

Vigniaux

**Practical
Watchmaking**

**Translated By
Richard Watkins**

© Copyright 2011, Richard Watkins, Kingston, Tasmania

Contents

Translator's Foreword	11
Preface	15
Part One.	17
Chapter One: The Watchmaker's Workshop.	17
Chapter II: Tools Necessary for a Watchmaker.	17
Chapter III: Steel.....	20
Annealing Steel.....	20
Hardening Steel.	20
Chapter IV: Brass.	21
Chapter V: The File and the Turns.....	21
Chapter VI: Tools for the Turns.....	22
Bows.....	22
Gravers.	22
Square Gravers to Make Recesses.....	23
Chapter VII: The Turns. Pl. 6, Fig.1.	23
To Make a Ferrule.	24
To Make Turning Arbors and Stems.....	24
To Turn the Points of Turning Arbors.....	25
To Preserve the Points of Arbors.	25
To Finish Arbors.	25
To Fix a Part on an Arbor.....	26
To Smooth a Part with Four or Eight Sides on the Turns.....	26
Putty.....	26
To Polish Arbors on the Turns.	26
Chapter VIII: Drills.....	27
To Form the Tips of Drills Properly.	27
Pivot Broaches.	28
Method of Boring Various Parts of Brass and Steel, such as Canons & Canon Pinions	29
Method of Correcting a Part with a Sharp Hammer.....	29
To Correct a Part with a Round Pean Hammer.....	29
Chapter IX: Various Methods of Soldering, and Various Types of Solder Used in Watchmaking.....	30
Silver Solder.....	30
How to Make Third and Quarter Silver Solder.....	31
Tin Solder.	31
Tin Solder with Sulphate of Ammonia.....	31
Tin Solder with Oil and Sulphate of Ammonia.	31
Solder with Tin, Water and Sulphate of Ammonia.....	31
To Make Tin Solder.....	31
Chapter X: Smoothing and Polishing Steel.	32
Polishing Steel.	32
Chapter XI: Choice of Compounds to Smooth and Polish Brass.....	32
Rotten-Stone and its Preparation.....	32
Charcoal to Polish Brass.....	33
To Smooth Brass.	33
To Polish Brass.	33
Burnishing Steel and Brass.....	33

Chapter XII: Screw Plates.	34
Taps.	34
To Recess the Heads of Screws.	35
Chapter XIII: Square Punch Tools and Riveting Punches.	36
Files and how to Fix Handles.	36
Chapter XIV: Pins.	37
Part Two.....	39
Chapter One: The Rough Movement.	39
Chapter II: Calibres.	40
How to Draw a Calibre Based on a Piece Already Made.	40
Chapter III: To Mount a Frame.	40
Method of Making the Plates.	40
To Make the Recess for the Center Wheel.	41
The Barrette.	41
To Round the Ends of Pillars	42
The Pillars.	42
The Top Plate.	42
To Rivet the Pillars.	42
Chapter IV: The Wheels.	43
The First Wheel.	43
The Center and Third Wheels.	43
The Contrate Wheel.	43
The Teeth.	44
To Cross the Center Wheel.	44
Crossing and the Arms of the Contrate Wheel.	44
How to Make a Balance.	44
The Size of Pinions.	45
Method of Making the Center Pinion.	45
To Center a Pinion.	45
To Thin Pinions of 10 and 12.	45
To Polish Pinions.	46
To Smooth and Polish the Shoulders and Stems of Pinions.	46
Stems.	47
Method of Facing Pinions with Oil Stone.	47
Method of Polishing Pinion Faces with Putty or Rouge.	47
To Rivet the Center Wheel onto its Pinion.	48
To Put the Center Wheel in the Frame, and to Take the Height at which it is Necessary to Make the Pivot.	48
To Make the Pivot of the Center Wheel and Others.	48
Chapter V: The Fusee and the Pieces of which it is Made.	49
To Make the Arbor of the Fusee.	49
Method of Roughing Out the Fusee and Soldering it to its Arbor.	49
To Recess the First Wheel.	50
The Spring of Click-and-Ratchet Work.	50
The Click.	50
The Fusee Ratchet.	50
The Small Recess to receive the Fusee Collet.	50
How to make the Pivots of the Fusee Arbor.	51
The Fusee Cock.	51
The Fusee Beak.	51
The Chain Guard.	51
Functions of the Chain Guard.	51
The Space between the First Wheel and the Center Wheel.	51

Chapter VI: The Third Wheel, its Pinion, and the Contrate Wheel.....	52
The Pinion of the Third Wheel.	52
Files to Thin Pinions of Six and Seven.	52
Method of Thinning Pinions of Six or Seven.	52
How to Round Pinions of Six or Seven.....	52
Method of making the Seat to be Placed on the Stem of a Pinion.....	53
Method of Soldering a Seat to a Pinion.....	53
Precautions to Take when Hardening Pinions and Verges.	53
To Polish Stems in the Turns.....	53
To Rivet the Third Wheel onto its Seat.	53
How to Make the Pivots of the Third Wheel, and Put it in the Frame.	54
The Pinion of the Contrate Wheel.	54
The Barrette for the Contrate Wheel.	54
Chapter VII: How to make a Barrel, and all the Parts of which it is composed.....	55
The Barrel.	55
Method of Recessing the Barrel.....	55
The Barrel Lid.	56
The Barrel Arbor.	56
To Take the Height between the Shoulders of the Barrel and its Lid.....	56
How to Put the Barrel in the Frame.	56
How to Make the Square on the Barrel Arbor.	56
The Ratchet.....	56
How to Make a Tool to Divide the Teeth of a Ratchet, and how to Use it.....	57
The Click.....	57
Chapter VIII: The Potence and the Counter-Potence.	57
The Boot of the Potence.....	58
The Counter-Potence.....	58
The Pinion of the Verge Escape Wheel.	58
Chapter IX: The Cock on the Top Plate.....	59
Method of Making the Slide.....	59
The Rack.....	59
The Location of the Slide.	60
The Rosette Wheel.	60
The Rosette.	60
Method of Placing the Cock.....	60
The Coqueret.....	60
Chapter X: The Method of Making the Motion-Work.....	61
How to Make the Pinion of the Canon Pinion.....	61
The Intermediate Wheel.	62
The Canon of the Hour Wheel.	62
Chapter XI: The Verge.....	62
How to Rough Out the Verge, Pl. 8, Fig. 31, 32, 33, 34.	63
The Seat of the Verge.....	63
To Assemble the Rough Movement.	64
Part Three.	65
Chapter One: Finishing in General.	65
Chapter II: Various Numbers of the Teeth of Wheels and the Leaves of Pinions.	66
The Numbers of Teeth and Pinions.	66
Number of Teeth of the Wheels and Leaves of the Pinions, to Have a Fusee of Seven and a Half Steps, so that the Watch Gives 17280 Vibrations Per Hour.....	66
Calculation of the Turns of each Wheel, and the Number of Vibrations which the Watch makes per Hour.....	66
Number of Teeth and Pinions of Seven to have a Fusee of Six Steps, and a Verge Escape Wheel of Thirteen Teeth.	66

Number of Teeth which one must give to the Wheels, and Leaves to the Pinions, to make a Watch with a Verge Escape Wheel with Thirteen Teeth.	67
Number of Teeth which one must give to the Wheels, and Leaves to the Pinions to make a Watch with a Verge Escape Wheel of Eleven Teeth.	67
Number of Teeth which one must give to the Wheels, and Leaves to the Pinions, to make a Watch with a Verge Escape Wheel of Nine Teeth.	67
Motion-Work Numbers.	67
The Number of Teeth of the First Wheel, and Leaves of the Center Pinion, for a Fusee which has Seven and a Half Turns.	68
The Number of Teeth of the First Wheel, and Leaves of the Center Pinion, when the Fusee has Six Steps.	68
Number of Teeth of the First Wheel and Leaves of the Center Pinion, For a Fusee which has only Five Turns of the Chain.	68
Chapter III: General Observations on Finishing.	68
The Fusee.	68
How to Equalize a Spring with the Fusee.	69
Pinions.	69
The Width of the Pallets of the Verge.	69
Friction.	70
Too Great Freedom of the Train.	70
Too Small Pivots.	70
Chapter IV: The Gears.	70
The Depthing Tool.	70
Precautions to take for making Good Gearing.	70
The Line of Centers and the Point of Contact.	70
Demonstration of Good Gearing.	71
Gearing considered in its Three Various Forms, Good, Strong, And Weak.	71
Various Observations on Gearing.	71
The Gearing of the Contrate Wheel.	71
The Uprighting Tool.	72
How to use the Uprighting Tool.	72
Chapter V: Springs.	72
The Mainspring.	72
The Mainspring Winder and how to use it.	73
Small Springs, Pl. 7, Fig. 6 and 8.	73
The Balance Spring.	73
Chapter VI: How to Round, Equalize, and Finish Teeth.	74
The Teeth.	74
The Method to use when a Pinion is a little Large, or is a little Full.	74
The Teeth of the First Wheel and the Center Wheel.	74
How to use the Depthing File, to make the Teeth of a Wheel equally deep.	74
To Equalize the Teeth.	75
Method of Rounding Teeth.	75
Method of Notching Teeth.	75
Chapter VII: How to Finish a Movement.	76
To Finish the First Wheel and the Center Wheel.	76
The Gearing of the First Wheel.	77
To Finish the Barrel.	77
The Bridle of the Barrel.	78
The Fusee Notch.	78
How to Choose a Chain.	78
How to match the Steps of the Fusee with the action of the Mainspring.	79
Observations on the Center and Third Wheels.	79
The Agreement of the Contrate Wheel Pinion with the Verge Escape Wheel.	79
Method of Making the Pivots of the Contrate Wheel and of Finishing this Part.	79

Observations on the Arbor of the Contrate Wheel, and that of the Vergé Escape Wheel.	79
To Finish the Contrate Wheel.....	80
Chapter VIII: The Vergé Escape Wheel and its Pinion.....	80
Method of Finishing the Pinion of the Vergé Escape Wheel.	80
The Vergé Escape Wheel Stem.....	80
The Size of the Vergé Escape Wheel.....	80
How to rough out a Vergé Escape Wheel, Forge, Recess and Cross it.	81
Method of Placing the Pivot Holes of the Vergé Escape Wheel.	81
The Size of the Pivot Holes of the Vergé Escape Wheel.	81
Method of fitting the Vergé Escape Wheel on its Pinion and Riveting it there.....	81
How to Turn the Vergé Escape Wheel without risking breaking its Pivots.	81
Precautions to be taken before Cutting the Vergé Escape Wheel.....	82
How to place the Vergé Escape Wheel on the Wheel Cutting Machine.....	82
How to remove the Sealing Wax stuck to the Pinion and the Vergé Escape Wheel.	82
Method of making the Vergé Escape Wheel centered and true, and of removing the Burrs after cutting it on the Wheel Cutting Machine.....	82
Chapter IX: To Finish the Vergé and the Balance.....	83
The Length of the Vergé.....	83
Of Ferrules to make the Pivots of the Vergé, and to turn its Seat.....	83
Precautions to take when making the Pivots of the Vergé.....	83
To Rivet the Balance onto the Seat of the Vergé.....	83
How to use the Figure Eight Calliper to true the Balance on the Vergé.....	84
To Correct the Balance.	84
Disadvantages to avoid when Striking the Balance Arms with a Hammer to correct them.....	84
To Poise the Balance.....	84
Method of Rebushing the Holes which receive the two Pivots of the Vergé.....	84
How to Smooth the Vergé.....	85
To Polish the Vergé.....	85
To Polish the Vergé before Soldering it.....	85
Tools to Polish Vergés easily.....	85
To Narrow the Pallets of the Vergé.....	86
The Bevels on the Pallets.	86
Method of making the Drops of the Escapement equal.	86
Overbanking of the Balance.....	87
How to make the Notch in the Rack, and place the Balance Spring Stud.	87
To make the Stud for the Balance Spring.	87
Chapter X: Functions of the Balance Spring. Oils and Oil Sinks.	87
The Collet of the Balance Spring.....	87
The Number of Vibrations per Hour which a Balance without a Balance Spring must give.	88
Observations on Oil and the Oil Sinks of the Escapement.	88
Method of making Oil Sinks for all the Pivots of a Watch.....	88
Chapter XI: The Variations of Watches.....	89
Chapter XII: The Dial.	90
Method of placing the Dial Feet.....	90
To mark the Hole for the Fusee on the Dial, and to bore it.	91
To Set Up the Watch Escapement.....	91
Part Four.....	93
Chapter One: Repairing.	93
Chapter II: Pieces to be Remade and Pivots to be Replaced.	93
Pieces to be Remade.	93
How to find the Center of a Stem.	94
How to Remake a Pivot of a Third Wheel.....	94

Method of Replacing the Pivot of the Vergé on the side of the Balance when a Pivot Shank still remains.	94
To Replace a Pivot on a Vergé with a Forked Stem.	95
Chapter III: On the way to Plug Holes.	95
The Quality of Brass for this Operation.	95
How to Plug the Holes of the Train, Vergé Escape Wheel, and Balance, without disturbing either the Gearing or the Escapement.	95
Eccentric Bushes.	96
The Compass with Three Points.	96
Compressing Holes.	96
Blind Holes.	96
Chapter IV: Method of Replacing the Teeth of Wheels and the Heel of the Potence.	97
Method of Replacing a Tooth in the Center Wheel.	97
Method of Replacing a Contrate Wheel Tooth.	97
Method of Replacing the Heel of a Potence and Riveting it.	97
Another way to Replace the Heel of a Potence by Soldering it with Tin.	97
Chapter V: Method of Equalizing the Vergé Escape Wheel and of Repairing its Pivots.	98
Method of Equalizing the Vergé Escape Wheel.	98
To shorten a Pivot of the Vergé Escape Wheel, when it touches the body of the Vergé.	99
Method of Filing and Polishing the Pivot inside the Vergé Escape Wheel without unriveting it.	99
Chapter VI: Various Faults and the Ways to Correct them.	99
Method of Adjusting the Teeth of Large and Full Pinions.	99
To Make a Barrel turn true and to Bush the two Holes.	100
Method of Repairing a Barrel Arbor which is too Small.	100
The Number of Teeth of the Wheel for the Endless Screw.	100
Method of Preventing the Chain from slipping under the Barrel.	100
Stoppages by the Finger.	100
The Chain Guard.	100
The Counter-Potence.	101
Means of giving friction to a loose Canon Pinion.	101
The necessity for pinning the Canon Pinion on the Center Pinion.	101
How to Solder a Cock.	101
Screws whose Threads are worn.	101
Method of Tin Soldering the Seat of a Vergé.	101
The Ends of the Pivots of the Vergé and the Holes which are Formed in the Steel Plates.	102
Oil Sinks to hold Oil on the Plates.	102
Method of Opening and Closing the Vergé.	102
Notched Verges.	102
Method of Repairing a Vergé whose Pallets are Notched.	102
Balances which Beat and Overbank at the same time.	102
The Pallets.	103
Various Stoppages caused by the Chain.	103
To Repair the Chain.	103
Defects of Mainsprings.	103
Agreement of the Turns of the Mainspring with those of the Chain.	103
Method of Weakening a Balance Spring.	104
Chapter VII: Finishing the Watch.	104
The First Wheel.	105
The Center Wheel.	105
The Third Wheel.	105
The Vergé Escape Wheel.	105
The Vergé.	105
The Motion-Work.	106

Chapter VIII: Method of Cleaning the Teeth of the Wheels, and of Repolishing the Fusee and other Parts.....	106
Chapter IX: The Development of the Watch and the Functions of the Train.....	107
Functions of the Movement.....	110
Method of Disassembling a Watch.....	111
To Reassemble a Watch.....	111
Causes which usually Slow down Watches.....	112
The Reason for Going Slow in Summer.....	112
Causes which Advance Watches, when they need to be Cleaned.....	113
Method of Advancing or Slowing a Watch with the Hand of the Rosette.	113
The Care which a Person must take with his Watch.....	113
Method of Tracing a Meridian by Corresponding Heights.....	113
Equation for Pendulum Clocks, by Mr. Vidal.	114
Table of the Equation.....	115
Vocabulary of the Terms of Watchmaking.	117
Approval.	131
General Privilege of the King.	131
Part Five.	133
Chapter One: Functions of the Pieces of the Dial-Work.....	133
Article One: The Collar.....	133
Article II: The Mainspring.....	133
Article III: The Small Springs.....	134
Article IV: Springs with a Double Action.....	134
Article V: The Barrel.....	134
Article VI: The Barrel Arbor.....	134
Article VII: The Small First Wheel.....	134
Article VIII: The Push Piece.	135
Article IX: The Winding Rack.....	135
Article X: The Chain.	135
Article XI: The Pulleys.....	135
Article XII: The Star Wheel.	135
Article XIII: The Hour Snail.....	135
Article XIV: The Quarter Snail.....	136
Article XV: The Valet or Jumper Spring.	136
Article XVI: The All-Or-Nothing Piece.....	136
Article XVII: The Surprise Piece.	136
Article XVIII: The Quarter Rack.....	137
Article XIX: The Quarter Rack Gathering Pallet.	137
Article XX: The Entries.....	138
Article XXI: The Hour and Quarter Pallets.	138
Article XXII: The Silencer.....	138
Article XXIII: The Bell.....	138
Chapter II: Repairing the Dial-Work.	139
Article One: Stoppages caused by the Collar.	139
Article II: Stoppages caused by the Mainspring.....	139
Article III: Method of making small Springs.....	140
Article IV: Stoppages caused by the Spring with Double Action.....	141
Article V: Defects of the Arbor of the Small First Wheel.....	141
Article VI: Defects of the Small Barrel.....	142
Article VII: Defects of the Push Piece.....	142
Article VIII: Stoppages caused by the Winding Rack.	143
Article IX: Stoppages caused by the Chain.	143
Article X: Stoppages caused by the Pulleys.	144

Article XI: Defects of the Star Wheel and the Hour Snail.	145
Article XII: The Quarter Snail.	145
Article XIII: Defects of the Jumper Spring or Valet.	146
Article XIV: Defects of the All-Or-Nothing Piece.	146
Article XV: Stoppages caused by the Quarter Rack.	147
Article XVI: Defects caused by the Quarter Rack Gathering Pallet.	148
Article XVII: Defects of the Hammers.	148
Article XVIII: Stoppages caused by the Hammers.	149
Article XIX: Defects of the Hour Pallet.	150
Article XX: Stoppages caused by the Quarter Pallets.	150
Article XXI: Stoppages caused by the Silencer.	151
Article XXII: Defects of the Bell.	151
Article XXIII: Method of making Ground Gold.	152
Article XXIV: Gilding with Ground Gold.	153
Article XXV: Gilding with Gold Leaf.	154
Chapter III.	154
Article One: How to Disassemble a Repeater.	154
Article II: Finishing the Repeater.	155
Article III: Method of Cleaning a Repeater.	156
Article IV: Method of Assembling the Train of a Repeater.	156
Article V: How to Assemble the Dial-Work.	157
Table of the Citizen Arlaud.	159

Translator's Foreword

The Author

It appears that nothing is known about Vigniaux. He lived and worked at Rue des Filatiers in Toulouse, where this book was published, and there are a few extant verge watches signed by him. Tardy *Dictionnaire des Horlogers Français* lists him as:

Vigniaux Pierre. Toulouse. Publie son "Horlogerie Pratique" en 1788. Ré-édité en 1802.

But he confuses matters by also listing:

Vigneaux Pierre. Toulouse. 1769. † 1774. — Toulouse. Rue des Filatiers, 1840.

If it is not an erroneous entry, and the 1840 date must be wrong, I presume this was our author's father, but I have not found any other reference to this person. As no-one else provides the given name Pierre, it must be in doubt.

This is the only book that he wrote. Baillie *Watchmakers and Clockmakers of the World* lists *Traite Elementaire d'Horlogerie* as a separate book published in 1800, and Robertson *The Evolution of Clockwork* also lists *Traite Elementaire d'Horlogerie*, but dated 1802. However, Robertson also states it is 12mo, 446 pp, 14 plates which is identical to *Horlogerie Pratique*. In addition, I have never found any other reference to *Traite Elementaire d'Horlogerie* or any copies for sale, whereas *Horlogerie Pratique* appears quite often. And so it is almost certainly an incorrect reference to this book.

Other than this meagre and inadequate information I have found nothing about Vigniaux. Unlike the other 18th century French writers, such as Sully, Thiout, Lepaute and Berthoud, it seems he was an unknown, provincial watchmaker.

The Text

The first edition, as the title implies, describes how to make a verge watch movement step-by-step and in great detail. I have translated the second, augmented edition, which adds nearly 100 pages on repeaters.

It must be noted that the book is in two distinct parts. It is clear, from the pagination, the use of the old long "s" (which looks like "f"), and the fact that a different artist was used for the last two plates, that the first 342 pages and 12 plates are simply a reprint of the 1788 first edition, probably using the original printing plates. And, for the second edition, the final 100 pages on repeaters (using the modern "s") and 2 plates were added.

On the whole, translating the text was straight forward. Allowing for the strange, and often inconsistent punctuation, and the occasional use of archaic, and so ambiguous words, most of the meaning was obvious. And many of the problems were resolved, as usual, by Berner's invaluable *Illustrated Professional Dictionary of Horology*.

Converting the old French into readable English offered the usual problems. With only a few exceptions, where I felt some comment is needed, I have simply rewritten the book appropriately. This was not difficult, the context and the technical, horological words generally making the meaning obvious. So anyone who compares the translation to the original French will find substantial differences in expression, but hopefully not in meaning.

However, some comments are unavoidable. Where it is necessary to provide further explanations, I have handled them in two ways. First, I have added footnotes to the text. (Vigniaux used only one footnote and, to clearly distinguish my comments, I have incorporated that footnote into the text.) Some of these footnotes provide the French where I feel my translation is doubtful; they are included in case anyone wishes to compare my words with the original. Second, I have, of course, reorganised Vigniaux's *Vocabulary* so that it is in order of the English words, and I have added a few entries.

The Plates

Of more concern were the plates. Indeed, at first I got the impression that they were largely unrelated to the text, because of innumerable errors referring to wrong illustrations! However, it became obvious that Vigniaux and the artist for the first edition, Schueler, never sat down together to coordinate their respective tasks, resulting in some chaos. Actually, Schueler just states that he was the sculptor (the engraver) and it is possible the plates were drawn by Vigniaux; if so, the author must have been very careless.

As I see no reason why the readers of this translation should suffer needlessly, I have done three things. First, I have edited the plates. In addition to enhancing them (the scans of

my copy of the book were very dirty), I have corrected the obvious errors and added missing labels. In the process I have replaced all the original labelling to improve legibility. Second, I have tried to ensure consistency between the text and the plates by correcting references to the plates in the text; however, in a few places I am not sure to which illustration Vigniaux should have referred and I have noted these in footnotes. Finally, I have enlarged plate 14 to make it more legible.

The Table of Contents

Vigniaux included an 18-page *Contents, In Alphabetical Order*. This is an obscure listing which is very difficult to use, so I have decided to delete it entirely, and replace it by a normal table of contents.

The Vignettes

The original book has a number of small vignettes scattered throughout it. Some appear at the beginnings of sections and others are used to fill pages. As these are attractive ornamentations I have reproduced them. They have been enlarged to suit the format of this translation.

Richard Watkins

HORLOGERIE P R A T I Q U E ,

A L' U S A G E

DES APPRENTIS ET AMATEURS.

SECONDE ÉDITION.

Revue , corrigée et augmentée de la connoissance de
la Répétition.

Par VIGNIAUX , Horloger de Toulouse.



A T O U L O U S E ,

Chez l'Auteur , rue des Filatiers ,

E T

Chez BELLEGARRIGUE , Imprimeur-Libraire , grande
rue , vis-à-vis les Carmes , Section 6 , N^o. 114.

M. DCCC. II.

PRACTICAL WATCHMAKING,

FOR THE USE OF
APPRENTICES AND AMATEURS.

SECOND EDITION.

Reviewed, corrected and augmented with information on the Repeater.

By VIGNIAUX, Watchmaker of Toulouse.

AT TOULOUSE,

At the Author, rue des Filatiers,

AND

At BELLEGARRIGUE, Printer And Publisher, grande rue,
opposite the Carmelite Friars, Section 6, N°. 114.

1802

Preface

The title of this work announces its purpose. It is not a complete treatise on watchmaking. This book is particularly intended for amateurs and for apprentices of this beautiful art. I have abstained from treating the theory of it, and sought only to express with clarity and order the various methods followed by the most skilful workers in the execution of all the parts which compose a watch.

The difficulty which I had during the time of my training, the trouble that I had to teach students, gave birth in me the idea of putting in writing what thirty years of experiment in watchmaking have taught me on workmanship.

I do not say anything on the style of this work; by reading it one will quickly realize that it is by an artist more accustomed to handling the file and the turns than the pen, and who endeavours only to explain with clarity. I would have done it with more precision, if I had not had to teach from the beginning, which obliged me to often return to the same ideas, and to make frequent repetitions, which is inevitable in an elementary book especially made for young people, to whom it is necessary not only to say all but even to repeat the same things several times, in order to render them comprehensible.

To achieve my goal, I divided this work into six parts¹. In the first, I give the manner of using the turns and the file; I go into many small details which, guiding the amateur and apprentices, gives them the facility to do various operations, and to start a little on a movement.

In the second part, I speak about the means which should be employed to make each particular part, and continue to give details of the various operations necessary to make a rough movement.

In the third part I describe the respective positions of all the parts which compose a watch, their functions, the action of one part with another, and their various effects. I teach in a few words the way of forming pivots, of finishing teeth, of making gears, of forming a good escapement, and of making a watch run according to the principles of the best artists.

In the fourth part I speak about repairing, of the defects to which a watch is prone, of the means to use for repairing well, and of the disadvantages to avoid. I unite with this the development of the watch, the functions of the train, the way of disassembling and assembling a movement, the method to trace meridian by corresponding heights, and a vocabulary of the terms in watchmaking.

The fifth part explains briefly the names of all the parts of a repeater, their movements, their effects and their respective functions.

The sixth part goes in great detail into the defects to which dial-work is prone and gives the means of correcting them. It teaches how to assemble and disassemble a train, and to finish it, to assemble and disassemble dial-work, and how to gild using powdered gold and gold leaf.

Those who want to acquire a wider knowledge should read the works of Thiout the elder, Lepaute and Ferdinand Berthoud; these are the main works, which unite the most sublime theory to the plans of watchmaking, dictated and supported by calculation and algebra, which will lead them by the hand to perfect their knowledge of this part of Mechanics.

A stylized, handwritten signature in black ink, appearing to read 'Vigniaux' followed by a decorative flourish.

¹ Actually only five parts because Parts 5 and 6 are a single Part 5.



PRACTICAL WATCHMAKING

Part One.

Chapter One: The Watchmaker's Workshop.²

No. 1. Whether watchmaking is for you a job or simply a recreation, the choice of the place where you will fix your work area is not indifferent. It is necessary that the position is such that one is safe from heat and cold. This kind of work requires especially very good light.

2. When the place has been chosen, make up a bench; a plank of an inch and a half thickness and a foot and a half wide is sufficient to give solidity and the necessary convenience. After having fixed it immovably, cover it with a green oil-cloth and fix on its outer edge a batten from four to five lignes high; without this precaution your tools would be likely to fall on the ground. An artist, jealous of order and cleanliness, will organise them by arranging them each evening and often cleaning the fabric on which he places them.

3. The bench fixed, you will attach a vice to it. It must be solid and of good hardness; preference is given to the English and they deserve it. It is necessary that this vice is fixed as firmly as possible.

4. For their use, convenience and arrangement, place on the bench or beside it, always within reach, a set of drawers to hold the work and the tools. There should also be some tinplate boxes, in which one puts the files with handles and other tools for daily use. These boxes are usually set on the bench.

Chapter II: Tools Necessary for a Watchmaker.

You will provide yourselves with the following tools and supplies.

Nº. 5. Twelve turning arbors. Plate 1, Fig. 17 and 31.

Screw arbors of three different sizes. Pl. 1, Fig. 10 and 11.

An eccentric arbor. Pl. 1, Fig. 6.

A riveting stake. Pl. 5, Fig. 9.

Two black gravers.³

² Part 4, Chapter IX is clearly an after-thought and should be read first.

³ *Burin noir*: Black probably refers to the quality.

Two pivot burnishers.
 Four tinplate boxes to hold polishing compounds.
 An anvil with two beaks. Pl. 6, Fig. 4.
 A depthing file. Pl. 3, Fig. 1.
 A steel spring-compass. Pl. 5, Fig. 3.
 A pinion gauge. Pl. 2, Fig. 8.
 A depthing tool. Pl. 6 Fig. 6.
 A blow-pipe. Pl. 2, Fig. 11.
 Six screw ferrules of different sizes. Pl. 1, Fig. 21, 22, 23, 24, 25, 26.
 Twelve dozen ferrules of different thicknesses and sizes. Pl. 1, Fig. 15.
 Four endless screw keys of different sizes.
 One figure-eight calliper. Pl. 5, Fig. 5.
 A square. Pl. 3, Fig. 11.
 Twelve broaches of different sizes.
 A screw plate. Pl. 5, fig 7.
 A set of cutters.⁴ Pl. 12, Fig. 7, 8.
 Two coarse hand files.
 Two fine hand files, seven to eight inches long.
 You will fit these four files with large, short handles.
 Two coarse carrelet files.⁵
 Two fine carrelet files.
 Two coarse notching files.⁶
 Two fine notching files.
 Two coarse barrette files.⁷
 Two fine barrette files.
 Two coarse crossing-out files (sage leaf files). Pl. 2. Fig. 2
 Two fine crossing-out files.
 Four rat-tail files of different sizes.
 Two files for dial-spring heads.
 A dozen assorted equalling files.
 Two carrelet files.
 Two verge escape wheel files.
 Four rounding-up files of different sizes. Pl. 2, Fig. 4.
 Two pivot files. Pl. 2 Fig. 3.
 A fusee adjusting rod.
 Six dozen file handles.
 A large forging hammer. Pl. 2 Fig. 9.
 A brass movement holder. Pl. 5, fig 11.
 Three hammers of different sizes.
 A sharp hammer.⁸
 A dancing master. Pl. 4, Fig. 1.

⁴ *Fraise*: Circular cutter for dividing wheels.

⁵ *Lime carrelet* or *carrelette*: In the vocabulary, Vigniaux refers to Pl. 2, Fig. 3; it is a rectangular file and may have one safe edge. Berner describes this as a “polishing” file (which does not make sense) and Britten as a “pottence” file.

⁶ *Lime à entrée*: According to Lepaute *Traité d’Horlogerie* it is a rectangular (or square?) file which tapers towards its end.

⁷ *Lime à barrette*: Tapered in width and thickness, and coming to a point. Only the flat side is cut, providing a safe edge and top.

⁸ *Marteau tranchant*: With a cutting edge.

A microscope.

An uprighting tool. Pl. 11, Fig. 4.

A domestic bird. Pl. 5, Fig. 8.⁹

A wheel cutting machine for flat wheels, with its uprighting tool to split verge escape wheels and its set of fraises. Pl. 12 Fig. 1.¹⁰

A fusee cutting machine. Pl. 11, Fig. 1.

One flat-nose pliers. Pl. 4, Fig. 3.

One taper-nose pliers.¹¹ Pl. 4, Fig. 8.

A portable microscope.¹²

A riveting clamp. Pl. 6, Fig. 5.

A hand vice. Pl. 4, Fig. 2.

One cutting pliers. Pl. 4, Fig. 6.¹³

A pin vice. Pl. 3, Fig. 7.¹⁴

Turns. Pl. 6, Fig. 1.

A square head hand vice. Pl. 5, Fig. 1.

A Turkey oil stone.

A mainspring winder or *estrapade*. Pl. 6, Fig. 2.

A saw.

A packet of Tripoli.

A riveting stake, two inches square.

A bluing pan, which is just a very thin tinplate, brass or steel plate.

Four feet of square steel of different sizes.

Four feet of round steel.

Pinion wire, of sizes according to the work which you propose to make.

Flat steel in several thicknesses.

Brass plate in several thicknesses

Round brass of various sizes.

A packet of rotten stone.

A packet of crushed emery.

A packet of crushed oil stone.

A packet of putty.¹⁵

A packet of English rouge.

A pumice-stone.



⁹ Used to measure the height of the verge escape wheel pivots, their distance from the plate.

¹⁰ The “uprighting tool” is presumably Pl. 12, Fig. 5, which replaces the arbor used to cut ordinary wheels. See N°. 314.

¹¹ *Pince à bec de bécasse*: Woodcock’s beak pliers!

¹² A loupe?

¹³ And Figure 7?

¹⁴ *Tenaille à vis à goupilles*. But there is no screw, so probably referring to Figure 8.

¹⁵ *Potée*. Powdered abrasive which is mixed into a paste with oil.

Chapter III: Steel

Nº. 6. When you want to buy steel, either round, flat or square, nick it with a file at the end of a piece, attach to it the vice close the small slit that you have made, and break it with effort. If it does not have cavities, glittering spots, or black spots, if it has an ashy colour and fine grain, it is of good quality.

7. Bad steel is usually brittle; it is difficult to work; when it has hard spots it spoils files and quickly makes them useless; when turning it blunts gravers, it prevents turning round, and often contributes to breaking the part on which you are working.

Pay attention, when choosing steel, that it is forged uniformly, and that you see neither flaws nor cavities; if so reject it.

Annealing Steel.

8. Either simply heat it on a fire until it becomes a cherry colour and let it cool on the hot ashes. Or wrap the steel in a ball of clay and, after making the whole red, let it rest until it is cold; then crush the clay and you will have steel which will be softer, because while hot it will not have immediately received the effects of the air, which are necessary to harden it.

9. Do you want to test it? Make a drill the size of a pivot, put it in the flame of a candle until it becomes a cherry colour, and quickly remove it from flame and shake it in the air; the drill will be hardened as hard as if you had thrown it into water or inserted it in tallow. It will be suitable for boring steel. It will break easily or will chip if you do not take the precaution of tempering it to the colour yellow.

10. If you work with steel which is too soft, and so prone to distort, which could have flaws or buckle when hardened, forge it cold. With some blows of a hammer it will take on a consistency that can be worked successfully.

Hardening Steel.

11. Let us now suppose that you have an arbor to harden. Place it on a coal and blow the flame of a candle or a lamp onto it with a blow-pipe, Pl. 2, Fig. 11, so that the breath which leaves the blow-pipe carries a ray of fire directly onto the part and reddens the arbor. When it is a cherry colour from one end to the other, throw it perpendicularly into water or oil, and the arbor will be hardened. Take especial care when hardening the part not to throw it in the water in a tilted direction or horizontally, which would almost certainly distort it.

12. While heating the arbor make sure not to redden it beyond a cherry colour, so that you do not risk oxidising the steel and so rendering it prone to break.

13. When you harden an arbor, test it with a file in several places; if the tool does not bite it is proof that the arbor is well hardened. Do not neglect to test every part which you harden, or you will risk making bad work.

