, William, 1792, “On the Pretended Plagiarism of the English”, *Gentleman’s Magazine*, Volume LXII, pages 708-713, London: Sylvanius Urban. (First published in the Journal des Sçavans, April 1781.)

Blakey, William, 1792, Letter concerning the Design of a Compensated Pendulum, *Gentleman’s Magazine*, Volume LXII, pages 718-719, London: Sylvanius Urban.

Blakey, William, 1792, “On the Navigation of the Ancients”, *Gentleman’s Magazine*, Volume LXII, pages 809-813, London: Sylvanius Urban.

Blakey, William, 1792, “On Pendulums”, *Gentleman’s Magazine*, Volume LXII, pages 1004-1005, London: Sylvanius Urban.

Blakey, William, 1793, *A Short Historical Account of the Invention, Theory, and Practice, of Fire-machinery: or Introduction to the Art of Making Machines, Vulgarly Called Steam-engines*, London: The Author.

Blakey, William, 1793, “Observations on Pumps and Pistons”, *Gentleman’s Magazine*, Volume LXIII (actually volume 73), pages 130-134, London: Sylvanius Urban.

Hilaire-Pérez, L. and Verna, C, 2006, “Cross-trade skills and business strategies: personal itineraries between medicine and metallurgy in Middle Ages and early modern Europe”, *XIV International Economic History Congress*, Helsinki 2006, Session 38.

Hilaire-Pérez, L. and Rabier, C, 2013, “Self-Machinery?: Steel Trusses and the Management of Ruptures in Eighteenth-Century Europe”. *Technology and Culture* 54(3), 460-502. The Johns Hopkins University Press. Retrieved April 17, 2014, from Project MUSE database.

Tardy, 1972, *Dictionnaire des Horlogers Français*, Paris: Tardy.

L'ART

DE FAIRE LES

RESSORTS

DE MONTRES.

Suivi de la maniere de faire les petits RESSORTS DE RÉPÉTITIONS & les RESSORTS SPIRAUX.

PAR

Mr. W. BLAKEY,

Ingénieur Hydraulique &c.

A AMSTERDAM,

CHEZ MARC-MICHEL REY.

MDCCLXXX.

Prospectus

Of all the typographical projects, none have presented so beautiful a plan as that of the arts and crafts under the supervision of the Royal Academy of Sciences in Paris. This plan once completed, as much as can reasonably be desired, will be the general repository of knowledge useful to mankind, a repository which will preserve for posterity the arts and crafts that it has lost from time to time, as happened to those of the Egyptians, the Greeks and the Romans, etc.

Having written in English of my theory and my experiments on the machines for fire and air, and wanting to join various machines of my invention to it, I informed one of my friends in Paris, showing him 29 drawings which I had finished of the fire machines, according to my principles. I also showed to him several sketches of my machines: A machine to roll hot blades of iron and steel 30 to 50 feet long (out of curiosity I made one 102 feet 8 inches long, measures of Paris, perfectly equal and less than a two liard piece of France in thickness). A mill which operates four hammers, two in front and two behind the axle. This manner of arranging the hammers, the invention of my father, is to make space for the workmen. A mill to draw pinion wire for watches and clocks, made as a consequence of an exclusive privilege which was granted to me by the King in 1744, after a report to the Academy; this mill can draw wire from two lignes up to nine in diameter, of iron or steel from a foot to twelve feet long, without making the marks of pincers; the wheel, 17 feet in diameter with the water dropping three feet, turns alternately from one side to the other to again take the points with pincers. The change of movement of this wheel is done in one second and without shock. There were also furnaces for various purposes, and several other machines necessary for handling the springs of watches and clocks, and pinion saws. All in considerable detail to require a great number of plates, without the need for repeating the engravings and the text, which could only be useful for booksellers, and those who write by the yard for these gentlemen.

My friend, having seen my drawings and my plan, which was in English, advised me to translate it into French, and told me that each art in proportion could make a volume. I communicated this advice to an academician I knew, and very well known for his expertise in mechanics. He approved my plan and appeared flattered by what I wanted to give to the art of making watch springs, etc. having acquired some reputation in this kind of manufacture.

I translated my work on the machines for fire, and united two more on other matters.

I wrote on the manner of making watch springs and balance springs, and presented them to the Academy, which did me the honour of approving my work, as can be seen by the extract of its registers placed at the end of this prospectus.

Being provided with the statements of these registers, at the beginning of September 1772 I addressed myself to Mr Saillant, bookseller, on the enterprise of the arts and crafts. I showed him one of my manuscripts, with my report signed by Mr de Fouchy, perpetual secretary of the Academy. But its proportions not having answered to my expectations, I decided to give the twelve folio plates on watch springs to Mr Benard, who engraved them exceptionally well. My business calling me to England and Holland at the time, I could not attend to the printing of my work, which I wrote with all the good faith that an artist must have when he speaks to the public. I have added observations which can be acquired only by experience.

While my plates were being engraved, I wrote on the art of making springs for clocks, and I drew all the machines which were used for my water mills that I had prepared for this purpose.

These are the three parts that I then offered by subscription, believing this best way to be refunded part of my expenses, and not to be exposed to plagiarism and frustration for my troubles. Being unable to succeed as I had hoped, for reasons which I conceal because they could be attributed to a great vanity on my part, I resolved to re-examine my works that I have made much more complete by additions which could be used in several types of factories, where forging, rolling and polishing by the force of water is employed. I will add the art of making elastic bindings for prolapses or hernias of which I am the inventor. These books will be the same size as those of the Academy, will be used as a continuation, according to their dates, and will be printed on beautiful paper, in conformity with what has been printed of this kind.

Since that time, other business having taken me to Holland, I went to the bookseller Mr M. Rey and arranged for this work to be published, at the price of 4 Dutch flor.

The Author has just given to the public *Observations on Fire Pumps, with Beams, and on the new Machines for Fire*, with remarks on the situation in Holland, and the machines suitable to drain the water of the marshes, in 4to. 2 part. fig. This work is in Rotterdam at Bronkhorst, in Leyde at Murray, in Amsterdam at Rey, and in Liege at the Author. Price 4 Dutch flor., or 8 French liv.

Extract From the Records of the Royal Academy of Sciences

Of 15 September 1772.[1]

Mr. Blakey made to the Academy a proposal to describe *The art of making the springs of watches and clocks*, to serve as a sequel to those that it publishes. The Academy, having accepted it, charged us, Mr Macquer and me, to examine this art when it is finished. We will give an account to the Academy of the first part which is already finished, that which deals with the manner of making watch springs.

The author, in the foreword, speaks in a few words of the time when watch springs started to be made. He then passes to the time when people were particularly occupied to improve the manufacture of them, taking care to be acquainted with the aspects that have contributed the most. Finally he examines, in this foreword, the different steels, the locations from where they come, and particularly the nature of the steel which must be employed in the manufacture of springs. This aspect is very important, because the goodness and the elastic force of springs almost entirely depends on the nature of the steel.

The art is divided into a series of articles in which the author describes, without omitting any operation, how to make watch springs, from when they are in round rods, capable of being drawn in a die, until the moment when they are ready to be put in the barrel, to be used in watches.

While dealing with all the various methods and practices which are used in the manufacture of springs, the author takes care to emphasize the most important aspects, such as hardening, and the annealing (or tempering) that must be given to springs after they are hardened, so that they do not have this first hardness, which would mean we could not use them without them breaking, and yet there remains enough for them to act promptly and to have much elastic force.

In the same way he insists on an important point, on the form which must be given to the blades, so that all their parts work equally, that these blades do not rub in the barrel, and that their effect is flexible. And as one can satisfy these various requirements only by ingenious machines, necessary to succeed in a sure way, Mr Blakey describes these various machines, which are the invention of his father and himself. Such as the wheel which is used to heat and redden a large number of springs all at the same time, with the greatest facility, and in a way that they cannot be more equal in all their parts. Also, such as that which the author calls the *large leads*, a machine intended to be used by one man that, although limited, is able to give to the spring's blade the form of which we have spoken earlier, a successive reduction in its thickness, from one end to the other, which makes the action soft and flexible without any friction.

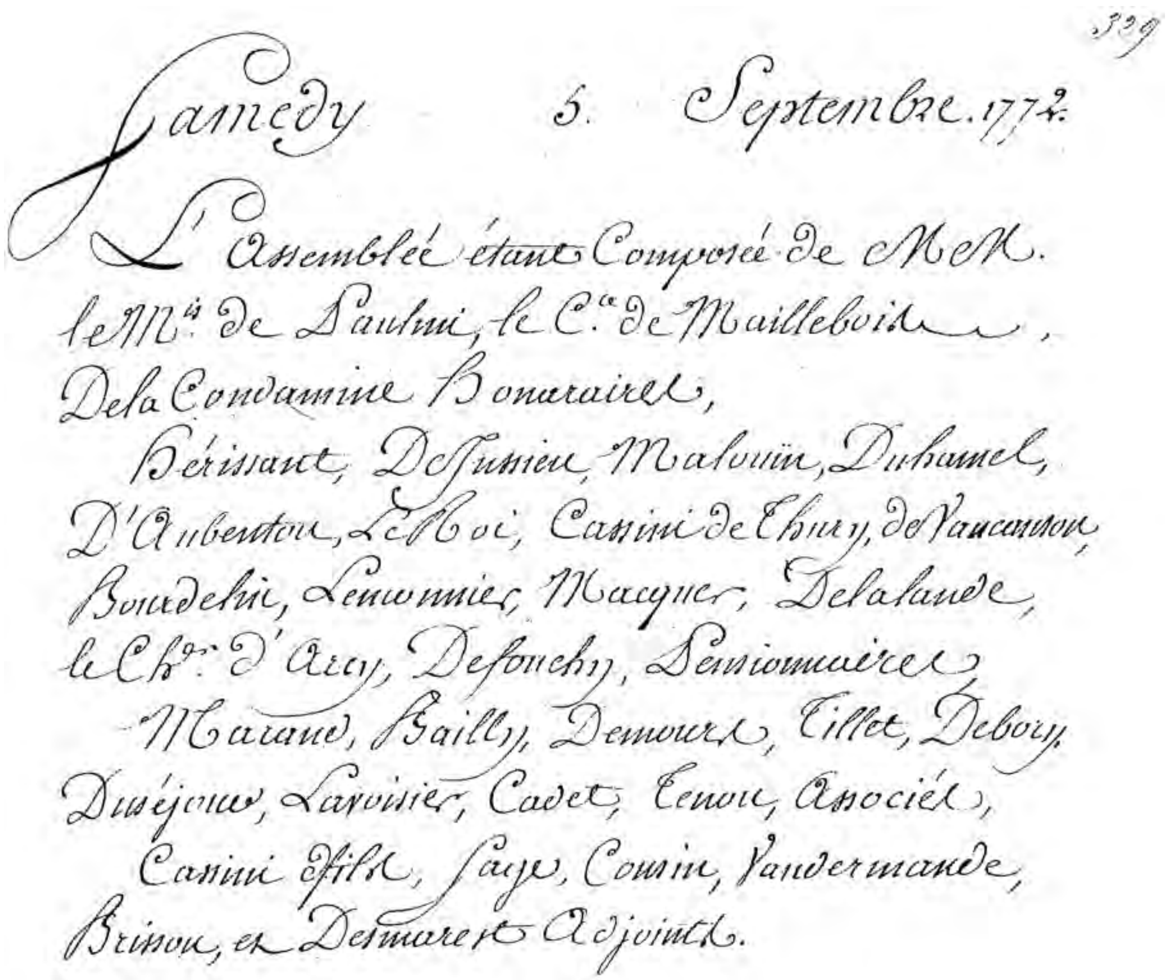
Finally, Mr Blakey describes this art as an artist perfectly educated in all its parts, and he does not neglect or hide anything at all that can make the reader or the artist perfectly well aware of all the practices and of the methods to make watches springs easily and with all possible perfection.

1 Actually 5 September 1772.

We believe, therefore, that this art, in which we see all the resources of industry used to achieve with ease and readiness to make such a difficult thing as a spring, which has all the required qualities, is worthy of the approval of the Academy, and to be printed following those that it publishes.

Signed, Le Roy, Macquer

I certify the above extract conforms to the original & the judgment of the Academy. In Paris, on 14 September, 1772. Grandjean de Fouchy, perpetual Secretary of the Royal Academy of Sciences.


339

Samedy 5. Septembre. 1772.

L'assemblée étant Composée de MM.
le Mis. de Paulmi, le Cte. de Maillebois,
Dela Condamine, Bonaraires,
Hérissant, De Jussieu, Malouin, Duhamel,
D'Aubenton, Le Roi, Cassini de Thury, de Vaucanson,
Bourdelin, Lemonnier, Macquer, Delalande,
le Chr. d'Arcy, Defouchy, Lemonnier,
Morand, Bailly, Demours, Tillet, Debory,
Dusejour, Lavoisier, Cadet, Tenon, Associés,
Cassini fils, Sage, Cousin, Vandermonde,
Brisson, et Desmarest Adjoints.

Nous croions en conséquence qu'il est très digne de l'approbation de l'académie et de faire suite aux arts qu'elle publie.

MM. Le Roi, de Vaucanson et Darcy ont fait le Rapport suivant de l'art de faire les Ressorts de montres du même auteur.

M. Blakey aïant fait à l'académie la proposition de décrire l'art de faire les ressorts de Montres et de Pendules, pour servir de suite à ceux qu'elle publie et l'académie l'aïant accepté elle nous a chargés MM. Macquer et moi d'examiner cet art lorsqu'il seroit fait. Nous allons rendre compte à la Compagnie de la premiere ou de celle qui traite de la maniere de faire les ressorts de montres qui est déja finie.

L'Auteur dans la préface parle en peu de mots du tems où on a commencé à faire des ressorts de montres il passe ensuite à l'epoque où l'on s'est plus particulièrement occupé d'en perfectionner la fabrique, aïant soin de faire connaitre les artistes qui y ont le plus contribué. Enfin il traite dans cette préface des différents aciers; des lieux d'où on les tire, et particulierement, de la nature de l'acier qu'on doit emploïer dans la fabrique des ressorts, cet article est très important car c'est de la nature de cet acier que dépend presqu'entierement la bonté et la force élastique du ressort.

L'art est divisé en une suite d'articles dans lesquels l'Auteur traitte, sans omettre aucune opération, de la maniere de faire les ressorts de Montres depuis le point où ils sont en verges rondes propres à être tirées à la filiere jusqu'au moment où ils sont en état d'être mis dans le barillet pour être emploiés dans les Montres.