14. Hardened steel must be tempered. For that, take a little pumice-stone soaked with a drop of water and rub the part until it becomes white. Then place it on the bluing pan which you move through the flame of a candle until the part is tempered to the colour yellow, preserving the hardness which arbors require.

15. Some artists, to avoid bleaching a part with pumice-stone, are satisfied, when the flame gives it a cherry colour, to plunge it in soap water, which leaves it hardened completely white. This method takes less time and is also useful for hardening delicate parts that the roughness of pumice-stone could break.

16. It is good to note that a hardened part, that is tempered on a bluing pan in the flame of a candle, takes on various colours; it becomes successively straw, yellow, purple red, violet, blue and grey. These changes of colour indicate to the artist the various degrees of hardness which he might need. You should be aware that when the part becomes white it loses almost all its hardness.

17. Observe that if you give a part a colour some number of times, yellow for example, you will almost always have the same degree of hardness until the part changes colour.

18. As you cannot redden a large part with a blow-pipe, place it on burning coals, liven the fire with bellows, and when it has become a cherry colour plunge it into a vase of water, with the precaution indicated at N°. 11. Having bleached it, temper it on coals to the colour necessary and according to the work for which it is intended.

Chapter IV: Brass.

N°. 19. The choice of brass is very essential, because the solidity of the parts of a watch depends on the quality of this metal. The best is that from Holland; it is black on two surfaces, and a gold colour in its thickness. That which is white is bitter and prone to fracture under the hammer; the teeth of a wheel of this metal can break. Never use melted brass, because it has flaws or is sour and is of no use for watches; it could however be useful for ferrules and other work of that type.

20 Brass does not heat harden; only the hammer will increase its hardness. It is what is called hammer-hardening. Thus by forging it one hardens it, and by setting it on a fire one softens it. Do you want to have a brass part of good resistance, which is prone neither to buckle nor to distort itself? Use that which comes from Holland. Choose it two and a half times thicker than you need for the part that you want to make, and forge it with the head of a hammer with small blows, until it has about the thickness which you want.

21. To preserve the hammer-hardened part of it, forge the brass to about the thickness required, so that you do not have a lot matter to remove, either in the turns or with the file. Because if you leave it too thick, you will have to file both surfaces, and will remove the hardest parts of them. Consequently the matter you leave, when the part is finished, will have less solidity. If it is a spring it will soon lose its elasticity and will be bad in use.

22. If, when forging brass, you realize that it has flaws or it has cracked, reject it; it can be of no use to you. If the edges of the part start to crack under the effect of the hammer, file the edge and all around the part, and reforge it. It cracks less if the brass is of good quality.

23. Forge brass slowly; too rapid blows of a hammer will crush the matter and make it flawed. Moreover they overheat it so much that it softens, and so becomes defective.

24. Especially avoid forging brass with the peen of the hammer; this manner of hammer-hardening would make it flawed or prone to crack. Always use the head of the hammer to forge watch parts.

25. As you forge a wheel or a plate of a watch, take care to turn it frequently in your fingers; by this means you are more certain to forge it of equal thickness, and it will not be prone to buckle.

26. When you want to harden round brass, take brass wire three times larger than that which you require, and pass it through a goldsmith's draw-plate until it is reduced to a third of its size. You are then assured that it will be well hardened.

Chapter V: The File and the Turns.

N°. 27. The file and the turns are the basis of watchmaking; you cannot apply yourself too much to filing and turning well.

28. Of the various files which you need, examine whether they are true and flat, if the cross-sections are sharp, if the size is even, if it is not chipped, and the steel is not flawed or cracked. Give preference to the English for hand and carrelet files which one normally uses. As for finishing files, such as pivot, equalising, rounding up, thinning, barrette, crossing out files etc., the best come from Paris, Geneva and Switzerland.

Take particular care that these files are only used for finishing, and especially never use the equalling and rounding up files to file steel; you would remove the sharp cross-sections

and the teeth would no longer have the same goodness. A worker jealous of the perfection of his work usually keeps them in a box and uses them only when absolutely necessary.

29. There are Watchmakers who, to ensure their files are well hardened, move them in the hand, looking carefully at the cutting edge. When they see that the bottoms are whitish, they judge that the file is well hardened.

30. If you want to be thrifty with files, use some to file steel and others for brass. There is a very great advantage to use a new file on brass until it is a little worn, waiting until the cutting edge is smoothed on brass; it then lasts ten times longer when employed on steel. The reason for this advantage is that when one uses a new file on steel, the cutting edge is chipped and becomes of little use. If, on the contrary, one starts by using it for brass, this metal not being so hard, the cutting edge of the file is softened, and when it can no longer file brass it is perfect for steel and will last longer.

In the care of files about which I speak, look not only at the hand files which one uses to rough out parts, but also at all the files used in watchmaking. You will never have a better pivot file than when you use it for a time to file brass; it is a known fact from the experiments of all artists.

31. Accustom your hand to have a fixed point, and to hold the file flat and true to the work which you have to make. Once you have started to file, do not change the position of either hand or file. This takes time, practice and constant application. Especially endeavour to file only while pushing the file, and always make its pressure proportional to the size of the part and the hardness of the material which you are working on.

If you have to file two pieces of the same size, one of steel, the other of brass, you will find more resistance to the file from the steel, and consequently you must press harder on this metal than on brass.

32. From the beginning apply yourself to filing true and sharp; on that the beauty and delicacy of the work depends. All must be finished in watchmaking, and this art asks for the greatest detail, and consequently the greatest care. Though there are many difficulties to overcome, when you can file well and turn well you will surmount the remainder by a sustained application and assiduous work. Impose on yourself the law that you let nothing leave your hands which is not finished, either from the file or from the turns.

Chapter VI: Tools for the Turns.

Bows.

Nº. 33. Bows are made of whale or cane, and they are shaped with a penknife or a file. Their size, their length, their strength, and the size of the cord must be proportioned to the piece on which they must act, either to bore or to turn. For a bow to be well made, it must decrease in size from one end to the other; thus shaped, it will be more flexible, less prone to break and will preserve its elasticity longer. One usually makes a slit at the large end, which is used to hold the cord when it is twisted on the end, and at the other one makes a notch which is used to hook the end of the gut string to tighten the bow.

Gravers.

34. Choose your gravers carefully. The English are likely to chip. The best known are the black ones that the supply merchants sell.

35. If you cannot get some of these, you can make one yourself good enough to use. For this, take square steel and file the four faces with a fine hand file. At one end form the point and at the other the tang. Harden it and then, for it to be ready for use, finish it on an oil stone.

36. If its point chips too easily, whiten the graver with pumice-stone and temper to it to straw; if it is tempered more it will not be good, because a graver intended to turn hardened steel must be very hard.

37. I have already said that before using a graver it must be sharpened on an oil stone. It is necessary that the face of the graver is quite sharp and bevelled, and as flat as possible. Test the point by pressing it on a finger nail; if it slips over it, it is proof that it is not sharp enough, and you will resharpen it until the graver stops on the finger nail.

38. The best oil stones come from Turkey; choose transparent ones, neither too hard, nor too soft. Though an oil stone is a little hard in the beginning, it should not be rejected for that reason, especially if it has neither black spots nor veins. The oil that you continuously spread on it to sharpen tools will soften it, and will result in a long life.

39. If over time your oil stone becomes recessed, rub it on a plate with sand and water; by this method it will become even and flat.

40. If you have an oil stone which is of bad shape, make it square by rubbing it on a plate on which you will often put sand. And if you want to preserve the ends or to divide an oil stone, then use a saw which you will rub on the oil stone, taking care to maintain a sufficient quantity of sand and water on it; with patience you will be able to divide it. Take care not to hit the oil stone when you advance your work, or you will risk breaking it into several pieces.

Square Gravers to Make Recesses.

41. When you want to recess the pillar plate for the center wheel, or you want to recess a barrel, a contrate wheel, etc., you will only be able to do it with square gravers.

42. Let us suppose, for example, that you have a barrel to recess. You will give to the square graver the form in Pl. 3, Fig. 2.¹⁶ To do this you will take flat steel or an old softened file and you will make a notch at the point *B*. That done, you will make the end into the hook *A*, so that it is broader on the side *A* than at its base *D*. When you have given it this shape, you will bevel the three parts *A*, *C* and *C*. After having filed and smoothed it, you will harden the square graver and temper it yellow; then sharpen it with crushed oil stone, which you will rub over it with an iron file until the three bevels are sharp and acute. You will be able to make several square gravers of the same shape, but different widths and lengths according to the different work which you will make.

43. The square gravers which are used to thin the bottom of a barrel, when it is completely finished, are a little different from those which I have just described. This difference consists in a small hook, Pl. 3, Fig. 3, placed at the end of its head on the end for the handle; the figure will make the shape clear. The tool thus made, you will have no fear that the barrel hook causes trouble in your work.



Chapter VII: The Turns. Pl. 6, Fig.1.

Nº. 44. The watchmaker must give all his attention to the choice of this instrument. That which you choose must be of hardened steel, and with packing strips. It is necessary that the two headstocks meet exactly, and that the square hole at the bottom of the headstock fits exactly and freely on the bed of the turns. If you find one which has a headstock with its arbor to turn in the air, give preference to it.¹⁷ Turns in the air are useful in many cases which one could not otherwise do, and you will be happy to have made this acquisition, especially if you intend doing repair work.

45. As for the runners for the turns, you will need half a dozen. You need two lunette runners, Pl. 6, Fig. 7; two to burnish and turn pivots, Pl. 6, Fig. 8; and two with an acute point on one end and filed square on the other, where you make several holes by means of a center punch; they are used to turn all kinds of arbors or stems. As well you need the two points *A* and *B* fitted in the headstocks of the turns *C*, *C*.

¹⁶ This is confusing because Figures 2 and 3 did not have the parts labelled and Figure 2 does not appear to have bevels. I have labelled Figure 3 appropriately.

¹⁷ *Tour en l'air*: Mounting the piece on a wax chuck instead of on an arbor between two points.

46. To start to turn a piece of brass, after having placed the turns in the jaws of the vice, fit the piece on an arbor and place it between the two points of the turns, and then tighten the two screws.

Take a bow, and put a turn of the cord around the ferrule. To turn the part you move the bow which you hold with the left hand, and with the right hand you hold the graver supported on the T-rest of the turns. Make sure that at all times when the bow is raised, you also raise the point of the graver that you cut with when the bow is drawn. Take care to hold the face of the graver in the air, and press it on the headstock with the second finger, while you hold the handle firmly in your hand.

47. Take care not to allow the graver to slip on the piece, because you would then turn neither true nor round. When in place, the graver should have no other movement than that of raising the point a little, when you raise the bow, and cutting lightly when you draw it; hold the graver firmly in your hand, and always press the second finger on its side, so that it cannot bite into the material further than you want it.

48. The graver must act on the T-rest as if it were fixed there by a hinge. From the start get accustomed, each time you raise the bow, to raise the point of the graver without changing the position of your hand, and making the graver cut each time you draw the bow. The work will go less quickly, but you will turn truly, and as this little movement of the graver and the bow become familiar to you, you will become faster.

49. Turn only with the point of the graver; the instrument presenting a small surface, you will more easily manage to remove the parts which are not round. Whereas turning with the face of the graver, which you apply to a greater area of the piece, necessarily makes it hop or slip.

50. Have bows which are a little long; because the more they move, the more you will traverse, and with only one movement of the bow you will make the ferrule turn a larger number of times, and consequently you will turn the piece faster, and it will be rounder.

51. Temper the brass that you propose to turn, and here is a little detail of this preparatory operation. Take a piece of brass, either round or flat. Having cut off a suitable thickness with a saw, forge it and bore a hole in the center a little smaller than the end of the arbor on which you intend to turn it. Using a broach, increase this hole until the arbor enters it and the end protrudes a little. With a compass, mark a circle of the size which you want to give it, and file the material until you reach this line. Then place this piece on the arbor, fix the whole on the turns, and turn it as in N°. 46.

To Make a Ferrule.

52. If you want to make a ferrule, after having turned it true and round form a hollow in its circumference; this cavity must be deep enough to contain the cord of the bow. It only remains to remove the marks; without this precaution the gut cord will wear quickly. For that use a rat-tail file which you place in the notch; while you make the ferrule rotate with the bow in one hand, press the file with the other, observing to push it when you draw the bow, and withdraw it when you raise the bow. When the hollow of the ferrule is smooth, rub the sides with a smooth carrelet file, which will round them and remove all the marks.

Then take a piece of wood smeared with pumice-stone crushed with oil, and rub it on the ferrule, making the same movement that you have just done with the file, until it is well smoothed.

To Make Turning Arbors and Stems.

53. Take a one inch piece of steel which you will file with four sides; to make them equal, file them one after the other opposite each of the four faces of the screw pincers. When the steel is formed with four sides, cut down the angles equally with a file; then the steel will have eight quite equal sides. Then file the eight sides for approximately five lignes while tapering towards the end where you will place the ferrule. That done, place the screw pincers a little beyond the place for the ferrule, and file the arbor tapering slightly until at the other end. To file the part round, when you have it with eight sides, roll it with one hand while pressing it onto wood in the vice, and file it with the other; by this means you will cut down the squares and will make it passably round, ready to put it in the turns.

54. File the two points of the arbor. Start by making them both with four sides, and then eight; then round the end, as in the above article. The points being quite round, drive a ferrule onto the arbor, and turn the two points.

55. When you roll the part by hand on wood in the vice, and file with the other, the movement which you give with the left hand should come from only the wrist, the arm must remain motionless. Accustom your wrist to this movement; it is essential to file round.

To Turn the Points of Turning Arbors.

56. Start by turning, cut them on the turns with the point of a graver a little tapering. After this first cut, you will have a point to polish, for which operation you will make a notch. You will place one end of the arbor in a point of the turns, and the other you will sit on the notch of the pivot runner. After placing the cord of the bow on the ferrule, you will press a fine carrelet file on the point of the arbor, Pl. 1, Fig. 17, and as you turn it with one hand on the bow, move the file with the other hand while supporting it on the runner. Repeat the same operation several times until the point is quite uniform, round and sharp.

These two opposite movements of the file and the bow are a little difficult to acquire; it is only by practice and with time that you will become familiar with them.

57. The two points turned and polished carefully, turn the arbor, always with the point of the graver; it is the way to advance the work and to turn round. When it is turned perfectly, you will harden it as above, N°. 11. Temper it to a straw colour, and turn it again. If the graver does not bite, temper it a little more. There is some steel that one can easily turn tempered straw, whereas other steel when it is tempered blue; by experiment you will learn how to judge quality of it. Keep the arbors as hard as you can, in order to prevent the points from blunting or wearing away.

To Preserve the Points of Arbors.

58. Frequently put oil on the runners of the turns, either those you use for arbors, or for stems and all other parts. The points wear rapidly when this precaution is neglected; in a little while the arbor turns out of round and consequently so does the part on which you work.

59. If the arbor does not turn round when you harden it, if it is distorted so much that you cannot hope to satisfactorily rectify it by filing the points, abandon it. Or, after having softened it and straightened it with the blows of a hammer, you will venture to temper it again. If it is not distorted to the point of being useless, file the point a little on the opposite side to where the arbor makes a bump. After that cut the point with a graver and polish it; that done, finish turning the arbor from one end to the other while slightly tapering towards the point.

To Finish Arbors.

60. You will put them in the turns and rub a smooth file over them, and then an iron file with oil stone. When you use the oil stone, while drawing the bow with one hand push the file with the other, making it run from the point to the ferrule; this method of smoothing will form a type of screw on the arbor, which, although almost imperceptible to the eye, will facilitate holding the part on the arbor, so much so that once fixed it will not be prone to move as you turn it.

There are workmen who, for this effect, rub the arbor with a smooth file in the shape of screw; the method above is preferable.

Every time that you file the end of an arbor or a stem, take care to cut it on the turns and to polish it if you want it to run smoothly.

61. You will need a number of turning arbors of different sizes; you will do well to make a dozen in advance. You will need a greater quantity of ferrules, to put on arbors, to place on drills, or to fit on parts which you want to turn. You will make some of different sizes according to the work which you have to turn, whose holes are small or large according to the size of the arbors.

Do not imagine that you will waste your time by filing and turning arbors and ferrules. If you do it with attention, it will contribute much, by training your hands, to learning how to file and turn.

62. If you buy some screw ferrules from the tool merchants, that will save you from having such a great quantity made of brass. But you always needs those which are placed on arbors, on drills and other tools about which we will speak later. If each one of these tools did not have its ferrule, and one was obliged to change them at every moment, that would put you to continual trouble and would waste much time.

To Fix a Part on an Arbor.

63. Take a broach and increase the hole if it is needed, until the part can fit on the end of the arbor on which you want to turn it. Then put it on the turns and make it turn while strongly pressing a wood block against the brass part, to fix it and make it turn true. If you intend it to be a wheel, turn it round, true and the thickness which your work requires. That done, remove it from the arbor, put the wheel on your fingers, and with a flat hand file make it slide on the file backwards and forwards, and often changing its side. By these operations it will become perfectly flat and of equal thickness, and you will be able to put it on the wheel cutting machine.

To Smooth a Part with Four or Eight Sides on the Turns.

64. I presume that you have made a steel arbor, and that after having filed it to four or eight sides, you want to smooth and polish all of it, or only a part. Take the arbor, on which you have been careful to preserve the two points on which you turned it, and put it in the turns so that that it can turn easily. Get a quite thick iron file, six inches long and four lignes broad. Then take well crushed oil stone, mix it in a crystal with oil, and put a little on the polishing file. Rest this file thus prepared on one of the four faces of the arbor, and rub it back and forth until you have removed all the file marks; you will do the same way on each face. Using this method, the faces will be as flat and as sharp as one can get them. This results from the arbor being set freely on the two points of the turns, and it follows the movement of the file, which rests flat on all the points of its surface. This is how the square of the fusee is made.

65. After this first operation, take tin putty and crush a small quantity with oil. After having cleaned the arbor and the file, put a little putty on the polishing file and rub the four faces one after the other until you see that they come to a black polish.¹⁸

Putty

66. There is putty which has to be crushed to black before using it. For this, one puts a little on the anvil with two beaks with a drop of oil, and one crushes it with the head of a hammer; it is the best method to give a beautiful polish to the work.

67. You will often find steel that is impossible to polish well, because it has flaws or it is brittle, or it was burned when hardening it. If you are aware of this defect, reject it, or use it only for common work, which does not require great care and which one need not polish.

To Polish Arbors on the Turns.

68. Fit a ferrule at the end of a arbor and place the piece on the turns. With one hand turn the arbor with a bow, and with the other remove the marks with an iron file smeared with oil stone. That done, clean the part and the tool, so that no oil or oil stone remains. Then take some putty and polish the arbor by pressing the polishing file on it, until it is polished black.



¹⁸ The surface is so smooth and flat that light reflected from it is not scattered. When the light comes from a single source, the piece will appear shiny if the reflected light enters the eye, but at other angles it appears to be black.

Chapter VIII: Drills.

No 69. There are several sizes and types of drills; there is the large one to bore brass or steel; there are pivot drills, square drills, tallow-drop drills¹⁹, etc.

70. If you want to make a large drill, take round or square steel approximately four inches long. File one of its ends for an inch with eight sides tapering a little towards the end. Make a sharp point there and drive on a ferrule with blows of a hammer; to do that put the end of the drill in a vice and put on the ferrule, which you will force on so that the point of the drill protrudes two or three lignes. Then with the screw pincers take the other end of the drill and round its tip, so that it is smaller than the hole than you want to bore. File the end of the drill to a point, and place it on a riveting stake in the vice or, without a riveting stake, on an anvil with two beaks; some strongly struck blows with a hammer will flatten it and will give it the form of a snake's tongue.

To Form the Tips of Drills Properly.

71. I told you to make the tip a third smaller than the hole than you want to bore; it is so that the drill cannot seize. After rounding the point you will strike it with some hammer blows, until it is the size which you need. A drill made in this way will be unlikely to seize in the hole and will bore quickly.

72. The best form that you can give to a drill is that of a snake's tongue, similar to Pl. 1, Fig. 2. To harden it, heat it with a blow-pipe in a candle, and when it is a cherry colour, insert it into the same candle; it will be hardened.

Harden the tip of the drill as close to the end as you can; that will prevent it breaking in the holes which you bore.

73. If you intend it to be used use with brass, after having hardened it approach the tip of the drill to the flame of a candle, and heat it until it is tempered purple red. It then should be sharpened on an oil stone, observing to successively rub it on all four faces, and to make the point centered and sharp. It is easy to make the four faces equal, if one takes care to incline the hand equally on each of them when moving it on the oil stone.

If you have to bore steel, you will give the drill another form, either by filing it or by sharpening it. You will make the tip round and flat-nosed, and it will bore steel faster. You temper this drill at most to the colour yellow.

74. The drill thus prepared, make it round for its whole length, and especially near the tip; if it is turned badly round, it will make a pip in the hole that you want to bore,²⁰ around which the drill would turn without advancing the work, and it would induce the point to break.

75. To make drills for pivot holes, use fine smoothing broaches, the size of a large sewing needle and approximately two inches long. Put one of them on the bluing pan and hold it in the flame of a candle until it becomes purple, and at once move it away from the flame and throw it in water to cool. After this preparation, put a small ferrule on the tail end of the broach, which you will have taken care to round. Then place the drill between two fingers and slowly turn it with the other hand. If the drill runs smoothly, leave it in this state. On the contrary, mark the place which bumps. Then take a piece of flat brass which you put in a vice, press the drill on the brass, and with the peen of a hammer, which must be round and not cutting, strike the bump. Repeat this operation one or more times, as necessary, and you will be able to put the drill true and round.

76. When it is straight, file the end opposite to the ferrule to form a drill tip a little longer than the thickness of brass that you have to bore. After sharpening the end, put it on a riveting stake and strike it to give it the form of a snake's tongue, then sharpen it on an oil stone, so that its four faces are equal and quite square. Thus made it will bore brass very quickly and will not be prone to break. If however that happens, it will be necessary to file the end again, to form the tip, the point, strike it on a riveting stake and sharpen it. The drill

¹⁹ *goutte de suif*: Tallow-drop (tear-drop) is descriptive of dome- or button-head screws which sit in a conical countersink. This drill cuts that countersink.

²⁰ *tétine*, teat. A small protuberance (or nipple) in the bottom of the hole.

being hardened from one end to the other, you will be able to renew the tip of the drill, until it becomes too short to be of use to you.

77. This kind of drill is preferable to those from sewing needles which many people use, because they are usually half iron and half steel, and by filing them one often removes the steel, leaving only the iron; in this state a drill can only be very bad. The drills from broaches are also a little longer, and it is easier to distinguish if they bore true, by observing if they are square to the part which one bores.

78. You can also make the drills from round steel. For this, take a foot of round steel, cut it into six parts, and file them tapering slightly to one of the ends. Then make the other end, the place for the ferrule, with eight sides. Put on a ferrule, make a point at each end, place it between your two fingers and roll it to see if it is round; I explained above the means to correct it if it is not. Take the now round drill, place it on a coal, blow the flame of a candle over it with a blow-pipe, and when it is a cherry colour from one end to the other, throw it as perpendicularly as you can into a goblet of water, and the drill will be hardened. The hardness will be softer and less breakable if you throw the drill into oil.

The drill being hardened, rub it with pumice-stone, temper it to red or purple, according to the grade of steel and the degree of hardness which you require, put a ferrule on it, and make it round, if it is not already. You will form the tip proportionally to the size of the hole which you want to bore. It is unnecessary to repeat that the drill must be smaller than this hole; the reason for this precaution is so that it can be increased or rectified according to need. Always observe that the ferrule must be proportioned with the size of the drill, and that one does not put a large ferrule on a small drill, nor a small ferrule on a large drill; the reason is that a small ferrule on a large drill, does not have the force to bore, because it does not have a large enough diameter, and that a too large ferrule can break a small drill.

As far as you can, place the ferrule at the extremity of the drill opposite to the tip; this is necessary to avoid the drill doing what is called to whip.

If the proportion between the ferrule and the drill is necessary, that of the bow is no less. The bow, which must carry a horse hair, should not have the force of that which is mounted with a gut string. It results from these principles that the proportions between the bow, the ferrule and the drill, if observed well, contribute more than one might think to the advance and perfection of the work.

79. If you want to bore a part, take a rather long drill, and after supporting its tail in a hole made in the jaw of the vice, hold your part in one hand and the bow in the other. After putting the tip of the drill at the center of the part, which you will have taken care to mark by a blow of a center punch, turn the drill with the bow and it will bore easily.

80. While boring a part, hold it as square with the drill as you can, and change sides from time to time; this change will facilitate boring true. If the part is thick, do not forget to put a drop of oil on the tip of the drill from time to time; this will prevent it from warming up too much, so it will not lose its hardness, it will facilitate the discharge of filings, and as well it will prevent the drill from breaking or chipping.

Pivot Broaches.

81. To make them yourself, take steel of a suitable size and file it round and tapering slightly from one end to the other; its length will be approximately an inch and a half. Give it four faces, and at the largest end make a tail on which you will make some deep marks with a file, so that it holds better in the handle.²¹

When you have finished it, harden and temper it to a red colour and if the broach is not true, you will correct it, as at N°. 86. The broach being true, you will make a brass handle with eight sides, the size and length of that in Pl. 1 Fig. 15.²² You will bore as large a hole as it will take, fill it with sealing wax, and fix the broach in it before it has cooled. Take care to place it true and in the middle of the handle as much as possible. That done, it should be filed with four quite equal faces, and then smoothed until the marks of the file have disappeared.

These types of broaches are preferable to those with five sides, which sometimes push back the material. It can happen that a hole that you believed to be large has suddenly tightened, and a watch ceases going because its running is constrained. The broach with four

²¹ *afin qu'il tienne mieux à l'acier*: so that it holds better to steel. I can only assume this is an error.

²² Obviously wrong. There is no illustration of such a handle anywhere.

sides does not have this disadvantage, because the angles, being sharper, remove the material better, the walls of the holes are not driven back, and consequently the pivots are freer in their holes.

Method of Boring Various Parts of Brass and Steel, such as Canons & Canon Pinions

82. To bore a metal part you usually employ a drill which you turn with a bow. The end of this drill with the ferrule goes in a hole made specially in the jaw of the vice, and you support the tip against the part which you want to bore. The drill thus set up, you operate the bow while supporting the part against the tip of the drill, and by this means the part is soon bored. If you have to bore a brass or steel rod, etc., you will do the opposite, and instead of making the drill turn, it will be the rod which you will drive with the bow in one hand, while you will hold the drill in the other, and you will push it against the part which you want to bore.

Do you want to make a seat? Take a brass rod two inches long, at one end give it eight sides to drive a ferrule onto it, and made a point at the other end; then, after filing it flat, mark the center with a center punch as near the middle of the rod as you can. Put the point in the hole in the jaw of the vice, hold in one hand the drill that you will place in the hole already marked, and while you operate the bow, press the drill against the rod. By this means you will bore true, whether seats, canon pinions or other parts.

83. When you want to make a hole in a canon pinion and you want to steady your hand, bore this part on the turns. Start by supporting one end of the rod on a runner in the turns, and place the T-rest of the turns at the other end so that it almost touches the piece which you will bore. While boring, support the tip of the drill on the T-rest, which will enable you to go more quickly, and will prevent the drill from breaking. Have care to often withdraw the drill from the hole, to release the filings from it; which, being in great quantity, form a type of body which binds the drill, or breaks or blunts its point. While doing this operation, frequently put oil on the drill.

84. If you want to make ferrules for arbors, take a brass rod of suitable size, set it up like the rod above, and bore it by following the same method. Place it on the turns by the end opposite to the ferrule, and form a ferrule, as in N°. 52. When it is finished and polished, cut the rod with the point of a graver to detach the ferrule from it. If the hole is found to be deep enough, make a second ferrule. You can continue to bore and make ferrules until you have used up all the rod.

Method of Correcting a Part with a Sharp Hammer.

85. If you want to succeed quickly in correcting a part after having hardened it and tempered it a yellow colour, sit it on a riveting stake or another tool of well hardened steel, and strike it with sharp blows in the hollow of the stem; it will straighten it appreciably. If you want to straighten a pinion, put it on the turns and, while driving the bow with one hand, mark it with chalk which you hold in the other hand like a graver. Then, by striking with a sharp hammer on the side opposite to that which you have marked on the pinion, you will more easily manage to straighten the arbor and the pinion on it. At all times when you correct a part using a sharp hammer, made sure that your part lies flat on the riveting stake, because if it is not you risk breaking it. When you use this method and the part is true, temper it to the colour straw; because if you file or turn it without this precaution, it will distort again as before.

To Correct a Part with a Round Pean Hammer.

86. Temper it red purple or blue. Put a brass block filed flat in the vice and place the part on it so that it does not overhang²³ and you can strike the bump. Give some sharp blows with the peen of the hammer, and examine it to see if the part is corrected; otherwise, you will repeat the same operation until it turns true.

By these two methods you will be able to correct pinions, arbors and verges. But take special care to temper all the parts which you have straightened.

87. One can straighten a long arbor without striking it with a hammer. Let us take as an example a arbor of three or four inches which was distorted when hardened. To straighten it use an iron or steel plate, which cannot bend as easily as the arbor. Put the part on the iron plate and bend against the other with screw pincers; the force of the pincers will make the

²³ *de façon qu'elle ne porte pas à faux.*

arbor spring. Then using a blow-pipe, blow the flame of a candle on the iron plate, which, being heated, will communicate its heat to the arbor, and when the arbor tempers yellow, cool it by throwing it into water with the pincers. If, after this operation the part did not temper true, repeat it until you get there. If the arbor resists several attempts, give some blows with a hammer to the iron part to make it a little hollow; then by fixing the arbor on the bump, repeat the same operation until you have succeeded. For this one needs only patience, a virtue which is very often needed in watchmaking.

Pay attention at all times to whiten the arbor with pumice stone before it is tempered yellow; without this precaution you could, when heating up the part, not see the colour which it takes and risk tempering it more than one should.

Chapter IX: Various Methods of Soldering, and Various Types of Solder Used in Watchmaking

Silver Solder

88. If you have to solder a steel arbor to a brass part, clean the arbor with pumice stone and, after boring a hole in the brass about the size of the arbor, increase it with a broach until the arbor enters it accurately. That done, take borax, that is usually kept in a small tinplate box, called a *bourachoir*, Pl. 5, Fig. 4, and crush it with pure water. Then take one or two small pieces of silver solder, and place them between the arbor and the seat with a little watered borax, with which you will moisten the solder and the part where you want that the solder to run. Everything thus prepared, sit the part on a coal and, with a blow-pipe, blow the flame of a candle or a lamp onto the part to be soldered, and when the solder melts and flows, the part will be soldered.

The method is the same to solder brass to brass.

89. If you want to solder two separate parts, file them so that they are well adjusted to each other and bind them with wire. Put solder and borax at the place where you want to solder and then heat the part, either with a blow-pipe or on burning coals until the solder runs. Remove to it from the fire and let it cool.

90. Take care to put on the part which you want to solder a quantity of solder proportional with its size, if you do not want to risk burning it while melting the solder, or deforming the work by too great a quantity of solder.

91. To make a collet, start by determining the diameter of it; this diameter taken three times will be the length of the brass plate needed to make this collet.²⁴ Put this plate on the fire to soften it, then file the two ends on their thickness and round it with hammer blows on the anvil with two beaks; by this means the two ends will approach as much as needed. Clean the part and put three or four small pieces of solder and wet borax outside and inside. Sit the part on coals, and let the borax calcine on a small fire; because if the borax were heated too quickly by the fire, it would disturb the solder. The borax calcined, blow on the fire until the solder runs, withdraw the collet, and let it cool. When heated, the borax becomes a type of very hard varnish which should be removed with a bad file. Forge the collet on the anvil with two beaks to make it round and to hammer-harden it; do not hammer-harden the place where you have soldered it too much, because you would break it.

92. Never hammer-harden hot brass; it cracks under the hammer and is then good for nothing.

93. To remove the borax from a soldered part without filing it, put half water and half nitric acid in a vase, sit the vase on a fire and boil the whole together; the borax will be removed easily. This is called to scour a part.

94. Borax has the disadvantage that it swells on the fire and forms a type of scum, which, while bubbling, moves the small pieces of solder away from where they were placed. To avoid this disturbance, calcine your borax. For that it is enough heat a quantity of it on a shovel,

²⁴ Three times: A crude approximation to π , 3.1415.

which you will place on burning coals; the borax will foam and will be calcined. Collect it carefully and put it in the container. It will no longer be prone to disturb solder, and you will be able to make use of it without disadvantage.

How to Make Third and Quarter Silver Solder.

95. To make third solder, put in a crucible two thirds of silver and one third of brass and dissolve the whole on a high fire; the silver and brass will mix together by fusion. This is called third solder; it flows easily.

One can easily get this solder from goldsmiths, and it is only when you cannot get some that you should make it yourself. This third solder is the best for watchmaking; when it is stronger one is likely to burn the steel before the solder flows.

96. If you have a large part to solder and you fear that the third solder will not be strong enough, make quarter solder. For that take three quarters of silver and a quarter of brass from Holland, dissolve the whole in a crucible and use it as above. When you make solder with silver, use the better brass from Holland; without this care the solder will be very brittle, or it will flow with difficulty.

97. When you must forge a brass part after soldering it, you can use the following solder: take three quarters of good silver and a quarter of copper, which you will melt together; this solder is very good, and is not prone to break when the part is forged.

Tin Solder.

98. There are several ways of soldering with tin. The first is with rosin. Rub the two pieces at the place where you will want to solder them. Then take two small pieces of tin solder, sit them on the rosin coated place, and then you will easily solder them with a hot iron or a blow-pipe, or on a bluing pan put over a candle, or by setting the parts on a burning coal. However take the precaution, before applying solder, to file or scrape the two parts with a graver; because if a part is a little dirty, or if you have touched it with your fingers, the solder will have difficulty adhering.

Tin Solder with Sulphate of Ammonia.

99. This is the second method of soldering with tin. To succeed in soldering a brass seat onto a steel arbor, mix sulphate of ammonia with water, take a drop of it on the end of a graver, and scrape the part of the arbor which must be soldered to the seat. Then put a little rosin in the hole of the seat and put the arbor on it. Place between the arbor and the seat some small pieces of tin solder, heat with a blow-pipe, or put the part on burning coals, and when the solder flows, withdraw the part from the fire.

Tin Solder with Oil and Sulphate of Ammonia.

100. This method of soldering is especially used for delicate pieces. To make it, grate a little tin solder, put it in a flask with crushed sulphate of ammonia, and cover this mixture with oil. To use it, take a little of this mixture which you will place on the part to be soldered and put the whole on the fire; the solder will start by smoking and then flow as usual. Heat the part as little as possible, especially if it is a wheel or another delicate part, because fire softens brass and the part, when it is finished, can no longer be hammer-hardened.

It is in cases of repairing where one cannot avoid soldering a part with tin. But take care to avoid the disadvantage about which I will speak.

Solder with Tin, Water and Sulphate of Ammonia.

101. For you to use it successfully, put a drop of water on a riveting stake and crush in it a little sulphate of ammonia. Rub this water on the two parts at the place where you want to solder, put two small tin solder pieces there, and sit the part on a bluing pan, which you will heat with the flame of a candle. When you see the solder flow, withdraw the part from the flame.

To Make Tin Solder.

102. If you cannot get tin solder, you can easily make it by putting one part of tin and two parts of lead in the bowl of an iron spoon. When the whole is molten and it forms yellow bubbles on the surface, this will announce to you that the solder is good.

Chapter X: Smoothing and Polishing Steel.

N°. 103. If you have to smooth a steel part, you will use for this operation oil stone from Turkey crushed under a hammer. When it is reduced to powder, put it in a tinplate box, and mix it with oil when you need to be use it.

Before hardening a part that must be polished, start by filing it flat and sharp with a smooth file. Your part smoothed with a file, harden it, and temper it to the colour which is appropriate for its purpose. Then take a bottle cork and place the part on it. Take an iron file about eight inches long and three quarters of an inch wide, spread crushed oil-stone on this file, and rub the part until all the marks are erased. Clean it, so that there is no more oil stone on it, and do the same with the file. It only remains to polish your part.

Polishing Steel.

104. You will use, for this operation, English rouge or putty. Both often need to be crushed; it is for you to judge.

Putty usually gives a black polish when it dries on the part, whereas rouge must be moistened with oil.

105. When you want to polish a piece and you want to have a beautiful polish quickly, put a modest amount of rouge or putty on the tool. Then choose a clean bottle cork, without lumps and cavities (because they could make marks on your steel). This done, put putty crushed with oil on the iron file, and rub the steel part, while moving your hand in a circular motion; by this you will erase the marks of the oil stone, and the piece will take on a beautiful polish. If, however, you still see some marks after the putty has dried on the file, add a drop of oil and rub until the part is quite polished. If the putty does not want to dry, remove some of it, again rub the file on the part, and the putty will then dry. The more steel is hardened, the more beautiful the polish will be, and the more quickly your part will be polished.



Chapter XI: Choice of Compounds to Smooth and Polish Brass.

N°. 106. Brass is smoothed with water stones; choose black ones that are soft and that have neither grains nor veins, which you will know by scraping them with a knife.

107. Take the lightest pumice-stone, that which has the finest grain is the best, and crush it in a mortar or grate it. It should then be passed through a silk sieve.

108. The finest and softest Tripoli is that which will give you the most shining polish. To prepare it, scrape it with a knife, and prepare the dust that you get like rotten-stone.

Rotten-Stone and its Preparation.

109. When you buy rotten-stone, choose the lightest that you can find; the softest and most friable is the best.

Before using it, you will have to wash it. To do this, take a piece of rotten-stone the size of an egg and turn it into dust by pressing it with the fingers. Avoid crushing it, for fear some grains of sand, meeting under the hammer, break and mix with the rotten-stone. When you have reduced it to dust, put it in a small vase of clear water, stir it up and leave it for a moment, and the largest particles fall to the bottom. Then pour this muddy water into a larger vase, again fill the small vase with clear water and agitate the grounds, let it rest for a moment and pour the muddy water into the large vase. After thus decanting the rotten-stone several times, you will let it rest for twenty-four hours, when the water will again become

clear, and a sediment will settle at the bottom of the large vase. To separate it from the water, incline the vase gently and pour off the water until only the sediment of the rotten-stone remains. Take this sediment, put it in a clean frying pan, and sit it on a fire until the rotten-stone is completely desiccated. Then put it in a box for when you need it.

As for the coarsest grains, keep them too. When it is dry it can be used to give a gloss to those coarse works that do not require great care.

Charcoal to Polish Brass.

110. Charcoal is also employed to polish, but not all charcoal is used. That from willow and fir trees is the best. To make charcoal, put pieces of these timbers in a covered pot surrounded by burning coals; when the pot suddenly reddens, the wood will be carbonised. Leave it on the fire until it stops smoking, and then withdraw the pot from the fire, and let it cool; make sure to always keep it covered, so that the charcoal does not take in air before it has cooled. Then grind it and use it like rotten-stone.

To Smooth Brass.

111. Start by filing the piece with a smooth file, to remove the large marks and burrs. If it is a small part, rub it with water stone until there are no more file marks. You will then be able to polish it.

Brass is also smoothed with water stone mixed with oil instead of water. This method of smoothing gives to the material a pleasant appearance to the eye, and also the brass is not prone to blacken.

112. If you have, for example, a piece four inches square to be smoothed, you will reach that point easily by spreading a little pumice-stone crushed with oil on whitewood or felt, which you will rub on the piece until the file marks have disappeared. Then rub with water stone, and polish it.

To Polish Brass.

113. The part smoothed, place it on a cork wrapped in linen and attach it to the vice. Take a piece of spindle wood covered with rotten-stone and rub it repeatedly on the brass; it will be rapidly polished. If it is a round part, put it in the turns, and while driving the bow with one hand, use the other hand to rub the part with the spindle wood smeared with rotten-stone; continue this movement until it takes a beautiful polish.

One also polishes brass by mixing rotten-stone with spirits of wine: it should be kept a little thin.²⁵

114. Do you have a silver or gold case to polish? Start by smoothing it with water stone. Then take rotten-stone and mix it in water, oil, or spirits of wine. Put a little in the hollow of one hand, and rub the case briskly and rapidly on the hand smeared with rotten-stone; in this way you will polish the outside of the case very well. If, on the contrary, it is the inside which you want to polish, make a small round dome of wood, wrap it in a little skin, and place it on the turns in the air. Put a little rotten-stone on it and turn it with a bow on the inside of the case. You will polish it easily.

115. When you have brass or steel to be polished, take all possible care to do it with cleanliness. Do not drop any brass or steel part on the rotten-stone, or other compounds used to polish; only one grain of filings or sand is enough to spoil your work, by tracing an infinity of marks on it, which often obliges you to start this operation again. To avoid these dangers, get some wood or tinplate boxes, in which you put the polishing compounds.

Burnishing Steel and Brass.

116. To make a burnisher, take a fine carrelet file and get a cutler to remove the teeth on only one side of it on a grinding stone; preserve the other side which will be used to file the part that you want to burnish. Then take a plate about a foot long, on which you will spread a little crushed emery. To sharpen the burnisher rub it on this plate from right to left. Take care to lift up the file each time you reach the end of the plate, and never rub the burnisher both going and coming because it would become round. A good burnisher must be perfectly flat.

²⁵ *il faut la tenir un peu claire.*

When you have a flat brass part to burnish, put it on a bottle cork and rub the burnisher over all its length, always while going and never while coming.

If it is a arbor, rotate the part by a bow and push the burnisher. The more the part has been smoothed with oil stone, the better it will burnish.

When you want to burnish the arms of a wheel, make a burnisher the shape of a crossing out file, harden it and temper it to the colour straw; then smooth it with oil stone until it does not have any marks. It is necessary to pass the burnisher longitudinally on the emery plate if you want to burnish transversely, and to pass it transversely if you want to burnish longitudinally. Always take care, as I have already recommended, not to rub the burnisher on the plate both coming and going.

117. You will also need two pivot burnishers; one the shape of a pivot file and the other a triangle, which will be used to make the shoulders of pivots flat when you finish them.

You will file these two burnishers as square and as sharp as you can. Make a point at both ends, harden them and temper them to the colour straw. Fix one of them on the turns, by the two points that you put on it. That done, take an iron file coated with oil stone with which, while going and coming on the burnisher, you will remove all the marks of the file. When you push the iron file on the part suspended between two points, it will follow the movement of the hand and will become perfectly flat. Temper the tail of the burnisher to blue and insert it in a handle before it cools.

118. Rub the prepared burnisher on the emery plate; take care to hold the file flat and firmly, and never go and come on the plate if you want to keep the burnisher flat, as I said above.



Chapter XII: Screw Plates.

N°. 119. The best are from Geneva; those of Suter and Lavoisi are reputed amongst watchmakers who pride themselves on having good tools.

They are preferred to English screw plates, which are prone to chip, and whose threads are usually too large; the more threads there are in the same thickness, more easily and more firmly one fixes parts onto plates.

Watch plates, not being very thick, require the threads of a screw plate to be fine, so that a screw can resist the effort that the screwdriver exerts every time it is necessary to assemble or disassemble a watch.

Taps.

120. For each hole in the screw plate one needs a tap. Make it of well softened steel. File it round and pass it through the screw plate. Then file the end with four angles, as if you want make it a point. After again passing the tap through the screw plate, harden and temper it according to the material you want to tap; the colour violet if it is brass and dark yellow if it is steel.²⁶ If the tap is large it is necessary, after threading it, to file it on each of four faces and then pass it through the screw plate again. These four faces are made on taps so that they tap more easily, and so that they remove the material more easily; with this precaution the threads are formed more cleanly, and the taps are less prone to break. Once all your taps made and numbered, fix handles on them.²⁷

²⁶ *gros jaune.*

²⁷ It is easy to number taps and other items using the Roman numerals I, V and X by filing the numerals into the handle.

121. If when tapping a part you feel resistance, broach the hole to enlarge it. When this precaution is neglected, the tap is likely to break in the part which you are tapping, which causes great trouble by the difficulty of removing the end of a hardened tap; especially if it is in brass, which, once hammer-hardened, cannot be heated without being softened. When the accident occurs in steel, you can soften the part, bore a hole a little smaller than the tap, and use a broach to enlarge it; by this means the end of the tap will leave the thread where it had broken. Use the same method when a screw breaks in a brass plate; it usually works.

122. It often happens that a tap broken in a part obliges the workman to give it up. To avoid similar accidents, make drills of the various sizes of the holes in your screw plate, so that the tips enter each of the holes exactly, and number each drill. By doing this, you are assured of boring holes of the correct size, and will be able to tap them without fear of accidents.

123. Then make a small plate of steel called a calibre, Pl. 5, Fig. 6, in which one bores as many holes as there are numbers on the screw plate, Pl. 5, Fig. 7. Number these holes and enlarge them to the size of the various taps which you have already made. When you want to make a screw, you will file it and turn it until it enters the hole of the calibre corresponding to the number of the screw plate. It is the way to tap with certainty, and without having to fear the accidents of which we have spoken. You will also find this method has the advantage of making a screw whose threads will be uniform and well shaped.

124. Without a calibre, when you want to be sure that a hole is of the right size to be tapped, take a broach which enters the thread of the screw plate, and mark with a little oil stone the place where the broach stopped. After taking it out, make it enter the hole until the mark that you have made touches the hole which you want to tap. That done you will tap the hole easily, and will not have to worry about the tap breaking. It is unnecessary to repeat that it is essential to put oil on the taps every time that they are used.

125. To make a screw, take a piece of round steel an inch and a half long; if it is square, you will give it four sides, then eight, and then round it. Form a point at each end and drive a ferrule on one end; to give it more firmness, form the place where it will be fixed with eight sides. File and turn the other end into the cylindrical form of a pivot, about the size which you want to make the screw. File the end a little smaller, so that the screw enters more easily into the threads of the screw plate.

126. Then take the screw plate and, while turning, introduce the end of the rod; make it go in and out of the screw plate until the threads are formed.

When starting to tap, it is necessary to put a drop of oil in the hole of the screw plate, which must be held square to the rod for the screw. If you distort the screw while tapping it, put the rod on the turns and strike the bump lightly with a hammer, until the screw runs smoothly. Then form the head, turn the shoulder flat, fit it to where it must be fixed in the plate, and file the end which protrudes so that it is level with the plate. Being well adjusted, remove the screw, round the end with a file, and polish it with a burnisher. That is done by fixing it in pincers and rolling it on a filing block in the vice. Never forget, when you round the end of a screw, to pass it through the screw plate again; it is the only way to prevent the threads in the plate from being damaged by burrs on the screw.

127. Place the screw in the screw plate, detach it from the rod with a slitting file and form a notch in the head of the screw for the screwdriver; this notch is made in the middle of the head with a knife file.

To Recess the Heads of Screws.

There are screws which one is obliged to recess, either in plates or in bars, or to hold springs. These recesses are made in two ways, one for a flat shoulder and the other for a tallow-drop or dome head; a different tool is needed for each.

128. You want to make a hole to receive a tallow-drop screw? Take a steel rod two and a half inches long and put points at both ends. On one end form it with eight sides and drive on a ferrule. After putting it in the turns, turn on the other end a slightly elongated point and burnish it; then file it with four quite acute angles. Harden this drill, temper it yellow, sharpen it with an iron file coated with oil stone, and use it like any other drill. To do that, place the point at the end for the ferrule in the jaw of the vice and place the square point in the hole which you want to recess and rotate it with a bow; the hole will take the shape which you have given to the end of the drill. When you tap the screw, give the shoulder a

shape the same as that of the hole which you recessed. Everything adjusted, put the piece in place with its screw, file the end until it is level with the plate, round it, polish it and pass it through the screw plate again. Remove rod with the screw, cut the head, make the slit with a knife file, put the screw in its place and file the head so that it is level with the piece. To finish it, put it in the rounding tool²⁸ and polish the head of the screw; see N°. 131 and 132.

129. For recessing the head of a screw whose shoulder is flat, like that for a cock, take a rod which you will lay out like the drill above, and file the end opposite to the ferrule square. Fix it by this end in the jaws of the vice and mark the center with a tap of a center punch. Take a drill about size of the screw of which you want to recess the head, and bore a hole in this rod, as explained at N°. 82. Put the rod in the turns and turn the end cylindrical for an inch, Pl. 1, Fig. 3. File a bevel on the two opposite sides of the end of this drill so that the end is sharp. After hardening it and tempering it yellow, sharpen it with an iron file coated with oil stone, and place a pin in the point *G*. Then make a brass collet *B* which has a hole large enough for the end of the drill to enter freely, so that the collet can lengthen and shorten the tip of the drill. See Pl. 1, Fig. 3.

130. When you want to recess a screw head, to regulate the depth of it you fix the collet on the drill by means of the screw *E*. The length of the tip which you let extend beyond the collet will give the depth of the recess. See Pl. 1, Fig. 3.

Suppose you want to recess the two screws of a cock to an equal depth. When you determine the length of the tip by the collet and its screw, recess the two holes one after the other without disturbing the position of the collet; then the two recesses will be of equal depth. Note that one uses this drill like an ordinary drill.

131. When you make a screw and have fitted it, it only remains to polish the head, which one does by placing it in a brass jaw fixed on a small turns in the air; the screw is tightened so that it can neither turn nor fall out. One then drives the turns with one hand while with the other one files the head of the screw with a smooth file. When it is well smoothed it should be polished with a burnisher.

Not all the workmen have a turns in the air to polish screw heads. You can compensate for this by taking a brass rod, at the end of which you will bore a hole and tap it with the same thread as the screw that you want to polish. Put in the screw and tighten the rod in screw pincers, which you will turn by hand, supporting it in a notch of the filing block. After filing the head polish it with a burnisher.

This method is slower than the first and it does not give such a beautiful polish; but for want of anything better, it is necessary to be satisfied with it.

If you want to use this screw at once after making it, remove it from the tool, place it on a bluing pan, and heat with the flame of a candle until it is tempered blue. Then sit it in a clean place to cool. Especially avoid, before and after this operation, it touching the hand or any other oily body, because then it will have spots and will never come to a beautiful blue.

Chapter XIII: Square Punch Tools and Riveting Punches.

N°. 133. To make square holes of different sizes, punch tools are needed. For that take steel about an inch long, file it round and, while tapering slightly to the end, give it four quite equal sides; to get this equality file it opposite each of the four faces of the screw pincers. The punch tool thus made, file the end a little bevel, which is necessary so that the end of the punch tool can enter the hole of the part that you want to make square more easily. Then put it on a bottle cork fixed in the vice and smooth it with an iron file coated with oil stone. Hardened it and temper it straw if you want it to punch steel, and purple red if it will punch brass.

Files and how to Fix Handles.

134. Get good sealing wax if you want tools that are well fixed and not prone to shake.

Take a stick of sealing wax, heat it in the flame of a candle, and fill the hole in the handle.

²⁸ *outil à arrondir*: From N°. 131 this appears to be a simple screw-head tool.

Then heat the tail of the file until it becomes blue and, after rubbing it with a cloth, insert it in the sealing wax and place it as true as you can.

If you take care to temper to blue all the tails of files which you want fix to handles, they will not be prone to break with the force which you will apply while filing or by dropping them.

Chapter XIV: Pins.

N°. 135. There are many workmen who make pins badly, either through negligence or because they consider this part to be unimportant. It is however essential. To make it hold, a badly made pin has to be forced into the hole of the pillar. If it is too large, it is likely to burst the end of the pillar, to fall out at the least shock, and to obstruct and stop the movement.

To make good pins, take the brass wire from which the strings of harpsichords or other musical instruments are made. Having put it loop pincers, Plate 5, Fig. 1, shape it on the filing block. When filing do not make the taper incline too rapidly, because a pin must be almost cylindrical in form.

When you have made a pin and it is of size, put it in its place. If it is too long, cut the end, and after rounding it, polish the pin. To polish it use a large burnisher. While rolling the pin in pincers in one hand, rub the burnisher over it with the other; the pin will be polished in a moment.

To make the best pins, use a pin vice, Pl. 3, Fig. 7, which the supply merchants sell. The handle is bored throughout its length, it is round and easy to roll in the hand. With this tool pins are made rounder and more quickly.

Make the holes for the pins small, so the pins are more firmly fixed in their holes, and so that you are not likely to burst the ends of the watch pillars or the dial feet.

End Of The First Part.



PRACTICAL WATCHMAKING

Part Two.

Chapter One: The Rough Movement.

N°. 136. To make a good watch, it should it be a little large, and the movement high.

It is this height which made the reputation of English watches; for this reason they are generally good and solid, though they are made with less care and perfection than French watches. Their movements being high, their train has all the space that one can wish for. The mainspring being broader, it is made with more understanding by the workman who manufactures it; he better knows the defects in them. Moreover, a spring of some width and flexibility always acts on the train with more activity and uniformity. If common watches have such an advantage from their height over those which are low, couldn't a solid high watch be made with the care and delicacy which the French put in their works? Should everything be fashion for us, even in things which should be the least susceptible? What use can one hope for from a watch the thickness of a small ecu. Even with the care which the worker took to make it and finish it, it will never have solidity, and will be always be very difficult to repair.

Design your watches so that the pillars are three lignes high, and the pillar plate an inch and a half of diameter; with this proportion you are sure to make it solid, and preferable to the best English watches.

Watchmaking in Paris has always had the greatest reputation. It is done there with all possible solidity and delicacy. It is unhappy for the art, that the taste for frivolity has attempted to make the watch a jewel, and has subjugated it to the whims of fashions. Small and flat watches were wanted, some made of a smallness which passes imagination, by the delicacy of the work which they require. What service can one expect of such a fragile instrument?

That does not prevent Paris from being an excellent school for a pupil who wants to perfect this art. It is there that the best workmen of all the nations go, to see the perfection of pieces of new invention that are manufactured there daily, and to visit the better artists. Also I will always advise those who want status and who want to be distinguished, to spend a few years in this motherland of arts and talents.

Chapter II: Calibres.

N°. 138. My object is not to teach how to draw a calibre; this work is beyond the skills of an apprentice or an amateur who, after exerting himself with the turns and the file, wants to try to make a rough movement. I repeat, the only goal of this work is to teach the practice of watchmaking. Thus we will be satisfied to choose a good watch which can be used by us as a model. For that let us try to get a carefully made watch, in which the spaces are well distributed and nothing obstructs its motion.

How to Draw a Calibre Based on a Piece Already Made.

Take a brass plate which is well hammer-hardened and a little thin, that you will turn to the size of the piece that you want to imitate. Bore the center hole *C*, Pl. 7, Fig. 3, and place in it a pin which is used to fix this plate onto the plate which you will take for a model. Then bore the hole for the barrel, put another pin there, and clamp two plates together with screw pincers, taking the precaution to put paper on the plate so as not to spoil the gilding. Have drills of the sizes of all the holes of the pillar plate and bore them all in the calibre, and mark the site of the four pillars, which you will bore after separating the two pieces.

140. However, before drawing the calibre, examine whether the hole *F* for the balance is bored on the pillar plate of the watch which you have taken for a model. If not, put the cock on the assembled and pinned frame, and use the uprighting tool Pl. 11, Fig. 4, to mark the hole for the verge. Bore the plate with a pivot drill so you will have no fear of degrading it. When you bore the holes of the calibre, take care to also bore this hole; by this means you will have the position of balance, which will be used as guide when you want to locate the cock, the slide and the potence. That done, trace the circles, *A*, *B*, *C*, *D*, *E*, Pl. 7, Fig. 3, with a compass, which mark the sizes of the wheels and the barrel. On the motion-work side, mark the sizes of the two wheels and that of balance, and bore the holes for the four pillars, 1, 2, 3, 4. The calibre thus drawn, you will use it as will be explained later.



Chapter III: To Mount a Frame.

Method of Making the Plates.

N°. 141. Take a brass plate twice the thickness of that of the model, and hammer-harden it until it is the thickness that you want. Then bore a hole in the center, and with a compass trace a circle the size of the calibre. File the piece on its circumference to the line. Its size thus determined, put on the plate-turning arbor²⁹ a quantity of sealing wax. Heat the piece and rub it with the stick of the same wax. Apply the plate to the arbor and place the whole between the two runners of the turns. Turn the arbor with a bow in one hand while, with a file handle in the other, press lightly on the still hot plate; it is the means of getting it true. Do not try to put it round, you will do that with a graver when turning it. If by chance it has cooled and it is not true, reheat it on the turns with a blow-pipe, and repeat the same operation until the piece turns true.

²⁹ Plate 1, Fig. 14?

142. To recess it, turn it round with the point of a graver, and then recess it with a square graver, from the center *A*, Pl. 7 Fig. 4, to the line *B*, taking care to preserve all the thickness of plate from outside the line *B* to the line *F*; this space will be sufficient to rivet the pillars. Leave a boss *A* in the center, and from there slightly incline the recess while moving towards the line *B*, so that the point *B* is deeper than point *A*. The plate thus recessed on the motion-work side, turn it on other side until it is perfectly equal in thickness.

143. Form the embichetage *H*, Pl. 7, Fig. 1. That is, recess the edge of plate by a third of its thickness for the width between the two marks *H*, *I*, Fig. 1. This recess is made so that the plate can be placed in the case without shaking, and presses on a filet specially made in the case body to support the movement.³⁰

To Make the Recess for the Center Wheel.

144. Make a recess in the center of the plate which is a little larger than the center wheel; make sure it is deeper in the center *C*, Pl. 7, Fig. 3, than the wheel which you will place there. This recess must be one third the thickness of the plate, and consequently deeper at the line *G*. Remove the burrs and smooth the recess. Then remove the plate from the wax arbor and file the pillar plate with a large, fine file until it is flat on both sides. There are two ways to file these plates. The first is to press them on a cork and pass the file over them; in this way it is the file which moves. The second is to support the end of the same file against the bench with its handle against the belly. One then moves plate over the file which is fixed. If you want to file it quite flat and of equal thickness, it is necessary to be careful during this work to change the direction of the plate from time to time.

145. To use the calibre that you drew, apply it to the plate, put a pin through the centers of the two parts, and fix them in the screw pincers. Bore the four pillars holes 1, 2, 3, 4, and put a pin in each one. Finally, bore in the plate all the holes of the calibre, not forgetting that of the balance.

146. Make a long square notch from point *D* to the point *E*, Pl. 7, Fig. 4. The dial-spring head can be made of either only one part or of two, Pl. 7, Fig. 5, by attaching them together with a screw and a foot. Make the dial-spring, Pl. 7, Fig. 6, as it is traced. Fix it at the point *G*, with a recessed tallow-drop screw.

147. To adjust it so that it follows the contour of the recess *B* of the plate, it is necessary to harden it and temper it purple. In this state it must be set up with the dial-spring head where you have made a notch to receive the end of spring, and you will make it act so that the movement of the dial-spring head is soft, active and does not shake. But as the shape of this part and its effect are a little difficult to understand from a simple description, do it having the model under your eyes, Pl. 7, Fig. 5.

The Barrette.³¹

148. Hammer-harden a plate a ligne and a half thick until it is reduced to one third. After giving it the form of Pl. 7, Fig. 10, fix it on the plate with screw pincers so that it lies against the contour of the recess, Pl. 7, Fig. 4.

149. To fix this piece firmly, it is necessary to use a screw and two steady pins. After placing the barrette on plate where one wants to fix it, bore the hole for the screw *H*. Set it up and make a hole on each side of the screw; the barrette and plate are bored together and a broach is passed through so that the two holes are exactly one opposite one another. Then take a suitable tap and tap these two holes in the barrette. Fix a brass rod in the loop pincers and tap it enough for the width of the barrette and the plate. Put this screw in the pincers with sufficient length protruding and file the thread of the screw; then the end will form a pivot attached to a screw, which you will pass through the screw plate again, and will insert tightly in the barrette. Make the second steady pin like the first. Put the barrette in place with its screw and file the two steady pins flush with the surface of the plate and round the ends.

³⁰ This use of the word *embichetage* may be incorrect. In Berthoud and Auch (page 16-17) it is defined as the amount by which the diameter of the top plate must be smaller than the diameter of the pillar plate, so that a hinged movement can be lifted out of the case (See Berthoud and Auch *How to Make a Verge Watch*). However, Vigniaux uses the word *embistage* for this purpose; see N°. 153.

³¹ *Barrette*: There is no corresponding English word. A thin bar or bridge to hold pivots.

150. To round and polish the steady pins of barrettes, made a rod like a drill. Put on a ferrule, and bore a shallow hole in the end. Attach this tool to the vice, place in the hole the drill with which you bored it, and strike the drill with blows of a hammer, while turning it in several directions, to form in the hole a type of cutting edge similar to that of a file. Harden the end of this tool and temper it yellow. It is used like a drill. Put the end of the steady pin in the hole and some turns with a bow will make it round and polished.

To Round the Ends of Pillars

151. You will use the same method, with the difference that the hole in the drill must be larger and with deeper notches. To achieve this, after forming the hole with a drill the size of the end of a pillar, divide the head of the tool into six equal parts with a slitting file, which you will insert almost to the bottom of the hole. And after attaching it to the vice, introduce the drill with which you bored the hole and, using a hammer, make notches there. Harden it and, after tempering it yellow, use it like a drill.

The Pillars.

152. The shape of a pillar must be simple and plain, and they must be hammer-hardened. Make two points and place a ferrule in the middle. Turn on each end a pivot about two or three lines long; one is to be riveted to the pillar plate, and the other to fit in the top plate and to be fixed with a pin. Turn the body of the pillar so that it is solid and of a simple and elegant design, Pl. 8, Fig. 36. Take care to make the pivots of the four pillars the same size, and use a pointed graver on the bottoms of the pivots to form the flat shoulder. It is unnecessary to say that their height must be appropriate for that of the movement which you are making. Finally, all four must be perfectly equal and made with delicacy. Make them equal in height by using a pinion calliper.

The Top Plate.

153. It must be size of the line K, Pl. 7, Fig. 2. It should be hammer-hardened and placed on the wax arbor to turn it true and round. Thus prepared, remove it from the arbor and file it on both sides. Then sit it on the pillar plate so that on the side of the barrel it is level with other plate. By this means the top plate will be a little eccentric; this is necessary to be able to open the watch easily when the hinge is put in.³² Bore the center hole in the top plate, put in a pin which crosses the two plates, and attach them together with screw pincers.³³ Bore the holes for the four pillars and put a pin in each one. Then bore all the holes which are on the pillar plate, and broach each hole. That done, separate the two plates, and file and smooth the pillar plate on both surfaces, so that there is nothing more to touch. Make a chamfer on the four pillar holes on the side of the motion-work, with a drill with four cuts, to receive the riveting of these pillars. Before riveting them, make five or six notches in the holes which have been chamfered; they are used to hold the pillars in the first position that you give them when riveting them.

There are workmen who, when they have turned and filed the top plate, simply bore the holes for the four pillars; after riveting them onto the pillar plate, they mark all the other holes on the top plate with an uprighting tool; by this means, at the outset, they are assured that their pieces are true in the frame. You will do well to use this method when you have an uprighting tool.

To Rivet the Pillars.

154. Mount two plates on the pillars; if the pivots are too long, file them so that there remains enough brass for riveting.

Before riveting them, take the precaution of putting a drop of oil on each pivot; when this is neglected, the mercury, when plates are gilded, will leave white spots on the feet of the pillars which are removed with difficulty. A little oil avoids this problem.³⁴

³² Vigniaux uses the term *embistage* for this whereas other authors use the word *embichetage*. Normally the top plate is not eccentric, but reduced in diameter to enable the movement to swing out of the case. See my note to N°. 144.

³³ Because the top plate is eccentric, the "center hole" is not in the center.

³⁴ In contrast, Berthoud and Auch (page 27) states that this is done to prevent the pillars being driven out during fire gilding by the evaporating mercury.

Two plates being assembled with their pillars, place a ferrule over the pivot of a pillar on the side of top plate, so that it enters exactly and free. Attach this ferrule to the vice, and with small blows of a hammer strike on the motion-work side until the pillar is well riveted. Do the same to the other three, paying attention when riveting to strike with as small blows of the hammer as possible, if you want your plates to be true and not adhere together.

155. If the frame adheres after having riveted the four pillars, and to be assured that the pivots enter the holes of the top plate freely, assemble it, take it in the left hand, and with the other hand strike it with the butt end of the handle of a hammer, sometimes one plate, sometimes the other. By this means the plates will become free. Then strike some hammer blows on the rivets and file them flush with the surface of the plate so that they do not stand out.

Chapter IV: The Wheels.

N°. 156. You will make them out of brass from Holland which must be hammer-hardened on a riveting stake with small blows of a hammer, in order to avoid corrupting the material; because if you forge brass quickly and with large blows, it will become flawed, or it will warm up so much that the wheel will become soft, and consequently of bad quality. From time to time turn the brass between your fingers when hammer-hardening it, and you will be certain to forge the wheel flat and of equal thickness.

The First Wheel.

157. The brass which you will use must be a ligne and a half thick. Forge it until it is reduced to about half a ligne; however this thickness must be proportional to the size of the wheel. When forging it, preserve at the center the thickness of a boss, which will be placed in the recess made in the fusee. After boring the wheel in the center, mark with a compass the size for the calibre. File it to this line and then turn it round, true and to size. To ensure that it is turned flat, use a small square which you will put on the surface that you want to dress; if it is not true, turn it until you cannot see any space between the square and the piece.

The Center and Third Wheels.

158. Forge and file these two wheels quite flat and of equal thickness, and turn them to the size for the calibre and about the thickness of a penny marked two pennies.³⁵ After separating them from the arbor, rub them on a large smooth file while pressing them with the fingers until they are flat on both sides.

The Contrate Wheel.

159. Choose brass which is three lignes thick and hammer-harden it until it is reduced to a ligne, forging it with small blows of a hammer; I cannot recommend work hardening too much, because the solidity of the work depends on it. File the part round and flat, turn it a little larger than it should be, and hammer-harden it again straight away. This second work hardening is necessary so that the teeth, which are on the circumference, have the greatest possible hardness. Recess this wheel with a square graver so that its bottom has enough thickness to form arms of adequate consistency. Turn the bottom of the wheel square, without which the arms would not be of equal thickness; there would, however, be no disadvantage if they are a little thicker in the center than at the edge, but this thickness must be hardly noticeable. To determine the thickness of the bottom of the wheel, use a figure eight calliper or needle nose pliers, with which you grip the rim of the wheel against the bottom; the thickness of the material of the wheel which exceeds the needle nose will be equal to that of the bottom, and gives the exact thickness of the arms.

160. Turn the rim of the wheel so that it is neither too thick nor too thin, so that the ends of teeth do not have too much friction. Bevel it towards the interior of the rim which must form the teeth, so that the teeth are thicker at their feet than at the points; this gives much strength to the teeth though they are cut away.

³⁵ *sou-marqué de deux sous.*

The Teeth.

161. To split wheels one uses the tool, Pl. 12, Fig. 1. See its description in the Vocabulary, the article on wheel cutting machines.

Make the teeth of all your wheels as full as empty.³⁶ Take care that the teeth are not too long because that removes the goodness and the strength of them; when finishing them you would be obliged to start your work again. If you happen to split a wheel whose teeth are too long, do not waste time crossing it out or setting it up; it is quicker to make another.

To Cross the Center Wheel.

162. After having turned it round, true, and the size for the calibre, make a line with the point of a graver at the point *C*, Pl. 8, Fig. 16, leaving the space *B* behind teeth wide enough so that there is a sufficiently large circle to give solidity to the wheel; this circle together with the teeth is called the rim. Divide the circle *C* into four equal parts, and draw straight lines from one point to another which, passing through the center, divide the wheel into four equal parts. Then bore several holes between the marks to give space for a rat tail or crossing out file, with which you will open the space between each line. When roughing out the arms carefully preserve the four points and the two marks *C* and *D* which you made on the wheel to guide you until the arms are finished. When you open them, mark a line on the wheel between the rim and the arms; you will file the rim of the arms by following the contour of the line until you leave a small file of material as thin as a hair. File all the arms to a gentle taper while going from the circumference *C* to the center *A*, opening them so that they are pleasant to the eye and of adequate strength; crossing well done gives much grace to the work. The third wheel is crossed with three arms like balances. See N°. 164.

Crossing and the Arms of the Contrate Wheel.

163. Certain workmen cross the contrate wheel, Pl. 8, Fig. 23, with three arms. It is better however to give it four; the work has more grace, and it is easier to straighten it when it is distorted. Make in the center, on the side opposite to the teeth, a line *A*, and another *B* on the edge of the rim, so that there remains only as much space close to the circumference as see you in figure 23. Divide the circle into four equal parts, draw lines from one point to another, and proceed as I have indicated in N°. 162. So that the arms are well made, it is necessary that they are equal and that they decrease in width from the center to the circumference; but this reduction must be slight. To make the arms for the contrate wheel, see the following number.

How to Make a Balance.

164. Choose a small brass plate three times the thickness that you want to give the balance, and forge it until it is reduced to one third its thickness. After boring it in the center, turn it round and true. With a compass, divide its circumference into three equal parts and from each one of these points draw a line to the center, and your three arms will be traced. Make three or four holes between each arm, and increase them with a rat tail file until you can introduce a crossing out file, with which you will open the inside of the arms as far as you can, always taking care to preserve the marks that you have made. Then take a barrette file, with which you will dress and open up the arms. File the center *A*, Pl. 10, Fig. 4, round with a notching file until you see a small file of material remains at each arm, and consequently the center will be as round as if you had turned it. File the circle of the balance to the line *B*, and cease filing when a small file of material remains. Make the arms quite true and well opened.

Do not forget that a balance requires much care and exactness. To be well done it must be well hammer-hardened, run smoothly and true, its circumference quite round and polished, its arms filed true and smoothed, and of perfectly equally thick.