En traitant de toutes les differentes opérations et de toutes les différentes pratiques qu'on emploie dans la fabrique de ces ressorts. L'auteur a soin d'insister sur les articles les plus importants, comme celui de la trempe, celui du revenu ou de l'espece recuit qu'on doit donner aux ressorts après qu'ils sont trempés pour que n'aiant pas cette premiere dureté qui feroit qu'on ne pourroit les emploier sans les casser il leur en reste assez pour agir avec vivacité et avoir encore beaucoup de force elastique il insiste de même sur un point non moins important sur la forme qu'on doit donner à leur lames pour que toutes leurs parties travaillent également, que ces lames ne se frottent pas dans les

barillet et que leur effet soit liant, et comme
il parvient à satisfaire à ces différentes données
que par des machines ingénieuses propres à
y réussir d'une maniere sure, M. Blackey
décrit ces différentes machines qui sont de
l'invention de M.r son Pere et de la sienne. Telle
est la Roüe qui sert à faire chauffer et rougir
un grand nombre de ressorts tout à la fois
avec la plus grande facilité et d'une maniere
on ne peut pas plus égale dans toutes leurs
parties. Tel est encore ce que l'Auteur appelle
les grands Plombs machine destinée à faire
qu'un seul homme quoique fort borné soit
en état de donner à la lame du ressort la forme
dont nous venons de parler tout à l'heure
où cette diminution successive dans son épaisseur
depuis un bout jusqu'à l'autre qui en rend
l'action douce et liante et sans aucun
frottement.

Enfin M. Blackey a décrit cet art
comme un artiste parfaitement instruit
de toutes ses parties et qui ne néglige ni
ne dissimule rien de tout ce qui peut mettre
le lecteur ou l'artiste parfaitement au
fait de toutes les pratiques et de tous les

moïens propres à faire les ressorts des montres facilement et avec toute la perfection possible.
Nous croïons en conséquence que cet Art, dans lequel on verra toutes les ressources de l'industrie pour parvenir avec facilité et promptitude à faire une chose aussi difficile qu'un ressort qui ait toutes les qualités requises, est digne de l'approbation de l'academie et d'être imprimé à la suite de ceux qu'elle publie./.

Foreword

The art of making the mainsprings of watches and clocks is perhaps, of all mechanical manipulations, that which provides the most physical knowledge of the properties of steel. By initially discovering the essential qualities to convert iron into steel, the artist cannot fail to recognize, in this work, the various qualities of this metal, such as its hardness, its malleability, its elasticity, etc.

To understand what I will say, it is necessary to know that an ordinary watch mainspring is a small, thin blade, from twelve up to twenty-two inches long, bent so that it has the elastic force to make a balance vibrate 540,000 times in thirty hours.

It is not easy to determine when steel and its various qualities were discovered, or even when the first spring was manufactured, but we can conjecture that the qualities of springs with elastic blades has been well known since the invention of the fusee which regulates the inequality of springs.

The first watch mainsprings manufactured as perfectly as the steel allowed it, were made in England, as well as those for fusee clocks. At that time the springs made in France, Germany and Geneva were much inferior. The Genevan prevailed over the French, because of the grade of German steel from which they were made. But on the other hand, they gave their clock springs and watch springs for going barrels the best form of all. They only erred by the grade of steel which they used, and by the little knowledge they had of this matter. This lack of knowledge still remains in France, in all the trades where steel is used, except for some watchmakers, who can today give this metal all the degrees of hardness which their art requires.

As the grade of steel is what determines the more or less elastic force of springs, it is important to start by speaking about it. There are two types of steel, one natural and the other artificial. Their properties are subdivided into a large number of grades, that the experienced artist of spring making can distinguish. I will not mention them here, because they will make more sense in the description that I will give of the manner of working. I will only say that the more they are wrought, when forged in bars, the more they become ferruginous.

The Germans, for a very long time, were the only ones to have manufactured natural steel, and their mines of Stiria, Carinthia and the Tirol produced the best steel in the world. These steels, transported to several provinces, were combined and worked in various factories, from which they took and naturally retained the names of Hungary, Pont, etc. But the best is that of Stiria, which is preferred over all others in spite of the cost of transport. All that which came from Poland, the Vistula in the Baltic and the North Sea, was named Danzig steel, because it was shipped from that port, and all that was sent from Venice in the Mediterranean, took its name from that city.

Artificial steel is made from iron bars in brick cases, where layers of these bars and other ingredients are put alternately. The whole is heated to a certain degree known by the steel makers.

This art was much improved in England by the work of the Mr Crowlay, who was informed by the makers of watch springs in London of what was missing in their steel, in its flexibility and hardness, in respect of its brittleness. Finally, without any principles and by trial and error, Mr Crowlay was able to chose the iron suitable to become the most perfect steel today, and superior to all including the fabled steel of Damascus, which probably was none other than that of Stiria, which the Venetians carried through all Asia and along the coasts of Mediterranean, and with which the Turks made the swords of Damascus that become famous by the rapid conquests of the Mohammedans.

It was 40 years after Mr. Crowlay, that the English found how to prepare artificial bars of steel in the fashion of Germany, which gave it a uniformity of body suitable to be used in any type of work. This is heating with coal which facilitated the means of achieving this perfection, which could not be obtained in the same way with charcoal, without much more trouble; moreover charcoal is too expensive for such work.

I am more certain about the time when we started to make watch mainsprings with some perfection. Toward the end of the last century, a French refugee made springs less breakable than the other workmen in London, because he hardened them in tallow. Mr Vernon, the most skilful in that city and who was his contemporary, learned this method and adopted it. His student, Sadler, followed in his footsteps, as I have learned from my father, who was also a student of Vernon, like Maberley, who all made springs to the degree of perfection where they stayed until certain tools were discovered, more suitable to give to springs their true shape. At the same time many watch springs, and also some for clocks, were made in Geneva, and the latter were as well made as the former were badly made.

Paris also had its artists in this work, but much inferior to those of Geneva and England, so the watchmakers of Paris usually bought their springs from Geneva, and paid triple and quadruple for those which they got from England.

In 1714 or 15, my father, educated in these facts, took some springs to Paris, which he showed to great advantage. Hardly had this happened, when Messers Gaudron, Masson, Le Roy, and several watchmakers persuaded him to remain in Paris, and to bring workmen from London, which he did.

In 1719, my father left Paris to take control of a considerable number of Englishmen who manufactured locks, edge-tools, files, steel, etc., that His Royal Highness the Duke Regent had established near Le Havre, and which was of great consequence for the hardware of France. But with the death of the Regent, its protector, everything was abandoned, as well as the manufacture in Versailles, that of drapery in Normandy, and other establishments that this father of the arts and sciences had created with much trouble and expense. In spite of this fatal blow to France, we took advantage of the remnants of watchmaking and drapery to put them on a good footing, as we see them now in Paris and Normandy. Two of my father's workers set up separately. Such is the time of the manufacture of English watch springs in France, which put an end to the French way of working. However clock springs are still made with bad steel, badly worked, but of good form.

In 1727, my father returned to Paris to manufacture watch springs. Two years later he brought steel blades from Stiria to make clock springs which, with the precision and the principles of the work on watch springs, together with the grade of the steel, were the most perfect that were made in Europe; so my father had a considerable output.

In 1733, the great market for watch and clock springs, together with that for the springs which I had designed to retain prolapses, resolved my father to establish water mills to forge and polish them, etc., after which I made almost all the additions to the machines and tools necessary to speed up and improve the work.

Here in general is what I know of the beginning and progress of the manufacture of watch and clock springs. In the description of these arts, you will see how we are able to give steel the specific qualities to make it a driving force which is used to divide, with precision, time into equal parts.

The Art of Making Watch Mainsprings.

Section 1

This art has so many different operations that I cannot give a true account other than by following the order of the operations, as they occur one after the other, forcing me to necessary repetitions for the clarity of the subject. But I will limit myself to those that are absolutely essential to make my work intelligible.

Section 2

To make good watch springs, it is necessary to use English steel as perfect as possible, forged into round rods 5 or 6 feet long and approximately 2 lines diameter (Plate 1, Figure 1). These rods are annealed in a wood fire, because this fire makes steel softer than any other heating. Charcoal is not as good; but coal is the last that we should use, because its sulphurous quality prevents the metal from acquiring all the malleability of which it is capable.

Plate 1, Figure 1

Section 3

When steel is heated, no matter what kind of heating, be sure to observe that it is not heated too much, because too much heat makes it brittle. Good and speedy heating is done thus: Take 8 or 10 steel rods from the forge and bind them together with iron wire to make a bundle (Plate 1, Figure 2).

Plate 1, Figure 2

Then place two parallel logs in the hearth of a fireplace, 2 or 3 inches apart, with a little charcoal in the bottom on the ashes. After which cover the two logs with another smaller one. When the fire is lit, put an end of the bound bundle of rods between the two logs, for three quarters of their length. When the end has reddened and has become the colour of a cherry that is not too ripe, draw half of the reddened part out of the fire, and thus let the part which was pulled into fire heat and redden. And by degrees the whole will be heated. (If you have to use German steel to make springs, you can give it a little more heat without spoiling it. But that will cause more scales, this steel being weaker in body.)

Section 4

The steel having cooled, fold it in your hands into circular or irregular spirals (Plate 1, Figure 3) to make the scale fall off. If this operation is done with difficulty, the steel is harder than it should be. And if the scale which falls off is thick and underneath it is a mottled tin white, it is a sign that it was too long in the heat. If, on the other hand, the scale which falls is thin, and underneath it the steel remains black, it has been made as soft as its nature will allow.

Plate 1, Figure 3

Section 5

The steel rods being straightened, they should be rubbed with yellow wax so they can pass through the die on a draw bench (Plate 1, Figure 4).

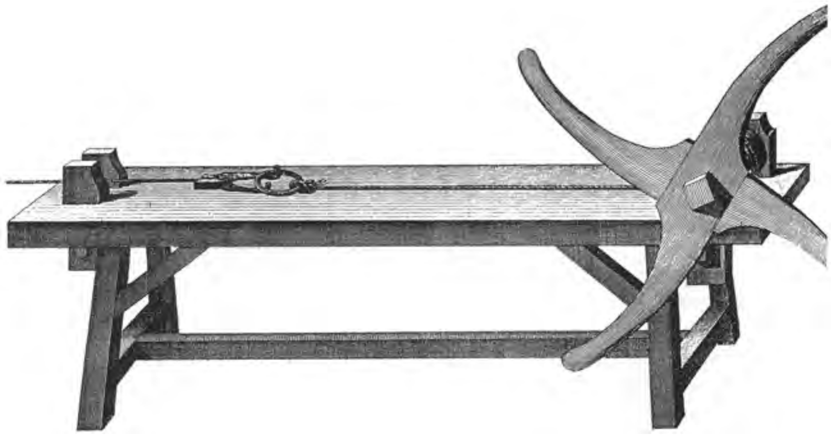


Plate 1, Figure 4

These rods heat up as they pass through the holes. It is necessary to take advantage of this heat to rewax them, in order to make them pass through another smaller hole. As the steel wire leaves the die it becomes smaller, hard, and brittle. Then it is necessary to reheat it, remove the scale, wax it and draw it in the bench from hole to hole, until it is the size which is needed. This operation is called *to draw steel through the die*. It can take three or four heatings and sometimes more due to the thickness of the forged steel and the smallness which you want the wire to have. Experience has shown that the steel should not be forced when drawing it through the die, and that it is better do the operation in three stages without effort, than to do it twice by forcing it, because you are likely to break it. And, moreover, by forcing it you scrape the hole of the die, which produces rough wire. Instead it must come out soft and uniform.

Section 6

The wire drawing bench must have a wheel with four arms, as in Plate 1, Figure 4. You must use a cord, attached at one end to an iron ring and at other to the shaft of the wheel; the cord must wrap about this shaft. Workmen making springs should not use straps to draw with the bench, as do goldsmiths, because the strap is too expensive and it increases the resistance as it rolls on itself.

Section 7

All the dies to draw steel must be made of billet steel in oblong plates from two to six lignes thick and 6, 8, or 10 inches long.(I will explain what is billet steel and how to make it in the art of making pinion wire.[1])

Section 8

The billet being reduced to the shape and the dimensions which I have just indicated, it is necessary to trace the plate and mark the places where you want to make the holes. After which it is reddened in the forge to be able to pierce three quarters of the holes with a blunt punch, as in Plate 1, Figure 5. That done, it should be put in a wood fire which you

1 As far as I know, Blakey did not publish anything on pinion wire.

let burn out, which makes it easy to be punched cold with a punch of about the same angle as that with which you pierced it hot; but as it must be used cold, its point must be more accurate. This punch must be turned after each blow while striking it with the hammer. By this means the holes become round and as true as you need. Then it is necessary to reheat the plate again and pierce the holes through with a drill (Plate 1, Figure 6) that is a size smaller than the wire that you want to draw.

Plate 1, Figure 5

Plate 1, Figure 6

Section 9

When all the holes are bored, a broach is used (Plate 1, Figure 7) with four or more sides, according to how quickly you want to go, to make the holes quite round. Broaches with fewer sides enlarge the holes more quickly and make them less round. On the contrary, a larger number of sides make them rounder and opens them more slowly. When the holes are the size that is needed, it is necessary to take the punch which is called an *opening punch* (Plate 1, Figure 5), and with some hammer blows smooth and open the entry of the holes a little, as you can see in the illustration of a broken die, Plate 1, Figure 8.

Plate 1, Figure 7

Section 10

The die being prepared as explained, take a handful of soot from a chimney where wood has burned, water it with urine to make it the consistency of a thin slurry, and add a spoonful of flour. (This composition is called a *package coating*, because the steel or iron which you want to harden carefully is coated with this mixture.) This paste being prepared, heat the die, coat its surface with it, and let it dry. The flour is used to make this mixture more sticky and consequently adhere better to the steel that you want to harden without encasing it. And the soot unites with the urine to have the qualities necessary to convert iron into steel.[2] These materials protect the surface of the steel from the excessive action of fire, and prevents it scaling and becoming ferruginous. Each workman has one secret or another for hardening, and they guard them very jealously. But as I know almost all of them, I give the simplest to avoid the length of the preparations that package coating hardening requires; the other secrets are no better than the method I have just described. Package coating hardening was devised only to give hardness to the surface of the iron, to convert it into steel and to give it, by quenching in cold water, enough hardness that a file cannot bite. I suppose that this discovery gave us the art to completely convert iron bars into steel, an art more important than all those which man has cultivated after being given iron, since tools cannot be made without steel, tools of which the number is infinite and essential in all the arts.

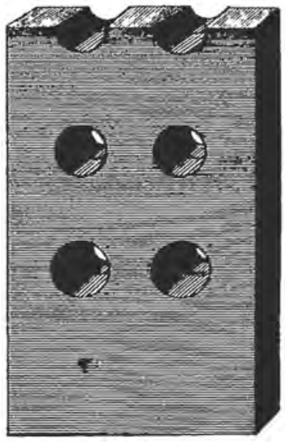


Plate 1, Figure 8

2 This is case hardening.

Section 11

When the paste has dried completely, put the die in a fire and cover it with charcoal. It is preferable to coal, especially in in France where German ferruginous steel is used, which does not take the hardness that it must have without many precautions. At soon as the die has taken the colour of a cherry which is not properly ripe, it should be taken by the end with pincers, as in Plate 1, Figure 9, and quenched in the coldest and hardest water.

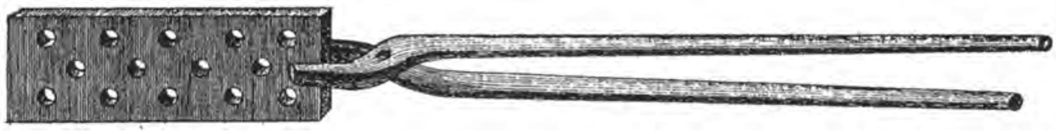


Plate 1, Figure 9

Section 12

To know if the operation of hardening has been successful, that is, to know if the steel is as hard as it can be, it should be tried by rubbing it with an English file. If the file does not bite and it slips while making a clear sound, the steel is well hardened. If instead the file grips and makes marks, it is a sign that it is not hard. When the die is well hardened, it should be rubbed with sandstone or a brick to whiten it, while taking care not to dirty it with perspiration from the hand. After which you put it on a charcoal fire. In few moments it takes the colour pale lemon, after that yellow, then orange, then red, finally purple and blue. Then it must be withdrawn from the fire and quenched in cold water so that the colour does not go further. Blacksmiths call this operation *annealing*, watchmakers say *tempering*, and the English *moderating* after hardening.[3]

Section 13

The steel having been drawn as wire, cut it to a length proportional to that of the springs which you want to make, observing that it must be an inch less because it lengthens during forging. Then put them in bundles to heat them on a wood fire. When the wire is heated, forge each piece with a hammer with an almost flat head, but which is not flat, because the work could scarcely be shaped without marking the hardest anvil, which would also happen to the springs and make them prone to crack. And if the head of the hammer is too round, there would be bumps on the edges, which workers call nipples or teeth. The wire being forged, it is necessary to reheat it, scale it and forge it again. And by reheating it and reforging it three or four times on an anvil ***A*** (Plate 2, Figure 1 opposite) with the hammer ***B***, we get small steel blades suitable for making watch springs.

Section 14

I do not know when we discovered how to make the blades of watch springs from drawn wire, but what I know about this particular way of working is that for over half a century it gave the English spring an equality of thickness superior to all those made in Europe. Forty years ago we found tools that gave such perfect equality, that it could be done without drawn wire. But routine prevented workers from departing from the method of preparing their steel as round wires and then forging them.

3 Both *revenir*, used by the French, and *temperer*, used by the English, have the same meaning, to temper.

Plate 2, Figure 1

Section 15

The blades being forged to a suitable thickness, it is necessary to take one, put it between files and take the two ends with pincers, as shown in Plate 2, Figure 2.

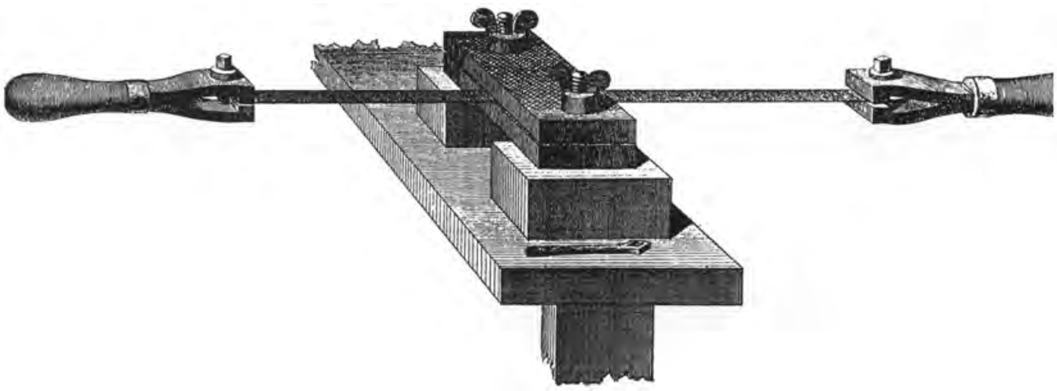


Plate 2, Figure 2

These files are mounted on benches supported at one end by a wall and at the other end by a post. The blade being tight in the pincers, a man holds one of them, and another holds the opposite pincer. The first pulls toward himself, until the opposite pincer is against the files. His comrade does the same, and thus by pulling alternately, the blade becomes as thin as is wanted. When the workers pull too quickly, it causes grains on the blades, which are so hard that the files cannot bite, or almost not at all, and which soon destroys the files. To avoid this, the master worker tightens one screw and loosens the other. Then he presses his fingers on the upper file on the side where the screw is loose, and so he makes the files bite as he sees fit. The operation of drawing with files achieves two tasks at the same time; one is to thin all the blade, and the other is to leave the two ends thicker than the remainder, for reasons than I will explain later.

Section 16

This manner of drawing with files was improved by my father, by adding oil to prevent grains, and by adding guides to reduce them equally on the flat, as well as to make them equal on the edges. The guide to reduce springs on their edges, is seen in Plate 2, Figure 3. It has a small slot to hold the spring, which is the height that you want for the width of the blade. It must be of steel hardened without tempering, because otherwise it wears too quickly. In spite of this care, it still should be repaired from time to time, so that it does not have too much play. To repair it, drive out the pins ***a*** which are only lightly riveted. Then soften the two faces to file them again, readjust them and harden them with a package coating. Then put back the small pieces of spring ***b*** in the base, which determine the play of the guide by their thickness, and put in the small pins which are riveted lightly. With these guides, you make a blade of a perfect width throughout its length. Plate 2, Figure 5 shows a blade in the guide without the file, and Plate 2, Figure 4 shows it covered by the file.

Plate 2, Figure 3

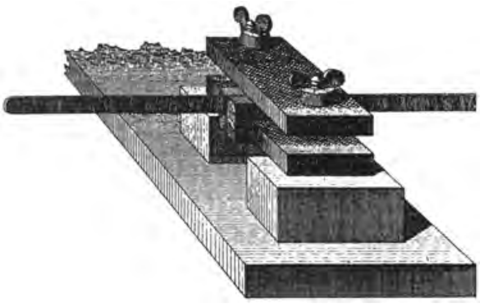


Plate 2, Figure 4

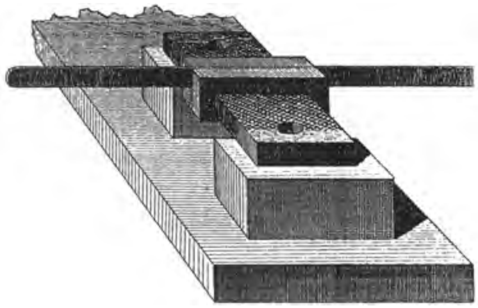


Plate 2, Figure 5

Section 17

Another design which my father made for this method of drawing with files was to have this work done by one man alone instead of two, by means of a frame with mounted pincers, as in Plate 3, Figure 6.

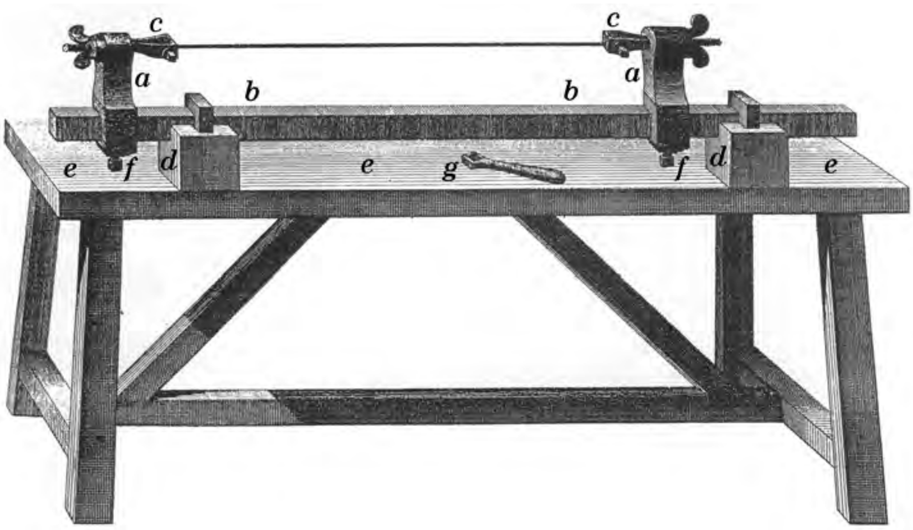


Plate 3, Figure 6

a, ***a***, are two headstocks mounted on an iron bar, ***b***, ***b***, like a watchmaker's turns. In the top of the headstocks there are square holes to hold the square tails of the pincers ***c***, ***c***. The ends of these tails are tapped to receive wing nuts. The bar ***b***, ***b***, is supported on two wooden cleats ***d***, ***d***, which are attached to the bench ***e, e, e***.

Section 18

The split frame ***a***, ***a*** that carries the files (Plate 3, Figure 3) is of wood and the files ***c***, ***c*** are mounted on it. It is held by the two clamps ***b***, ***b***.

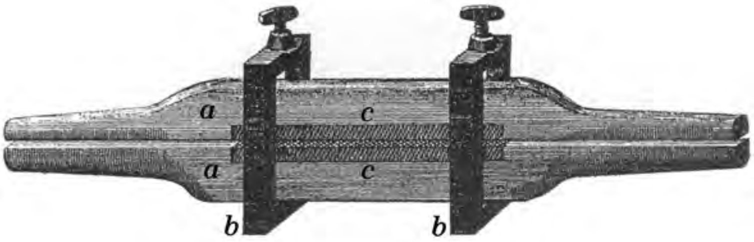


Plate 3, Figure 3

Section 19

To reduce springs on their edges it is necessary to use the split frame in Plate 3, Figure 4, on the bar in Plate 3, Figure 5, by passing a blade through the guide ***e***, and attaching its two ends to the pincers ***c***, ***c***, whose square tails are put in the holes cut in the headstocks ***a***, ***a***.

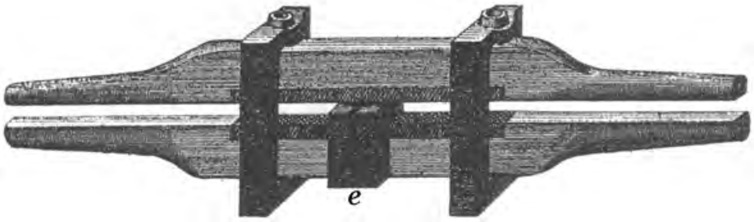


Plate 3, Figure 4

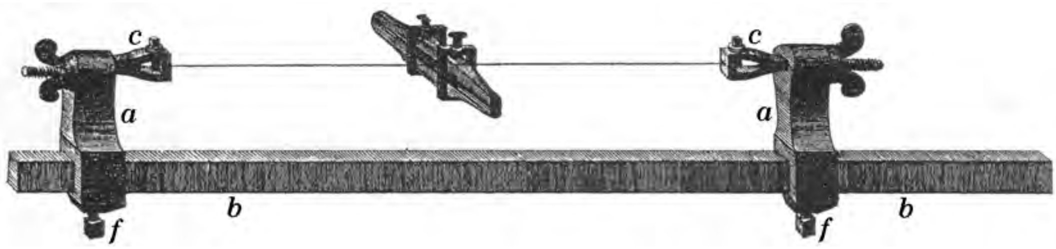


Plate 3, Figure 5

These pincers are rotated a quarter turn which holds them in position. Then tighten the spring by means of the headstocks which are fixed where necessary by tightening the screws of the headstocks ***f*** with the key ***g***, Plate 3, Figure 6. Then it is necessary to turn the wing nuts of the pincers to tighten the blade. (Do not tighten it too much, because clumsy people sometimes break the blades.) Then put a little oil on the blade, pull the frame until it touches a pincer, and then withdraw it to touch the other. And thus alternately make the files come and go until they no longer bite and the spring is the height of the guide. This operation is done without screws, the hands having enough force to tighten the files against each other. And also, without screws you go more quickly and without so much wear of the files. But the width of the spring is not so exact as when using screws.

Section 20

The blade of the spring being finished on its edges, it is necessary to unscrew the pincers from the headstocks and to change them a quarter turn to hold the blade flat, as in Plate 3, Figure 5, where the spring and pincers are seen placed horizontally. The pincers being positioned, the workman takes the frame, Plate 3, Figure 3, which has better files than those that were used to reduce the edges, and puts it on the bar ***b b***, Plate 3, Figure 5. Then two small pieces of the blade of a spring are put between the files near the clamps, to be guides for the one that will be filed. Then put a blade between the files, attach the two ends to the pincers, and tighten it, as was done when filing the edges. After which oil is put on the spring and the frame is pulled and pushed a few times to spread the oil on the files. After turning the screws of the clamps ***b b***, (Plate 3, Figure 3) to make the files bite, continue to pull and push, until the blade is the thickness of the guides. This operation of reducing with screwed guides gives a great equality to the blade and makes completely unnecessary the trouble of making round steel wire in a draw bench.

Section 21

The blades of the springs having been reduced by the files, they are dried with ashes and wiped to remove all the dirt. Then the ends that were in the pincers are filed to the same width as the rest of the blade. To see what is necessary to file, take the stepped and numbered gauge, Plate 3, Figure 2, to put in the ends and to see their width.

Plate 3, Figure 2

Plate 3, Figure 7

After that, put the blade in a vice, as in Plate 3, Figure 7, to file the too wide part on the edge. It is then turned and filed as much on the other edge until the end passes through the gauge. The other end is also filed, and you end up making the blade the necessary width. But the parts filed by hand are not as correct as those that had been filed in the frame with guides.

Section 22

After the previous operation, it is necessary to use a wood filing block (Plate 3, Figure 1) in the vice to take off the burrs which have just been made on the ends of the spring by hand filing. This is done by holding the blade in the left hand, resting it on the wood, and the right hand, which holds a file, is moved on the flat while inclining a little to the edges; this operation is called to deburr by draw filing: To do this operation more precisely, it is passed one or two times in the *large leads*, which will be described later (Section 45, page 16).

Plate 3, Figure 1

Section 23

All the blades being filed, take one of them and bind its whole length with iron wire, Plate 4, Figure 1. It is necessary to bind half of the blades.

Plate 4, Figure 1

Then take the longest unbound blade and attach its two ends together with iron wire, one against the other, to form a circle.