I have already said that all the wheels are crossed with three or four arms; the center and contrate wheels usually have four, and the others three. Apply yourself to doing both well; this attention is essential for the perfection of the work.

³⁶ The width of teeth and the spaces between them are equal.

The Size of Pinions.

165. Do you want to determine the size of a pinion of twelve leaves? Place a point of the calibre compass, Pl. 2, Fig. 8, on the point of a tooth of a wheel, open or close the compass until the other point sits on the point of the fifth tooth; this is called to take five teeth on the points.

If it is a pinion of ten leaves, you will take four and a half teeth of a wheel, and for that you will press a point of the calibre compass on the side of a tooth, and will open up the compass so that the other point is in the middle of the space between the fourth and the fifth tooth.

For a pinion of eight leaves, take four teeth on their points with the calibre compass.

Do you have to make a seven-leaf pinion? Press a point of the calibre compass on the side of a tooth of the wheel, open or close the compass so that the other point is in the middle of the space between the third and fourth teeth.

If it is a pinion of six leaves, take three teeth of the wheel on their points with the compass.

Be exact in sizing pinions. The exact communication of the moving forces depends on this the agreement of one part to another, and this uniformity gives equal vibrations. Note that pinions which are large weaken the forces of the mainspring so much that they cause stoppages by the finger.³⁷

Method of Making the Center Pinion.

166. To make a center pinion of twelve leaves, after having turned the first wheel to the size of the calibre, you will round five teeth, and take the size as in N°. 165.

167. Get pinion wire of twelve, and take an end from it which is twice the height of the frame; this is the length necessary to make the two stems *A, B*, Pl. 8, Fig. 17, one of which is to put the pinion in the frame and the other to carry the canon pinion. Put the middle of this steel in the screw pincers and place a ferrule, which is about a ligne and a half thick, on the pinion *E*. Using a crossing out file make, close to the ferrule, a notch in each leaf of the pinion and file it to the bottom of the groove. Turn the pinion around and, after fixing it in the screw pincers and putting on the same ferrule, make another notch all around the pinion; you will then have the pinion *E* separated from the two ends, which you must form into the two stems *A, B*. It is easy to extend the groove on the space which must form the two stems. It is only necessary to take two or three leaves in the loop pincers, and by tightening the tool with effort you will easily break them one after the other.

When you have broken them, file the two stems round, but leave a trace of the groove there. Point the two ends as centrally as you can. Turn the pinion true and round on each end. Leave the shoulders *C* and *D*, which are used to make the pinion equally deep, as a guide when you file the bottom of the leaves, and so that when you recess and face it there exists all around the foot of the leaves a small filet of matter equal for all its circumference.

To Center a Pinion.

168. Place the pinion in the turns and rotate it by one hand with a bow. Hold a piece of red chalk in the other which you will press on the pinion as if using a graver, and the part which forms a bump will be marked by the chalk. To center the pinion, file one of the points on the side opposite the chalk mark. If, after this operation, the pinion is not centered, repeat it until it becomes so.

To Thin Pinions of 10 and 12.

169. There are two ways to thin pinions of 10 and 12. The first uses thinning files, Pl. 2, Fig. 5, which one rubs on each leaf of the pinion to give them a beautiful form.

As it is very difficult to find good thinning files, especially in Province, one advantageously substitutes equalling files for them; choose a half-dozen that you will put in handles and number according to their different thickness.

Take one which starts to enter the leaf of the pinion, and file until it touches the bottom. If the leaves are too full, use another which is thicker until the pinion is a little emptier than

³⁷ See the vocabulary.

full.³⁸ While thinning, hold the pinion and the file quite true, so that the leaves do not lean. To know if the pinion is well thinned, take it in needle nose pliers, and examine it with a microscope in broad daylight, to see if it has some defect; for example, if its leaves lean, if they are too fat, either at the foot, or on the side, or if they have a bad form.

Correct these various defects with a rounding up file, quite fine and of good cut; work it on a cutler's grinding stone, so that it is flat from the middle of the back to the cutting edge. This file will easily fit to the bottom of the pinion. It will very convenient for filing the leaves from one end to the other; with it, you will straighten those which lean, and thin those which are too fat at the bottom, or too full on the side. It is also suitable to give the pinion the form which is considered most appropriate. One reaches that point by following the leaves, one after another, and by correcting the defects of each one. In the course of the work, do not forget to examine your progress with the microscope from time to time. This attention is necessary to avoid irrevocable faults.

Pinions are rounded with a rounding-up file which is a little thick; if it is too thin it will spoil the bottom of the pinion when filing the foot of the leaves. When a leaf is rounded, you will round all the others successively, so that they do not have edges and the two flanks are quite plain. This is done easily, provided that while pushing the file one takes care to turn it at the same time, rounding toward the point.

It is necessary, when the leaves of the pinion are rounded, to leave a small square at their tips, and to remove it only when the last stroke of the file is given. Without taking this care, the leaves might be made of an unequal length.

170. Then turn both pinion shoulders with a hair bow. Take an equalling file, narrow enough to pass freely between the leaves, in order to equalize and round off the bottom, and which takes the contour of the two shoulders; take care not to deepen the center pinion too much, because the leaves would be prone to break, either by the force of the mainspring, or when turning the minute hand if its friction is a little hard.

171. Put the pinion in the turns and made a third shoulder at the point *E*, Pl. 8, Fig. 17, which will be used to rivet the center wheel onto the pinion. Form a recess at the bottom of the stem as deep as you can, and so that it slopes up to the edge for riveting *F*; this forms a point at the end of each leaf which will be riveted onto the wheel.

The pinion thus made, harden it and then touch it with a file, to be certain that it is well hardened. If it is, from one end to the other, whiten it with pumice-stone, and temper it purple. If it is not hardened from one end to the other, you will heat it red, cherry colour, and harden it again. Then temper it to the colour violet, and place it in the turns to see if it was distorted by hardening; in which case you will correct it by the points, see N°. 168, and then polish it.

To Polish Pinions.

172. Take a stick of spindle wood. If you do not have any, use whitewood; willow is the best. Give it the shape of a knife, so that it enters the leaves of the pinion. Coat this wood with oil stone and rub it in the leaves, until you have removed all the marks of the file. Clean the pinion and the polishing wood with bread crumbs and, after putting a little fine oil stone on the wood, rub the pinion to smooth it. Clean the pinion again with all the possible care. Rub the leaves with another piece of wood of the same form coated with putty mixed with oil. English rouge must be preferred, because the polish is faster and more shining. When the pinion is well polished, put it in the turns, and see if it is centered; if not, correct it by filing the points. Then turn the stem to the shoulder *D*, Pl. 8, Fig. 17, to form a pivot of the size of the pivot *G*, Pl. 8, Fig. 15, which must enter the center hole of the pillar plate; leave the shoulder as large as you can, and make it square and sharp. Form a thin line in the angle between the shoulder and the stem, which will allow you to smooth and polish the shoulder flat. Turn the stem so that it tapers slightly to the point.

To Smooth and Polish the Shoulders and Stems of Pinions.

173. Take an iron polishing file, which you will file quite flat, and whose inclined sides form a sharp bevel. The file thus prepared, put the pinion in the turns, after fixing a ferrule on the stem opposite to that which you want to polish, and with a bow rotate it with one hand, while with the other hand make the file go and come on the stem in the contrary

³⁸ That is, the spaces between the leaves is a little wider than the leaves themselves.

direction; that is, when you raise the bow you will draw the file toward you, and you will push it when you draw the bow. It is necessary to become accustomed to this movement from the beginning because it is essential.

While smoothing the stem, take care to always hold the iron file square with the pinion; that is necessary to maintain the shoulder flat. When you realize that the file is blunt, file it again to make sharp. Rub the stem until all the marks have been removed, and the shoulder is quite flat. That done, clean the pinion, the stem and the polishing file with bread crumbs. When everything is clean, put a little putty or English rouge in a crystal and mix it with oil. After putting some on the polishing file, rub it on the stem, and press it against the shoulder, so that both are polished at the same time. One can also smooth and polish the shoulders with the head of a nail; for that use the method below, N^o. 175.

In the same way turn the other stem, from point *A*, up to the point *C*, where you will make another shoulder as above, always observing to turn the stem tapering slightly from the shoulder *C* to the point *A*, Fig. 17, Pl. 8.

Stems.

174. Make your stems a little large, they resist better in the event of dropping the watch, and they are less prone to distorting. However one should not be excessive; all of a watch must be proportioned in all its parts; goodness and solidity must always be joined with cleanliness and delicacy.

Method of Facing Pinions with Oil Stone.

175. To make the face of a pinion, form an undercut with the point of a graver; by making it run close to the shoulder *C*, you will deepen the undercut until you reach the bottoms of the pinion leaves. After turning the face of the pinion flat, take a quite soft iron nail, whose head is broad and half a ligne thick and make five or six holes of the size of the arbor. File the head of the nail quite flat, and put a little oil stone in each hole. After putting a ferrule on the stem *B*, opposite to the face of the pinion *C*, support the end in the hole in the jaw of the vice, and put the other end into a hole in the head of the nail. While holding the tail of the nail in one hand, with the other turn the pinion with a bow, while lightly pressing the head of the nail onto the face of the pinion coated oil stone. When you believe it is smooth enough, examine it to see if it is flat, and if all the marks have gone; if not, repeat the same operation until it achieves its effect. While moving the bow, hold the head of the nail so that it presses well and lightly on the face of the pinion, and so that the hand which holds the nail follows the movement that the bow makes the pinion make. This agreement is necessary to make a face quite flat. Especially remember to file the head of the nail quite flat from time to time; this is the only way to succeed in this operation. After some movements of the bow, change the pinion to a new hole; the work will go quickly, and the pinion will soon be flat. When you have passed the pinion in all the holes in the nail, if the face is not well formed, again file the head of the nail flat and repeat until the face is well made.

To steady your hand in this operation, place the turns in the vice and put the end *B* of the stem in a runner in the turns. While pressing the head of the nail against the face (as above), support one hand on the headstock or the T-rest of the turns, while with the other hand turn the pinion with a bow. By this method you will smooth and polish the faces more rapidly.

Method of Polishing Pinion Faces with Putty or Rouge.

176. Clean the pinion and the head of the nail very well, and make a slightly larger hole, in which the stem can shake. Take a quite fine file, file the head of the nail flat, and put a little putty or English rouge mixed with oil on it. Turn the pinion in the nail head as above, always following the movement of bow and the pinion; the shaking of the face of the pinion in the nail will remove the marks of the oil stone, and the face will soon be polished. After you have done this for a while, if you hear the part make a clear noise while it is turning, do not be surprised; this noise is made because the putty has dried on the part. Then remove the pinion and clean the face with very uniform cork, or better still with the pith of the elder tree, which will not be likely to leave marks, which sometimes happens with cork. Do not give up if, in the beginning, you do not manage to get the faces flat and polished; to succeed needs practice and long experience.

I must observe that sometimes one finds steel with which it is not possible to polish the face of a pinion well, because it is brittle or it is burnt. Before polishing a pinion, take care to rivet it onto the wheel, if you do it afterwards, you would risk dulling the face of it.

To Rivet the Center Wheel onto its Pinion.

177. Examine whether the riveting is quite centered; for this present a graver it to in the turns. Then take the center wheel, Pl. 8, Fig. 16, and increase the hole *A* with a broach, until the wheel fits exactly on the riveting *F* of the pinion. The wheel being adjusted, make sure the riveting does not protrude too much; it should be just level with the thickness of the hole. If it protrudes too much, you would have great difficulty riveting the wheel, and would have much trouble getting it true and centered. So it will be necessary to put it on the turns and to remove some of the excess until it is level with the wheel.

Sit the pinion on a riveting stake, and with a riveting punch strike the riveting while lightly pressing the punch against the arbor; and as you rivet the wheel, turn it until you have riveted all round the wheel. If it does not turn true, mark the wheel with chalk and then give some hammer blows to the punch on the side where the chalk has marked the wheel; and repeat this operation until the wheel turns true. You will center it by turning it on its circumference.

To Put the Center Wheel in the Frame, and to Take the Height at which it is Necessary to Make the Pivot.

178. Take a broach and enlarge the hole in the center of the plate, until the pivot *G*, Pl. 8, Fig. 15, which is after the shoulder *D*, enters exactly and freely. Examine whether the wheel is level with the plate and if it protrudes from the recess, use the recessing tool to deepen the recess until the wheel is level with pillar plate. Remove the center wheel, mount the frame, introduce the feet *B B* of the dancing master, Pl. 4, Fig. 1, between two plates, and take the height from the recess in the center of the pillar plate to the top plate. Open the dancing master until it enters exactly and freely between the two plates; the end opposite to the feet of the dancing master, which is in the form of a compass, will give the length of the stem from shoulder *D*, to the part *H*, where you must make the other shoulder. Apply this opening from the shoulder *D* to the end of the stem, mark the place indicated by the dancing master, and make the pivot there.

To Make the Pivot of the Center Wheel and Others.

179. After you have made sure that the pinion and the arbor run smoothly, and have cut the two points on the turns with a graver, you will burnish it on a pivot runner. Temper to blue the two ends on which you must make the pivots. If they are too hard, you could neither center them nor turn them as is necessary. Also, they would be prone to break, either while they are being worked or with the least shock that the watch might receive. Many workers make the mistake of keeping their pivots too hard; they have much trouble centering, turning and polishing them, and they do bad work.

When you want to turn a pivot, carefully sharpen the graver. See N°. 37.

180. Put the center wheel in the turns and turn the pivot to the height which the dancing master gave you; do it centered and cylindrical. Turn the shoulder *H* flat. Put in the turns a runner filed square at the end, in which you will make a notch to hold the pivot, and place a ferrule at the other end of the arbor. Thus set up, introduce the point of the arbor into a hole in the runner of the turns, and make the pivot rest on the notch of the other runner. Put the cord on the ferrule and, while with one hand you move the bow, with the other you will use the pivot file. One burnishes the pivots thus, until they became cylindrical and all the marks are removed. To give the pivot a cylindrical form, before placing the file on the pivot to burnish it, start by putting it on the stem, and when it is felt that it rests flat, lift the hand taking care not to disturb the position of the file, which must be as horizontal as is possible, and in this state sit it on the pivot which is to be burnished, taking care to hold the file the square with the wheel which facilitates keeping the shoulder flat. This ability will only be acquired with practice. To begin with, when it is not familiar, you are likely to break many pivots. To avoid breaking pinions or verges, you will do well to practice on a steel stem. After having filed it round, hardened it, and tempered it deep blue, turn a pivot on the end, and make it cylindrical and polished. That one made, break it, and make several more, one after the other, until you manage to make some which are cylindrical and polished. It is the best

way to accustom the hand to turn and finish pivots. One must expect to break several, when turning them, burnishing them, or polishing them. But a worker who wishes to improve does not give up, and tries again until his work reaches the perfection which is the object. Carefully avoid making the pivot smaller at its foot than at its tip; the opposite is to be preferred. After burnishing it with the pivot file, use the burnisher in the same way as the file, and continue until the pivot is well polished.

If the pivot is too long, place it in the turns in the pivot runner, Pl. 6, Fig. 7, and burnish it with a pivot file until it is sufficiently shortened. Then round the end, and polish it so that it does not scrape on a finger nail. The pivot thus finished, put it true and free in the hole in the plate and put it in the frame. There is nothing more to do with this part until you want to finish it.

181. To more easily make pivots cylindrical, add a screw *C*, close the notch *B* of the pivot runner, Pl. 6, Fig. 8, which you can raise or lower at will. When the pivot file rests on it and the pivot at the same time, it is easy to give it the form that you judge correct, and to make the two pivots of a piece the same size.



Chapter V: The Fusee and the Pieces of which it is Made.

To Make the Arbor of the Fusee.

182. Take a piece of steel large enough to make the arbor, Pl. 8, Fig. 9, which fills the hole in the large wheel, Pl. 8, Fig. 12, so that the shoulder of the arbor is big enough, and the square *B*, which extends from the shoulder *F*, is large enough to be solid. If the steel you use is square, file it to four then eight faces, and file it quite round. Make points at the two ends *C* and *D*, and cut these two points all around. It is necessary to burnish them with a pivot file, on the pivot runner, until they are sharp and centered. Harden the arbor, and after touching it with a file to be sure of its hardness, temper it purple or blue, according to the quality of the steel. Put it back in the turns, turn it, and give it a slight taper from the point *E* to the point *F*, which is the place where the fusee will be soldered. Then smooth it with oil stone and polish it with tin putty. As for the place where the fusee will be soldered, rub it with a coarse file to form the marks at *A* *E*, to which the tin solder will stick, and which will make it more solid.

Method of Roughing Out the Fusee and Soldering it to its Arbor.

183. Take a plate of brass from Holland thicker than needed for the fusee, so that you have enough material to hammer-harden it well. After forging it to thickness, make a hole a little smaller than the arbor in the middle, and turn it in the form of a cone, Pl. 8, Fig. 11.

The top of the fusee must be narrower than bottom. Leave a square flat at point *A*, and form a recess at the point *I*; it will be used to hold the boss on the first wheel.³⁹ The fusee thus roughed out, enlarge the hole until the arbor enters it exactly and free.

Hold the end of the arbor in pincers; hold it rather long on the end for the hook, to make space for the pivot shank *H*, and the pivot *D*, Fig. 8. Then put the fusee on the arbor until it touches the pincers. Take sulphate of ammonia and rub it on the arbor at points *A* and *E*, where it must be soldered. Clean the hole in the fusee, and place in the recess two or three small pieces of tin solder and a little powdered rosin. With a blow-pipe blow the flame of a candle over it and, when you see tin melt, raise the fusee a little and see if the arbor is soldered. To facilitate the adherence of the solder to the arbor and the fusee, when the whole is hot, quickly slide the fusee back and forth on the arbor, and push it against the pincers. If you fear that the two parts are not well soldered together, blow on them with the blow-pipe again, and let them cool.

Put the fusee in the turns and turn it true and round. When removing the solder which will also be there, take care not to dull the arbor on the side of the recess. This arbor has to receive the boss of the first wheel, and it is essential that it is well polished, so that it does not enlarge the hole in the wheel.

³⁹ *au point I*: *I* is not marked on Fig. 11, but its position corresponds to Fig. 12 *L*.

To Recess the First Wheel.

184. Attach it to an arbor and place it in the turns. Make it true by turning the arbor with a bow in one hand, and pressing on it with a piece of wood in the other, until it is fixed on the arbor and it turns true. Take a square graver and make the recess half the thickness of the wheel from the boss *L*, that you leave there, to the edge of teeth *I*, Pl. 8, Fig. 12, where you will leave only a fillet of material to give strength to the bottom of the teeth. This recess must be level and well smoothed; it will hold the spring of the click-and-ratchet work.

The Spring of Click-and-Ratchet Work.

185. To make this spring, take a brass plate and, after hammer-hardening it well, bore a hole in the center. Turn it round and true, giving it about half the thickness of the wheel. The diameter of spring must be a little larger than the recess in the wheel, so that when you place this spring in the recess, it enters so exactly that the spring and the wheel appear to be a single piece. After turning this spring to size and thickness, form with the point of the graver a line which you will deepen until you have removed a circle about the width shown in Pl. 8, Fig. 10. Form the spring so that it tapers slightly from the point *B* to its end *A*. It must be soft, elastic and strong enough to drive the click. Cut approximately a ligne from this spring to give space for the site of the click *I*.

The Click.

186. The click is made in the form of a comma, and is riveted onto the large wheel at the end *A*, Pl. 8, Fig. 37. To make it, take a piece of flat steel, an inch and a half long, half a ligne thick, and a ligne and a half wide; the steel must be proportioned to the size of the click which you want to make.⁴⁰ With a rat tail file, form a hollow on one side over its length. On the other, transversely round it by filing it, so that it has an sharp point on the end *B*, and that on the end *A* it has sufficient width to form a round pivot. Bore a hole in the first wheel on the edge of the recess so that the pivot of the click enters freely and exactly, and with a drill make a chamfer in the hole in the wheel where you will rivet the click. If the pivot is too long and it protrudes more than the thickness of the wheel where it will be riveted, file it so that the riveting is right. To rivet the click, place the steel bar in the jaws of the vice, and place the hole of the wheel over the pivot, and strike it a few times with a hammer. When you believe the click is sufficiently riveted, move the wheel to ensure that the click, though riveted, moves freely; file the steel bar of the click with a barrette file close to the wheel, until the click, which must remain fixed to the wheel is separated from the bar. Then file it until it is level with the teeth. The click thus finished, take the spring, Pl. 8, Fig. 10, and insert it by pressing it into the recess *I* of the wheel *K*, Pl. 8, Fig. 12. Adjust the spring so that it is behind the end *B* of the click, so that by pushing it makes the click return to its original position. Bore three holes *1, 2, 3*, which cross spring and the wheel *K*. Chamfer the three holes in the wheel, drive in three pins, and, after cutting them off almost flush with the surface of the wheel, rivet them.

The Fusee Ratchet.

187. Turn the base *A* of the fusee so that it has, on the edge of its circumference, a small circle of brass which is the thickness of the recess in the first wheel, and wide enough to be able to cut a ratchet by hand; make the teeth as equal as you can. Insert the stem of the fusee exactly in the hole of the first wheel. When turning the wheel to the right, the spring will drive the click, which, entering the teeth of the ratchet, will prevent it turning to the left.

The Small Recess to receive the Fusee Collet.

188. Make a recess in the first wheel on the side opposite to the fusee boss, and which is a little smaller than the boss *L*, Pl. 8, Fig. 12, that you left in the first wheel. Then make a steel collet, Pl. 8, Fig. 13, and bore the hole *O*, which enters exactly and with friction on the arbor *F* of the fusee. Turn this collet round, true and flat on both sides, and make it go with force on the fusee arbor. The collet will sit in the recess which you made in the first wheel, which will be fixed against the fusee by friction.

⁴⁰ The click is made on the *end* of the steel bar and it is not detached until it is finished. Vigniaux does not explain how to shape the pivot. It used to be possible to buy fusee click wire already formed into the right shape.

How to make the Pivots of the Fusee Arbor.

189. Put the fusee in the turns and turn the arbor at the end where you will make the square of the fusee, so that there is a shoulder *F* high enough to provide space between the center wheel and the wheel of the fusee, Fig. 8. Turn and polish the shoulder as already explained in N°. 173.

Mount the frame. Take, with the dancing master, the height from the pillar plate to a little above the top plate, and mark this height on the arbor from *A*, Fig. 9, where the shoulder *F* is already made, to the place *D*, where the pivot of the fusee must be made. Turn it cylindrical and make the shoulder flat. Smooth both with an iron file coated with oil stone, round the end of the pivot on the lunette runner and polish all with putty. Enlarge the hole in the pillar plate so that the pivot on the end of the fusee square enters it exactly and freely.

The Fusee Cock.

190. Make the square cock, Pl. 9, Fig. 13. Bore in it the hole *A*, the size of the pivot of the fusee. Put the wheel in the frame, and place the pivot of the fusee in the hole of the cock. When the wheel is true in the frame, use pincers to hold the cock onto plate and bore the hole *B* to attach it by means of a screw. The screw made and fitted, again put the wheel true and fix the cock the plate with its screw and make the two steady pins at the points *C C*. If the fusee is too high, turn it until it has enough space so that it can turn freely and without friction, and so that you can fit a beak which does not rub on the plate.

The Fusee Beak.

191. Take a plate of steel, Pl. 8, Fig. 14, and turn it round and true, and so that it is a little thicker in the center than on the edge. With a file form the notch *C* to the point *G*, which is the size of the fusee. Fix the hook on the top of the fusee by the screw *B*, which you will have taken care to recess. File the edge from the point *D* so that it gradually decreases to the front of the hook *C*. This hook is used to stop the hand when the watch is wound.

The Chain Guard.

192. The chain guard, Pl. 7, Fig. 2, and Pl. 9, Fig. 12, is nothing more than a piece of steel rounded on one end, whose other end has a flat and sufficiently broad head to be fixed to the stud *O*, that is fitted on the top plate. After riveting it there and making the slit in which the flat end *A* of the chain guard is placed, both it and the stud are bored with a hole which crosses both of them. It is necessary that the chain guard is free in the notch, and that its spring is similar to that in Fig. 7, Pl. 7, so that the end passes under the chain guard and always makes it rise; it is fixed to the plate by the screw *B*. File the spring slightly tapered from the point *C* to the point *D*. It is essential that this spring is soft and elastic, and that it follows the contour of the edge of plate. See Pl. 7, Fig. 2.

Functions of the Chain Guard.

193. The chain guard is a small lever which rises and drops, according to whether the chain presses on it or it is free. When the watch is completely wound, the chain moves the chain guard which presses on the beak of the fusee on the edge of the plate, which, supported on the end of the chain guard, forms a detent, and informs us that the watch is wound. When the fusee unwinds, the chain moves away from the chain guard, and it rises and leaves free passage for the beak of the fusee.

Although I have not neglected anything, to explain clearly and to give the shape of the tools, the pieces, and the ways of making them, amateurs and apprentices who know little of watchmaking will perhaps sometimes have trouble understanding what I tell them in the course of this work. Because indeed, it is difficult to grasp, from a simple description, the shape and the functions of certain parts. They must then resort to a good watch, and attentively examine the object which they have trouble understanding. Then what had been obscure to them will become clear and intelligible.

The Space between the First Wheel and the Center Wheel.

194. Put the first wheel and the center wheel in the frame, so that the first wheel has sufficient space and there is no fear that it can touch the center wheel. It is also necessary that the beak of the fusee is placed so that it cannot rub on plate. After taking these precautions, turn the fusee and give it the shape of a cone. It must be a little flared in the center, and above the ratchet there must be a square about half a ligne thick, which allows one to start cutting the fusee.

Chapter VI: The Third Wheel, its Pinion, and the Contrate Wheel.

The Pinion of the Third Wheel.

N°. 195. To make the pinion of six for the third wheel, round three teeth of the center wheel, and with the pinion compass, Pl. 2, Fig. 8, take the distance of three teeth on the points. Then take pinion wire of this size, and file off an end long enough to form the arbor, the pinion and the pivot shank. File the pinion with the angle of a crossing out file to separate it from the stem and pivot shank. That done, break the leaves off the pinion one after the other where it will form the stem and the pivot shank, see N°. 167, retaining the leaves which will form the pinion *E*, Pl. 8, Fig. 20. File the stem until the groove appears. Make two round and sharp points, take a screw ferrule and put it on the long stem, and turn the pinion with a hair bow. If it does not turn centered, mark it with chalk, take a small hammer, and strike the stem with small blows on the side which the chalk has marked it; leave the pinion on the turns while you strike it to correct it. Again examine it with the chalk to see if the pinion is centered, and continue to strike it with small blows of the hammer until it is. Then turn the pinion, whose stems must be round while tapering slightly towards the point. Give a light cut all around on the points of the leaves to be sure that the pinion is perfectly centered. Care should be taken to turn it so that it is the size indicated in N°. 165.

To avoid making pinions small, pinion wire is used that is a little larger than needed. After centering it, turn the points of the leaves until it is the size for the calibre.

Files to Thin Pinions of Six and Seven.

196. Get a dozen thinning files to thin pinions of six or seven; it is necessary that they are fine and of good cut. The English ones are too hard; those of Paris, Geneva or Switzerland, of the first quality, are to be preferred. For you to use them, it is necessary to test them and number them according to their thickness. With this precaution it will be easier for you to use them, according to the size of the pinion which you have to thin.

Method of Thinning Pinions of Six or Seven.

197. To thin a pinion of six or seven, you will hold it with the first two fingers of the left hand, with which you press it on a filing block; in the other hand hold the thinning file which you will insert into each leaf to its foot. This operation done, turn the pinion and file again, until you have traversed all the leaves. Then hold the pinion with needle nose pliers and scrupulously examine it with a microscope to see if it is true, if its leaves are too large at the feet or too full on the sides. In these two cases, take a thinning file thicker than that which you used and pass it in the leaves of the pinion.

While thinning pinions, make sure to hold the file quite true, and push it so that it is in line with the two stems; it is the way to prevent the leaves of the pinion from leaning.

If you do not successfully thin the first pinion that you make, do not be discouraged. Make several attempts, until in the end you will make one which is of a beautiful form, whose leaves are true, and are neither too full nor too thin. Then you will round it.

How to Round Pinions of Six or Seven.

198. To round a pinion of six or seven, hold it between the first two fingers, as when thinning it. Support the rounding-up file on one side, on the flank of the leaf, and push it while turning the hand, and rolling the file toward the point. Round the other side in the same way. Round it evenly, so that there are no ribs, and especially do not bite into the point while rolling the file; because if you file to the point at the beginning, you would risk making some leaves longer than others. To avoid this problem, keep small square surfaces on the points of the leaves, which you will remove only when you finish rounding with a fine file.

I always assume that, to be sure that the leaves are true and quite round, you place them in pliers to examine their form using a microscope. And that when rounding them, you look at the leaves one after the other, and you take care to correct any defects.

Method of making the Seat to be Placed on the Stem of a Pinion.

199. Take a piece of brass an inch and a half long and a little larger than the seat you want to make. Bore it as in N°. 82, and deep enough to make the seat *B*, Pl. 8, Fig. 20. Put the rod in the turns, and turn it to the size and length necessary. While boring it or turning it, put water or saliva on the drill; because if you put oil on it, it will enter the hole in the seat and you would have trouble making the solder run. Then cut the seat off with a graver, making it sufficiently long. When it is detached from the rod, enlarge the hole with a pivot broach, until the stem of the pinion can enter it, and put it at the height at which you consider it necessary to place the third wheel. See Pl. 8, Fig. 20.

Method of Soldering a Seat to a Pinion.

200. After you are sure that the pinion is centered, cut one or two small pieces of third solder, and place them with a little wet borax on the seat beside the pinion. Place the pinion on a coal with the stem at the bottom and the pinion at the top. Place it like this so that the solder cannot run into the leaves of the pinion, which would give you trouble when you have to remove it with a file or oil stone. Besides, the polish of the pinion would never have the same look, the solder would whiten the parts on which runs, and you could not remove these spots without risking spoiling the shape of the pinion. To solder it, place the whole on a coal and blow the flame of a candle onto the seat until the solder runs. Then heat the pinion to the colour cherry, and throw it in oil. The pinion thus hardened, touch it with the file at each end, and in the middle, bleach it by lightly rubbing it with pumice-stone, and temper it to deep yellow.

Precautions to Take when Hardening Pinions and Verges.

201. When you solder a seat onto a verge or a pinion, and the solder has run, at the same time redden the part from one end to the other a cherry colour, and throw it into water or oil to harden it. By following this method, you will avoid having to redden the steel several times, and will have less fear of burning it. When you heat it, if it passes the red cherry colour, you are likely to burn the steel, and to break the stems while turning them and the pivots when finishing them.

Make sure, when throwing a pinion or a verge into oil or water, that they fall perpendicularly, because if you drop them sideways, they are certain to be distorted. If a pinion is distorted, temper it to deep yellow to correct it with a sharp hammer; if you want to use a hammer with a round peen, temper it to red purple, as in N°. 85 and 86. After correcting it, temper it again to at least deep yellow, cut the two points with a graver, and then burnish them on a pivot runner; without this precaution you will never turn the part centered. The points burnished, turn the stem, the pivot shank, the seat and the face true and round with a sharp graver, the point of which you will slide along the stem. Make a line at the bottom of the pinion leaves, which will form a small recess to facilitate making the face flat. Polish the pinion as in N°. 172, and the face as in N°. 175.

To Polish Stems in the Turns.

202. When stems are turned quite even and cylindrical or slightly tapered, smooth them in the turns with an iron file coated with crushed oil stone. When all the marks have been erased and the stems have been cleaned, polish them with putty or rouge. Polish stems in the turns with a bow, and continue to use the iron file coated with putty or rouge until they take on a beautiful brilliance.

To Rivet the Third Wheel onto its Seat.

203. Make the riveting by turning the seat to sufficient size to support the wheel and to rivet it. To place the wheel there, turn the part *A*, which is called the riveting, Pl. 8, Fig. 20, smaller than the part *B*, called the shoulder. Turn it to the size of the hole *C* in the third wheel, Pl. 8, Fig. 19, so that the end starts to enter it exactly, and so that the riveting is even and a little inclined. Then make the shoulder *B*, which is at the bottom of riveting, quite flat and make a cut with an acute graver between riveting and the shoulder. Close to the stem make a recess with the point of the graver, so that riveting is quite acute. If it does not completely enter the hole in the wheel, broach the hole until the wheel rests on the shoulder *B*, Pl. 8, Fig. 20. When the riveting protrudes above the wheel too far, it is necessary to put the pinion in the turns and remove some of it. If the riveting is too long, the force of striking

it will crush the seat; if on the contrary it is too short, you will not rivet it firmly. Take care to avoid these two defects.

The riveting thus prepared, chamfer the hole on the side where the wheel will be riveted with a large drill and make four or five notches with a crossing out file. Place the seat in the hole of the wheel, so that it enters there exactly, and the wheel rests flat on the shoulder; if the riveting shakes in the hole, you will make bad work, because of the difficulty which you will have to put the part true and centered.

Place the riveting clamp, Pl. 6, Fig. 5, in the vice, put the pinion on it, and press the seat onto the riveting clamp, so that it sits flat. Place a punch on the riveting, and rivet with the blows of a hammer, taking care to strike equal blows and to turn the wheel as you strike the riveting; it is the way to ensure a part is riveted round and true.

204. To true the wheel after riveting it, place it on the figure eight calliper, Pl. 5, Fig. 5. Turn it, and using the arm *E* on the figure eight calliper or a card, which you will press lightly on the wheel, it will be easy for you to see the place where the wheel touches. Mark it with chalk, then put the wheel on the riveting clamp and strike some blows of a hammer on the riveting on the side which you marked. Repeat this operation until the wheel is true. Again put the part in the turns and turn it lightly true and centered.

Bore the two holes for the third wheel and the contrate wheel in the barrette. To do this, set up the barrette with its screw, and then made a drill which exactly enters the hole already made in the plate; it will be used as a guide to bore the hole in the barrette. Do the same operation for the hole of the contrate wheel. Remove the barrette from its place, and increase the two holes of the third wheel and the contrate wheel, so that the pinion of the third wheel can pass freely in this hole, and the stem of the contrate wheel can be placed freely in the thickness of plate without rubbing on it. Then put the barrette in place with its screw.

How to Make the Pivots of the Third Wheel, and Put it in the Frame.

205. Turn, on the end of the wheel, a cylindrical pivot of a size proportional to the piece. Burnish it in the turns with a pivot file. Leave a shoulder there which is quite flat and make the pivot shank rather long so that there is sufficient space between the third wheel and the beak of the fusee. Mount the frame, and with the feet of the dancing master, which you will introduce between the plates, take the height between the barrette and the top plate. Press a point of the dancing master on the pivot shoulder already made, and the other will determine the precise place where you must turn the second pivot. After turning it, burnish it cylindrical, polish it, file it to length, and round the end so that it no longer scrapes on a finger nail. See N°. 180. Then enlarge the holes, and put the part in the frame.