After that, take two blades, one bound and the other not bound, and put them in the circle already made by the unbound blade. Be careful when filling this circle with bound and unbound blades, that the latter do not touch, and thus put two blades, bound and unbound, one on the other, until the inner circle is about four inches in diameter, as in Plate 4, Figure 2. This inner circle should not be too small for reasons which I will give. All the blades within the first circle are bound outside with iron wire to hold them together.

Plate 4, Figure 2

Section 24

This method of preparing or binding springs for hardening, so different from the old and so important for good hardening, is due to my father. And all spring makers adopted it, because it saves much trouble and gives better results.

Section 25

All the springs being prepared in circular packets as I have just described, make a fire in a hardening furnace; it is made like an kiln, with a chimney that is half a brick wide. There are many ways to make these furnaces, but I will restrict myself to indicating the simplest, most economic and the best, as that has always been my goal in all that I do. This brick furnace is shown in Plate 4, Figure 3.

A A is the solid base, ***B B*** is the body of the furnace, ***C*** is the door or mouth, ***D*** is the chimney, and ***E E*** are vents to supply air. The chimney and the vents are closed more or less as needed, the former with a brick or iron plates and the latter with ash.

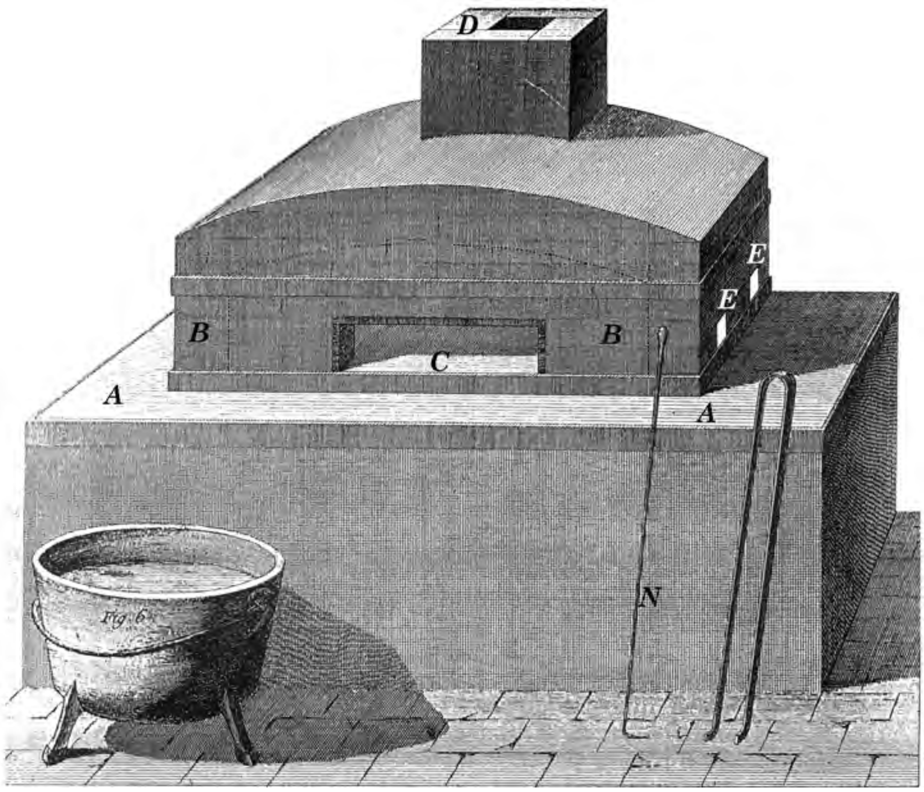


Plate 4, Figure 3

Section 26

The iron wheel for hardening is a tool of great importance for this task; by using it springs can be heated very evenly. This wheel is an invention of my father. I remember seeing, about 50 years ago, springs hardened by folding them into small circles about three inches in diameter, which put them in danger of breaking during the various operations before tempering them. This wheel is made as in Plate 4, Figure 4. ***A*** is the handle, ***b***, ***b***, is the circle on which the spokes ***c***, ***c***, ***c***, ***c***, ***c***, ***c*** are riveted, ***d*** is the hub to which the spokes of the wheel are attached. This hub turns around a pivot or a small axle about an inch and a half long. The ends of the spokes protrude from the circle to have something to push against and turn the wheel when it is hot.

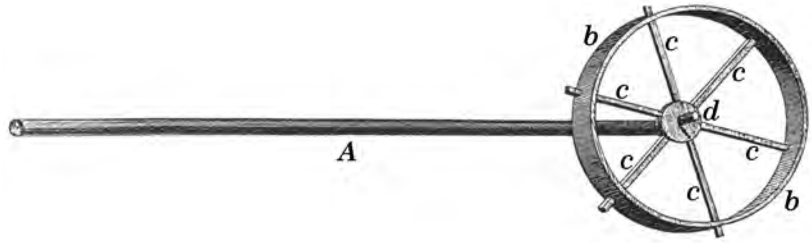


Plate 4, Figure 4

Section 27

All being prepared for hardening, a boiler full of oil is put to the left of the workman, Plate 4, Figure 6.

Then make fire in the furnace with charcoal; a few wood chips can be put in to accelerate the heating. After waiting until the furnace is at its correct degree of heat, put the wheel in the furnace so that it takes the required heat; that is seen by the colour that the wheel takes, which must be the same as that of the furnace. The smoke or vapour having subsided so as to see clearly into the furnace, immediately cover the chimney ***D*** with a brick and stop the air vents ***E E*** with ash. Then withdraw the wheel from the fire and put a packet of springs in it, as at Plate 4, Figure 5.

Plate 4, Figure 6

Plate 4, Figure 5

Then put the wheel in the furnace by holding its handle ***A*** in one hand and resting it on the base of the furnace door. Push down a little to raise the wheel in the furnace, and with the other hand push against the ends of the spokes of the wheel with an iron rod ***N***, Plate 4, Figure 3, to make it turn; by this means all the parts of the packet become equally heated. Then withdraw the wheel from the furnace, turn it over and drop the packet of springs into the oil. And as of this moment the springs have the extraordinary elasticity that the hardening has given them. Care should be taken not to leave the steel in the fire after it has taken the heat necessary for hardening, because scales would form and its quality would deteriorate. After this operation, promptly put another packet in the wheel before it loses its heat, and thus going from packet to packet all the springs are hardened.

By continuously putting cold bodies into the furnace, its heat drops. To avoid this, it is necessary from time to time to add a handful of charcoal and to open the chimney and the air vents, if it is seen that the fire needs air to revive. It is up to the master craftsman to judge the size the openings should be made to let the air and smoke pass. If they are too large, the furnace develops too much heat. If instead they are not open enough, the cold charcoal will take too long to give the heat which is required.

Section 28

Another very important observation to the artist, is that he must be very careful to ensure the steel does not get too hot, because that will harm the quality of it. It is useless to expect that it will return to the right point by letting the heat of the furnace decrease. The only course to be taken in this case is to withdraw the packet from the fire, let it cool completely and to wait until the heat of the furnace and the wheel is at the point necessary to heat the packet again.

Section 29

When you want to know if the hardness is good, unbind a packet, remove a spring, wipe it and then rub it with a good file. If it bites the steel is not hard, but if the file slips the spring is hard. To know if the steel was well heated, clean a spring properly, break off an end and examine the grain with a microscope. If the grain is fine and dull it was correctly heated. If instead the grain appears coarse and shining it should be concluded that the steel had too much heat. Note that after hardening, the steel with the weakest body is more prone to form scales and appears a tin colour underneath. On the contrary, the steel with the strongest body forms almost no scales and has a blackish colour.

Section 30

The springs being hardened, it is necessary to unbind them, pass them through hot ash to degrease them, and wipe them. After which make packets of 18 or 20 blades that are bound leaning one against the other, as in Plate 5, Figure 1, with the shortest outside and the longest inside.

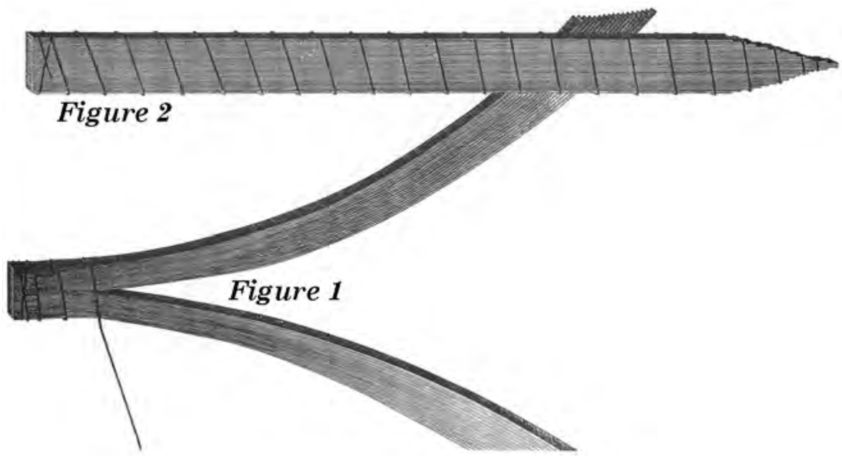


Plate 5, Figures 1 and 2

Then continue to bind the packet for its whole length with strong iron wire, as shown in Plate 5, Figure 2, so that the edges can be whitened with brick or sandstone. Having prepared all the hardened springs, to fix them in this bound state heat the furnace, put in the packet and temper it yellow on the hardening wheel. Those who do not have a large enough furnace for this operation must light charcoal in an earthen stove (Plate 5, Figure 3) on which there is an iron plate ***a***, ***a***. To know if the plate is hot enough, rub it with a file which makes white marks; if it is hot enough, these marks become blue in a few moments. Then put one end of the packet (Plate 5, Figure 2) on it. As the colour advances, move the packet until the whole is yellowed. You can even let it go to the colour orange if the steel is fragile, but you should not pass that colour to avoid harming the following operation.

Plate 5, Figure 3

Section 31

When all springs are fixed, larger packets should be made, putting the longest in the middle, as I said, and so that they are as far as possible of the same length. A packet of this type must contain three or four dozen springs. On each side of the packet` it is necessary to put soft strips which are a little thicker, in order to protect the springs from the compression of the iron wire with which they are bound. The packet being made, it should be bound at five or six places, as in Plate 5, Figure 4.


Plate 5, Figure 4

Then it is necessary to again rub the edges with sandstone or brick. The latter material is the best, because the powder which is detached absorbs the grease or the sweat from the hands of those who hold the packets, and this grease would cause false colours, which could mislead the worker.

Section 32

All the hardened springs being put into packets like Plate 5, Figure 4, take a length of thick iron wire, put one end in a vice, and with other start to wrap at the butt end of the packet by tightly bending the wire, and continue until all the packet is bound as in Plate 5, Figure 5. Be careful not to have sweaty hands when making these packets, because that would prevent the true colour from appearing.


Plate 5, Figure 5

Section 33

The preceding preparations being finished, put a packet in the furnace to temper it to the desired colour. Or if the furnace is not large enough, instead, as I have already said, pass it over the iron plate ***a***, ***a***, of the stove (Plate 5, Figure 3) starting by tempering one end the colour which is wanted, and continuing to the other end. This operation is of great importance for the quality of the springs, and the workman must pay the utmost attention to it, since more or less colour fixes the degree of elasticity. In order to know the correct colour of tempering that the steel must have, to make as good a spring as its quality allows, take a piece of a hardened blade, whiten it, and then temper it to a purple colour. That done, fold it on round-nose pliers (Plate 6, Figure 1) and if the blade breaks, (which is common with this colour) it is necessary to heat it more and to advance the colour to blue. If it still breaks, it should be advanced to light blue, to grey, to the colour of dirty brass, pale red copper, dark red copper, and finally to the colour of slate. If the piece continues to break it must be concluded that this steel is not suitable to make springs. Also, after the tests at these various colours, the steel no longer gives a true sign to recognize its degree of tempering, of heating or of its temperature after quenching. So you can no longer use sight, and the crude tests of burning oil or tallow on them, or seeing in the dark if the steel takes some shades of red, are not reliable.

Plate 6, Figure 1

Section 34

In general Styrian steel requires less tempering than that of England, and usually it should not be advanced further than pale blue to be quite elastic and unbreakable. But of all steels the best is that made in England from Swedish iron. The operations which follow will show even better the qualities that the steel suitable for making good watch springs must have.

Section 35

The operation of strongly binding a quantity of springs together to temper them has two purposes. First, it is to make good contact, so that they communicate their heat reciprocally and so make the tempering more even. Second, it is to firmly press the blades against each other, and make them flatter than it is possible to do with a hammer. Also this operation makes the use of planishing with a hammer unnecessary, and one should only use it after hardening for what is called dressing. This method of tempering springs is the invention of my father.

Section 36

The springs being hardened and tempered, they are unbound. Then they are found flatter than they could be made with a hammer, but they are not always as true on the edge as required. To fix this, use a hammer lighter than that used to forge them and which has a rounder head. And as each spring is thin and hardened, it is impossible to forge it on the edge by making the bad part bear on the anvil. To succeed in dressing it, hold it flat to the anvil in the left hand (Plate 6, Figure 3) and with the hammer in the right hand strike it with

Plate 6, Figure 3

small blows on the flat of the interior curve ***A A*** (Plate 6, Figure 2) while taking care not to touch the edge of the exterior curve.

Plate 6, Figure 2

Section 37

When all of the springs that you want to finish are prepared, they should be whitened with oil and emery in the *large leads* (Plate 7, Figure 1; see Section 45, page 16).

This operation is essential for two reasons. The first is to remove the dirt and the small amount of scale which forms on the flats of the springs when they are hardened. The second is to remove the colour which the first tempering gave them, so that the colour of the second tempering is easily distinguished.

Section 38

What has caused the need to temper the springs again is that, after dressing them with a hammer and polishing them, blueing makes them become curved, not quite as much as after the first tempering, but still enough to have a bad effect. On seeing it, my father decided that it could only come from the few hammer blows that the blades received when dressing them, and that the parts which had not been touched pulled the others when the blades returned to the degree of heat that tempering had given them. He concluded from this that they had to be whitened out of the packet, bound again, and tempered a second time, which worked as well as possible. The blades became flatter and less curved, because of their restriction from this second binding.

Section 39

After this operation of a second tempering, my father again dressed the springs with a hammer with a less round head, so that each blow covered more of the surface. That also worked very well, and the first spring that was blued to finish it was found to be perfectly straight.

Section 40

This second tempering is the reason why it is necessary to make the first less strong, to leave something for the second. By following these steps the springs are truer and flatter than if you had taken all possible trouble the first time.

Section 41

The springs having been tempered for the second time, they are put in a vice to repair the small errors on the edges which the hammer blows can cause, and also to make the end which is attached to the barrel arbor a little narrower than the rest.

Section 42

It should be noted that a spring maker's vice must have long jaws with even and soft edges, so that spring holds over the entire length of the jaws, and the hard edges do not make marks and do not make it brittle, especially if it is very thin.

Section 43

When the springs have been filed on the edges, they must be filed on the flat, to give them the whip shape that is necessary; I will give the reason later. This operation is done on a filing block in a vice. The spring is attached with screw pincers, as in Plate 6, Figure 4. Then repeatedly file what is needed, while feeling it to see that no sudden inequality has been made each time you change place. And thus by degrees, the spring is filed thinner at one end than at the other. Leave approximately an inch and a half untouched, for a reason that I will give later.

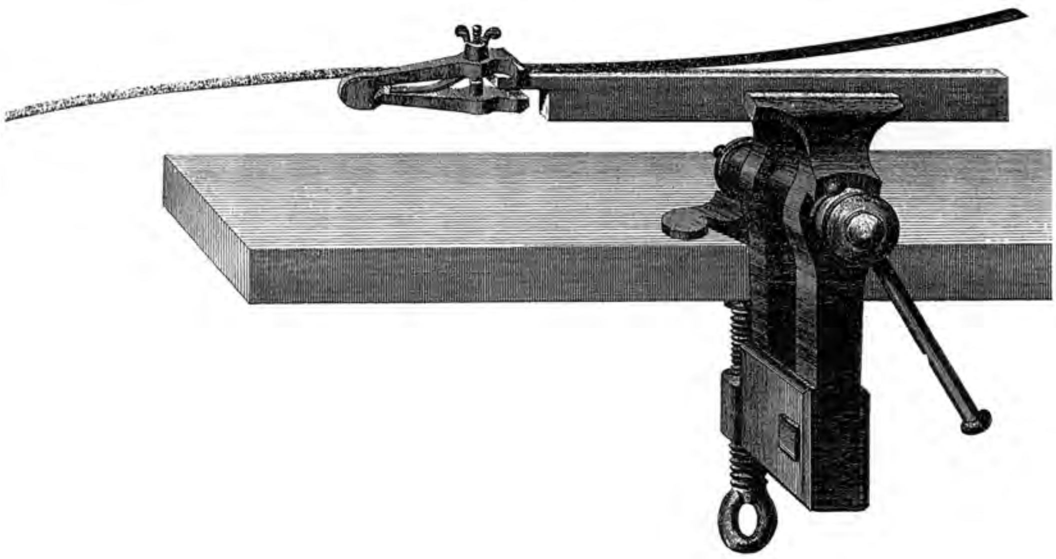


Plate 6, Figure 4

This operation of filing a spring on the flat is perhaps most delicate that can be done in metal working. Having no instruments suitable to measure the necessary gradations, you can only use touch and the swinging of the blade in the fingers. Sight must distinguish the various thicknesses which the blade must have, which is also recognized by the more or less regular curve. Feeling together with long experience is the only judgment that can make a man able to do such an operation.

Section 44

To remove the small inequalities which the file makes, the most skilful artists go over their springs with oil and emery between plate plates of lead, mounted like the files in Plate 2, Figure 2. By this means the spring loses all its bumps and the file marks disappear. But the blade becomes equally thick, and it should be improved from time to time with a file (the finest bastard) to maintain its gradual thinning. This can only be known by touch, by holding the spring with two fingers and pressing with the thumb to feel the bumps and different thicknesses. All these operations are done by degrees and require much time.

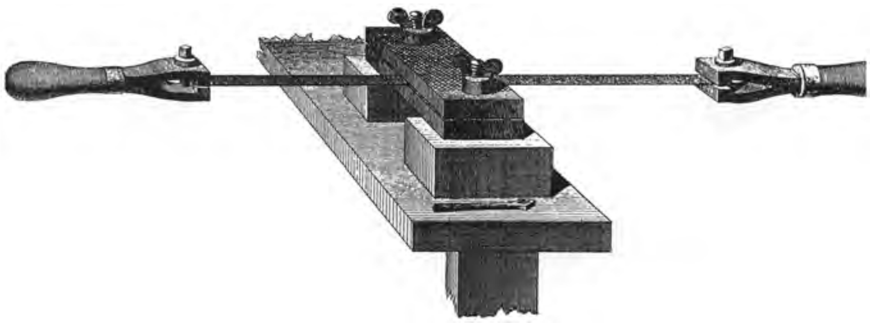


Plate 2, Figure 2

Section 45

To speed up this difficult and long work, I invented a machine which I called the *large leads*, Plate 7, Figure 1. For this purpose I used the time that my father was in the countryside and I made all the necessary parts before he returned (to have all the honour, a quite natural vanity of youth). As the principles of the machine are simple, it worked the first time. Here is its description.

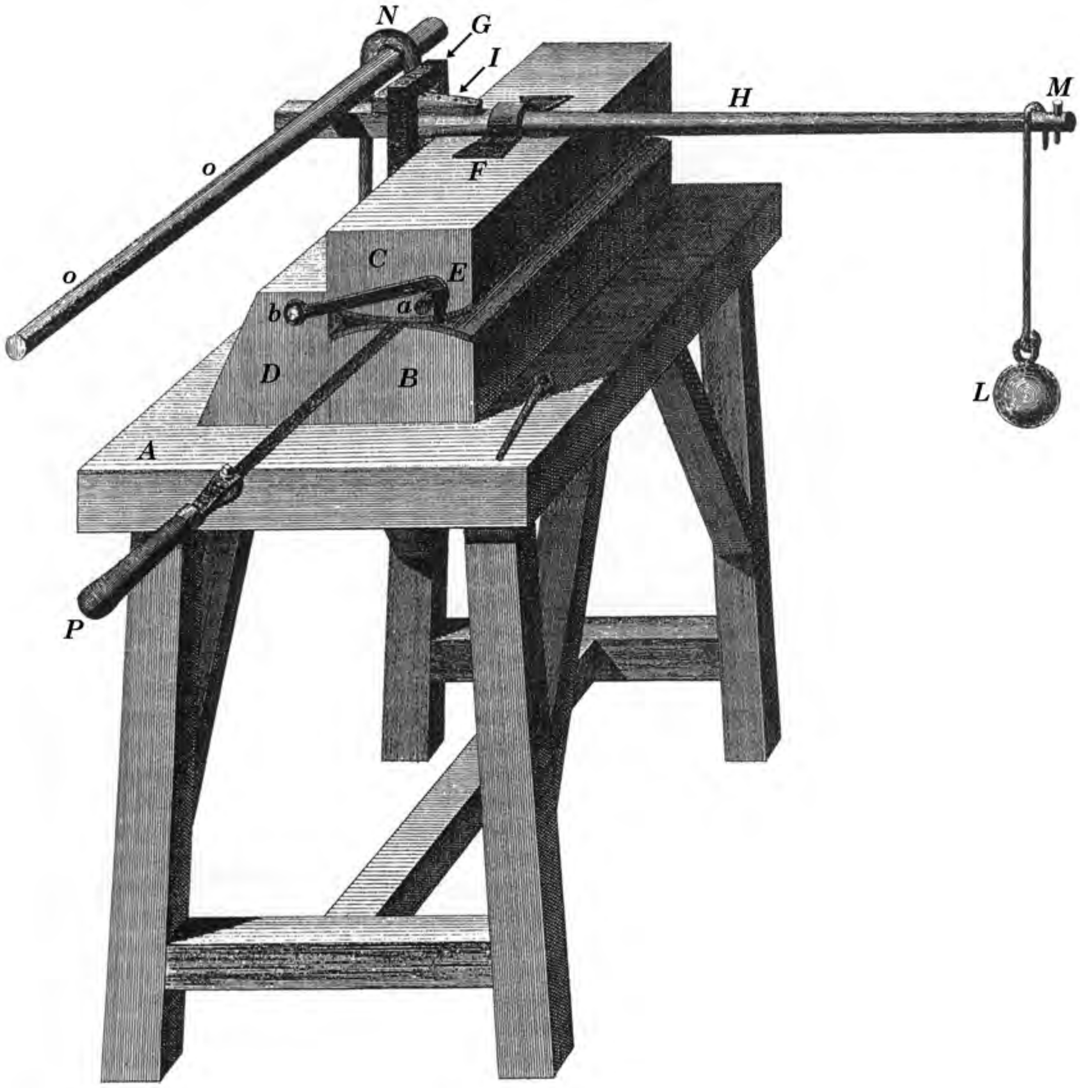


Plate 7, Figure 1

A is a bench, ***B*** and ***C*** are two pieces of wood 18 or 24 inches long, to which are attached two plates of lead, which led me to name it the *large leads*. ***D*** is a wood cleat against which ***B*** and ***C*** are supported, to hold them in respect and parallel to each other. ***E*** is a hook attached by one end to the cleat ***D*** with a flat-head pin ***b***. The curved end of the hook is on another pin ***a***. On the piece of wood ***C*** there is an iron stirrup ***F*** attached with wood screws. In the bench there is a square hole to put in and hold another iron stirrup ***G***, of different shape. The lever ***H*** passes through the stirrup ***F*** where it is firmly attached. Between this lever ***H*** and the stirrup ***G*** there is a wooden wedge ***I*** which has several holes to put in a pin which prevents the wedge from being withdrawn. At the end of the lever ***H*** is a weight ***L***, and ***M*** is a pin. ***N*** is another stirrup, through which the lever passes to the handle ***o***, ***o***. The pincers ***P*** are attached to a spring blade.

Section 46

To use this machine, it is necessary to take off the upper lead ***C*** to put oil and emery on the lower lead ***B***. Then put back the upper lead ***C*** and rub one against the other to spread the emery everywhere. (Emery is a hard stone which comes from the East and several places in Europe. It is pulverized with rammers and then passed through a sieve to give the fineness that is wanted, and it is washed when it is needed still finer.) Then put the hook ***E*** on the pin ***a***, the wedge ***I*** under the stirrup ***G*** and the pin in one of the holes of wedge ***I***, and finally put the weight ***L*** on the lever ***H*** more or less towards the end according to the load which is needed.[4]

Section 47

The leads being well charged with oil and emery, take a spring by the end which must remain thick and put it in pincers, as in Plate 7, Figure 2.

Plate 7, Figure 2

Then press on the handle ***o***, ***o*** with the left hand, which opens the leads like a jaw, and with the other hand which holds the pincers, flick the spring to put it in the place where they pinch the best. After which remove the left hand from the lever ***o***, ***o*** and put it with the other hand on the handle of the pincers ***P*** (Plate 7, Figure 2) and pull with both hands. And after about 20 strokes the spring has the gradual tapering which is necessary.

Section 48

The reader having seen how to taper springs with the *large leads*, it is appropriate that I give an explanation of how it becomes thinner at one end than at the other. It is necessary to ensure the leads are parallel and they touch for all their length. So when the spring is in the leads, it is squeezed from one end to the other, and by this reason when the workman pulls the first inch out of the leads, it has an inch of friction. Then the second inch also being outside, it receives two of them, the third inch receives three, the fourth the same, and thus each division over the length of spring receives as many frictions as it will have spent a longer time in the leads. So that if the blade is 24 inches long, the last inch receives 24 times more polishing than the inch which is at the pincers. It is seen that this way of shaping a spring includes the correction with it. And experience shows that you can get this perfection in two minutes when the worker has prepared his blade well.

---

4 The description of this tool and its use are a bit vague, and not helped by the labels G and P being missing from the original plate. Also, the illustration is wrong, because the leads are only about 24 inches long and so the bench they are mounted on is only about 30 inches high!

The lever ***H*** is rigidly attached to the lead ***C*** and its left end is wedged within the stirrup ***G***. ***G*** can move vertically but not sideways because its bottom sits in a hole in the bench, and so the lead ***C*** is held parallel to the lead ***B*** by the hook ***E*** and the lever ***H***. Note that both leads are convex and only a small part of ***B*** and ***C*** touch.

Because ***C*** can rotate, the weight ***L*** counterbalances the combined weight of the handle ***o o*** and the stirrup ***G*** to keep ***C*** in its neutral position. But where the leads touch depends on the wedge ***I***. By moving this wedge to the left ***C*** will rotate a little clockwise to keep ***I*** and ***H*** in contact with ***G***; and vice versa. So different parts of the leads ***B*** and ***C*** can be used by moving ***I***.

Pressing the handle ***o o*** does not lift ***C*** up, as suggested in Section 47, but forces it to rotate, so that a blade can be put on ***B*** and then pressed between ***B*** and ***C*** when the handle is released.

But as this manner of polishing with coarse emery in the large leads quickly thins the blades, ordinary workers benefit from it, at the expense of the correction of their work, by often changing the ends in the pincers, and so they remove the good form which a spring must have and that is given in very little time by the means that I have just indicated.

Section 49

As good workers draw their springs between files before hardening, there is a length of two or three inches at one end which is thicker than the rest, which becomes very useful, because it can be held by the thin end and passed 5 to 6 times in the *large leads* without thinning the thick end too much, and so remove the file marks and whiten it. Then again hold the spring by thick end and pass it in the leads until it acquires the necessary form.

Section 50

Plate 7, Figure 3

The spring having the shape that is required, it is put in a slot, which is made as in Plate 7, Figure 3, and mounted in a vice. Put the spring in this slot and hold it with the left hand. In the right hand have a smooth file which is drawn the length of the edges to round them; the position of the file on the spring is shown in Plate 7, Figure 4. Make use of this opportunity to decrease the width of the thin end for two or two and a half inches from the end.

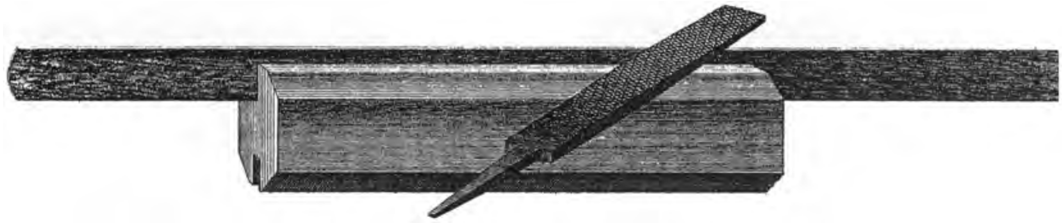


Plate 7, Figure 4

Section 51

After this operation it is necessary to put the spring in the frame Plate 3, Figure 6, as when drawing it on the edges between files.