The Pinion of the Contrate Wheel.

206. Take the size of the pinion, as I explained in N°. 165, rough it out like the pinion in Pl. 8, Fig. 24, and make a short pivot shank near the pinion *D*. The stem must be as long as the height of the frame, and the pinion must have about twice the thickness of the center wheel. Solder a seat *C* onto it, so that the wheel is roughly in the middle of the frame. Harden the pinion and, after tempering it red purple, center it, face it and polish it as in N°. 168 and 175, and turn the pivots, N°. 205.

The Barrette for the Contrate Wheel.

207. Make a barrette for the top plate which is in the shape of a square, and similar to Pl. 7, Fig. 9. Bore a hole of the size of that in the plate and put in a pin which crosses the barrette and plate. Then attach the barrette with screw pincers and bore in the angle a hole where you will put a screw with a recessed tallow-drop head, as in N°. 128. When it is finished, set it up and bore the two holes *A* and *B* to fix two steady pins, on which you will round the ends as in N°. 151.

208. Every time you put steady pins in barrettes or the potence, or some other part, screw them in and then give some hammer blows to rivet them; in this way the steady pins will never fail.

Remove the pin that held the barrette to make the two holes, and take off the barrette to increase the hole for the contrate wheel which is in the top plate, and make it the size necessary for the pinion of the contrate wheel to pass freely. Put the barrette back and fix it with the screw. Make a riveting, a recess and a shoulder on the seat, and fit the wheel on it

so that it enters the riveting exactly. When riveting the contrate wheel on the riveting clamp, turn it while you strike it, then put it in the turns or the figure eight calliper to test if it turns true. If not, mark the place where the wheel is highest, and strike the riveting on that side, until the wheel turns true. Make the pivot of the contrate wheel so that the third wheel meets the middle of the pinion, Pl. 8, Fig. 24. Use the dancing master to get the length of the stem, N°. 178. The pivots finished and polished, N°. 180, put the contrate wheel in the frame.

Chapter VII: How to make a Barrel, and all the Parts of which it is composed.

The Barrel.

N°. 209. It is necessary to put the center wheel and the fusee in the frame, and to measure the distance between the top plate and the wheel of the fusee. Then choose brass from Holland at least as thick as the height that you took. Hammer-harden it until it enters exactly between top plate and the first wheel. Find the center, and make a hole a little smaller than the size that you want to give to the barrel arbor. Take care, in making this hole, to change the face of the brass from time to time. It is the means of boring true.

Then measure with a compass the size which you must give the barrel, and trace it on the brass, which you will file up to this line and as round as you can; remember that a well roughed out part is half made.

To turn the barrel, take an arbor a little larger than the hole and enlarge it until the point of the arbor protrudes a little from the barrel. Put a ferrule about the size of the barrel on the arbor, to turn it with a rather strong bow and a proportioned cord. Use a bow a little less strong when you finish the barrel and make the snap.

Method of Recessing the Barrel.

210. Fix the barrel on its arbor with friction, turn it true and round in all senses with a graver. Then use the square graver, Pl. 3, Fig. 3, to make a recess proportional with the size and height of your piece. Leave in the center a brass boss which is a little smaller than the arbor. When the barrel is recessed rather deep, if you want to know if its bottom is a good thickness, measure it with the figure eight calliper, which, while embracing the thickness of the bottom of the barrel with its two points, will show you this thickness between the two opposite points. When its depth is suitable, and of the necessary width, make the bottom flat and level.

As for the thickness of the side, it is necessary that it is sufficiently strong to be able to form the snap to receive and fix the lid of the barrel, and that it has enough strength on its circumference to place the screw hook to hold the eye of the mainspring, as I will describe later. You will leave on the circumference of the barrel, at the end of the snap, a filet of material which exceeds the side of the barrel by an amount equal to the width of the chain. This filet is kept in order to prevent the chain from slipping when it is on the barrel. Present it to the plate, and turn it until there is sufficient space on the side of the center wheel as well as the top plate.

211. Form the snap so that the edge is narrower than the bottom, and it is deep enough to hold the lid, Pl. 8, Fig. 2, which must be about the thickness of a penny marked two pennies. However this thickness must be in proportion with the size of the barrel.

Decrease the boss A in the barrel with a graver, Pl. 8, Fig. 5, to about the thickness of half a ligne; this thickness together with that of the bottom of the barrel will give the hole enough firmness to prevent it from enlarging. Make this boss flat, and use a graver to bevel the sharp edge. Smooth the inside of the barrel with a piece of spindle wood coated with pumice-stone, which you do while turning it with a bow.

I believe that it is unnecessary to say that the barrel must be smoothed outside as well as inside; use a graver to bevel from the snap to the edge of the filet reserved to hold the chain. Remove the burrs, and separate the barrel from its arbor.

The Barrel Lid.

212. Take a little brass the size of the opening in the barrel, and after hammer-hardening it and boring it, make a circular line with a compass, and file to this line. Turn it true and centered until it starts to enter the snap with force. Keep the boss *B* at the center, Pl. 8, Fig. 2, of sufficient thickness and a little smaller than the arbor of the barrel. Before putting on the lid, make the notch *A* in it, so that by introducing a point there, you can remove it easily.

The Barrel Arbor.

213. The size of this arbor must be one the third of the diameter of the barrel. To make it, take steel a little larger than it will be when it is finished. and make two points *A*, *B*, Pl. 8, Fig. 3, on the two stems of this arbor, one of which will enter the pillar plate, and the other the top plate. File the long stem *E* with eight quite equal sides, and then round. Do the same on small stem *A*, and after filing it round, as in N°. 53, turn the arbor at the point *C*, so that it is only one third of the size of the barrel. Turn it true and centered, and the same with the two stems which must be a little larger than when they are in place. Bore the hole for the hook *D* of the barrel arbor. Harden and temper it blue. While turning the stems make them taper slightly towards their points. When they are about the size of the hole in the barrel, turn the two parts of the arbor true and flat. Then smooth the stems and polish them. Smooth and polish the shoulders at the same time as in N°. 173. To determine the height which the arbor of the barrel must have between the two shoulders, measure the inside of the barrel from the boss *A* to the boss *B* in its lid; see the following number. Enlarge the holes with a broach until the stems enter true and freely, put the arbor in the barrel and put the lid on. If the work has been done according to the rules that I have just given, the barrel will turn true and centered on its arbor.

To Take the Height between the Shoulders of the Barrel and its Lid.

214. To fit the arbor in its barrel, insert in the center hole a piece of flat brass, which can only just enter. Make a notch *A*, Pl. 9, Fig. 20, which sits on the boss of the barrel. Then make another notch *B* which you will file until it enters exactly between the bosses of the barrel and the lid. Take the height of this type of pallet with the calibre compass, Pl. 2, Fig. 8, which will give you the distance from one shoulder to the other.

How to Put the Barrel in the Frame.

215. With a crossing out file, mark a line on the stem which is a little above lid so that you leave a space between the barrel and the top plate. Then turn the pivot cylindrical from the place marked to the end and make the shoulder flat. All being smoothed and polished, take the height of the frame with a dancing master, transfer it to the arbor and mark this height on it. Turn from the place marked to the end, and make another shoulder *F*. When the pivot and this shoulder are smoothed flat and polished, make the two holes in the plates the size of the pivots of the arbor, and retain the stem *E*, which protrudes from the pillar plate, so that a ratchet can be placed on it.

How to Make the Square on the Barrel Arbor.

216. After putting the barrel arbor in the frame, with a crossing out file mark the point *E* on the side of motion-work, where the arbor starts to protrude from the plate. Disassemble the frame, and put a ferrule on this stem which is thick enough to be level with the mark that you made with the crossing out file. This ferrule in place, make the square from the shoulder *E* to the end *B*; if the file slips it cannot spoil the pivot. The whole thus prepared, fix the arbor in screw pincers, file the end with four quite equal sides, smooth them in the turns, and polish them as I described in N°. 64.

The Ratchet.

217. To make a ratchet, Pl. 8, Fig. 6, take flat steel and, after making a hole in the center *A*, push through a square punch which is the size of the square of the barrel arbor. Turn it true and centered, then divide it on the wheel cutting machine or with a crossing out file. Although these teeth *B* can be unequal, do it as exactly as you can, if only to give it a beautiful form.

How to Make a Tool to Divide the Teeth of a Ratchet, and how to Use it.

218. Take a piece of flat steel. With a slitting file give it the shape of a pivot file, file the middle of it longitudinally, and deepen it as if you wanted to divide the steel into two parts, until you have enough width from one side to the other to form the thickness of a tooth of the ratchet. Then file it flat until it is thin on the two sides. Use a crossing out file to make a type of saw on one on the sides of this tool, and keep the other side plain. After hardening it and tempering yellow, put a handle on it.

To use it, make a small notch on the ratchet which you want to divide. Place the smooth side of the tool in the notch and make another notch with the side that is in the shape of a saw, which you press on the ratchet to file it. Continue to thus mark from one tooth to the next. In going round the ratchet in this manner, the teeth will be well divided.

Mark the last four teeth lightly, and if their division is not equal to the others, divide them by eye as best as you can. The ratchet divided, use a crossing out file to file its inclined teeth, so that their feet are wide and their tips sharp. See Pl. 8, Fig. 6.⁴¹

The Click.

219. It is necessary to make the click the same form as in Pl. 8, Fig. 38, and to fix it to the plate at the point *B* with a countersunk tallow-head screw. The click must be strong at the end opposite the screw and free in its hole, so that when turning the arbor one way, the click falls on each tooth of the ratchet, and if one turns it the opposite way, the end *A* of the click, which enters the teeth *B* of the ratchet, prevents it from turning backwards.

Chapter VIII: The Potence and the Counter-Potence.

I have already recommended making the hole for the balance on the calibre; so you must have bored it on the pillar and top plates. It will now be used to place the potence. For that, trace the line *B G*, Pl. 7, Fig. 3, on the inside surface of the top plate which, by crossing the plate and following the direction of the holes for the first and center wheels, will indicate the site for the potence which will be made on this line. This line, which is about half a ligne away from the hole *F*, will allow you to make the heel of the potence. From the hole *F* to the edge *H* of plate, trace a second line beside the hole *E* for the contrate wheel, and as square to the line *B G* as possible. This line will give you the position of the verge escape wheel.

N°. 220. As it would be difficult for you to comprehend the shape of the potence by just a description, it is necessary that you get a well made one and use it as a model. Take a brass plate which must be well hammer-hardened and use a saw to quickly remove the parts of the brass which are not needed. Rough out the potence quite square, and square with the plate. Give everything some thickness; however it is not necessary that it is too substantial. After roughing it out, made a slot on the front *B*, Pl. 9, Fig. 9, and with a potence slide file, file this notch true, of equal width from one end to the other and of equal depth. Make the slide of the potence, Pl. 9, Fig. 10, a little bevelled on the two sides *A*, *B*,⁴² so that it exactly enters the notch which you have already formed, and it moves forward and back with friction in the notch, where it must be so well fitted that it there no space between it and the walls. When the notch and the slide are carefully fitted together, they must appear to be just a single part. Fix the slide to the potence by a screw at the point *C* and enlarge the hole in the slide so that the screw which crosses it, and which is tapped into the potence, does not prevent the slide from moving in its groove. The only function of the screw is to hold the slide on the potence, and to fix it in an invariable way. You will easily make it move with the screw *D*, Pl. 7, Fig. 2, which is placed behind the potence. This screw must have a broad head so that it engages in

⁴¹ Vigniaux rarely mentions measuring by units such as lignes, and does not use douzième gauges; indeed, he doesn't measure anything. Which is presumably why he does not do the obvious: Multiply the diameter of the ratchet wheel by 3 (π) and divide the result by the number of teeth which you want. Then make the width of the tool this distance.

⁴² Dovetailed into the slot.

the notch in the slide; by turning it, the slide will move easily in its notch.⁴³ Leave the nose *F* of the slide broad and thick, to be adjusted as you will find out when you finish the watch and you make the escapement.

221. To fix the potence on the plate, sit it on the line *B G*, Pl. 7, Fig. 3 and fix it on the plate with screw pincers. Make a hole at the point *H*, Pl. 7, Fig. 2, and when the hole in the heel of the potence is opposite the hole bored in plate, tighten the screw and bore the holes *N N* in the potence, which must cross plate at the same time. Fit two screwed steady pins in them. Before fixing it, chamfer all the holes of the potence and the plate; file both well flat, so that nothing prevents them from sitting flat against each other, and so that when you tighten the screw, there is no space at all between the potence and the plate. Then set up the center wheel and the potence in the frame, and see if there is enough space between these two parts; if the potence is too thick, file it until there is enough space to give freedom to the wheel. Then make a steel plate which you will fix onto the potence with a screw *H*, Pl. 9, Fig. 9. So that this screw does not prevent the top plate from sitting flat against the pillars, bore a rather large hole in the pillar plate in which the head of the screw can easily enter.

The Boot of the Potence.

222. Take a thin steel plate, and file it flat and of equal thickness on both sides. Bore a hole at the point *H*, Pl. 9, Fig. 8, in the potence and tap it. Make a screw with a flat shoulder, like that for a cock. Temper the boot to blue and, after setting it in place and fixing it with its screw, turn over the potence and mark a line on the plate with a sharp point; then file it to this line. Put the boot back, and if there is some part which protrudes from the potence, file it so that these two parts, when fixed together, seem to be only one piece. Put the center pinion in place, mount the frame, and see if there is enough space between the potence and the center wheel; if not, file the top of the potence until the wheel does not rub on it. Leave a tail *P* on the boot, which is necessary so that it can be easily turned when it is fixed by the screw, and one want to expose the hole for the balance to rebush it, or to examine whether it is too large, or to renew the oil in it.⁴⁴

Also examine if the back of the potence is likely to touch the barrel; if it touches file it until this defect is removed.

The Counter-Potence.

223. Make a notch in the plate at the point *H*, Pl. 7, Fig. 3, centered on the line *E* traced on plate. This notch must be square, and deep enough to receive the pivot carrier of the counter-potence, which holds the pivot of the verge escape wheel. So that the teeth of the contrate wheel can pass freely, and they cannot touch the counter-potence, you will give the counter-potence the form of *E*, Pl. 7, Fig. 2, and will attach it to the plate with the screw *I*. Bore a small hole in the opposite end of the counter-potence, at the point *L*, where you will drive in a pin to form a steady pin, which you will file close to plate and round the end with the drill for rounding the steady pins of barrettes, N°. 150. After fitting the screw, file it level with plate, round the end with a polishing file, and finish it in the screw plate.

To avoid useless repetition in the following, when I tell you to make a screw I will always suppose that, after fitting it in the piece, you take care to file it flush with the surface of the plate, round the end, polish it, and pass it through the screw plate. All these small details are essential, and the solidity of the work depends on it.

To make a counter-potence, you do well have a model to look at. This part must have enough body to be stable and solid, without being too large.

The Pinion of the Verge Escape Wheel.

To make this pinion, round three teeth of the contrate wheel and take three teeth on the points with the calibre compass; use pinion wire of six of this size. Turn it, file it, remove the fluting, and round it as you have done with the other pinions about which we have already spoken, N°. 167 and following. However, with the difference that you will leave on it a pinion of at least double the length, on which you will make a riveting at the end of the pivot shank, and then a recess, by running the point of a graver close to the small stem, until you have formed the end of the leaves into an acute peak. This recess is necessary to fix the verge

⁴³ The notch is not illustrated.

⁴⁴ This tail is shown in Figure 8, but not in Figure 9.

scape wheel which must be riveted there. The pinion being thus laid out, Pl. 8, Fig. 27, harden and temper it to purple; if it is tempered blue it would be too soft. If it distorts when it is hardened, straighten it with a sharp hammer, or with a round peen, N°. 86 and 87. When one uses the latter, one is less likely to deform stems; use the former as rarely as possible. When you have straightened the pinion of the verge escape wheel, or any other, take care to temper the part again at least to yellow, if you do not want to risk it distorting again when you turn or polish it. After having smoothed and polished the stem and the pinion, you will face it.

Chapter IX: The Cock on the Top Plate.

No 125. Take a brass plate which is two and a half times thicker than the finished part. Forge it to thickness and file it flat on both sides. Mark above and below a circle of the size of balance, Pl. 10, Fig. 3, mark four points on this circle at equal distances from each other, and draw from these points the two lines *A*, *B*, which, going through the center, will divide the circle into four equal parts. Use a compass to place the two screws of the cock at equal distances from the center. Put one point in the hole *D* of the cock, and with the other point mark the two holes in the ears *C C*, on the straight line *B* and beyond the circle *E*. Bore these two holes away from the line *E*, so that when filing the inside of the ears of the cock, you will not reach the holes for the screws. Take the counter sinking drill, Pl. 1, Fig. 3, which has a pivot *G* on the end and a collet *B*, which you will lower until the drill tip is long enough to be able to recess the screw half the thickness of the cock. Tighten the screw *E* and, without disturbing it, recess the two holes until the collet *B* touches the cock; it is the way to recess the two screws of the cock equally deep. File the contour of the cock to line *E*, which is the size of balance, and the form of the cock, Pl. 10, Fig. 3. Give it the thickness of about a third of a ligne. To finish it, to file it flat and sharp, remove the two runners from the turns, and put the two ears of the cock *C C* in the holes of the headstocks, so that they enter exactly and freely; while pressing a file on the cock, it will follow the movement. When the top of the cock is perfectly flat, file the ears flat underneath so that they are of equal height.

Make a circle on the top plate with a compass which marks the size of balance; it is also needed for that of the rosette.

Method of Making the Slide.

226. Take brass at least twice as thick as needed, forge it until it is the thickness and size of the circle *A*, Pl. 9, Fig. 2, and turn the two sides flat and level. To do this easily, use a square which you will apply to the slide from time to time, and turn the part until the square lies flat, so that there is no space between the slide and the square, which will indicate that the part is flat. Using a compass, trace the circle *A*, which must be the size of the balance, Pl. 10, Fig. 4, and another smaller circle *B*, which marks the width of the slide. With a square graver recess the space between the two circles so that this recess has the depth of two thirds thickness of the slide. Recess beyond the circle *B*, to the center and at the same depth; by this means you will leave a fillet at *B*, which will have the same thickness as the slide. Then with a square graver cut off half the height of the fillet *B*; what remains of it must be square. Use the turns and the point of a graver to cut the slide beyond the line *B* until the center is separated from the slide. This part, when divided into two equal parts, will give you two slides. Mark the two ears *C C*, and made a hole in each for a screw. Remove the material from the line *A* to the two points *C C*, and file it like Pl. 9, Fig. 2.

The Rack.

227. The rack is part of the circle of a wheel which fits in the slide and which is divided into two parts. To make it, take brass twice as thick as the slide. After forging it until it is reduced to half its thickness, file it to the size of the balance, and turn it so that it enters the recess of the slide exactly, Pl. 9, Fig. 2. The turned rack must be flat and centered. On the turns remove about a third of its thickness at the place *A* where you will make the teeth of the rack, and then divide this wheel on the wheel cutting machine.

Put the rack on the turns and with a small square graver make a recess in which the fillet of the slide at *B* can enter. That done, place the rack on the slide and adjust it so that these two parts appear to be only one, without, however, preventing the rack from moving with friction in the slide. Divide the rack in two, and file away the center to the line *C*, in the middle of which you will leave a tail *D*. This operation finished, you will have a rack of the form of Pl. 9, Fig. 4.

The Location of the Slide.

After making a circle on the top plate which marks the size of the balance, which is the same as that of the slide, bore the hole for the rosette at the point *I*, Pl. 9, Fig. 1. After putting the slide on the line for the balance, with a compass, of which you will put one point in the hole *I* of the rosette, you will easily place the ears of the slide *C C* at equal distances from the hole of the rosette *A*. Tighten the slide against plate with the sliding ring pincers and bore the holes for the screws *C C*. Set up the rack, which will run with friction between the slide and plate, and finish it by rounding its teeth.

The Rosette Wheel.

229. Turn this wheel to the size traced on the calibre. After turning it, split the teeth the same size as those of the rack. Make an arbor which, at one end, is the size of the square of the fusee, and form on the other a shoulder, a riveting and a recess. Give the riveting five or six sides and hammer on the wheel until it rests on the shoulder, and rivet it with a punch. That done, turn the pivot, polish it, file it flush with the surface of the plate, and round the end into a dome.

The Rosette.

230. To make this part, take a plate of silver of the size traced on the calibre, and after forging it, make a hole in the middle. When it is filed and turned, make a recess as deep as the rosette wheel is thick, so that when you place the rosette on the wheel, the wheel fits inside it. Make a hole at the point *F*, which also goes through plate, and put in a tallow-drop screw. With a compass take the size of balance, put one point of the compass at *D*, and with the other point mark a circle on the rosette.⁴⁵ That done, file this part at the point *E*, Pl. 9, Fig. 3, with a crossing out file. When it is filed, set up the slide and file the rosette so that it follows contour *A* of the slide exactly. It is necessary that there is space between them, but that they are well fitted and appear to be just one piece. After rounding the wheel of the rosette, make an opening at point *A*, so that the teeth of the wheel of the rosette can engage with the rack. The part thus made and set up, turn the square of the rosette wheel and make the rack move back and forth. If you find that the gearing of the rack with the slide is too strong, decrease the circumference of the rosette wheel, or round the teeth more pointed, so that the friction is softer.

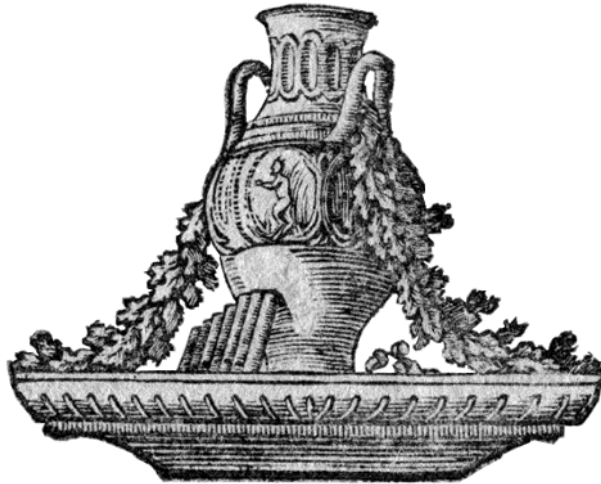
Method of Placing the Cock.

231. Removed the potence, mount the frame and put a straight stem in the holes of the two plates that I recommended you bore. To set up the balance, you will take care that this stem exceeds the top plate a little more than the height of the cock. Enlarge the hole in the cock so that the stem can enter it, and place the cock so that its two ears are the same distance from the ears of the slide. The cock thus positioned, fix it to the top plate with pincers, and bore the two holes for the screws. The screws made, set up the cock, and give it the form of Pl. 10, Fig. 3. To do this well, have a model which to imitate as best as you can.

The Coqueret.

232. You will make the brass coqueret similar to Pl. 9, Fig. 6, and bore two holes in which you will place two screwed steady pins. Bore a third hole between the first two for the screw which will fix the coqueret to the cock. Make a steel coqueret of the same form as the brass one, and bore the hole for the screw that you will recess in a cone. This screw made, put the steel coqueret on the brass one, fix them together with the screw, and file these two pieces so that they have same contour and the same form. Also file the steady pins and the screw flush with the surface of the cock, and finish by rounding and polishing them as in N^o. 150.

⁴⁵ The point *D*, Pl. 9, Figs. 1 and 3, is clearly wrong. I assume it should be the hole in the top plate for the balance, and I have added the missing label *E*, Pl. 9, Fig. 3, accordingly.



Chapter X: The Method of Making the Motion-Work.

N°. 233. Take two brass plates, which, well hammer-hardened, are the thickness of a farthing,⁴⁶ and of the size for the calibre. Turn these two wheels true and centered, and file them flat. Split the hour wheel with forty teeth, and the intermediate wheel with thirty-six. To get the size of the pinion of the canon pinion, round five teeth of the intermediate wheel, which will give the size of the pinion, N°. 165. Turn the stem of the center-wheel pinion from the hole in the pillar plate to the end so that this stem tapers slightly towards the point, and make a shoulder close to the plate on which the canon pinion will sit.

How to Make the Pinion of the Canon Pinion.

234. Use pinion wire of twelve, of the size as measured in N°. 165, and take two inches of it. After making a point at one end and placing a ferrule there, file the other end flat and mark the center with a center punch as exactly as you can. Then put it in the turns. If the pinion does not turn centered, it will be necessary find the center with a drill, or a center punch. Then bore the canon pinion by supporting the point in the hole in the vice, and holding the drill in the other hand, as in N°. 82. It will be necessary to bore the hole as deep as the stem is long. Remove the leaves which are not needed, and separate the canon pinion from the wire; see Pl. 10, Fig. 2. Broach the hole in the pinion until the stem enters the canon pinion with friction. Then thin it and round it, as in N°. 167, and following.

235. One can easily center pinions with a centering tool. To use it, hold it in one hand while you introduce the end of the pinion into the hole formed into a cone, and turn the pinion with a bow as if you wanted to bore it. The point which is in the middle of this tool, and which is pushed forward by a spring, marks the center of the pinion.

236. Make drills whose tips have clearance, and whose ends are acute and round, if you do not want to risk breaking them in holes. If that happens, you must temper the pinion grey, and rebore the hole with a larger drill. With patience you will come to the end of the drill tip broken in the hole, and you will continue to bore until the hole is the depth which you need.

To bore the canon pinion more easily, from time to time put oil on the end of the drill tip. There is steel which is bored more easily by moistening the drill with water or saliva from time to time.

If you find that the steel of the pinion is too hard, reheat it. This is the way to bore it, file it and turn it more easily. You can also bore canon pinions in another manner; see N°. 83.

⁴⁶ A *liard*, a small French coin equivalent to a quarter of a sou.

To make a pinion, take care to use pinion wire a little larger than is needed, in order to be able to turn the points of the leaves centered and to size. When you bore it and adjust it to the stem of the center pinion, which must enter the hole of the canon pinion with friction, you will turn the canon tapering slightly towards the end, which must be almost cylindrical, and of the size of the square of the fusee. Smooth it and polish it as in N°. 68, and face it; see N°. 175.

The Intermediate Wheel.

237. After rounding four teeth of the hour wheel, take the size for the pinion of six with the calibre compass; see N°. 165.

To make this pinion, take a piece of pinion wire, mark the center and bore a hole as was done with the canon pinion; see N°. 83. Turn this pinion true and centered on an arbor; it must then be thinned, rounded, polished, hardened and riveted, like the center wheel pinion; see N°. 169 and following. Fit the wheel, Pl. 10, Fig. 6, on the riveting and rivet it with a punch, as in N°. 177. Put the wheel in place by means of a hole bored in the plate, in which you put the canon of the intermediate wheel.

You can also fit this wheel with a stud screwed onto plate. Make the hole in the pinion the size of this stud, so that the wheel turns truly and free.

The Canon of the Hour Wheel.

238. To make this canon, Pl. 10, Fig. 5, hammer-harden a piece of brass, and bore a hole in it a little smaller than the size of the canon of the canon pinion. After turning it make a shoulder at the point *A*, a riveting and a recess; by running the side of a graver close to the arbor, you will make the riveting easily. That done, it is necessary to increase the hole of the hour wheel with a broach, until it fits exactly on the riveting, and chamfer and notch the hole of the wheel on the side where you must rivet it. After placing the canon on a riveting stake and riveting the wheel with a punch or the peen of a hammer, put it in the turns to test if it turns true and centered on its canon. Place it in the turns, and while rotating it with a bow, lightly press the point of a graver on the wheel, which will trace a portion of circle on it. Put the wheel back on the riveting stake and strike the riveting on the side which the graver has marked; and repeat this operation until the wheel is true. Then turn it round and enlarge the hole in it, so that the canon of the canon pinion enters the hole of the canon of the hour wheel.



Chapter XI: The Verge.

N°. 239. A movement can never be regulated if the verge is not made according to the rules of the art. This part requires the greatest care and long experience, because it is the most delicate and most difficult part in the watch. You will make several before succeeding in making one of them which is good. However, do not get discouraged by the obstacles that you will meet; you will succeed with patience and constant work.

The two principal parts of the verge are the stem *A*, *B*, Pl. 8, Fig. 30, and the two pallets *C*, *D*. The part *E*, located between the two pallets, is called the body of the verge. The part from the pallet *C* to the point *A* is called the stem, and the end from the small pallet *D* to the point *B* is called the pivot shank.

The verge, which is a single piece, is thus made up of five parts: the body *E*, the two pallets *C*, *D*, the pivot shank *B*, and the stem *A*. Each pallet also has its name; the first, *C*, which is soldered to the seat, is called the large pallet; and the second, *D*, is called the small pallet.

How to Rough Out the Verge, Pl. 8, Fig. 31, 32, 33, 34.

240. Take good flat steel, and file it uniformly thick and proportioned to the size and the strength which the verge must have. See Pl. 8, Fig. 31.

Let us suppose that you want to make a verge. Having filed the steel flat and uniformly thick from one end to the other, Fig. 31, file from the pallet *D* to the end *B* with a barrette file, Fig. 32. Do the same to the other end from the pallet *C* to the point *A*. Make a notch *E* in the middle, which will form the body of the verge, and file this notch until it is quite square. If you have done this well, you will have a square stem quite equal in size and strength over all its length. Take this verge by the pallet *C* and give all the length which is the body and the pivot shank eight quite equal sides. This perfect equality is essential to make the body of the verge round and equal from one end to the other. Also file the two pallets to be of equal width and quite square. Round the body from one end to the other. Then hold the verge with pincers by the pallet *C* and press the small pallet *D* and the body *E* on a riveting stake. By striking the pallet *D* with small hammer blows, you will be able to turn it to the left; continue until the two pallets have between them an angle wider than square by about five degrees. If the body is distorted, straighten it, and if while turning the verge you find some defects, correct them with a file, and make the body and the stems perfectly round and of equal size from one end to the other.

Then hold the verge in loop pincers by the large pallet *C*, press the body and the pallet *D* on a flat vice block and thin the pallet with a good fine carrelet file until almost half its thickness, and as close to the body of the verge as you can. Notch the other pallet in same manner. And when you file it flat, you will use a fine file and file the angles which will be opposite each pallet, until the whole is rounded, and follows the body of the verge.

For a verge to be well roughed out, it is necessary that the body is even and centered, that the pallets are filed square, and are thinned flat close the body.

Make points on each stem of the verge, give it initially four, then eight faces, then round it as I have already explained several times. Fix a screw ferrule on the end of the stem of the verge, and after putting it in the turns, make it centered and true with a hammer. See N° 168.

File the bottom of the pallet *C*, which forms an angle with the stem, Fig. 32. This angle is left to enter the notch which you will make in the seat, Pl. 8 Fig. 29, so that when the verge is soldered to it, it will be more firmly fixed, and so that one can polish the pallet more easily, when one wants to finish it.

The Seat of the Verge.

241. Take a small brass rod and bore a hole as in N°. 82. If by chance the drill grips, put a little saliva on the drill tip instead of oil, which would prevent the solder running. The seat bored, turn it to size, and cut off a suitable length. Make a notch in the head to receive the angle *C* of the pallet, Fig. 32.

If the hole in the seat is not large enough, enlarge it with a broach until the stem enters the seat exactly, and so that the angle *C* of the large pallet sits in the slit. The seat put in place, Fig. 34, see if the verge is open about five degrees more than square, and if the body turns centered and true.

These two parts thus set up, take a small piece of solder and put it behind the pallet on the seat. Put a little Spanish whiting crushed with saliva on the front of the pallet, so that the solder while running does not spread on the front of the pallet. This would cause great trouble when you try to smooth and polish the verge. Put a little borax on the solder, blow on it with a blow-pipe, and then harden the verge in oil. Then lightly press the verge on a vice block and rub it with pumice-stone. Do this operation carefully, because if you press the pumice-stone too hard against the part, it will break like glass. When it is well whitened, put it on a bluing pan and temper it deep yellow. Then put it in the turns and, if it does not turn centered, correct it with a hammer, in the way that we have already explained in N°. 85 and 86.

242. You will proportion the body of the verge to its height. If it is too large, you would make the escapement with difficulty. Neither make it too thin; this part requires a certain strength, so that the weight of the balance does not make it whip. This defect would necessarily cause variations. Make the balance as I described in N°. 164.

To Assemble the Rough Movement.

243. The rough movement made, pass a fine file over the plates and the various brass parts of which it is composed, and then smooth them with water stone until there are no more marks. Then polish all the stems, the faces, and the heads of the screws; and, after cleaning the movement, assemble it.

If you want to prevent the brass plates and parts becoming black, smooth them with water stone mixed with oil; your movement will have a more beautiful appearance.

End Of The Second Part.



PRACTICAL WATCHMAKING

Part Three.

Chapter One: Finishing in General.

N°. 244. To become a good finisher, make rough movements for a long time; it is the best way to become a great worker. When you make good rough movements, you will quickly progress in finishing. This first work having made you accustomed to scrupulously follow the various methods and proportions which one uses to make a watch, you will have much more ability to understand the defects that a rough movement maker will have made.

Finishing requires the greatest care and the most exact precision; the solidity and the fidelity of a movement depends on a good finisher. He can often make a good watch from a mediocre movement; but a bad finisher of an excellent movement will only make bad work from it. Thus you cannot apply yourself to finishing too much. This type of occupation, which is very delicate, will become familiar to you through practice, by the care with which you distribute the space in a movement, turn pivots cylindrical and well polished, and make teeth carefully. It is also necessary to form the gearing with precision, to lay out and make a good escapement and put the wheels free in the frame. Finally, you must file and finish all the parts with taste, as I will explain to you below, and to follow, in a word, all the rules that I propose to outline.



Chapter II: Various Numbers of the Teeth of Wheels and the Leaves of Pinions.

The Numbers of Teeth and Pinions.

245. Experience has shown us that a watch which gives approximately seventeen thousand two hundred and eighty vibrations per hour is that which is least prone to the effects of the air, the various positions in which it will be, and the jolts that it will receive at every moment. Thus you will give a watch the following teeth.

You will give your watches the following numbers. You will find they vary according to the number of steps on the fusee, and according to the number of teeth on the verge escape wheel.

Number of Teeth of the Wheels and Leaves of the Pinions, to Have a Fusee of Seven and a Half Steps, so that the Watch Gives 17280 Vibrations Per Hour.

246.	First wheel.	48 teeth.
	Center pinion.	12 leaves.
	Center wheel.	54 teeth.
	Third wheel pinion.	6 leaves.
	Third wheel.	48 teeth.
	Contrate wheel pinion.	6 leaves.
	Contrate wheel.	48 teeth.
	Verge escape wheel pinion.	6 leaves.
	Verge escape wheel.	15 teeth.

The train of a watch gears one wheel with the pinion of another, to the verge escape wheel. If you calculate the number of the vibrations, you will see that it will give seventeen thousand two hundred and eighty per hour, as I will show next.

Calculation of the Turns of each Wheel, and the Number of Vibrations which the Watch makes per Hour.