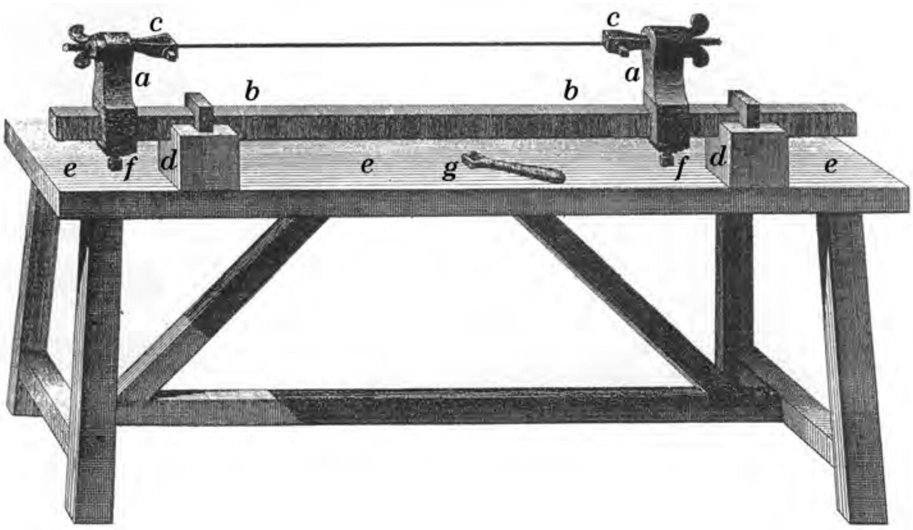


Plate 3, Figure 6

Then take the wood handle Plate 8, Figure 2, on which the oilstone ***d*** is mounted with goldsmith's cement, and put it on the bar ***b***, ***b***, of the frame.

Plate 8, Figure 2

Plate 8, Figure 1

Put the lower edge of spring in one of the slots in this stone and tighten it with the pincer screws. After which take the other wood handle, Plate 8, Figure 1, which also has an oilstone ***c*** with similar slots, put the upper edge of the spring in one of the slots, and put oil on the spring. These oilstones being plumb, one with the other, take the ends of these handles with both hands and, while lightly pressing them together, make them move from one pincer to the other. In a few moments a good polish is achieved.

Before the invention of the frame in Plate 3, Figure 6, the operation of polishing the edges with oilstone was very long and difficult, because then a wood slot was used to support spring while the oilstone was passed over it. When one edge was finished, it was necessary to repeat the same operation on the other edge, during which time the polished edge, which was then in the slot, lost some of its polish because of the dirt that is there.

Section 52

The edges of the springs being polished, it is necessary to turn the pincers to make them hold the spring flat, put it in the frame and tighten it, as in Plate 3, Figure 5.

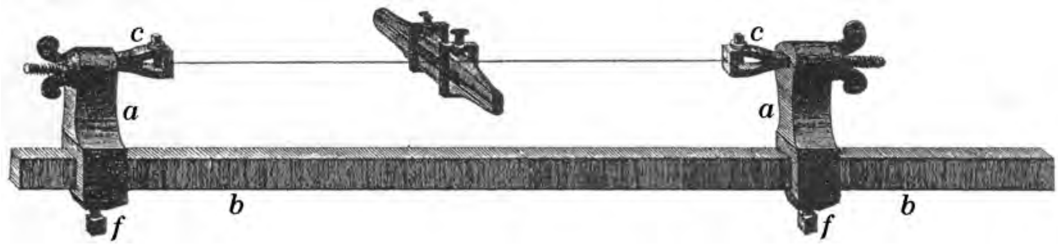


Plate 3, Figure 5

Then take the small lead, Plate 8, Figure 4 and put it on the bar of the frame. Put oil and fine emery on this lead. Then put the small lead, Plate 8, Figure 3, on the spring. Take them by their handles in both hands and, holding them quite tight, push them alternately from one pincer to the other. Take care to refresh the oil and the emery from time to time until the spring is polished. This method of polishing also has the advantage of acting on the spring equally, so it does not disturb the shape that it was given in the large leads, and leaves the thick end which is necessary for the hook on English springs, or for the bridle on French springs about which I will speak later.[5]


Plate 8, Figure 4


Plate 8, Figure 3

5 The bridle is a metal strip slotted into the base and the lid of a barrel. It holds the last turn of the mainspring against the wall of the barrel, so that the eye cannot escape from the hook. See Vigniaux, *Practical Watchmaking*, 2011, www.watkinsr.id.au/vigniaux.html

Section 53

After the springs are polished they should be blued. For this wipe them with well dried wood ash. Then make a fire in the stove, Plate 5, Figure 3, on which, instead of the iron plate, ***a***, ***a***, put old files with rough cutting edges.

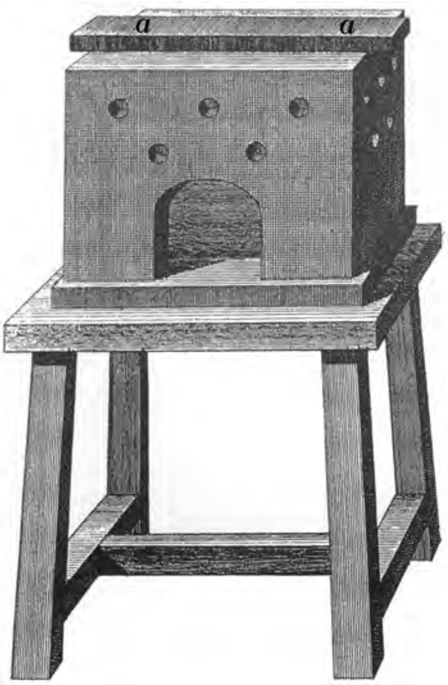


Plate 5, Figure 3

When they are hot, take a spring in the left hand and rest an inch of it on one of these files. When this part approaches the colour which is wanted, take the end with a flat grip which is held in the right hand. Then advance the spring on the file with a sort of rocking to communicate the heat and make the colour even, and as the heated parts acquire the colour, draw them off the file at the opposite end to that where you started. Files with a rough cutting edge must be preferred to a level plate, because they heat more slowly and give the workman time to advance the colour uniformly. And several files provide the convenience to be able to choose that whose heat is at the point necessary to blue equally and promptly.

This blue will be more or less bright in proportion to gloss that the steel has taken by polishing it. Neither painting nor dyeing produce colours as brilliant as those which fire gives to polished steel.

Before 1730 the operation of bluing was done with plumber's irons that were fixed in vices after heating them, and on which the springs were passed. But in addition to the large consumption of charcoal required for such a small object, much time was lost in heating and moving these irons. However this method was much less wasteful than that which was used in England, where bluing was done on a thin copper strip which was heated by grain spirits, which is vulgarly called spirits of wine.

Section 54

After bluing the springs, they should be carefully examined and at the same time the clearest face should be recognized. Then break them to the length required at the thinnest end, so that the small curve which remains at the broken place is turned to the least clear face, and thus fixes the direction in which spring must wrap around the arbor on which it will be mounted. Because the clearest face must be outwards, so that cracks or other faults do not open; otherwise spring could break while winding it. Then heat the broken end in the flame of a candle, making it red for about two or three lignes, then further along temper it a slate colour, then three or four lignes further a red copper colour, then for four or five lignes a paler copper colour, and finally as much of light blue. You must, while advancing and by imperceptibly moving back the end of the blade on the candle, merge all these nuances into each other for the length of an inch or two along the thickness of the spring, remembering that the stronger the spring is, the longer the annealing of the end must be. This operation prevents the blade from breaking in the first turns, when you give the spiral form to the spring.

Section 55

When you work with large numbers of springs, take about 24 of these springs and assemble them by the broken ends to make a packet whose end must be bound as in Plate 8, Figure 5.

Plate 8, Figure 5

Then remove the plate ***a***, ***a***, from the stove (Plate 5, Figure 3 opposite), to put the end of the packet on the coals, flat with the fire, and let the end warm up until you see the colours appearing, as described above while heating on a candle.

Great care must be taken not to heat behind where you are colouring; that is, only the end should be heated and it must increase only by degrees, colouring approximately two inches. When this operation is done, you will see the colours merging gradually, one into the other, from the end to the blue of the spring, and in a subtle way which you will see at first glance is impossible to do as well with a candle, or in other way.

Section 56

The next operation is to round the other end of each spring with a file, as in Plate 8, Figure 6. Its end must be filed in a bevel on the convex part. Then redden it with a candle for about a ligne and a half at this end, so that it can be easily bent around round-nose pliers.

Plate 8, Figure 6

After which make a hole which is called the *eye* (as seen Plate 8, Figure 7) with the file Plate 8, Figure 8.

Plate 8, Figure 7

Plate 8, Figure 8

And after removing the burrs, take the round-nose pliers again and fold the end of spring as in Plate 8, Figure 9.

Plate 8, Figure 9

Section 57

The inside eye being prepared as I have just explained, the spring winding tool, Plate 9, Figure 1, is put in the vice by its tail ***H***.

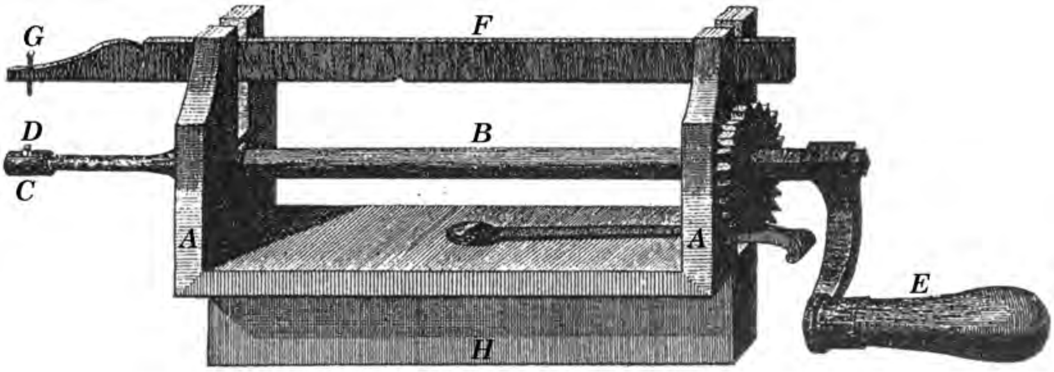


Plate 9, Figure 1

This tool consists of a brass frame ***A*** which has an arbor ***B*** whose end ***C*** has a hook ***D***. At the other end of this arbor is the crank ***E***. In the notch in the frame there is a small flat bar ***F*** which also has a hook ***G***. The end of the arbor must be made in a spiral; The geometrical view of this end of the arbor is shown in Plate 9, Figure 2.

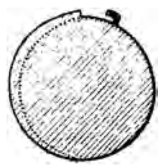


Plate 9, Figure 2

Section 58

The end of spring being bent as in Plate 8, Figure 9, it is necessary to take a piece of parchment that is a little thick, the width of the blade, and about 3 and a half inches long. Thin it gradually at its end for about an inch, and put it inside the fold of the blade with the thinnest end beside the eye of the spring. Then attach spring to the hook ***D*** of the small arbor ***B***, take the spring in the left hand with a piece of quite dry linen, so that sweat from the hand does not stain it, and turn the crank with the right hand until the blade is rolled around the arbor. That done, release the crank by holding the spring in the left hand as it is, and then release the spring. This operation gives the spring the spiral form in Plate 9, Figure 3.

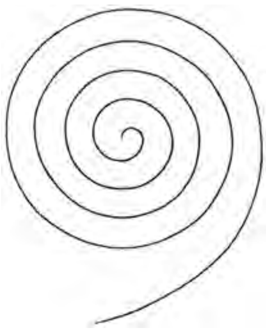


Plate 9, Figure 3

Section 59

The preceding operation being done, it is necessary to roll the spring again, without the parchment, on an arbor of the size which you want the finished spring to be, which makes it take a more compact spiral form, as in Plate 9, Figure 4.

Plate 9, Figure 4

Section 60

It is now time to decide where to break the strong end of the spring. If you want to have an English hook, a stronger end should be left. If instead you want to have a French bridle, some more must be left, because the bridle decreases the run of the spring by nearly a quarter of a turn, and the strong end should be that much more. This is the reason why it is not necessary that the outer ends of springs are as strong for bridles as for ones with

English hooks. I would always advise using a French bridle rather than an English hook, because the action of holding the outer end against the wall of the barrel is greater. And also, if the strong end of the spring breaks an English hook is useless and lets the blades rub. Having broken the end of the spring, straighten about two or three inches to be able to reheat its end more conveniently, enough to fold on the round-nose pliers as in Plate 9, Figure 5.

Plate 9, Figure 5

Then put this end on the tail of an old, annealed file attached to a vice, as in Plate 9, Figure 6, and make an eye as small as you can, but large enough to easily take the hook of the barrel.

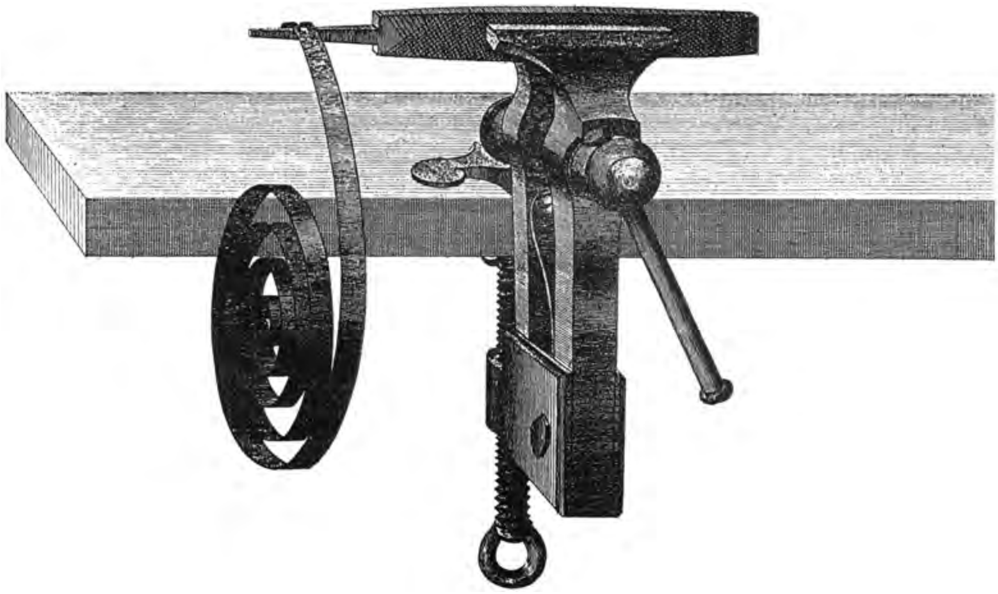


Plate 9, Figure 6

Section 61

When the eye is made, put the outside end on the edge of the bench to straighten it with a small hammer or the back of a file, and use the tip of a file, as in Plate 10, Figure 1, to give the bevel necessary for it to hold to the hook of the barrel.

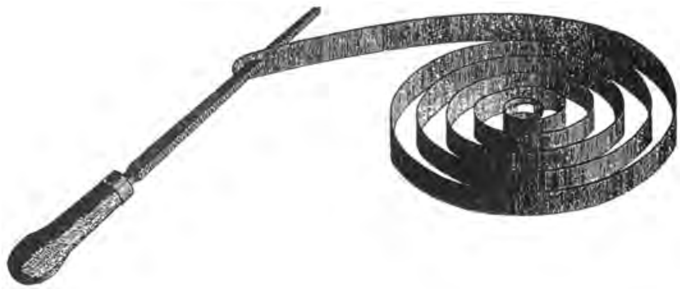


Plate 10, Figure 1

Then, with large round-nose pliers, bend about a half or three quarters of an inch of the end of spring so that it closely follows the internal contour of the wall of the barrel.

Section 62

All being prepared, the spring is rolled up for the last time. To do this it should be held with a dry and clean piece of linen. Put the hook ***D*** of the arbor (of the spring winding tool, Plate 9, Figure 1 opposite) in the inner eye, and then put the hook ***G*** on the bar ***F*** in the outer eye, holding the sides of the spring firmly to prevent them getting out of order. Let the spring slip between the fingers of the left hand while the right hand turns the crank ***E***.

When spring is rolled up tightly, so that all the blades touch, allow the crank to turn back, and then the spring has the spiral form which is required, as in Plate 10, Figure 2.

Plate 10, Figure 2

Section 63

For a long time, springs which have undergone this last operation were considered finished. But by pulling them by the end to open them, the blades lost their spiral shape and remained almost straight, with the result that watchmakers believed that the steel did not have body, without noting that the blade was straight before being rolled up and, by the same reason that it had bent one way, it could bent in the contrary direction. On hearing that springs did not again take their spiral form after being pulled out, I cured this prejudice by putting all the springs on the hot iron plates of the stove (Plate 5, Figure 3) while taking care that the eyes did not take a colour by too much heat. This operation is called fixing and it gives the steel a stiffness which prevents the blades from being straightened, but it gives them almost no elastic quality.

Plate 5, Figure 3

Section 64

You can see by the number of operations that the blades have been subjected to, what a difference they make to the finished springs, both in their elasticity and their shape. The elasticity of a spring depends, as I have shown, on the body of the steel, its hardness and tempering. It is at its highest degree of perfection when you can temper the hardness the blade received so that it can be wrapped around an arbor without it breaking, and that while developing it opens well; that is, all the parts of the blade are detached from one another in spiral curve. And as the shape of a blade is essential to provide a good, elastic spring, it is necessary to explain this shape, more especially because few workmen in this area, and even very few watchmakers, know the theory.

Section 65

The first idea of our predecessors, in making watch springs, was to make the blades as equal as they could. The more perfect this equality was, the more spring was considered good. But this is what resulted from that shape. While putting the spring on the end ***C*** of the arbor ***B*** of the spring winder, Plate 9, Figure 1 (page 22) the first turn of the blade wraps around it, so that it is stressed due to the diameter of this arbor. The second turn is not stressed as much, because it wraps around the arbor and the first turn of the blade. The third turn is even less stressed because it wraps around the arbor and the first and second turns of the blade. And so from turn to turn the blades are stressed and spring is a spiral figure, as I described in Plate 10, Figure 2, except the last outer turns are even more separated from each other than you see them in the figure.

Section 66

Having observed the effect of bending a blade of equal thickness throughout, we should see how the spring acts while unwinding. For this it should be wound in the spring winder, Plate 9, Figure 1, until the crank can no longer turn. This tightly wound spring should be attached to the hook ***G*** of the small bar ***F***, and then put in a barrel. After which loosen the crank and the spring naturally detaches from the arbor. Takes the barrel between the fingers and turn the small bar in the contrary direction to the hook. Then press a finger on the front of the blades and withdraw the small bar, which leaves spring by itself in the barrel. This operation being done, put the arbor into the barrel and take its square in loop pincers, as in Plate 10, Figure 3.

Plate 10, Figure 3

Then hold the barrel with the third finger and thumb, leaving the second finger free to press on the blades of the spring that want to rise when they are wound. That done, turn the loop pincers to wind spring all the way, which makes the blades touch from one end to the other. The spring being wound, let it turn gently in the pincers. It will be seen that the turn which was stressed the most, to make it wrap against the arbor, is the first to develop and push against the second. Then the second pushes against the third, and thus from one end to the other there is a continual friction until the spring is relaxed. All these frictions are so considerable that the spring can only relax by jolts, and they are even so strong in clocks that they shake the walls to which they are attached.

Section 67

It is seen that so much friction absorbs part of the force of the spring, and the watchmaker must take care if he wants his springs to work without the effects of such obstructions. So to avoid this, the most skilful made all possible observations and realized that it was necessary to thin the blades from one end to the other, so that the first inner turns did not have as much force while developing as the last towards the wall of the barrel.

Section 68

As a consequence of the discovery of the shape which it is necessary to give to the blade of a spring, some of the first artists did what they could to reach that point. But as they only had files and other small tools which were not fit for this purpose, they could do nothing comparable to what we can do today. And it was only at the beginning of this century that it was possible to give a spring the appropriate shape to take full advantage of the benefits that the fusee provides, Plate 10, Figure 4. (We do not know who invented the watch fusee. But anyway, it is one of simplest and most clever mechanical inventions for not only communicating the force of the spring, but at the same time to use the excess force of the blade of the spring and so make the watch go for a longer time than it would otherwise. This is why. A spring usually makes four and a half turns and the watch cannot work until it is wound at least half a turn. To

Plate 10, Figure 4

avoid the danger of the spring breaking, it should not be wound to its end, and another half a turn is unused, which leaves three and a half turns of development for the spring. However, as the chain wraps seven and a half times around the fusee, its wheel makes seven and a half revolutions in 30 hours for three and a half turns of the spring, which would have made the watch run only half the time without the invention of the fusee.)

I believe that my father was the first to make a spring without friction. This was pointed out to me in a rather remarkable anecdote on this subject. Mr Sully, watchmaker to the Regent, one day showed him a spring that my father had made, which developed in a barrel where all blades moved without touching. The surprised Prince asked him "how is it possible for a man to make a blade eighteen inches long act in a space as small as that of a watch barrel without the parts touching?"

Section 69

There are several other types of springs, for repeaters, alarms, etc., but they are inferior in quality to those made for fusee watches. There is an art to making them pull the least unequally as possible, which is done by making the inner end strong. Even so, it is necessary that the blade is much longer, which causes great friction; but by it making it thicker in the middle for all its length, as I think I have said, and oiling it, it works rather well. However, this does not preclude a going barrel, Plate 10, Figure 7, making fewer turns than would the same quantity of steel processed for a fusee barrel of the same diameter.

Plate 10, Figure 7

The Way to Make Repeater Springs

Section 70

Repeater springs could be made in the same way as those which I have just described. But they can be made faster and with more economy.

It is necessary to take the ends of ordinary spring blades of the best quality steel for hardening and tempering. Finish them with emery in the *large leads*, while turning their ends from time to time, until they are very close to the required thickness. Then they are split with shears, Plate 10, Figure 5. If the shears cut well, you can make two or three small blades from them, but if the shears are not in good condition, you can only make one spring with difficulty, by shearing one edge after the other.

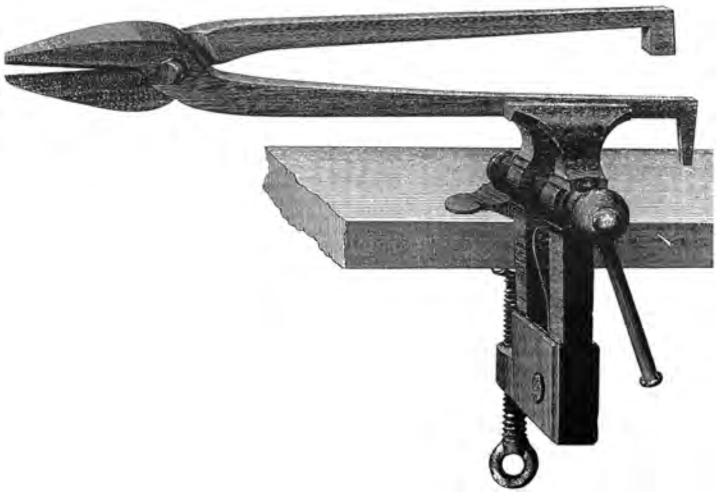


Plate 10, Figure 5

Section 71

Having made the blade about the right width, it should be put in a vice to file it on the edges and make its width equal to that of the caliber. This operation requires the jaws of the vice to be soft so that they do not mark the springs, which would break because of the small impressions that the teeth of the jaws made on them, as I have already said.

Section 72

After this operation, take an end of the blade of an ordinary spring which has not been rounded, and put it in the vice to make a slot of the depth which is wanted. Then this piece being fixed in the vice, put part of the repeater spring in the slot, and file it round with a smooth file. Then continue, pushing the small blade to the end. After which turn over the blade and do the same on the other edge, paying attention to draw the file lengthwise so that the marks of the file are parallel as far as possible; otherwise the polishing of the edges with oilstone will not be done well.

Section 73

To polish repeater springs with oilstone, it is necessary to have small stones mounted like those of Figures 1 and 2, Plate 8. Usually one end of the spring is attached to a vice, and the other held by a screw pincer which the workman holds in his left hand to keep it true and to bend the spring a little. The other hand holds the oilstone in which

Plate 8, Figure 1

there are slots, and the spring is placed in one of them. Then the oilstone is pushed and pulled back between the pincer and the vice, while pressing it in proportion to the strength of the spring so as not to break it.

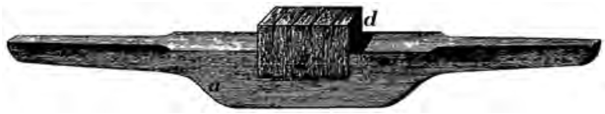


Plate 8, Figure 2

And in twelve or twenty alternate strokes the edge will be polished, which you know by passing a fingernail over it. Then the spring is turned over and the same is done on the other edge.

Section 74

The repeater spring being polished on its edges, it should be mounted on the frame Plate 3, Figure 5.

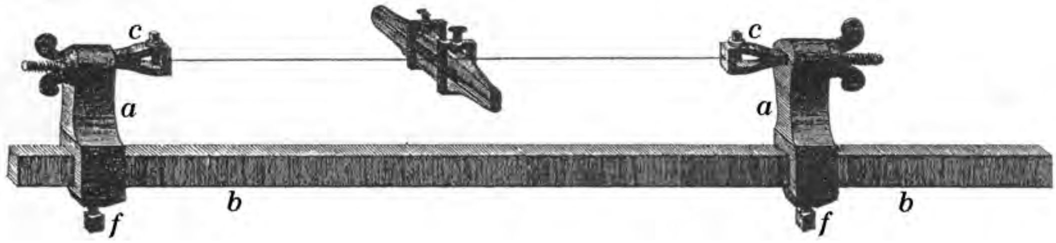


Plate 3, Figure 5

Then take the small leads (Plate 8, Figures 3 and 4), put oil and fine emery on them, and alternately push them, while pressing slightly with both hands, until the spring is a suitable thickness. Feeling, bending and looking are, as I have already said, the only guides to knowing this thickness.


Plate 8, Figure 3


Plate 8, Figure 4

The polishing done, the spring should blued, as I have indicated. Break the ends and make the eyes with small files proportional to the size of the spring. Then put a small arbor in a screw pincer as in Plate 10, Figure 6, taking care that its hook is not too high; otherwise it would form bumps all along the blade.

As it is the watchmaker who adjusts the outside end of this spring, do not make an outer eye. And thus a spring which requires more accuracy than the others, because it is small, is finished.

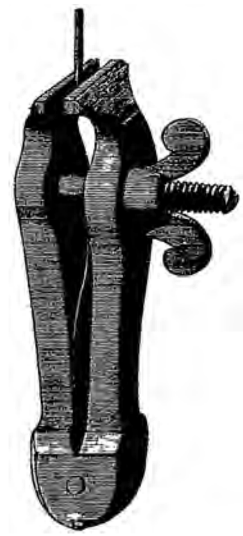


Plate 10, Figure 6

The Way to Make Balance Springs.

Section 75

The springs which are attached to the verges of balances are with reason considered to be very important for the running of a watch. Since their invention by Doctor Hook and their execution by Tompion in 1658, English watchmakers have made them with what are called *bobbins*, where a small steel wire which is passed between two hardened and well polished steel cylinders to roll them. The French make very few balance springs, and use those made in Geneva, which are rather poor because of their inequality in thickness and in width. So they do not work as well as this invention merits, to maintain the vibrations of the balance. I have made some balance springs for special cases and I obtained the blades to make them from Genevans working in Paris (women make balance springs in Geneva). I helped them to improve their work and I will explain the way in which it is necessary to begin in order to make good balance springs with hardened steel blades.

Section 76

In order to make balance springs, it is necessary to get from watch spring makers broad blades of four or six lines, hardened and tempered blue, and 18 or 20 inches long (as in Plate 11, Figure 1) and as thin and of the form which is wanted.

Plate 11, Figure 1

It is necessary to make them the right strength at the first attempt, because you cannot alter them after they have been sheared without giving them imperfections, either of form or of equality.

Section 77

The blades being the requires strength and form, they should be cut to the length which is needed for balance springs, making sure to put the weakest ends on the same side, and remembering that the thin and short blades are for small balance springs and the long and strong for the large ones.

Section 78

All being prepared, take the shears which have a backrest ***A*** attached, Plate 11, Figure 2.

Plate 11, Figure 2

This backrest is used as guide to determine the width of the small blade which you want to shear. I have shown these shears from above, so that you can see the width of the balance spring that can be sheared, using a backrest ***A*** which is attached by rivets ***1*** and ***2*** to the jaw ***B***.

Section 79

Plate 11, Figure 3 is the side view of the entire length of the shears so that you can distinguish the outside of the backrest ***A*** with its rivets ***1*** and ***2***.

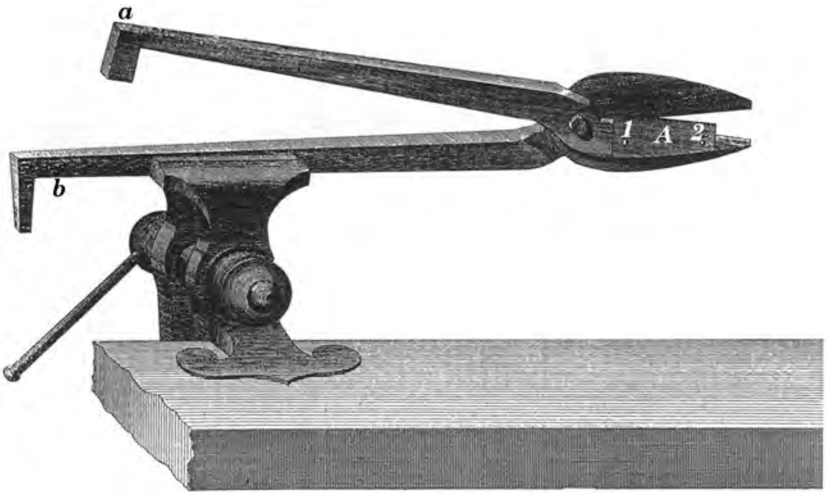


Plate 11, Figure 3

Section 80

Plate 11, Figure 4 is a view of the opposite side, in order to show the rivets of the backrest, which must be countersunk into the jaw ***B***, so that while working they cannot touch the edge of the jaw ***C***.