247. The center wheel has 54 teeth and it engages with the pinion of the third wheel, which has six leaves; so this one makes nine turns while the center wheel makes only one.

The third wheel has 48 teeth and it engages with the contrate wheel pinion, which has six leaves; and which consequently makes eight turns when the third wheel makes only one. Multiply 9 by 8 and you will have 72, which is the number of the turns which the contrate wheel makes per hour. This wheel has 48 teeth and it engages with the verge escape wheel pinion which has six leaves; it thus makes eight turns for one of the third wheel. Multiply 72 by 8, and you will have 576 turns which the verge escape wheel will make in one hour. The verge escape wheel has 15 teeth and each turn of this wheel causes the balance to make thirty vibrations. By multiplying 576 by 30, the product will be 17280 vibrations which the watch will make per hour.

Number of Teeth and Pinions of Seven to have a Fusee of Six Steps, and a Verge Escape Wheel of Thirteen Teeth.⁴⁷

248.	First wheel.	50 teeth.
	Center wheel pinion.	10 leaves.
	Center wheel.	70 teeth.
	Third wheel pinion.	7 leaves.
	Third wheel.	58 teeth.
	Contrate wheel pinion.	7 leaves.
	Contrate wheel.	56 teeth.

⁴⁷ Giving 17,234.29 vibrations.

Verge escape wheel pinion.	7 leaves.
Verge escape wheel.	13 teeth.

Number of Teeth which one must give to the Wheels, and Leaves to the Pinions, to make a Watch with a Verge Escape Wheel with Thirteen Teeth.⁴⁸

249.	Center wheel.	60 teeth.
	Third wheel pinion.	6 leaves.
	Third wheel.	50 teeth.
	Contrate wheel pinion.	6 leaves.
	Contrate wheel.	48 teeth.
	Verge escape wheel pinion.	6 leaves.
	Verge escape wheel.	13 teeth.

Number of Teeth which one must give to the Wheels, and Leaves to the Pinions to make a Watch with a Verge Escape Wheel of Eleven Teeth.⁴⁹

250.	Center wheel.	60 teeth.
	Third wheel pinion.	6 leaves.
	Third wheel.	54 teeth.
	Contrate wheel pinion.	6 leaves.
	Contrate wheel.	52 teeth.
	Verge escape wheel pinion.	6 leaves.
	Verge escape wheel.	11 teeth.

Number of Teeth which one must give to the Wheels, and Leaves to the Pinions, to make a Watch with a Verge Escape Wheel of Nine Teeth.⁵⁰

251.	Center wheel.	66 teeth.
	Third wheel pinion.	6 leaves.
	Third wheel.	56 teeth.
	Contrate wheel pinion.	6 leaves.
	Contrate wheel.	56 teeth.
	Verge escape wheel pinion.	6 leaves.
	Verge escape wheel.	9 teeth.

Motion-Work Numbers.

Pinion of the canon pinion.	12 leaves.
Intermediate wheel.	36 teeth.
Intermediate wheel pinion.	10 leaves.
Hour wheel.	40 teeth.

By means of these numbers, you will slow down the hour hand so that it will make only one turn while that the minute hand makes twelve.

253. The calculation of the motion-work is simple. The pinion of the canon pinion has 12 leaves and the intermediate wheel 36 teeth; so this pinion will make three turns to make the intermediate wheel do one. The intermediate wheel has a pinion of 10 which engages in the hour wheel which has 40 teeth; so it is necessary that the intermediate wheel pinion makes four turns to make the hour wheel do one. If the pinion of the canon pinion in three turns makes the intermediate wheel do only one, and if the pinion of this last wheel needs four turns to make the hour wheel do one, then by multiplying four by three, you will have twelve. Thus it will be necessary that the pinion of the canon pinion makes twelve turns in the time that the hour wheel will do only one.

⁴⁸ Giving 17,333.33 vibrations.

⁴⁹ Giving 17,160 vibrations.

⁵⁰ Giving 17,248 vibrations.

If you give ten leaves to the canon pinion, you will give the motion-work the following numbers:

254.	Canon pinion.	10 leaves.
	Intermediate wheel.	30 teeth.
	Intermediate wheel pinion.	8 leaves.
	Hour wheel.	32 teeth.

This number will give the same product because, while the canon pinion make twelve turns, the hour wheel will make only one.

The Number of Teeth of the First Wheel, and Leaves of the Center Pinion, for a Fusee which has Seven and a Half Turns.

255. The number of teeth of the first wheel and leaves of the center wheel pinion must be proportioned to the number of the steps which one wants to give to the fusee. These two parts do not influence the calculation of the vibrations which a watch must give. The center pinion is limited to make only one turn each hour. It, by the means of the canon pinion, carries the minute hand.

You will make the number of the teeth of the first wheel, and that of the leaves of the center pinion proportional to the steps of the fusee. If you have a high fusee which has seven and a half steps, you will give first wheel 48 teeth, and the center pinion 12 leaves, so that for each turn of the first wheel the center pinion, which revolves in one hour, will make four. Thus multiplying 4 by 7 and a half, you will have 30, which is the normal number of the hours that a watch must run without being wound.

The Number of Teeth of the First Wheel, and Leaves of the Center Pinion, when the Fusee has Six Steps.

256. If you find that the fusee is not high enough to be able to cut seven and a half steps, and that it can have only six, compensate for the height of the fusee by increasing the number of teeth of the first wheel, and by decreasing that of the leaves of the pinion. For example, by giving the first wheel 50 teeth, and 10 leaves to the center pinion, each turns of the wheel will make the pinion do five. By multiplying the five turns by the six steps of the fusee, you will have the thirty hours that you seek.

Number of Teeth of the First Wheel and Leaves of the Center Pinion, For a Fusee which has only Five Turns of the Chain.

257. Make the first wheel with sixty teeth, and the pinion with ten. With this number, when the wheel of the fusee makes one turn the center pinion will make six. This number multiplied by five, will give thirty hours.

When you have sufficient height to give seven and a half steps to the fusee, make it as in N°. 255, because it is easier to equalize a fusee of seven and a half steps, and to know its defects, than when it has only five steps.

Chapter III: General Observations on Finishing.

The Fusee.

N°. 258. One gives the fusee the shape of a cone to compensate for the degree of force of the mainspring as it unwinds, by the various lengths of the levers which the conical form gives. When the mainspring is completely wound and it starts to unwind, it has its maximum force and acts on the smallest diameter of the fusee. While unwinding it loses its force and the diameter becomes larger, producing a compensation of force between the fusee and the mainspring. So that its action is always maintained about equal, especially if the spring is of good quality, one takes care to equalize it with the fusee. To do that, you use a fusee adjusting rod. Put the barrel and the fusee in the frame, put on the chain, and tighten the mainspring three quarters of a turn. After the chain has finished being drawn onto the fusee,

you will take care to mark, with a file stroke, the angle of the end of the barrel pivot, and you will also make a mark on the top plate beside the pivot of the arbor; it will be used by you as a reference mark, to always tighten spring to the same point.

How to Equalize a Spring with the Fusee.

259. Fix the adjusting rod, Pl. 9, Fig. 18, on the square of the fusee by screw *A* of the jaw *C*; and turn it until the chain guard stops your hand. Then increase or decrease the force of the adjusting rod with the weight *E*, which you will move along the arm *D* of this tool until, when in the horizontal position, it is in balance with the force of the mainspring. By turning to each step, examine whether the fusee acts more on one than on another. Assume that the spring draws the first five steps from the fusee equally, and then the equilibrium is broken, and the adjusting rod is raised by the force of the mainspring on the sixth and seventh steps. Then remove the fusee, and with a square graver for fusees, Pl. 9, Fig. 14, decrease the diameter of the last two steps in the turns. When you think you have removed enough material, put the fusee and the barrel in the frame and tighten spring until the barrel pivot is opposite the reference mark traced on the plate. Use the adjusting rod to again test if the fusee is equal to spring. If it is not, put it back on the turns and repeat the same operation, until the spring is perfectly equal to the fusee.

Especially avoid using an equalling file to form the steps of fusees; it usually spoils them. Whereas the square graver makes the steps level, square, and almost as well formed as with the fusee cutting tool.

Pinions.

260. When you finish a piece, take care to gauge all the pinions, to be certain that they are of the sizes that I gave above, N°. 165.

This is of great consequence, because the exact communication of the moving forces, and this perfect agreement from one part to another, which gives uniformity to the train and produces equal vibrations, depends on it. The sizes were given for pinions which are driven by wheels. These must be small, so that the wheel which acts on this type of lever has more force than the pinion. It is a general rule to observe for all the parts which are to drive others.

If a pinion drives a wheel, you will keep it a little larger than the dimensions given in N°. 165, so that the pinion which drives has the force of a lever higher than that of the wheel which it drives.

The Width of the Pallets of the Verge.

261. Several tools have been invented to give to the width of the pallets of the verge the precision that the escapement requires. These operations are long, require knowledge that not many workers have and who sometimes cannot afford the high prices of the tools which give this precision. They will successfully make use of the following method. When one wants to set the width of the pallets, take the size of the verge escape wheel, and divide it according to the number of teeth which it has on its circumference.

Suppose, for example, that this wheel has fifteen teeth. Take its diameter with the calibre compass, press the two points into a playing card and draw the two straight lines *A* and *B*, Pl. 9, Fig. 15. Then with the compass, divide these two marks into six equal parts. One of these parts will give you the width of the pallets proportioned to a wheel with fifteen teeth.

For a wheel with thirteen, also take its diameter with the calibre compass and make two marks *C*, *D* on the card, Pl. 9, Fig. 16. Divide them into five and a half parts and one of these parts will be the width which the pallets must have.

For a wheel with eleven, you will also divide its diameter into five equal parts, etc. See Pl. 9, Fig. 17.

I do not know of a more convenient, practical and simple method to make the width of the verge pallets proportioned to the size of the verge scape wheel.⁵¹

⁵¹ Which may be true if the method were intelligible! To begin with, Vigniaux states that the width of the pallets should be the same as the distance between two teeth. This makes sense in the case of a 15-tooth escape wheel: Using 3 as an approximation for π , this distance is $3d/15 = d/5$ and Fig. 15 is correct (where d is the diameter). But in the other two cases the width should be

Friction.

262. Carefully correct the frictions of a wheel on another or any other part, if you want to your watch not to stop. All the parts of a watch must be free and have space; without that the train is constrained in its running, and prone to variations and stoppages.

Too Great Freedom of the Train.

263. After several experiments on friction, it was discovered that when all the parts of a watch are supported by coquerets of steel or agate, the frictions of the pivots being too small, the watch was prone to strong variation. Indeed, the inequalities of the mainspring not being deadened nor compensated for by the friction of the pivots and shoulders, are easily communicated from one mobile to the next to balance; resulting in intermittent vibrations, and consequently variations.

Too Small Pivots.

264. Small pivots also cause variations in a watch, and rapidly enlarge their holes. Therefore, you will make your pivots a little large. They will be more solid and less prone to being distorted, the holes will not be enlarged as rapidly, and consequently the piece will be better regulated and less prone to stoppages. However, do not conclude from what I have just said, that the pivots should be as large as stems. This excess would have its disadvantages, since it deadens the train, but especially the verge escape wheel and the verge of the balance. Thus it is necessary that the size of the pivots is proportioned to the piece being made, and to decrease them in proportion to which they are further away from the driving force. This is the only way to make a work according to the rules of the art. It is unnecessary to point out that the shoulders must be flat.

Chapter IV: The Gears.

The Depthing Tool.

N°. 265. To make good gearing you need a depthing tool. It is the most invaluable and most useful tool for a watchmaker; look after it carefully and you will be more expeditious in your operations. By using it, you will not be obliged to bush the same hole several times to get the gearing right, and to make windows in the plates to see them. It is enough to put the two wheels between the two points, and when you form the gearing, as in N°. 268, you will tighten the screws, so that the tool cannot get out of alignment. Then place one of the points in the hole opposite to that which you want to mark. It is necessary, when you mark gearings, to put the two points square the plate, to mark a line or a point with the tool, and to bore the hole exactly on the line or point which you have made.

Precautions to take for making Good Gearing.

266. When making gears, it is necessary to gauge the pinions to be sure that they are of the right size, and to remake those which are too large or too small.

The Line of Centers and the Point of Contact.

267. The line of centers is that line which is traced from the hole of the pivot of a pinion to the hole of the pivot of a wheel, like the line *E*, Pl. 10, Fig. 8, which is drawn from the center of the wheel *C* to the center of the pinion *B*.

When a wheel which drives a pinion loses contact with a leaf, the tooth which follows makes a small movement to fall on the next leaf; it is called the drop.

The point of contact is, after the drop, where the wheel starts to move the leaf of the pinion.

3d/13 and 3d/11, and so $4\frac{1}{3}$ and $3\frac{2}{3}$ respectively, not $5\frac{1}{2}$ and 5. Finally, Vigniaux does not explain how to divide a line into 5 or $5\frac{1}{2}$ parts with a compass; not a trivial problem.

Demonstration of Good Gearing.

268. To know if the gearing is good, we will suppose that wheel *A* in Pl. 10, Fig. 8, gears in the pinion *B*, and that the tooth *F* of the wheel, will drop onto leaf *I* of the pinion. If the tooth *F* drops onto the leaf *I*, and the point of contact takes place at the moment that this leaf is on the line of centers *E*, it is proof that the gearing is good.

Gearing considered in its Three Various Forms, Good, Strong, And Weak.

269. To express it in a few words, when the tooth *F* of the wheel *A*, Pl. 10, Fig. 8, drops and meets the pinion when its leaf *I* is on the line of centers *E*, the gearing is perfect.

When the tooth *F* of the wheel *A*, Pl. 10, Fig. 9, falls on the pinion *B* before its leaf *I* is on the line of centers *E*, the gearing is weak.

When the tooth *F* of the wheel *A*, Pl. 10, Fig. 7, drops and meets the pinion *B* after its leaf *I* has passed the line of centers *E*, the gearing is strong.

Various Observations on Gearing.

270. Make the gearing with the greatest care and the greatest attention. If it is strong or weak, you will have precipitateness or slowness, and consequently variations and often stoppages.

In general, it is to be preferred that gearing is rather strong than weak, because then one does not have to worry about stoppages. Moreover, by keeping the gearing of the contrate wheel a little strong, the wheel will not have as much recoil, and the watch will be fixed more easily, in a more permanent way, and will be less prone to variations.

It is very difficult to understand gearing and to make them, especially in a watch which, because of its small size, requires that they be made with all the possible accuracy and precision.

The Gearing of the Contrate Wheel.

271. The gearing of the contrate wheel cannot be done with the depthing tool. Put the contrate wheel in the frame, hold the watch in the left hand, and through the hole in the top plate, through which the verge escape wheel goes, lightly press the small finger of the right hand on the wheel while holding a microscope in the two large fingers. By this means one gives a rather light friction to the wheel. Push the contrate wheel with a finger of the other hand, to turn the verge escape wheel and examine the drops and the points of contact. If at the moment that this takes place, two leaves of the pinion of six divide the two plates, you are sure that the gearing is good. If the wheel makes the point of the contact before the two leaves are one on top and the other at the bottom, according to the line of the direction of the stem of the contrate wheel, you are sure that the gearing is weak. If, on the contrary, the drops of the wheel are made after the two leaves have ceased dividing two plates, the gearing is too strong.

If the gearing is too strong and the rim rather high, so that you have no fear of giving a bad form to the wheel, turn the end of the teeth until you have formed your gearing. If you have to remove part of the rim, and there is no danger of degrading the wheel, you will unriver it and lower the shoulder until the gearing is good.

When the gearing is weak, try to overcome this defect by means of the barrettes fixed to the plates, or by raising the pivots. If that is not sufficient, after riveting the wheel solder another seat onto the pinion, or remake it. A contrate wheel must be well formed, the barrettes true, and the rim square. This part being the most conspicuous in the watch, you will do it with all possible care.

There are occasions where the frames hide the space so much that one cannot see whether the gearing of the contrate wheel is correct. In that case one resorts to the light of a candle or the rays of the sun. The reflections of one or the other, in illuminating the interior of the frame, will give you enough light to see the space between the wheel and the pinion. Consequently you will be able to see the drops of the wheel onto the pinion, and the moment of meeting when the two leaves must be opposite the two plates.

The gearing must be done from one wheel to the next. When you do that of a wheel to a pinion, put this true wheel in the frame, and then make the next gearing. If you try to make two gearings together it would be difficult for both to be good, because it is much more

difficult to determine rigorously, and at the same time, the point of two gearings than of only one. It is thus to better do them one to the next, and one after the other.

The Uprighting Tool.

273. This tool is most essential, and it very much shortens the work. It is just two brass plates about two and a half inches wide and three to four lignes thick, Pl. 11, Fig. 4. When they are joined together, one carries at its center a pipe two and a half inches long, of which the base is square. The other plate also carries a pipe of the same length and the same diameter, with the difference that it does not rest on the center, but on two points on its circumference, by the means of an arc open enough to place a watch movement there, as large as it is. These two plates are turned with the greatest accuracy, and are joined together by an assembly of the highest precision, and by three screws which fix them in an invariable way. We said that these two plates each carry a pipe, whose hole is perfectly cylindrical, to receive a cylinder which enters it freely and exactly. These two stems have steel points which, when they are turned centered and extremely sharp, must, if the instrument is good, meet when they approach one another.⁵²

How to use the Uprighting Tool.

273. Start by attaching it to the vice by the square base *G*, Pl. 11, Fig. 4, which we mentioned in its description. For example, if you want to plant the center wheel upright, mount your frame, and place the center hole of the pillar plate on the point *D* of the tool. Take care that when putting the watch plate on the plate of the tool, that it sits good and flat everywhere.

When you are sure of its horizontal position, lower the point *B* by the knob *A* and tighten it on the top plate. Then bore on the point that it will have marked. This point will be exactly perpendicular, because the points, when they approach, touch at their extreme end, and consequently the points which they mark are perpendicular to each other.

This tool is used to plant all the wheels upright. When there are parts protruding from the plates, like barrettes, bridges, etc., which prevent the plate of the watch lying flat on the plate of the tool, the collet, Pl. 11, Fig. 3, is used, on which the watch plate is put; this produces the same effect as if the plate was put on the plate of the tool.



Chapter V: Springs.

The Mainspring.

No 274. Go to good workmen for mainsprings. When they are of good hardness, quite flexible, and their blades are uniform, they very good and preserve their elasticity for a long time. Do not use springs whose blades are too strong; because not only do they rapidly enlarge holes, but they are prone to break, lose some of their elasticity, and cause watches to vary.

⁵² The strange arrangement *C* on the bottom is a spring to press the bottom point *D* up above the plate.

The Mainspring Winder and how to use it.

275. When you have a mainspring to place in a barrel, hang the eye of the center of the spring on the arbor of the mainspring winder, Pl. 6, Fig. 2, and then turn the crank and wind the spring up onto itself. To fix it, slide the steel blade, and hang the eye of the outer end of the spring on the hook at its end. To place it in the barrel, you only have to introduce it and release the click; the spring will expand and take up the correct position. One sees, from this description, how necessary and convenient this instrument is to set up mainsprings without damaging them; because it often happens that when one uses an arbor attached to pincers, the spring, while escaping, will break or bend incorrectly which will damage it.

Small Springs, Pl. 7, Fig. 6 and 8.

276. Small springs in general must, like large ones, be elastic and well hardened. Temper them to purple/violet, and make them softer by slightly tapering their width from one end to the other. A spring made thus acts throughout its length and is not prone to break or to lose its force.

If, after hardening a spring, you find that it has too much force when tempered to purple, you can file it, but always tapering its width slightly, so that it is broader at the foot *A* and tapers to its end *B*.

When hardening it, redden it from one end to the other, so that its colour is equal throughout; if passes the colour cherry you will burn the steel, which would be prone to break or to distort easily.

The Balance Spring.

277. For a balance spring to be good, it is necessary that its blades, while moving away from the center, form a spiral line, so that they cannot rub one against the other, and that they are an equal distance apart in proportion to their development. Do you want to test the goodness of a balance spring? Take end *A*, Pl. 6, Fig. 9, in needle nose pliers and hang the small pallet of the balance on the other end *B*. If it forms what is called a hen's bottom,⁵³ and if it restores and returns to its original shape, you can consider it to be good quality and use it. On the contrary, reject it if it does not return to its original shape, if it is distorted, or if it is of unequal thickness.

This spring influences the regularity of a watch very much, because many variations depend on it. And although it acts only lightly, it speeds up or slows down the vibrations of balance. Thus one cannot emphasise its choice too much.

When fitting it, take care to put it in the notch in the rack.⁵⁴ Its movement must be free, so that it is not obstructed when turning the hand of the rosette, and the movement of the rack does not cause it to touch the plate or the balance, because the slightest touch will cause variations or stoppages. Check that the balance spring, when developing, does not touch the rack, the stud, or any other part; these various frictions would cause the watch to vary or to stop.

If you find that the balance spring that you put in causes the movement to run fast, because of its too great force, take one of the ends of this spring in tweezers, and hang the pallet of the verge on the other. Then by raising balance spring, the balance will follow, and its weight will make the spring take the shape called a hen's bottom. While it is suspended, examine its elasticity. If it is too strong, choose another, which, by making the hen's bottom more elongated, will show to you that it is weaker. True it and put it in the escapement. When a balance spring is too weak, the force of it can be increased, by cutting off about a quarter of one of its turns from the center. This reduction in its length will much increase its elasticity.

When you find a balance spring with a strength proportional to the piece, lay out its blades so that they develop equally, and that while widening or tightening them with the balance spring tweezers, Pl. 2, Fig. 10, they follow a spiral. This tool is of a great help for giving the spring a good form. To widen the blades of a balance spring turn the hollow of the tweezers outwards, and turn them in to tighten it.

⁵³ *cul de poule*: Perhaps a provincial term? I assume Vigniaux did not mean a whore's bottom!

⁵⁴ Instead of the common curb pins, Vigniaux uses a notch.

One cannot treat a balance spring with too much care. It is easy to distort it or to give it an incorrect contour. When you want to adjust it and put it in a form to be useful, examine with care where it is defective, and act only on that part; by adjusting it elsewhere you will make it defective. For the rest, it is very difficult to adjust such a delicate part. It is only from long experience that one can be assured of reaching that end. One can give opinions to a worker, but experience alone will give him means of benefiting from them.



Chapter VI: How to Round, Equalize, and Finish Teeth.

The Teeth.

N°. 278. The teeth of wheels must normally be as full as empty; that is, the space between two teeth must be the width of a tooth. The work has more grace, and more solidity, especially if the pinions are well made, if they are emptier than full and with a beautiful form. In this state, the forces will be communicated with more equality from one wheel to the next. This uniformity will be transmitted to the last mobile, and the vibrations will be uniformly accelerated.

The Method to use when a Pinion is a little Large, or is a little Full.

279. When a pinion is full, you should not follow the general rule; you will make the teeth emptier than full, and by this means you will avoid butting or engagement of the wheel teeth with the pinion leaves. To make teeth of a beautiful form and solid, do not split the teeth too long; because not only will they resemble the legs of a spider, but also the least shock can distort them and be the cause of an infinity of stoppages.

The Teeth of the First Wheel and the Center Wheel.

280. You must especially pay attention to the first wheel, because it receives the first efforts of the mainspring. So that it is solid, keep the teeth a little short and full. The center wheel could have longer teeth, because it does not immediately receive the effort of the mainspring; but as it is necessary that it resists the effort made when turning the minute hand, which sometimes is greater than that of the mainspring, it is preferable to keep its teeth short and full. It is the way to avoid it distorting or breaking.

It should be observed that the first wheel, being at least three times thicker than the center wheel, the latter is exposed to having its teeth distorted or broken. So it is prudent and necessary to give it enough strength. When the teeth are not made on this principle, you must not hesitate to remake the wheel. Note that before finishing the teeth, you must be certain that the wheel turns true and centered, and that it is equal in thickness.

How to use the Depthing File, to make the Teeth of a Wheel equally deep.

281. Take the depthing file, Pl. 3, Fig. 1, and put in it a file which has the thickness of the space between the teeth. Adjust it in the depthing file so that it touches the bottom of the teeth. Hold this tool square to the wheel, and in this position pass it between all the teeth. After this they will be of equal length.

Before rounding the teeth, cut down the angles of each tooth on the wheel with a rounding-up file, preserving a square to be used as a guide and to show that, when equalizing or rounding, you have equalized or rounded all the teeth. When it is equalized and rounded, you will finish by rounding this tooth like the others.

To Equalize the Teeth.

282. Take an equalling file of a thickness to exactly enter the teeth and successively pass it in all the spaces between the teeth, and file while pushing it quite true, flat and square to the part. To guide you in this work, have a piece of flat wood, two lignes thick and three inches square, which you fix in the vice and against which you hold the wheel flat, so that only the ends of the teeth protrude above it. If the stems obstruct doing this, make several holes in this wood through which the stems pass freely, and then you will round the teeth easily. If you find, after having traversed all the teeth, that they are not equalized enough, use the thicker side of the file. If that is not enough, choose one of a thickness proportional to your teeth.

Method of Rounding Teeth.

283. Now round the teeth. To do this, use a coarse rounding-up file. While rounding up, do not touch the points of the teeth; if you do you will risk giving them unequal lengths. While rounding them, do not touch the fine point; you must leave a little material there which you will remove with a smooth file when you give them the last cut; it will guide you not to file the end of the tooth and to keep them equally long.

When you round or equalize teeth, place the file as true and as horizontal as you can. Then, without looking from one tooth to another, file all of them until you reach the tooth which you left square, to show you that you have gone around the wheel. It is the correct way to have quite equal and quite round teeth.

Press equally on each tooth, and give each one about the same number of file strokes. Mark a line on the two sides of the teeth with a quite acute graver. This line must be a little way away from the teeth, so that there remains a small filet of material, which runs all around the circumference of the feet of the teeth.

Method of Notching Teeth.⁵⁵

284. Before notching a wheel, smooth it with water stone. Do not use files to notch; you will succeed much better with the end of a spring on which you will file a little bevel edge on the two sides. Fix it in a handle and rub it on oil stone. Well finished teeth badly notched will be deformed; whereas badly made teeth, if well notched, will be passable.

When teeth lean a little, you can seemingly correct them by notching them. For that, notch less near the foot on the side where the tooth leans, and you will press the tool a little more against the opposite side. You can notch all the teeth on one side, until you have gone round the wheel, and then do the same thing on the other side.

The wheel thus notched, again smooth it with water stone, and finish the bottom of each tooth with the last equalling file which you used. Thus you will remove the burrs which the notching tool will have made, and make the bottom quite square and quite sharp.

Apply yourself to the teeth. This part is very much neglected since the invention of the finishing tool which, handled well, gives more exact teeth with a more beautiful form.⁵⁶ But it does not make the ordinary worker who uses it more skilful, and he is embarrassed when he is deprived of it. This reflection is especially for those which intend to work in Province; they must endeavour to train their hands, and compensate by their talents for the lack of this instrument.



⁵⁵ *Crânage*: See *Notching Teeth* in the Vocabulary.

⁵⁶ This tool is not described. Presumably an early form of the rounding-up tool.

Chapter VII: How to Finish a Movement.

No 285. Before beginning to finish a movement, closely examine all the parts of which it is composed, and check that they were manufactured according to the rules of the art; because it is always necessary to be wary of a movement which one did not make. Disassemble the rough movement. Examine whether the plates are quite true, if the frame assembles well, if the pillars are well riveted, and if they are as high as each other. If you see a defect in these various parts, correct it. It happens sometimes that the top plate does not fit freely on the pillars; that occurs if they adhere, or the holes are too tight.

In the first case, you will comply with N°. 155. In the second, increase the holes of the top plate with a broach.

The frame assembled exactly and free, pin it, making the holes for the pins small so as not to fear bursting the ends of the pillars. Moreover, small pins always hold much better.

Examine whether the steady pins are well fitted on their barrettes; if they are not, it is necessary to make new ones and readjust the barrettes.

Examine the head of the dial spring. If it is too tight, make it free, and if you doubt the spring's hardness, retemper it.

Then put all the parts, one after the other, in the turns. If they are not true and centered, turn them to correct these defects. If a part is badly made and you cannot hope to make good work of it, do not hesitate to make another.

Gauge all the pinions to be sure they are the right size; if they are too large or too small make new ones.

Also examine all the pinions after touching them with a file. If the stems are too hard, temper them red purple, and blue at the ends where you will make the pivots. Repolish the stems and the pinions when the flame has changed their colour and tarnished the polish.

If, on the contrary, the stems are too soft, harden again those which will stand a second hardening, or make new ones. One often wastes less time remaking a defective part than correcting the defects in it. A part that has been improved several times almost always produces bad work; it takes a considerable time to repair it, which is often wasted by the need to remake it. So stop doing all these repairs and go true to the goal, which is to make exact and solid work. In watchmaking, more than in any other art, you should be neither lazy, nor impatient, nor awkward.

To Finish the First Wheel and the Center Wheel.

286. Put these two wheels in the frame and see if they have enough space between them, so that there is no danger of rubbing. If the space is not well distributed, you will be able to make some by decreasing the thickness of the wheel of the fusee a little, or by lowering the center wheel. If you fear that the beak of the fusee touches the top plate, take it out and remove enough material from it in the turns to give it a little space. Then take the center wheel, turn it true and centered and, if its shoulder is not well made, finish it and polish it.

Then put the center wheel in the frame. For that take the height between the two plates with the feet of the dancing master, tighten the screw of this tool, and mark with its points the space between the shoulder of the wheel and the place where the other pivot shoulder must be.

Use a hair bow to turn the pivot centered and cylindrical, at the height which the dancing master gave. Turn its shoulder quite flat. Then put the part in the pivot runners and burnish the pivot until there are no more marks, keeping it cylindrical. If it is a little too long, you will easily shorten it in the lunette runner. To do this, make a hole which the pivot can enter freely. That done, put it in the turns and burnish the end with a pivot file, shortening it so that it is neither too long nor too short, and rounding the end. Then burnish it with the pivot burnisher. Remove it from the lunette runner, again put it in the turns and use the pivot burnisher until it is cylindrical and without marks and waves.

Rebush the center hole if it needs it. For this, forge a small brass plate and make in it a hole a little smaller than the pivot which is beyond the shoulder. Turn this piece of brass carefully, giving it the shape of a quite true and quite centered collet. Insert it in the center

hole which you will have enlarged. Chamfer this hole on the motion-work side and, after making some notches there, insert the collet from the side of the pillars, and rivet it on the side of the motion-work. Enlarge the hole in the collet with a broach until the pivot enters it exactly and freely. Then stop the hole in the top plate with a screw plug, rivet the screw and file it. The frame mounted, mark the center hole on the top plate with the uprighting tool. After boring it, enlarge it with a broach until the pivot enters exactly and free, and put the part in the frame.

It is necessary to take care to keep the pivot of the first wheel a little large, so that it can better resist the efforts of the mainspring.

The Gearing of the First Wheel.

287. Carefully examine the gearing of this wheel to see if it is good. If it takes a leaf of the pinion before the line of centers, Pl. 10, Fig. 9, it is a sign that the gearing is weak; then it will be necessary to stop the hole and to bring it closer to the pinion. To do this, enlarge the hole with a rat tail file, moving it towards the center. When you think you have brought it sufficiently closer, make a small, well hammer-hardened round collet, that you will turn to the size of the hole to make it enter there with force. Chamfer it, notch it, and rivet the collet on the motion-work side. That done with care, increase the hole so that the pivot of the fusee can enter it freely and exactly, and examine the gearing again. If the defect is not corrected, repeat the same operation.

If the gearing is too strong and you cannot move back the hole for fear that the wheel will protrude from the plates, cut the wheel on the turns to decrease its circumference until the gearing is good.

Then examine the click-and-ratchet work and its spring; if it is defective, you must repair it or make another.

See if the fusee and the first wheel lie flat against each other. If they are not well adjusted, that can be because of the boss, the ratchet, or the click; it will be necessary to examine them.

Sometimes the steel boss does not join the fusee and the first wheel together with enough accuracy and solidity. It is then necessary to make one which is exact.

288. Turn the fusee and give it the form of a truncated cone, Pl. 8, Fig. 8; it is the shape most suitable to make the action of the mainspring equal to the fusee, because, as I have already said, its diameter increases at the same time as the mainspring develops and loses its force. The fusee creates larger levers, and by this means compensates for the loss of force of the mainspring as it develops. Then put the part free in the frame.

289. To avoid repetition, when I say to put some part in the frame, I assume that you will always put in the four pins, to be sure that the part is free and exact. It is a precaution which should never be neglected, because it is the only means of giving freedom to the train.

290. One cannot recommend too much that you chamfer the holes every time you have enlarged them and filed them flat. A finished work should not have burrs. To remove them use the drill with two ends, Pl. 1, Fig. 9. One end is specifically to chamfer holes, and other to mark the center when one has to rebush. It is also used to mark a hole on a line traced to form the gearing.

To Finish the Barrel.

291. After putting the arbor in the barrel, hold the square in loop pincers and examine whether it turns exactly and free; if it has too much play it is necessary to stop the holes or to remake the arbor. Then see if it runs smoothly and true and if not, try to center it by changing the position of the lid; this slight change is often enough to make it true. However, when that is not enough, remove the lid and strike the side where it drops, after having filed the opposite part a little. You will then manage to put it true, exact and free on its arbor.

292. Leave a rather large space between the top plate and the barrel, and between the barrel and the first wheel. It also should be prevented from touching the center pinion and its stem. If that happens, it will be necessary to stop the pivot holes and to move the barrel away from the stem. Also, sometimes you will manage to give freedom to the barrel by filing the back of the potence, which you can do without problems if you do not fear weakening it too much; in that case, it would be better to make another barrel.

If the base of this part is not quite level and flat, put it on a screw arbor and correct this defect. Then put a sharp bevel on the filet which the rough movement maker left on the barrel to prevent the chain from slipping into the train. This part finished, put it in the frame with the first wheel, the center wheel and the potence. If you see the spaces are well distributed, you have no fear of rubbing. Remove the part from the frame and make the hook *D*, Pl. 8, Fig. 3, which must be fixed to the arbor of the barrel to hold the inner eye of the mainspring; for that, make a deep enough notch with a crossing out file, to hook the mainspring.

293. Bore a round hole in the middle of the side of the barrel, tap it, and put in an iron or steel screw, whose end protrudes a little inside the barrel. Make a small hook on the end with a crossing out file; this hook must be notched close to the barrel and on the right side. It is used to hold the outer eye of the mainspring, Pl. 8, Fig. 7. Then make an angled hole *L* in the snap of the barrel, Pl. 8, Fig. 5, to receive the chain hook.

294. Then take a good elastic mainspring, of a height proportioned to the depth of the barrel, so that the width of this spring will not rub on the lid or the bottom of the barrel. To prevent the eye of the mainspring from escaping from the hook in the barrel, insert a bridle there.

The Bridle of the Barrel.