Plate 11, Figure 4

Section 81

The shears are mounted in the vice by the handle ***b***, as in Plate 11, Figure 3. Hold one of the short blades by the thin end with the fingers of the left hand and press it against the backrest, as in Plate 11, Figure 5. Then push on the handle ***a*** to close the shears so it cuts the blade to the end of the backrest. Then raise it and advance the blade while always pressing it against the backrest, and by closing the shears again cut as much blade as with the first stroke. Finally, by opening and closing the shears and pressing against the backrest, a blade will be made as wide as the backrest allows. Then continue to cut all the pieces in the same way, putting all the thin ends on the same side.

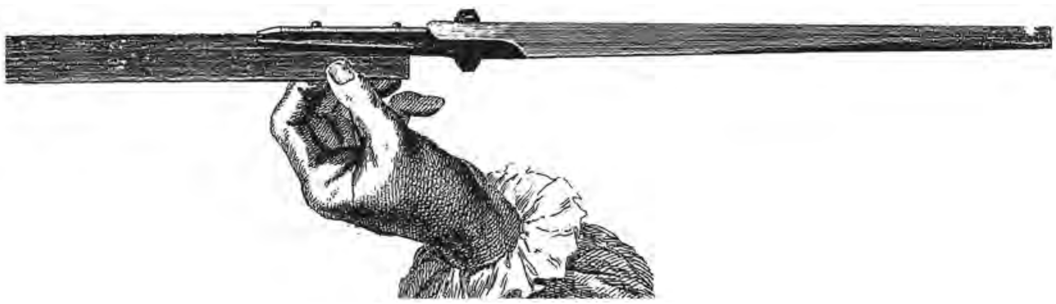


Plate 11, Figure 5

Section 82

If you need balance springs of different widths, you must fix the backrest to be more or less far from the cutting edges of the shears, which is done by putting a blade of the thickness needed between the jaw ***B*** of the shears and backrest ***A***.

Section 83

When all the small blades are cut, a good workman must finish them on the edges with oilstone. However if the shears are in good condition there is no great need for this operation, because there are almost no burrs.

Section 84

The small blades for balance springs being prepared, put a sheet of paper or some black fabric on the table, in order to be able to see the small blades better because they are white. Then take the stronger end of one of the blades and put it in loop pincers, as in Plate 12, Figure 1, which is held firmly in one hand.

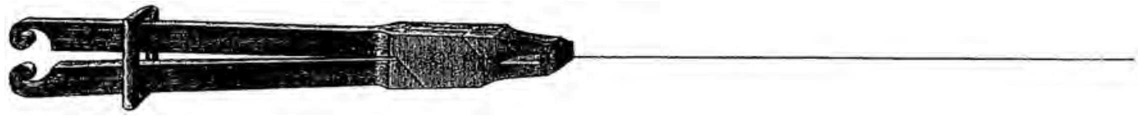


Plate 12, Figure 1

Then take the flat pliers, Plate 12, Figure 9, from which the cutting edges have been removed on a grind stone and the corners smoothed with oilstone. With the right hand, grip the blade tightly two or three lignes from the end and bend it a quarter turn or a little more, which makes a hook as seen in Plate 12, Figure 2.

Plate 12, Figure 9

Plate 12, Figure 2

Then, while always holding the loop pincers quite firm and stable, take the small blade loosely with the flat pliers an inch away from the small hook, make a quarter turn of the pliers on the blade and slide the pliers to the hook. This makes it take the form in Plate 12, Figure 3.

Plate 12, Figure 3

Then repeat the same operation of sliding the flat pliers, making its corners press against the blade, and holding the loop pincers firm and stable, which makes it the spiral form in Plate 12, Figure 4.

Plate 12, Figure 4

After which the same operation with the flat pliers is repeated a little further along, which puts the spring into the form of Plate 12, Figure 5. And so from distance to distance, always moving the pliers towards the hand which holds the loop pincers, you manage to give the small blade a spiral form, as shown in Plate 12, Figure 6.

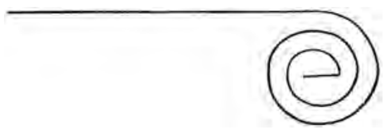


Plate 12, Figure 5

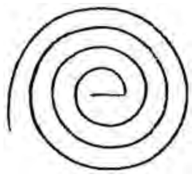


Plate 12, Figure 6

Section 85

All these small manipulations that you have just done require a great deal of skill, as much with the left hand as the right hand, to press the blade on the corners of the flat pliers sufficiently to put the different turns of the balance springs at suitable distances apart and as flat as is necessary. But despite all the care that you can take, a balance spring is never perfectly flat. So there is one more operation to do.

Section 86

For this it is necessary to have a type of flat pincers rather like curling tongs, Plate 12, Figure 7. They should not be too heavy, nor have arms that are too short, but the pallets need to be thick enough to hold their heat for some time. Great care should be taken that the pallets or jaws of the pincers are quite flat inside, so that they retain their parallel position when they are used.

Plate 12, Figure 7

Section 87

The spiral springs being bent, and separated according to their strength and size, rub some of the external parts of the pincers with a file, to whiten them. Then put them on a gentle fire, and when they take a pale blue colour they are ready to use. Take them out of the fire, put a balance spring inside the jaws and close them for a second or two to heat the spring. This forces it to become flat and gives it the colour that is wanted. Then open the pincers to let the spring fall out and put in another. And so continue to use the pincers to blue as long as they have enough heat. And when they do not, put them on the fire and use another pair, which must be very hot, and continue in the same way until all the pieces are blue.

Section 88

The operation of bluing balance springs is used to heat the fibres of the steel and fix them in the position where the heat found them. And so when cold, they have as much force on one side as the other; that is, while opening or closing. Thus the balance springs made with sheared blades are finished.

Section 89

To make balance springs the English way, that is, with *bobbins*, it is necessary to have a small rolling bench as in Plate 12, Figure 8. ***A*** is the bench at one end of which a roller ***B*** is mounted. In the middle of the bench a chassis or iron frame is mounted, which has two cylinders ***C*** and ***D***, of very hard and well polished steel, about an inch or two in diameter. On the top of this frame there are two screws ***E***, ***F***. On the arbors of the cylinders are two pinions or wheels, ***G*** and ***H***. The lower cylinder has its arbor longer than the upper one to carry the crank ***I***. At the other end of the bench there is another light wood roller ***L***, which is carried on supports attached to the bench. This roller has an arbor that carries the small roller ***M***, on which is wrapped a cord holding the weight ***N***.

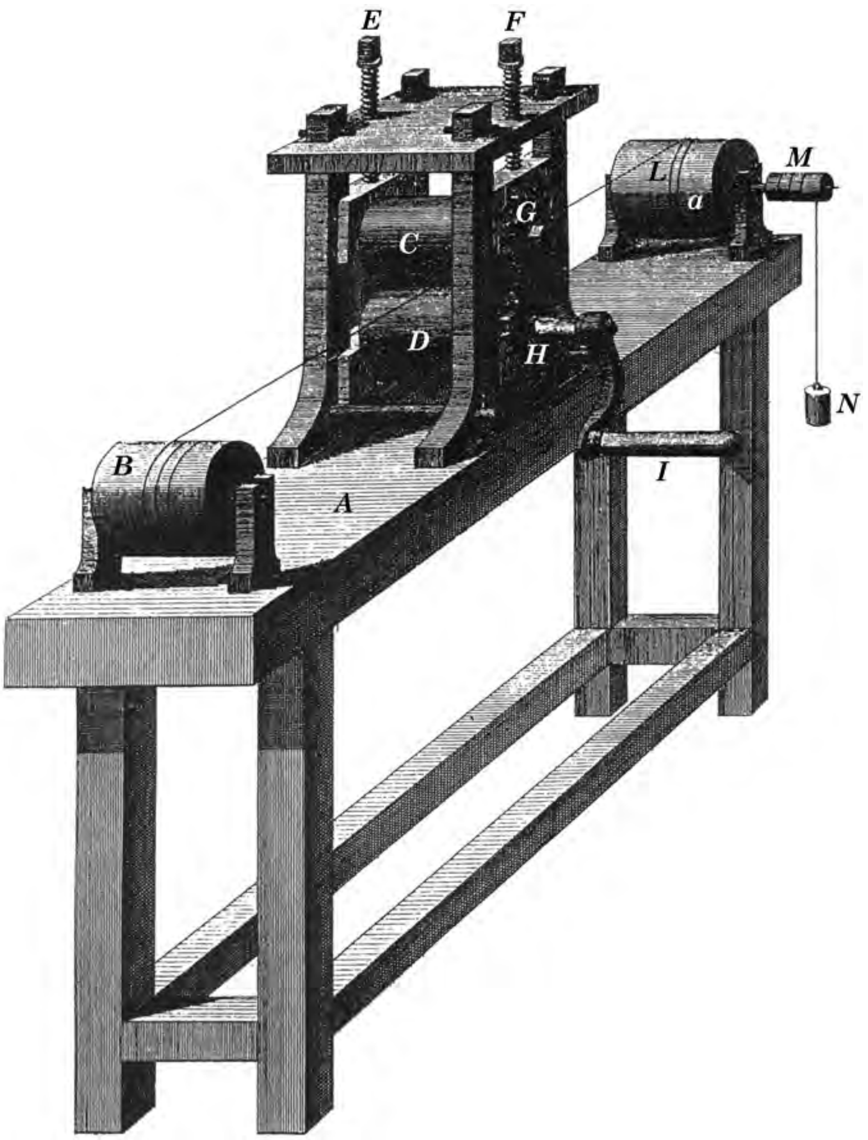


Plate 12, Figure 8

Section 90

To use the bobbins, take small steel wires from bundles of several sizes, such as those used for harpsichords, and heat them in a charcoal fire, taking care not to heat them too much to avoid as far as possible the scales that too great heat creates. After the wires have cooled, take one of them and put it on the roller ***B***, separating the turns of the wire so that they cannot tangle. That done, take one end of the wire and push it between the rollers ***C*** and ***D*** with the fingers of the left hand, while the right hand turns the crank ***I***. As soon as you see an inch or two to leave the rollers, tighten the screws ***E*** and ***F*** as much as you need, or that the steel can support without cracking or breaking, and then turn the crank with the left hand while drawing the flattened wire with the right hand until about 18 inches or 2 feet has come out.

Section 91

The wire being thus prepared, take its end and thread an inch or two of it into the small hole ***a*** in the roller ***L***. That done, hold the roller by the left hand and with the right wrap the small cord which holds the weight ***N*** around the roller ***M***, lifting this weight as high as you can. Then let go the weight ***N***, which should not weigh more than a pound or two, and which winds the small blade onto the roller ***L*** from the cylinders ***C*** and ***D***.

Section 92

All being set up, the workman returns and takes the wire in the fingers of his left hand to guide it to the place between the cylinders ***C*** and ***D*** where he wants it, while turning the crank ***I*** with his right hand. As the small blade wraps around the roller ***L***, the weight ***N*** falls. But before it touches the ground, stop, hold the roller ***M*** with the left hand and wind up the weight ***N*** with the right one; this is done very easily, the roller ***M*** being at the end of the arbor. And so by turning the crank ***I*** and wrapping the small cord which holds the weight ***N***, all the wire that was put on the roller ***B*** is flattened.

Section 93

If the small blade is not thin enough, it is necessary to spread it out on the floor so that it cannot pick up any refuse or get tangled. Then turn the two screws ***E*** and ***F*** slightly. With the left hand thread one end of the blade between the rollers ***C*** and ***D***, while turning the crank ***I*** with the right hand. Then reverse your position, take the end of the blade with the right hand and lead it until a length of two feet length has come out, in order to attach it to the roller ***L***, as we have already seen. That done, go back to the first position to guide the blade between the rollers ***C*** and ***D***. When the blade is the thickness that you want, it should be put on a bobbin. From this last operation the small wires thinned to make balance springs takes the name of *bobbin wire*.

Section 94

It is seen that the small blades made in this manner must be quite equal in thickness and in width, and with edges that are well rounded and smooth, which cannot be done with sheared blades even when smoothed with oilstone as well as is possible.

Section 95

When you want to make balance springs with this bobbin wire, it is necessary to cut them to length and use the same operations that were described in Section 84 (page 31) and following, while taking the same precautions for the lengths and thicknesses, in order to match them.

Section 96

There are people who believe that hardening is essential for a balance spring. But experience proves that the only value of hardening is to give stiffness to the blade which must be sheared to be able to make it as thin as necessary and the shape that is wanted; this shearing is impossible to do exactly with a soft blade. Hardening is not necessary for balance springs, as all English watches have been so far, except recently those from Geneva are so cheap that many English watchmakers cannot be bothered to make them, because they cannot see any difference in the quality of a balance spring whether hardened or not. Indeed a steel blade that has no other quality than the stiffness that it acquires while being blued, works as perfectly as is possible, because balance springs do not bend or relax enough to force or deteriorate this quality that the steel received by the heat necessary to colour them blue.

Section 97

There are various opinions on the shape which the blade of a balance spring must have. I have heard of watchmakers for whom it was necessary to make them perfectly equal from one end to the other. Others claimed that they ought to be weaker on the outside. And others, on the contrary, say that it is necessary that the weak end is inside, and increases imperceptibly to the outer end. All that I can say about these various opinions is that all balance springs work well, so admirable is this invention, because the blades of these springs do not touch each other when acting, and balance springs move in full freedom from one end to the other. But what you must pay attention to, when you want to adjust a watch, is the sensitivity of the balance spring. For example, if the spring is weak outside, it is necessary to turn the rosette more to regulate the action of the balance. If instead it is stronger outside, you can only touch the rosette to advance or delay, as it makes a large change in the motion of the balance, faster or slower. It is seen by this that these springs act unequally in their different whorls and, despite these defects, these small regulators always act in a way very advantageous for the accuracy of watches. We may ask whether there should be a certain proportion of their length relative to their strength for their isochronism. This question has occupied watchmakers for a long time. The ingenious Mr Le Roy the elder has just written in a detailed and interesting way on this matter, and we turn the reader to his work.

END