295. After putting in the mainspring, tighten it so that its last two blades are a little separated. Put between them a piece of brass wire, and release the mainspring which, being held by the brass wire put between these first two blades, will leave space for the passage of a drill. Bore a hole in the bottom of the barrel and make it square using a punch. Make a square notch *C* in the lid of the barrel, Pl. 8, Fig. 2, and make a bridle, Pl. 8, Fig. 4. This small blade must have a shoulder *A* at one end and another shoulder *B*, which fit well between the bottom and the lid of the barrel. File the two ends of the bridle so that, when set up, it is level with the bottom of the barrel and the top of the lid. That done, put the mainspring in the barrel, introduce the bridle and close the lid. Hold the barrel tight in one hand, hold the arbor with pincers in the other, and turn it right or left until the mainspring is completely wound. If it has a uniform action while unwinding, it is proof that spring acts freely in its barrel and that the part is finished.

The Fusee Notch.

296. When you cut the fusee, as we explain in the Vocabulary, make a notch in the first step at the base of the fusee for the chain hook; to do this use a small cutter made in the following way.

297. Take a small piece of round steel a little larger than a runner of the turns and file it like Pl. 1, Fig. 16. To make the stem, on one side place a ferrule, and on the other make a long stem of about eight lignes, on which you will leave a small wheel *A*, the thickness of a penny marked six liards, on which you will make teeth in the shape of cutter. Harden this tool, and temper it to violet. To use it, put the cutter in the turns, turn it with a bow, and press the fusee against the cutter at the place where you want to make the notch. Turn it until you have made this recess deep enough to hold the hook of the chain. Check, while making it, that it is true and the right thickness, and it is cut to the bottom of the steps. Then set up the first wheel, the barrel and the chain and, after having set up the spring three quarters of a turn, see if the chain is the right length. When the watch is wound, only four or five links should remain on the barrel; if there are more, it is necessary to remove the excess, and in the contrary case to add a piece of chain and a barrel hook.

How to Choose a Chain.

298. See if the chain, because of its thickness, binds in the steps of the fusee, or it slips from one to the other. In the first case, roll the chain onto the fusee, place it on the bench, and take the hook of the chain and raise it perpendicularly. If, while unwinding, it binds in one of the steps, it is proof that it is too thick. Then change it or widen the steps of the fusee.

In the second case, take another chain thin enough to enter the steps of the fusee freely; consequently the chain will not slip, and will not be likely to get out of order.

How to match the Steps of the Fusee with the action of the Mainspring.

299. Take the barrel arbor and make a small notch on the pivot on the side of the top plate. Put the first wheel and the barrel in the frame, and tighten the mainspring so that the chain leaves the fusee and all of it wraps on the barrel. Give three quarters of a turn more so that the ratchet and click fix the mainspring at this point. Then mark on the top plate a point opposite the notch which you have already formed on the pivot of the barrel, to be used in the future as a reference mark. This precaution is necessary so that you can always find the same point of bending of the spring. When you equalize it with the fusee, use the adjusting rod and a square graver to equalize the fusee to the mainspring.

Observations on the Center and Third Wheels.

300. Put the center and third wheels in the frame and see if there is enough space between the wheel of the fusee and the beak;⁵⁷ if there is not enough, try to raise the pivot, or lower the third wheel shoulder, which is done by unrivetting the wheel to put it in the turns and lower the shoulder on the seat.

After having set up the wheel, make the pivot and, after having taken the exact height from the plate to the barrette, determine the length of the stem from this height. Then turn the wheel centered and true, and make the teeth. If the arms are not well made, improve them and finish them carefully. Put the center and third wheels in the depthing tool. The gearing determined, put a screw plug in the hole for the third wheel and mark the position of its pivot with the depthing tool. Bore the hole and enlarge it with a broach, until the pivot enters exactly and free. Plug the hole in the top plate, which you will plant with the uprighting tool, and after boring it and enlarging it with a broach, put the third wheel free in the frame.

The Agreement of the Contrate Wheel Pinion with the Verge Escape Wheel.

301. The pinion of the contrate wheel requires the greatest attention. It is necessary to put it exactly at the height of the third wheel, and so that the arbor of the verge escape wheel cannot touch that of the contrate wheel.

Method of Making the Pivots of the Contrate Wheel and of Finishing this Part.

302. Make the pivot on the side of the small barrette. Then measure the space between the two barrettes with the dancing master and make the second pivot according to the height which the opening of the dancing master has given. Take care to make the shoulder on the side of the long stem quite flat, because it supports all the action of the movement, by communicating it to the pinion of the verge escape wheel, and it also has to endure the efforts of balance in its recoil. The two pivots must be of a size proportional to the size of the part and exactly cylindrical. After having polished and rounded them carefully, make the gearing of the third wheel with the contrate wheel. Plug the hole in the top plate. After checking, on the depthing tool, that the gearing with the third wheel is in agreement with the contrate wheel pinion, mark, with the same tool, a point on the barrette of the top plate, and make a hole there which the pivot enters exactly and free.

Then plug the hole of the barrette on the pillar plate, and mark it with the uprighting tool. Bore it and enlarge it until the pivot enters exactly. Put the contrate wheel in the frame and examine the gearing of the contrate wheel again; the strength or weakness of the gearing will indicate the side on which you must give play.

Observations on the Arbor of the Contrate Wheel, and that of the Verge Escape Wheel.

303. If the arbor of the contrate wheel touches that of the verge escape wheel, move the hole in the counter-potence a little. And if the pinion of the contrate wheel touches the arbor of the verge scape wheel, it is necessary to put it in the turns and cut it until it has enough space; without doing this you will risk stoppages.

Place the contrate wheel quite true in the frame. This position is essential to make your watch go well.

⁵⁷ An error? Presumably it should be the space between the first and center wheels.

To Finish the Contrate Wheel.

304. Take a piece of wood about three inches long, mark the center of one end and make a hole deep enough to receive the stem of the contrate wheel. Turn this end flat and its diameter to the size of the wheel. Fix this tool in the vice and place the wheel on it. Then take an equalling file and, instead of passing it in a straight line towards the stem of the contrate wheel, file teeth according to the position of the two stems of the verge escape wheel and the contrate wheel. If, when these two wheels are in the frame, you see that the stem of the verge escape wheel pinion passes on the right side of the stem of the contrate wheel, pass the equalling file on the left side and close to the stem of this wheel. Round the teeth by following the same direction with the rounding-up file. Make a line on the contrate wheel close to the feet of the teeth, so that you leave between the line and the feet of the teeth a small fillet of material which finishes the bottom of the teeth. After having notched the teeth, finish it with the last equalling file that you used, in order to remove the burrs made by the notching tool and to make the bottom very flat.



Chapter VIII: The Verge Escape Wheel and its Pinion.

Method of Finishing the Pinion of the Verge Escape Wheel.

N°. 305. Before making the verge escape wheel, check that the pinion turns true and centered. Make the pivots cylindrical and well polished, and cut their feet bevel with a graver. They should be turned so that almost no shoulder remains, because the pinion of the verge escape wheel should be carried only by the end of the pivot of the long stem, supported on the plate of the counter-potence. Moreover, the shoulder at the end of the verge escape wheel does not rest on the nose of the potence, because this wheel is always driven by the action of the verge, which moves it to the end of the counter-potence.

The Verge Escape Wheel Stem.

306. Make the stem of the verge scape wheel, Pl. 8, Fig. 27, the length of the top plate, so that when the holes enlarge, this wheel is less prone to butting against the verge. And as this stem passes beside that of the contrate wheel, and the contrate wheel cannot naturally form its gearing on the pinion of the verge scape wheel, it is necessary to give the teeth of the contrate wheel a form which answers to the position of the pinion to in which it gears. See No 304.

The Size of the Verge Escape Wheel.

307. You will measure the verge escape wheel with the calibre compass. Place one point on the top plate and open or close the compass until the other point carries almost to the heel of the potence. See that there is space between the compass and the heel of the potence, so that when the wheel is in place it is not likely to touch the heel. And it is necessary to proportion these spaces to the size of the verge escape wheel.

How to rough out a Verge Escape Wheel, Forge, Recess and Cross it.

308. To make a verge escape wheel which has a rim of one ligne, take a small piece of brass three lignes thick and hammer-harden it until it is reduced to a third.

Because of its smallness, it is sometimes difficult to hold it between the fingers, so take a playing card on which you will place the brass; a few blows of a hammer will be enough to make a hole in the card into which the brass will fit, so that while turning the card the brass will turn with it. Thus you can hammer-harden the piece without danger of losing it or of crushing your fingers.

The brass hammer-hardened, bore in the center a hole smaller than the riveting on which you will place the wheel. With a compass trace the size and, after filing it round, turn it and recess it until the bottom is the thickness of a penny marked two pennies. To form the arms *B* on the bottom, Pl. 9, Fig. 19, mark a line close to the edge of the rim, divide this line into three equal parts, and draw from each one of these three points a line which passes beside the center. Bore several holes between the arms, and form the three arms, which you will make quite equal, with a crossing out file.

Keep these three points until you have crossed out the wheel. Smooth the arms on a finger with a water stone, clean the wheel, and finish by polishing it on a finger by passing a large flat burnisher over it.

If the wheel is so small that you cannot hold it in the fingers to make the arms, put a hole the size of the wheel in a brass plate the size of a small ecu. When you place the wheel in it with force, you will be able to cross it easily.

Method of Placing the Pivot Holes of the Verge Escape Wheel.

309. Determine the height at which you must place the hole in the nose of the potence with the domestic bird, Pl. 5, Fig. 8, and tighten the point of this tool so it cannot move. Press it on the plate and mark a line on the nose of the potence, and also on the pivot carrier of the counter-potence. To make the hole in the nose of the potence opposite the body of the verge, place the drill on the line that you made there. Also bore the hole in the counter-potence on the other line, so that the stem of the verge escape wheel will not touch that of the contrate wheel.

The Size of the Pivot Holes of the Verge Escape Wheel.

310. Make the hole in the nose of the potence so that the pivot of the verge escape wheel enters it exactly and free, and the hole in the counter-potence rather large so that the pivot of the long stem has play there. It is the way to avoid butting of the verge on the verge escape wheel, and so that this wheel preserves its freedom for a long time.

Method of fitting the Verge Escape Wheel on its Pinion and Riveting it there.

311. Turn the riveting on the pinion of the verge escape wheel until it exactly enters the hole in this wheel. When it fits well on the riveting, turn it until it is flush with the arms. Then place the face of the pinion on a riveting stake and rivet the wheel with small blows of a hammer, while turning it from time to time. Put it on the figure eight calliper and, by pressing a card on the edge where you will make teeth, you will easily know if it turns true. If it does not, mark the place where it touches the card, put the pinion on the riveting stake and strike the riveting on the side of the mark that you made, and repeat this operation until it is about true and centered.

Then put the wheel in the turns and turn it until it is perfectly true and centered. When the circumference is turned, if it is not of equal thickness on the edge of the rim, it is easy for you to turn the inside of the wheel with a square graver.

How to Turn the Verge Escape Wheel without risking breaking its Pivots.

312. Make two lunette runners which have holes larger than the pivots, chamfer the two runners and put them in the turns. When you insert the pivots in the holes of the lunette runners, the shoulders of the stem will enter the holes which you will have chamfered, which will enable you to turn the verge escape wheel without you risking breaking the pivots, because the two shoulders placed in the lunettes support all the force of the turns. Take care, while turning, to often put oil on the runners; if you take this precaution, the holes in the lunettes will not enlarge rapidly, and you will be able to turn the verge escape wheel without

danger of breaking the pivots. Make the edges of the teeth thinner than their feet; this form will make the wheel more open and more solid.

Precautions to be taken before Cutting the Verge Escape Wheel.

313. After turning the verge scape wheel true and centered, set it up and examine if the front is flush with the hole in the heel of the potence. If it goes beyond the hole for the verge, decrease the rim of the wheel until there is a small distance between the hole in the heel of the potence and the wheel.

Follow this method every time you make a verge escape wheel, if you want to avoid the nuisance of remaking the wheel or the plug in the potence.

How to place the Verge Escape Wheel on the Wheel Cutting Machine.

314. This wheel is put on the wheel cutting machine with sealing wax, and in doing so take care to make it turn true and centered.⁵⁸ If it were not centered, its teeth, after being split, would be larger on one side than the other, If it were not true, the ends of the teeth would be of different sizes. If the wheel is put on the tool true and centered, the teeth will be split to the same depth, and their points will be perfectly equal.

How to remove the Sealing Wax stuck to the Pinion and the Verge Escape Wheel.

315. When this wheel is split and you have removed it from the wheel cutting machine, fill a small pot with water, in which you will throw a handful of ashes passed through a sieve. By boiling the wheel in this detergent, the sealing wax will be detached easily.

You can also successfully use spirits of wine, which is put in a flask whose neck is large enough to put in the verge escape wheel, and it is left there until the wax becomes liquid. This infusion will easily detach wax from the wheel and the pinion, which you will wipe with a cloth afterwards, or rub with a brush.

Method of making the Verge Escape Wheel centered and true, and of removing the Burrs after cutting it on the Wheel Cutting Machine.

316. To know if this wheel has been distorted while splitting it, or if its teeth are equally long, after putting the wheel in the turns, test it with a graver and a bow. If the teeth are not true and centered, slightly turn them until their points are of equal length. When the wheel has been corrected, bore a hole in the middle of a handle which has the diameter of the verge escape wheel. Fix it in the vice, and after filing the end flat, insert the stem and the pinion into the hole in this wood. Use an extremely fine barrette file to round the angles which are on the front of each tooth. Then use a burnisher which has the same form, and give a stroke of a rounding-up file on the end of each tooth to remove the sharp edge from it. Place the wheel in the turns, and smooth it with a water stone on which you have put a drop of oil. Having finished it, degrease it with bread crumbs.

Notice that the teeth of this wheel have a form and a position different from those of the others. They are made so, so that the vibrations of balance have more freedom. If the slope is too rapid, the wheel, by striking the points of its teeth on the pallets of the verge, would form a little hollow there, which dulls the escapement and cause variations and stoppages.



⁵⁸ This is presumably Pl. 12, Fig. 5, which replaces the arbor used to cut ordinary wheels.

Chapter IX: To Finish the Verge and the Balance.

The Length of the Verge.

N°. 317. Before taking the length of the verge, see whether there is enough space between the center wheel and the plate on the heel of the potence. If there is not, it is easy to make a little more by filing the steel plate, if it is too thick, or by decreasing the height of the potence. Give the heel of the potence a proportional thickness. Examine whether the verge is a sufficient height. For this sit the small pallet on the heel of the potence and see how its seat relates to the top plate; if it touches these two parts exactly, it will be rather high. If the verge does not turn centered, correct it with a sharp hammer or a round peen, and temper it red purple. There are artists who keep their verges harder, and this part must indeed have a good hardness. But it is necessary to be able to make the pivots and narrow the pallets, and not risk, at every moment, breaking a part to which one has devoted so much time.

Of Ferrules to make the Pivots of the Verge, and to turn its Seat.

318. To make the pivots of the verge and turn its seat, it is necessary to place a ferrule on the pallet or the body of the verge. Each one has their own particular method. There are workmen who have small ferrules which have a large hole that they fill with sealing wax, into which they introduce the verge while the wax is still hot. This method prevents the verge from whipping, even if balance is riveted to it. But the heat which the wax communicates to the verge can distort it. It is also very difficult to remove the wax from it when the part is finished, considering one cannot make use of the methods which I gave for the verge escape wheel, and one is obliged to remove this wax with a penknife or a graver.

Others use notched ferrules, which have a screw that is tightened against one of the pallets of the verge.

319. The best are the slit steel ferrules, which embrace the body and the pallets of the verge. They can be advantageously replaced by wooden ferrules, Pl. 1, figures 18, 19 and 20, because they are easily assembled and disassembled without fear of distorting the body of the verge.

To make them, take a piece of wood the size of a screw. On one end, place a ferrule and on the other make a hole the size of the body of the verge; see N°. 82. Place this wood in the turns, and turn the point a little inclined. After you have cut it to length, split it in the middle with a saw, until you have reached the hole which you made in its length, and saw the end in triangles, about the depth of a pallet. That done, you will put the verge into the end of this wood which will embrace the body and the pallets of the verge. Make a ferrule which starts to enter onto the end of the wood, and by tightening it like one tightens a pincer with a loop, the verge and wood will appear to form a single body.

Precautions to take when making the Pivots of the Verge.

320. Before making the pivots, turn the seat centered and to height. Cut the two points of the verge in the turns, and after burnishing them, make a pivot close to the small pallet if the verge escape wheel is large. But if it is rather small one can form a small pivot shank, between the pallet and the pivot, and bevel it; the work is better, because this bevel prevents the oil put in the holes from flowing back to the pallets, which causes variations. The pivot finished, put on the cock and measure the height with the calibre compass, which is from the heel of the potence to the coqueret, to determine the length that the verge and its two pivots must have. Make and finish the pivot on the end for balance, making it same size as the one you have already finished.

To Rivet the Balance onto the Seat of the Verge.

321. Set up the verge. Check that there is enough space between the cock and the seat so that balance is free and can touch neither the cock nor the slide.

With a graver, form the riveting at the bottom of the seat, and turn it until it exactly enters the hole of the balance. Take care that there is not too much riveting. Chamfer the hole of the balance on the side where you will rivet it, and then make five or six notches there with a crossing out file. Fit the seat to the balance and put it on the balance riveting

tool, Pl. 3, Fig. 10, in the jaws of the vice. Place the balance on it and rivet it to its seat; as you strike the riveting, turn balance so that you rivet all round the seat.

How to use the Figure Eight Calliper to true the Balance on the Verge.

322. Place the pivots of balance between the points of the figure eight calliper. After putting them in the holes made purposely to receive them, turn the balance and examine whether it turns true, by supporting a card lightly against it. If you see that certain parts of balance rub on the card, and that others do not touch it, mark the spots which touch, strike the riveting on that side, and repeat the same operation until it balance turns true.

If you have difficulty making the balance turn true, and you fear crushing the seat, use the following method.

To Correct the Balance.

323. When, after putting the balance in the figure eight calliper, you note the part which touches the card, take the balance in one hand and a one inch nail in the other, with which you will squeeze the arm on the side where you noticed that balance touched the card. Put the balance on the figure eight calliper to see if it is true, and repeat the operation if it is needed.

Disadvantages to avoid when Striking the Balance Arms with a Hammer to correct them.

324. Take care to avoid striking the arms with a hammer. It is a dangerous practice, which, because it lengthens the arms of the balance, prevents it from turning centered. It has yet another disadvantage because, by striking the arms sometimes in one direction and sometimes in another, you will cause them to have opposite effects which would give the balance a shape that one usually calls *cliqueti*,⁵⁹ which the average workman has trouble to rectify. You do not have to fear this problem if you correct the balance with a nail.

To Poise the Balance.

325. When you have centered and trued the balance, smooth it with water stone. After putting it on the figure eight calliper, Pl. 5, Fig. 5, examine it by making it turn on its pivots, to see if it is poised. When you hold the figure eight calliper upright, if the part *B* of balance always falls on line *A*, it is proof that the part *B* is heaviest, and it prevents the balance from being in equilibrium in all its parts. Then you will file a bevel in the rim of the balance between the two arms at the point *c*. To succeed in this operation, file the balance little by little, and frequently test if it is in poise. You will know that when the moving balance stops indifferently on all the parts of its circumference.

One should never forget, when finishing a balance, that it must be perfectly poised on its pivots; without that one cannot hope to adjust a watch despite the care which one took to make and finish all the parts.

Method of Rebushing the Holes which receive the two Pivots of the Verge.

326. If the holes for the verge are too large, you will plug them, starting with that in the heel of the potence. After it is bored smaller than it needs to be, enlarge it with a broach until the end of the pivot enters it. To remove the burrs from it, use the drill with two ends. Continue to chamfer the hole in the potence until the end of the pivot protrudes a little from the thickness of the heel. By taking these precautions, the shoulder will not touch the hole and balance will be free. Use a reamer to remove the burrs and to polish it; the pivot will have more freedom. Plant and stop the hole in the coqueret, according to the rules which I have just given. You must note that it is necessary that the points of the balance pivots exceed the holes of the heel of the potence and the coqueret a little, so that they rest their ends on the plate of the potence and the coqueret, and that the shoulders do not touch the edges of their holes; it would deaden the vibrations or cause the watch to vary. Set up the balance, and give it the necessary freedom so that it turns easily on the ends of its pivots.

⁵⁹ *cliqueti*: wavering up and down?

How to Smooth the Verge.

327. Take an iron file six inches long and about three lignes broad, which is quite flat and whose two sides have a quite sharp bevel. Give the other end the shape of a square graver half a ligne wide and a ligne deep.

To round the body of the verge, hold it by the balance. While you turn it with one hand, lightly pressing it on a filing block, transversely round and smooth the body of the verge and the backs of the pallets with the file coated with oil stone in the other hand, which you will make as flat as you can, and carefully remove the inequalities or marks which you see on the body and the pallets of the verge.

Then make a small notch at the other end of the polishing file, which must be rather broad so that it is about one third of the body of the verge. Lightly press the verge onto the filing block and rub the body with this tool coated with oil stone, which you will move longitudinally. Continue to make this tool move back and forth on the body the verge, until it is true, round, and no more marks remain.

These parts of the verge being smoothed, make the front of the pallets flat. For this, place the verge on the filing block, and with the iron file coated with oil stone, smooth the two pallets until they are flat, and no features remain. To develop the habit of using the iron file flat, take care to press it on the filing block from time to time and, without changing its position, carry it to the pallets and continue to smooth them until they are quite flat. Pay attention, during this work, to file the iron file quite square and quite sharp from time to time. I warn you that one needs long experience to hold the pallets quite flat. When they are well smoothed, use the end shaped like a square graver on the body of the verge again to make it quite uniform and round.

To Polish the Verge.

328. After cleaning and degreasing it with bread crumbs or the pith of elder trees, file the iron file flat and sharp. Put on its end a small amount of putty or English rouge, and rub the backs of the pallets until they have a black polish. In the same way, polish the body of the verge, by following the method indicated immediately above, and also polish the fronts of the pallets with the iron file coated with putty or rouge. In this work, you will take care to move the file in a circular way; it is the way to cut the marks of the oil stone, and to give your work a black polish and brilliance. If you can get good English rouge, the polish will be faster and blacker.

The difficulties which you will have at the beginning, to polish a verge well, should not discourage you; you will reach that point by assiduous work and long experience. Do not worry about the time it takes; it takes more or less time according to the dexterity of the worker and his application to the work.

The polish also depends on the hardness, the quality of the putty or the rouge, and the method of using them. Especially prevent any bit of steel, emery or oil stone falling on your work or polish compounds. Just one grain will be enough to spoil your work.

To Polish the Verge before Soldering it.

329. If you want to smooth and polish a verge before soldering the seat to it, use small pincers with a sliding ring, Pl. 1, Fig. 12, to handle your part more easily while you smooth and polish it as above.

This done, take the seat with tweezers, and put a little rosin and two small pieces of solder on its hole. Dampen it with sulphate of ammonia in water, which you will rub on the part of the stem of the verge that you want to solder. Hold the tweezers in the flame of a candle, so that the flame does not touch the seat and that the heat of the tweezers melts solder. Put the stem of the verge in the hole in the seat where it will usually be soldered. If not, put the tweezers into the flame of the candle until the solder runs. Using the wood ferrule, turn the seat to size, true, and centered, and make the riveting, etc.

Tools to Polish Verges easily.

330. Everyone is aware that it is very difficult to smooth and polish the pallets of a verge well, and that one reaches this point only after much work and experience.

The desire to make this operation easy for amateurs and apprentices, led me to seek a tool which filled this need. I found one with which I succeeded very well, although it is also simple, easy and expeditious. Here is the method of making it.

Take a piece of brass or steel which is three lines thick and file it square and sharp on all four faces. Cut it long enough so that it can be placed between the two headstocks of the small turns, Pl. 5, Fig. 10. After you have made a hole in each end, put it between two points in the turns, and put the verge on it. Support it there lightly with one hand, while with the other smooth and polish it as above. This tool, suspended between the two points of the turns, will form an equilibrium. When you use the polishing file on the verge, it will follow the various movements of your hand, and will enable you to smooth and polish the pallets of the verge flat. By using this method, you will in a short time be able to smooth and polish this part well.

To Narrow the Pallets of the Verge.

331. Measure the width of the pallets with the calibre compass, as in N°. 261, and make a small slit in the filing block in which you will place one of the pallets. Then file them, one after the other, to the width which the compass has given you. Without this precaution, their levers not being equal, the vibrations will not be uniform.

One can easily understand the reason for this inequality in the vibrations. Because when the verge escape wheel strikes the broadest pallet, by leading the pallet further, it will make the balance describe more of a circle than it will describe when the narrower pallet is moving it. The levers being unequal, they will communicate more or less wide vibrations to the balance, and hence cause variations. You will correct these defects easily by gauging the pallets and giving them the same width.

The Bevels on the Pallets.

332. File a sharp bevel on the back of each pallet. When the two bevels are perfectly equal, smooth them with oil stone and round the edges, so that there are no burrs; they would cause friction every time the verge escape wheel makes a vibration of the balance, and would also make the watch vary.

The backs of the pallets are bevelled so that, because of their thickness, they do not touch the backs of teeth of the verge escape wheel, which would consequently cause friction, variations, and often stoppages.

Method of making the Drops of the Escapement equal.

333. After setting up the verge escape wheel and the verge, and tightening the two screws of the cock, put the contrate wheel in the frame. Then lightly push this wheel with the thumb of one hand while with the other lead the balance with a point of spindle wood. If the drops are too strong, dismount the frame and file a little off the nose of the plug of the potence. Continue the same operation until you have made the drops neither too strong, nor too weak. If you have followed all the various instructions which I have given, the balance will describe equal and rather wide vibrations while moving the contrate wheel with the end of a pivot broach. The watch when assembled will give uniformly accelerated vibrations.

334. For the escapement to be exact, there should not be too much play given to the verge escape wheel between the nose of the potence and the counter-potence. When this wheel has too much freedom, it will strike the pallets of the verge more or less, according to whether, by its movement, it is moved more or less to the end of the counter-potence, which will cause unequal vibrations.

Sometimes the verge escape wheel escapes with difficulty; this can result from it being too close to the body of the verge. To cure this problem, cut a little from the ends of the teeth of the verge escape wheel. This operation must be done with much delicacy and precision, to avoid breaking the ends of the teeth or making them unequal. If this is difficult for you to do, and you fear deforming your verge escape wheel, then remake the plug of the potence. After having traced the hole in the nose of this part, with the domestic bird, bring the escapement nearer until the drops are sufficiently strong to avoid butting.

When the drops are unequal, correct this defect with the potence key, with which you will make the plug go and come, according as the circumstances require it.

Overbanking of the Balance.

335. This defect is corrected by placing a pin on the balance which is called, in watchmaking, a banking pin.⁶⁰ To place it exactly and not have to bore several holes in the balance, put a notch in the middle of the cock, opposite the coqueret, which you will make with a crossing out file. The verge escape wheel, the contrate wheel and the balance set up in the frame, put a little paper between the balance and the cock to obstruct the balance. These parts thus set up, gently push the contrate wheel with the big finger of the left hand, and lead the balance with a point of wood held in the other hand, until a tooth escapes from the verge escape wheel. Mark the balance, with chalk or the sludge of oil stone, opposite the notch made in the cock. Make the verge escape wheel escape by leading the balance in the opposite direction and again mark the balance opposite the notch in the cock. You will have two marks in the middle of which bore a hole which will be the position of the banking pin. If this pin is too long, it will touch the rack or the barrette of the contrate wheel; if it is too short it will pass over the slide. Avoid these two defects; the first would stop the watch and the second would overbank the balance. Make your banking pin carefully, because it can blunt, overbank, and sometimes break the teeth of the verge escape wheel.

How to make the Notch in the Rack, and place the Balance Spring Stud.

336. Make the tail of the rack a ligne long, and at the end of it make a small slit, with a small piece of spring toothed in the shape of saw. This small notch is made to hold the last blade of the balance spring. Remove the burrs with the side of a graver. After setting up the rack, move it to the right side, mark a hole opposite the fork of the rack with a drill, and bore this hole to fix the balance spring stud in it. If the tail of the rack is flat, and you cannot form a notch in it as above, put in two pins, one beside the other, so that there is only the space between them necessary to hold the balance spring; so that one can lengthen or shorten it by the means of the fork, without obstructing it. After boring the two holes and putting in the pins, rivet them on the opposite side.

To make the Stud for the Balance Spring.

337. Take a round or square piece of brass, put on a ferrule and make a point at each end. Make a cylindrical pivot on it. Enlarge the hole which you made beside the slide, so that the pivot enters it exactly and with friction. Make the head of the stud square and cut it in the turns to about the same level as the slide. Before detaching the stud from its arm, make the hole which will receive the pin used to fix the balance spring. Put it in place, file its pivot flush with the surface of the plate and round the end. After detaching it, file it flat in every direction, and remove the burrs.

Chapter X: Functions of the Balance Spring. Oils and Oil Sinks.

The Collet of the Balance Spring.

N°. 338. Though this part is rather easy to make, it requires care. After forging a brass plate, make a hole in it and enlarge it with a broach until the collet starts to enter the seat of the verge. File this plate round, and turn it to the thickness of the seat. Then bore in the middle of its thickness the hole to receive a pin which will fix the center of the spring. Recess the foot of the collet with a graver on the side which will touch balance. Turn a bevel on the opposite side, from the hole for the pin almost to the edge of the collet, which will be flush with the seat of the verge; remove it from the turns, and split it on the side close to the place where you made the hole for the pin. Use a smooth file and then a polishing file on the part which is flush with the seat. If I recommend that you make the slit in the collet almost at the edge of the hole where balance spring must be fixed, it is because the collet will keep its elasticity; if you made this slit on the side opposite to the hole that you bored, the collet would

⁶⁰ *Etoto*. Vigniaux also spells this *étoquio* and *étoteau*. It is a word that I have not come across before.

not spring. It would be prone to break and it would often slip on the verge, and would necessarily cause variations and often stoppages.

The Number of Vibrations per Hour which a Balance without a Balance Spring must give.

339. Let us suppose the movement is finished, and all the parts are in the frame except for the balance spring. In this state the vibrations of the balance will be slow. So that its weight is related to the action of the mainspring, the various frictions, and the other consequences to which it is prone while running, it is necessary that the balance without the balance spring makes the minute hand describe only twenty-seven or twenty-eight minutes per hour. If it does not describe this number, it is necessary to decrease the weight of the balance in proportion to the slowness of its vibrations. This is done by decreasing the thickness or the width of the rim of the balance. For that one files a bevel on the part *B*, Pl. 10, Fig. 4; this method does not harm the shape of the balance. One can arrive at the same goal by decreasing the width of the rim of balance. It is desirable that all its weight is on its circumference; but as one can only do it by losing much space, because of the greater thickness which one would give to balance, it is to better stick to the ordinary design.

If, on the contrary, the minute hand describes more than twenty-eight minutes per hour, it is proof that the balance is too light. Make another rather heavy, so that it gives only twenty-seven to twenty-eight in the same space of time. Experience proves that this number of vibrations of the balance per hour is the best for the various frictions, movements and accidents to which a watch is exposed. So follow this rule if you want a well adjusted watch.

Observations on Oil and the Oil Sinks of the Escapement.

340. Never put oil on the teeth of verge escape wheels, or on the pallets of the verge. If you find some there, carefully remove it, because any that remains would cause variations.

However, take care to put one drop of oil on the pivots of the verge, and those of the verge escape wheel, to prevent them rusting in their holes, and so that they do not corrode the brass quickly, or they themselves are corroded by it. Besides, this oil will give freedom to the escapement. But as it sometimes runs onto the pivot shank of the verge, someone thought of forming two types of lenses, one on the heel of the potence and the other on the coqueret. Form them in a bevel; file the circumference until you have removed almost all the thickness from it, and continue to form the bevel to the hole. By this means you will give the head of the brass coqueret the shape of a lens. This shape is given to it so that, when a drop of oil is put in the hole for the balance and the steel coqueret is put on the brass one, the drop of oil between the two coquerets is attracted by one and the other. The oil will be held there as if it were in a tank, and will maintain the pivot. By taking the same precaution for the heel of the potence, you will have no fear of the oil seeping onto the pallets of the verge. As for the nose of the potence, the only way one can prevent the oil being communicated to the pinion or the verge escape wheel, is to make a small recess in the pivot hole to contain the oil.

Method of making Oil Sinks for all the Pivots of a Watch.

341. Oil is almost as necessary to the pivots of the other wheels, as with those of the verge escape wheel and balance. To make the oil sinks to contain it, use a drill with a round head for recessing the holes. Make the recesses deep enough for the ends of the pivots to protrude a little above the hole in the plate. Without that the pivots, by corroding the walls of the hole over time, would form a type of cavity under the plate, which, engaging or obstructing the pivots, would stop or vary the watch. Thus with each hole make a small oil sink which can hold one drop of oil, which, held in the thickness of plate, will not be likely to be communicated to the pinions and will keep the pivots safe from rust. You could also use the set of cutters, Pl. 11, Fig. 4.⁶¹

The oil which one puts on the pivots must be of the first quality. Many workers prefer that which is purified with lead, or which is clarified simply by filtering it through grey paper.

⁶¹ This plate reference is wrong; it probably should be Pl. 1, Fig. 4.



Chapter XI: The Variations of Watches.

N°. 342. It takes much time to regulate watches. It is from the many experiences and the skills of the best artists that we owe the exactness of these machines. If you reflect on the causes of their variations, you will be surprised that one can eventually regulate them as well as it is done.

I would never finish, if I wanted to go into the details of all the causes which contribute to making watches vary. I will speak only about those which are most common, and which are most easily observed. These are:

1. The elasticity of the mainspring;
2. The friction of the train and the pivots;
3. The thickening of the oil;
4. The changes of the seasons;
5. The various positions of the watch which affect the movement of the balance;
6. The action of the balance spring.

1. The action of the mainspring especially influences the regularity of a watch. It is very difficult to make its blade of equal thickness, to harden it and temper it so that its elasticity is the same throughout its length, and to equalize it to the fusee, so that the fusee compensates for all the inequalities of the spring on all the steps on its spiral circumference.

2. No matter how much care a skilful worker takes, he will never make teeth perfectly identical. At the same time the pinions are made with the greatest care, but they always have roughness which, although not visible, prevents the train being uniform. The pivots have larger or smaller shoulders, and they are more or less round, more or less polished. Unite with these the difficulty which one has giving, by means of the gearing, perfect agreement of one part to the other.

3. One needs oil to prevent the pivots rusting, and to prevent them rapidly corroding their holes. Oils are more or less thick, according to how much the pivots form dirty oil in their holes.

4. Nobody can ignore the variations of the seasons which make springs more or less elastic and oil alternately fluid or thick, according to the degree of cold or heat. The first gives freedom to the train, and the latter impedes.

5. If you reflect on the various situations of a watch, such as resting, moving, shocks, blows, and the other effects to which it is exposed, you will not be surprised that the vibrations of balance are sometimes slow, sometimes fast, and so the machine is prone to vary.

6. The balance spring is about three or four inches long, and about the thickness of a hair, and it presents to the air a very large number of the parts of which it is composed. This element influences the spring which, intended to regulate the watch, communicates the various effects of it, to which it is prone by its nature.

Let us conclude from all that I have noted in this chapter, that an excellent watch, though well regulated, is not free from variation. The best vary about a minute in twenty-four hours. Such are the observations of our most skilful artists and our best authors.



Chapter XII: The Dial.

Method of placing the Dial Feet.

N°. 343. To place the three feet of the dial, make three holes in the pillar plate about equally distant from each other, so that they form a triangle and they cannot obstruct the train. Put the first opposite the contrate wheel, the second opposite the plug of the potence, and the third between the barrel and the first wheel. This method for placing them is not a general rule. One can deviate from it according to the circumstances, especially when one fears obstructing some part.

If you are within reach of an enameller, bore the three holes for the dial feet in the plate, and give it, with the case, to the workman who, making the dial for this particular part, will give it more grace. Besides, he will bore the holes in the center and for the fusee more accurately, and the whole will fit better than if you use a dial from the tool merchants. You will have much trouble to set up a dial chosen randomly, and it will never fit as well as one which has been made for the piece.

If you want to fit a dial taken randomly to a watch, take one rather large, so that the copper plate, which exceeds enamel, also exceeds pillar plate and can be flush with the seat of the case. Hold the feet of the dial with pincers, and put them as true in every direction as you can. Then put the dial on a playing card and press it down so that each foot makes a hole in it. Cut it to the circumference of the dial and bore the holes of the center and the fusee, and mark the point of midday. After doing this, remove the card from the dial and place it on the plate, making sure that the point of midday exactly divides the hinge into two equal parts. With loop pincers hold the card on the plate and mark with a drill the holes for the feet, which are already bored in the card. After boring them in the plate, chamfer them so that the feet will enter more easily. The dial thus fitted must overflow the plate all around.

Hold the dial on the plate and bore, on the side of the train, the holes in the feet which you will pin close to plate. Make these holes small if you want the pins to hold, and so that the pillars do not burst. Being made of copper, they will be very difficult to bore if you do not take care to put oil on the drill frequently. That done, cut them off a little beyond the holes with cutting pliers, and round the ends with the tool to round the ends of pillars, N°. 150.

If the squares of the fusee, the canon pinion, and the hand of the rosette are not the same size, make them the same size; then smooth and polish them in the turns, as in N°. 64 and 65.

As for the canon of the hour wheel, leave on it a shoulder which is used to hold it under the dial. To make this shoulder, turn the end of the canon until it can enter exactly and freely the hole in the dial, and so that there is a little play between the pinion of the canon pinion and the dial. Set up the two motion-work wheels, pin the dial, and turn the center wheel. If the motion-work is not free, if it binds, you cure it either by giving freedom to the wheels or by reforming the gearing. The hour canon must rise above the surface of the dial to receive the hour hand.

To mark the Hole for the Fusee on the Dial, and to bore it.

344. The position of the hole for the fusee is marked on the dial with the uprighting tool. See the description and use of this instrument, N°. 273.

There are two ways of boring a dial. The first is to mark the place of the hole with the point of a graver. Little by little one breaks the enamel with the point of this tool, until the part of the plate where the hole must be made is exposed. It is bored with a rather small drill so that it cannot grip and burst the enamel.

Then place the dial on plate, to see whether the hole is exactly opposite the square of the fusee. Enlarge it with a rat tail file until it is rather large, so that the watch key can be put on without being likely to break the enamel.

Take the precaution, when doing this, to file the enamel only when pushing the file; you would inevitably break it if you press on such fragile matter when withdrawing it. Take care to use a file which cannot grip in the hole, if you do not want to risk breaking the dial. If, however, the file grips, you can withdraw it by rotating it carefully until it is released.

345. The second method to bore holes in a dial is faster and more certain. Take a well hardened and well sharpened graver, mark the hole on the dial and sit it on a bottle cork fixed in the vice. Take this graver in the left hand, hold the point at the place that you want to bore, and strike it with small hammer blows. You will remove the enamel by changing the place of the point of the graver at each blow of the hammer. It is the way to break the enamel little by little, and of reaching the copper plate. When you bore it, bring the hole to size with the precautions indicated above.

346. To round and smooth a hole in the dial, make on the turns a copper drill. Place a ferrule on the end and use it like a drill by resting it in the hole in the jaw of the vice. After coating it with emery, introduce it into the hole in the dial, and turn it with a bow until the hole is round and even.

347. Then fit the two hands. The hour hand must have a round hole, and turn with friction on its canon. The minute hand must have a square hole, so that it can be fitted onto the end of the canon pinion. If the hole in this hand is not large enough, enlarge it with a square punch with blows of a hammer. You will do better using punches rather than a square file, because while filing you cannot be certain that you will form a square whose angles are sharp, which contributes much to fitting a hand firmly on the square of the canon pinion.

348. Before leaving the work of finishing, it cannot be recommend too much to go over the movement again. To smooth the plates, barrettes and other parts of the watch with water stone. To polish all the stems and faces of the pinions. To carefully blue all the screws, and to polish the springs and other steel parts. To clean the movement, soap it with a brush, and wipe it on a cloth with bread crumbs. When it is quite clean, put all the free pieces in the frame, one after the other. After assembling the movement and pinning it, put on the slide, the rack, the rosette and its wheel.

To Set Up the Watch Escapement.

After pinning the inner end of the balance spring to the collet, and making it true, pin the other end to the stud. Then put on the cock, and fix it with its two screws. The whole being set up, gently push the contrate wheel with a finger to make it run, and the balance will vibrate. If the vibrations are stronger on one side than the other, release the pin and move the balance spring to the side of the strongest vibration. Repeat this operation until the balance escapes as much on one side as the other. Tighten the pin in the stud, fix the cock with its two screws, and wind the watch. If you followed the principles that I given you, both in the rough and when finishing, you will not have to worry about its running.

Note: Articles XXIII, XXIV and XXV of Part 5 (on gilding) should appear here.

End Of The Third Part.



PRACTICAL WATCHMAKING

Part Four.

Chapter One: Repairing.

N°. 350. One usually looks at repairing as easy and simple work. The experts and true artists consider it from a quite different point of view.

A workman with little talent, and after several years of work, will manage to make good rough movements, while he would never succeed if he had devoted himself to repairing.

There are also cases which would cause trouble for a good finisher.

It is not only necessary that a good repairer is in a position to make and finish a movement, but further, that he is endowed with an inventive genius which can be applied according to the circumstances, and that he has long experience in this work. A repairer must have more extensive and more varied knowledge than that of a rough movement maker and an ordinary finisher. From which it is easy to conclude that a watch needing repair should only be entrusted to watchmakers who have acquired a good reputation for their talents, their probity, and their experience.

Do not be negligent, nor fail to be meticulous in repairing. In the first case, you would miss many defects which could stop or vary a watch.

In the second, you would make many useless repairs which would not make the watch better, and would waste much time.

Chapter II: Pieces to be Remade and Pivots to be Replaced.

Pieces to be Remade.

N°. 351. When you are obliged to remake a part: If it is a wheel, examine whether it is a good thickness, and if the spaces are well distributed. If it is a pinion, see if it is the right size. If the plates have pips⁶², file them. Take these pieces for a model, if they were made according to the rules of the art. If not, when remaking these pieces to avoid the faults which make them defective.

⁶² *tetines.*

How to find the Center of a Stem.

352. Take a brass plate two lignes thick, and make a hole in which the end of the stem enters exactly and to half its thickness. Using the hole, make a drill of the same size, harden it and sharpen it so that the point is in the middle and quite acute. Put the stem in the hole which, entering it exactly and half way through, will allow you to introduce the drill on other side. The whole thus set up, by using a bow as if you want to bore the stem, you will mark the center of it exactly.

Let us now suppose that you have to replace a pivot on the center wheel. Temper the end of the stem to the colour of ash for about the length which you must bore it. Put the end of this stem in the hole which you made in the copper plate, and with a drill of the right size and a bow, mark the center as we have already explained; it is the sure way to mark the center of the stem exactly. Bore the hole for the pivot by holding the drill in one hand while turning the stem with a bow in the other hand. See N^o. 82.

If the stem is not softened enough, it is necessary to temper it by a candle or with a blow-pipe. When the hole is rather deep, take a piece of steel rounded with a file and of a suitable size. After hardening it, temper it blue and file it cylindrical, so that the end starts to enter the hole in the stem. Cut it rather long so that, when you drive in it into the hole, enough remains to make a pivot on it.

To insert this steel piece into the stem, put a ferrule on the vice whose hole is large enough to hold the long stem of the center wheel. Put the stem into the hole of the ferrule until it supports the shoulder, and put the steel piece that you prepared into the hole in the stem. Strike it with light blows to drive it the bottom; you will know when it touches when the hammer is pushed back by the piece. Make a point at the end of the pivot so that the pinion and the stem run centered. Cut this point on the turns. After burnishing it, make the pivot cylindrical, and when it is burnished, finished and polished, put the part free in the frame.

How to Remake a Pivot of a Third Wheel.

353. Let us take, for example, a broken pivot on the end of the pinion. This pivot usually runs in a barrette. If enough of the stem remains, make a pivot on it, N^o. 205. The pivot shank having been shortened by the second pivot that you have just made, to put the part in the frame you will compensate for this fault by taking a little brass which is as thick as the height of the pivot. File it round so that it enters the thickness of plate and presses on the barrette. When it is well fitted, make two holes opposite each other, which you will chamfer to rivet in each one a pin which must cross it. Now bore in this part the hole which must receive the pivot of the third wheel; make this hole by introducing the drill into the old hole in the barrette. Put the part in the frame true and free; examine whether the gearing is good, and remake it if it is bad.

Method of Replacing the Pivot of the Verge on the side of the Balance when a Pivot Shank still remains.

354. If the pivot on the side of the balance is distorted, it is best to break it, because it is very difficult, if not impossible, to make it perfectly true. However, you can try with tweezers, but I doubt with success. Thus let us suppose the pivot is broken. In this case, make a point there by rolling the balance on the bezel runner and make a pivot with a graver as cylindrical and polished as you can. Plug the hole in the cock with a screw bush and, after setting up the coqueret, bore the hole in the cock by introducing the drill into the hole in the coqueret. If the balance is not true, plug the hole again and mark it with the uprighting tool. The pivot made and the hole plugged, you drive in and rivet a brass pin in the hole in the coqueret, on which the pivot will bear. If the pivot is too short and it cannot reach the coqueret, make a recess in the cock, that you will deepen until the end of the pivot exceeds the hole a little. In order to be sure that the pivot will rest on its point and not on its shoulder, fit in the coqueret a long brass pin which, protruding from the coqueret, will enter the recess and meet the end of the pivot to support it, and will put the balance true and free.

To Replace a Pivot on a Verge with a Forked Stem.⁶³

355. Make two holes in the seat on the side of balance, so that they go through the seat; it is necessary that there is a distance of about half a ligne between these two holes and the body of the verge. While boring them, from time to time turn the balance in the hand; it is the means of boring true. Enlarge them with a broach, put a pin in each one, and measure with the calibre compass the distance from one pin to the other. That done, choose a piece of round or square steel, it does not matter which, put on a ferrule and turn the end to the size which the compass gave you; this size is the space which is between the two holes. Leave a small shoulder where the feet of the fork must be made; it is necessary that its length is equal to the thickness of the seat of balance. Then turn the opposite end which will form the stem, leaving a shoulder on which the fork will be formed. File the two sides flat where you will make the fork. The head of the piece must be then filed so that there remains in the middle only a type of steel blade which you will split with a fusee file. This last operation will give you two pins which you will round and file so that they start to enter the two holes which you made in the seat; leave this steel piece rather long so that you can make a stem on it and turn a pivot. Harden the piece and temper it blue, put it in place, and strike it with hammer blows until it is flat on the balance. When the fork is driven in, file the point so that the verge and the balance turn true and round. Place a wood ferrule on the verge and turn the stem a proportional size. Turn the shoulder centered and, after making a cylindrical and well polished pivot on it, put your part in the frame true and free. Read Chapter IX on the verge.

Chapter III: On the way to Plug Holes.

The Quality of Brass for this Operation.

N°. 356. The best brass to plug holes that we know of is boiler brass; as it is extremely soft, it should be hammer-hardened much more than ordinary brass. This brass is very fatty and it sticks to the drill, which will break in the hole if you do not take care put oil on it frequently; take the same precaution when you bore copper or silver. If you cannot get boiler brass, use flat brass from Holland, three times thicker than one needs. Forge this plate until it is reduced to one third of its thickness, and cut it into small strips with shears. It is the way of making well hammer-hardened brass; whereas, if you use brass passed through a wire drawing plate, it could be flawed, soft, and of bad quality.

How to Plug the Holes of the Train, Verge Escape Wheel, and Balance, without disturbing either the Gearing or the Escapement.

357. Take a piece of brass as in the last number, file it round and tap it with the smallest number of the screw plate. Measure the size of the hole in the screw plate with a broach; to do this, after inserting the broach in the hole, mark it exactly with a file cut on the angle of the broach. To enlarge the hole that you must plug, make the broach enter it up to the mark that you made. Tap the brass piece on which you will make the bush. cut it and file it flush with the surface of the screw plate. Use the drill with two points to mark the center of this bush as exactly as you can and bore the hole true. To do this, hold the brass piece in one hand, and drive the drill by means of a bow with the other. As you bore, turn the brass in your fingers; it is the way to bore truly. Place this bush in its hole, cut off the piece close to the bush with cutting pliers, and hit it with a hammer so that it can no longer move. After filing it all properly, and having enlarged the hole until the balance pivot enters it exactly and free, countersink it with the drill with two points until the pivot protrudes a little from the hole. This precaution is taken so that shoulder of the verge does not rub on the brass, and the point of the pivot rests on the steel plate. Set up the balance and the cock; if you done this work well, you will have put the balance as true as it was, without disturbing the escapement.

⁶³ See Pl. 6, Fig. 10 and 11.

If, however, balance is not true, bore an eccentric hole in the bush, which you will move to one side in proportion as the defect is more or less large. Through practice with this work, you will be sure to put the balance true.

By following the same method, you can plug the pivot holes of a wheel, and put them in the same places, without disturbing its gearing. However, take care to examine it to be sure it is correct.

You can successfully plug the hole of the nose of the potence in the same manner, without fear of disturbing the hole for the verge scape wheel, which will be set horizontally and the gearing of the contrate wheel will remain the same; always look at it to be sure that it is good.

The smaller the tap with which you plug the holes, the easier it will be to find the center of it, and the less you will risk moving the holes.

Small holes must always be plugged with a screw. This method is more solid than plugging them with friction, because a smooth bush gets out of order easily, and is likely to leave its place at the least accident. One does not have to fear this when the bushes are tapped.

Eccentric Bushes.

358. If you do not have depthing and uprighting tools, it will be necessary seek ways not to have to plug the same hole several times. You will compensate for these instruments by making bushes a little large. Tap them, file them flush with the surface of the screw plate, and mark the holes off center. When they are in place, turn the bush in plate, until the piece is true in the frame. In the same manner one plugs the holes of the balance. This method is also used to weaken or strengthen the gearing by turning the bush as required. The gearing made, cut the bush flush with the surface of the plate, and strike it with few blows of a hammer to fix it immovably.

The Compass with Three Points.

359. One can successfully use the compass with three points to plug a hole in the same place. Here is how to use it. Mark one of the three points to distinguish it from the others, place it in the hole which you must plug, and by pressing the other two points on plate, you will impress two points there. The hole plugged, place the two points in the two marks made on the plate, and third point, which is that on which you made a reference mark, is used to mark the hole by pressing it against the bush. After boring it, enlarge it and put the part free in the frame, and examine the gearing; if it is wrong, remake it.

Not all workers are equipped with a depthing tool. If you do not have one, resort to the ordinary method, which is to make windows in the plates, through which you will be able to see the effects and the precision of the gearing.

When you have a hole to plug, never trust the gearing already made; examine it with care and ensure that it is accurate. Without this precaution, you will have the nuisance of seeing a watch stopping after having wasted a considerable time.

Compressing Holes

360. There are negligent workmen who, instead of taking the trouble to plug a hole, are satisfied to compress it. For this operation they fix a punch with round head in the vice, on which they place one side of the hole to be compressed and, after putting a second punch of the same form on the other side of the hole, they strike the latter tool with a hammer until they have narrowed the hole, which becomes smaller. But it is narrowed only at the expense of its thickness; consequently, the brass being thinner, the hole will enlarge very rapidly or will mark the pivot. Avoid these two disadvantages which are to be feared. However, you can compress holes when they are the full thickness of the plates, and they have not have been countersunk. Such are those of the barrel, the first wheel, and the center wheel. You can then use this method, but I cannot advise you to do it, considering the reasons which I gave above. You will avoid these disadvantages by plugging the holes when they are large.

Blind Holes.

361. When you have to plug a blind hole, like that of the balance, or a pivot that runs in a blind hole, make a hole in a small brass plate and enlarge it until the pivot enters it exactly.

Put in a broach that will enter it as exactly as you can, and break off the end of it which protrudes above the plate. After removing it from this hole, sharpen it on an oil stone so that it becomes straight and sharp. This tool thus prepared, make a bush that you will tap and put in. After boring a hole in it, introduce the end of the broach which you will roll in your fingers until it touches the bottom: the shape of this tool will make this hole straight. Chamfer the edge to remove the burrs and to prevent the pivot shoulder rubbing on them. It is the most certain way to be sure that a pivot does not grip in a blind hole.

Chapter IV: Method of Replacing the Teeth of Wheels and the Heel of the Potence.

Method of Replacing a Tooth in the Center Wheel.

N°. 362. To form a notch in the place of the broken tooth, use an equalling file which you will insert to a depth of about half a ligne. Form there, with a small potence slide file, a dovetail notch and file all the edges sharp. Then take piece of brass, forge it carefully, and give it the same form, so that it fits well in the notch which you have made. Put it in the notch and strike it with small hammer blows on a riveting stake, until the tooth is well riveted on both sides. When it is well fixed, form it in the shape of the nearby teeth. If it is fitted skilfully and with care, it will be hard to distinguish it from the others.

Method of Replacing a Contrate Wheel Tooth.

363 Make, as with the preceding wheel, a dovetail notch in place of the broken tooth, and fit the small brass piece which will form the tooth, so that it enters the notch exactly. Remove it, clean the wheel and the piece of brass at the place where you will solder them together. After rubbing them with a little rosin, fit them together and put two small pieces of tin solder on the dovetail. Hold the wheel on a bluing pan with pincers over the flame of a candle, and when the solder runs move away it from the flame. File the tooth to give it the same form as the others and finish it.

Use this method to solder wheels when they do not have enough solidness to be riveted. Always give preference to riveting as far as you can, because the flame softens the brass of the wheel. When doing this operation, never use a blow-pipe, whose too strong flame would soften the brass and spoil the part to the point that it would not be usable.

One can also solder the teeth of wheels with tin solder and sulphate of ammonia dampened with oil; or you can successfully use solder with sulphate of ammonia dampened in pure water, N°. 100 and 101.

Method of Replacing the Heel of a Potence and Riveting it.

363. File the old heel of the potence, and form a dovetail notch at the place where you must insert the new heel. Then take a small plate of hardened brass, in which you will make a plug which has the shape of the dovetail so that it will enter the notch with force. Bore two deep holes in the plug and drive in two pins with the blows of a hammer. Plant the hole for the balance, bore it, and give the heel of the potence the same form that it had.

Another way to Replace the Heel of a Potence by Soldering it with Tin.

364. File the top of the potence until you have removed the heel, which is of no more use. To fit another there, forge a brass plate and, after filing it flat on the two sides, put it on the steel plate and bore the hole for the screw. Put a pin into this hole which crosses the two plates. Rough out the brass plate so that it is about the same contour as that of the steel plate, keeping the former a little broader. Clean these two parts, and scrape them with a graver so that they are quite clean. Rub both with rosin, put one on the other, and fix them together with a piece of wood which you put into the screw hole. For greater solidity, bind them with wire, and put on the junction of the plate and the potence two small pieces of tin solder. Place the potence on a bluing pan and heat it by the flame of a candle until the solder runs. The plate soldered, let it cool, plant the hole in the heel of the potence, make the contour, and file

the heel in the shape of a lens, as I have said in N°. 340. Remove the spindle wood which you put in the screw hole to fix the plate, and to prevent solder from entering it.

If you have to replace the heel of a potence which does not have a steel plate, bore a hole in the brass plate and another in the potence, and drive in a pin which will fix the plate on the potence to which you must solder it, and which will give it more solidity. Observe that it is necessary to take the precaution of keeping the brass plate a little broader than the top of the potence, so that if this plate moves a little when soldering it, you can then file it to the contour of the potence. This small space will also be used to put solder on it; you will file it when the two part are soldered.



Chapter V: Method of Equalizing the Verge Escape Wheel and of Repairing its Pivots.

Method of Equalizing the Verge Escape Wheel.

N°. 365. The regularity of the vibrations depends much on the exactness of the division of the verge escape wheel; one cannot take too much care to ensure the equality of its teeth. This wheel is the rock on which many workers founder, especially those who have little experience and who believe that one cannot disassemble a watch without being obliged to touch it. They then resort to the ordinary échantillon, Pl. 3, Fig. 9,⁶⁴ an unsure tool, and difficult to use to find the true division of a wheel. It often happens that after making a turn of a wheel by measuring the space between each tooth, one finds the last a little broader or a little narrower than the others, and then, wanting to improve it, one spoils the part instead of mending it. The smaller the wheel is, the more difficult is this repair, and one should make use of this tool only after having carefully measured all the teeth on the circumference, and closely examined those which are unequal. It was used in the past for all watches that needed repair, because the wheel cutting machine for verge escape wheels was not known. But it cuts them with such a great precision that it is unnecessary to equalize them, so it is only a matter of preserving them in their original state.

Scrupulously examine if the verge escape wheel has some distorted or blunted teeth, and see whether it is true and centered.

A wheel which is not true will strike the pallets more or less, give unequal vibrations and cause the watch to vary. One must regard the two pallets of the verge as two levers, which the teeth of the verge scape wheel operate alternately. To make the vibrations equal, it is necessary to turn the verge escape wheel to make its teeth of equal length. If the verge escape wheel is not placed horizontally, the escapement will have the same defect; because the teeth of the verge escape wheel, entering the pallets of the verge more or less, will give more or less large vibrations.

⁶⁴ Tooth equaliser. A better illustration appears in Diderot and d’Alambert *Encyclopedie ou Dictionnaire Raisonne des Sciences, des Arts et des Metiers* which is reproduced in Crespe *Essay on Repeater Watches*.

To repair the verge escape wheel, turn it lightly true and round. Use a rounding-up file which is thin and has an extremely fine cutting edge. Place it on the flat of the teeth, while rolling the file so that you remove their sharp edges; their fronts will become round like a pin, and the friction of the wheel on the pallets will be softer.

If, after turning the verge escape wheel, the backs of its teeth are not recessed enough to let the pallets of the verge pass freely, file it with a verge escape wheel file. If the points are not acute enough, file them so that they no longer have this defect, but do not forget to leave a tiny, almost unperceivable flat on their points. You will finish your work by filing the end of each tooth with an extremely fine rounding-up file. By repairing the verge escape wheel this way, you are assured that all the teeth will be of equal length.

To thin and file the verge escape wheel, hold it with the first fingers of the left hand, which, while pressing it on a filing block, will by its movement enable you to file it flat and sharp with the right hand. Remove the sharp edges and the burrs, put the wheel on the turns, and pass a smoothing stone coated with oil over it.

To shorten a Pivot of the Verge Escape Wheel, when it touches the body of the Verge.

366. Let us suppose that the pivot of the verge scape wheel exceeds its teeth, or that the body of the verge touches the pivot of the verge scape wheel because of its size. This defect, which not only slows down the movement of the watch but also causes it to vary, can be corrected only by remaking the wheel, or by shortening the pivot. For the latter operation, you will take a piece of steel which you will bore with a drill the size of the pivot shank of the verge escape wheel. Put a little emery in this hole, and turn the pivot shank in the hole with a bow, as if you wanted to bore it. The emery will grind off the end of the pivot, and it will shorten rather quickly. It is the way to avoid remaking a verge escape wheel, and sometimes its pinion.

Method of Filing and Polishing the Pivot inside the Verge Escape Wheel without unriveting it.

367. Sometimes it happens that this pivot is corroded by rust; in this case it is necessary to file it and polish it in the following way. Make a square graver smaller than the interior of the wheel and use a razor to cut the edge of this tool; guide the razor on the cutting edge by a finger nail, which you will withdraw equal distances, as best as you can, for each cut of the razor that you give it. The square graver cut in one direction, you will cross-cut the edge in the opposite direction. After hardening it, make a polishing file of the same form, and finish it on an emery plate like a burnisher, N°. 118.

These two tools will be used, the first to remove the marks on the pivot, and the second to polish it on the pivot runners.

Chapter VI: Various Faults and the Ways to Correct them.

Method of Adjusting the Teeth of Large and Full Pinions.

N°. 368. If a wheel gears with a pinion that is a little large and full, and the teeth of the wheel are fuller than empty, use an equalling file to make them thinner, and round the teeth a little at their peaks.

If the pinion is too large and one cannot form a good gearing, remake the pinion, or turn it to size, and round it again. That requires much work because, the pinion being hardened, it is difficult to file it as necessary and to give it a good form. Thus this operation must be done with great care.

To smooth and polish it, use the ordinary method, N°. 172. If some circumstance prevents you from using it, do it in the following way.

I suppose that you have put a ferrule on the stem of the third wheel and put it in the turns. Rotate your part with a bow in one hand. In the other hand take a piece of softened spring, filed square at its end. Press this spring on the headstock of the turns, and make the

end of this blade, coated with oil stone, enter the leaves of the pinion, so that while moving the bow back and forth, spring follows the leaves of the pinion in all directions. The mutual friction of these two parts will remove the marks on the pinion. When the pinion is smoothed, clean it with bread crumbs, take putty to polish it, and repeat the same operation. This method of smoothing and polishing works rather well.

To Make a Barrel turn true and to Bush the two Holes.

368. It is necessary to turn a well hammer-hardened collet, enlarge the hole in the barrel, make the collet enter it exactly, and rivet it well.

If the barrel does not turn true, put it exact and free on its arbor, place it in the turns and, while turning it with one hand, make a light mark on its lid with the other. Separate the lid from the barrel, forge it on the side which the graver has marked, and file the opposite side a little bevel. If, after this attempt, the barrel is not true, repeat this operation until you succeed.

Method of Repairing a Barrel Arbor which is too Small.

369. The size of this arbor must be proportioned to that of the barrel. To determine the size, measure the diameter of the interior of the barrel, and divide it into three equal parts; one of these divisions will give you the size of the arbor. It often happens that the mainspring breaks when the arbor is smaller than this proportion. If, when repairing, you find an arbor which has this defect, bore and turn a collet, whose size is one the third of the diameter of the barrel. Force it onto the arbor, bore a hole in it and put in a hook to hold the eye of the mainspring. This collet is called, in watchmaking terms, a jacket.

The Number of Teeth of the Wheel for the Endless Screw.

371. When you have to make a wheel for the endless screw, make a square hole which enters exactly on the arbor of the barrel. After turning the wheel to size, place it on the arbor, put it in the frame without pinning plates and, while with one hand you hold the two plates together very tightly, turn the endless screw with the other, until the wheel has made a turn. Count the number of marks which the endless screw has made, and give the wheel two teeth less. By following this method, it will give you the agreement necessary to form the gearing of this wheel with the endless screw.⁶⁵

Method of Preventing the Chain from slipping under the Barrel.

372. If the barrel is inclined, turn it cylindrical. This defect is also corrected by putting a brass stud on the plate between the barrel and the first wheel, opposite the point where the chain finishes developing. It is necessary to make the stud the height of the barrel. The chain thus supported, it will no longer be likely to slip under the barrel.

Stoppages by the Finger.⁶⁶

373. Pinions which are large interfere so much with the forces that they often cause stoppages by the finger. Bad gearing can also cause this defect. When you find similar stoppages, remake the pinions which are large, or reform the gearing.

There is another type of stoppage by the finger; it is that which happens when, after winding a watch, it does not start itself running. In this case, make a chain guard spring, and a screw and a steady pin to fix the spring to the plate at the point A, Pl. 6, Fig. 3. Bore the hole and file it oval. Place it on a round post screwed in the plate, so that when the beak of the fusee stops on the point C of the chain guard, the spring, compressed by its elastic force, will react against the fusee and the balance will start moving again.

The Chain Guard.

374. It often happens that the chain guard slips under the beak of the fusee instead of stopping it. To fix this, made a notch in the end of the chain guard with the angle of a crossing out file. The beak of the fusee is stopped by this notch and held there, and will no longer slip.

⁶⁵ The wheel is deliberately given the wrong number of teeth so that the wheel and the endless screw mesh with great friction. Consequently the wheel (and the barrel arbor) cannot rotate unless turned by a key.

⁶⁶ See the vocabulary.

The Counter-Potence.

375. The stud or pillar, which used to be made to support the pivot of the long stem of the verge scape wheel, is prone to various accidents. If it thin, split or cracked, the pivot carrier can no longer hold to it with friction. These defects can disturb the escapement in the event of the drops, break the verge escape wheel, or disturb the pivot carrier. Correct them by filing the stud flush with the plate and make a small counter-potence, which you will fix on the plate with a screw and a steady pin. You should do that when there is a stud; the counter-potence will be more solid, and you will not degrade the plate.

Means of giving friction to a loose Canon Pinion.

376. There are workmen who, to give friction to a canon pinion which is loose on the stem of the center wheel, introduce into the canon one or two hairs. This method is rather good. It is better, however, to heat the stem in the flame of a candle and coat it with half white, half yellow wax.

That is enough to give to the canon pinion a soft and permanent friction. If the wax forms a drop on the end of the pinion of the canon pinion, take care to remove it before pinning the stem.

The necessity for pinning the Canon Pinion on the Center Pinion.

377. When one neglects to pin the canon pinion on the stem of the center pinion, it is to risk the canon pinion becoming loose; then it is not moved by the train and the hands stop. Besides, it can, by leaving its place, obstruct the hour wheel to the point of stopping the movement, or let the intermediate wheel pass under the pinion. These defects are cured by pinning the canon pinion. When there is no hole in the stem of the center pinion, never fail to make one, and always pin the canon pinion with it.

When the stem of the center pinion is too short, so that one cannot pin the canon pinion, notch the canon on two sides so that this part forms a spring. Then put the stem in the turns and decrease it a little in the middle. After hitting the canon of the canon pinion with a hammer to make it spring, set it up. By this method it will hold with friction, much as if it were pinned onto its stem.

How to Solder a Cock.

378. Many workmen solder this part with tin. This solder is neither solid, nor pleasant to the eye. It is better to solder with silver, and here is how to do it. Take a coal and file it flat. Attach the cock with brass wire, place on each broken part a small piece of third solder and a little borax crushed with water, and heat the part with a blow-pipe until the solder runs.

The part soldered, remove the borax by plunging it into second water; second water is just one third nitric acid mixed with two thirds common water, in which the part is boiled to scour it. Also use this method to solder gold hands.

Screws whose Threads are worn.

379. If you find screws which turn endlessly, it is necessary to do something other than to make them useable by striking them with a hammer. This method is bad; the threads of a screw thus crushed wear rapidly, and spoil the plate. Resort to this method only in a pressing case, when you do not have time to remake the screw. To make it less bad, after having struck the end of the screw with a hammer pass it through the screw plate.

Method of Tin Soldering the Seat of a Verge.

380. When the verge of a balance wavers on its seat, separate them, clean the hole, and scrape the verge with the side of a graver. Dampen a little sulphate of ammonia with water, put one drop of it in the hole of the seat, and rub the stem of the verge where it will be soldered. Put the verge in its seat, and place a small piece of tin solder between the seat and the back of the pallet. Take a piece of copper about the size of a writing quill and file the end in a bevel. Then heat this tool with a blow-pipe, and rest it on the seat. The heat having melted the solder, the verge will be soldered to its seat. If this operation did not succeed, repeat it until the part is soldered.

The Ends of the Pivots of the Verge and the Holes which are Formed in the Steel Plates.

381. Long use blunts the pivots of a verge, especially if care is not taken to renew the oil there. The ends become square and make holes in the steel plates which support them, which causes variations, lessens the vibrations, and sometimes causes stoppages.

Every time you disassemble a watch, examine whether it has this defect. If it does, round and polish the ends of the pivots on a pivot runner, so that they do not scrape on a finger nail, and erase the holes which they formed in their plates with oil stone. The movement will then have much more freedom.

Oil Sinks to hold Oil on the Plates.

382. When you find watches which do not have oil sinks you will make them. They are necessary to hold the oil which ensures the pivots do not rust, prevents the holes enlarging and reduces friction. These oil sinks are made with a countersink tool with a round head, with which one countersinks the holes until the ends of the pivots start to appear. If you have a set of cutters, use them; the work will be better done, and you will be sure to make the recess in the middle of the hole which you want to countersink.⁶⁷

Method of Opening and Closing the Verge.

383. For this operation, it is necessary to twist the body of the verge. To succeed, use a wax candle whose wick has only one or two threads. After lighting it and fixing it in the vice, put one drop of oil on the body of the verge. Take the balance in one hand, and hold the small pallet with pincers in the other. Heat the body in the flame of the candle, and when the oil boils turn the small pallet to the left to open it, and to the right if you want to close it. Remove it from the flame, and hold it in the same position until it is cold. If the first attempt does not succeed, repeat the same operation until the verge is opened or closed as much as desired.

Notched Verges.

384. When you find verges whose pallets are notched by the teeth of the verge escape wheel, correct this defect by smoothing and polishing the pallets of the verge; see N°. 327 and 328. Then round the front of the teeth of the verge escape wheel, as in N°. 316. By following this method, you will be sure that the verge escape wheel will not have as much friction on the pallets of the verge, and also that the verge will not be prone to being notched.

This defect usually comes from the bad quality of the brass which was used to make the verge escape wheel, or the great friction of this wheel on the pallets of the verge. Also it often comes from oil running onto the pallets of the verge which communicates it to the verge escape wheel. This collects various atoms which fall into the watch, and these atoms join with the oil to form, by the various frictions of these two mobiles, a type of emery which notches the pallets of the verge. It is another proof of the need to make oil sinks in the heel of the potence as well the coqueret. See N°. 340. Indeed, they make these accidents much rarer.

Method of Repairing a Verge whose Pallets are Notched.

385. It often happens that the verge escape wheel, by making hollows in the pallets of the verge, decreases the vibrations of the balance and produces variations. Remove these hollows with oil stone; see the method for smoothing the pallets of the verge N°. 327. Then round the front of the teeth of the verge scape wheel, as in N°. 316. By giving them a round form, they will have a friction light enough to no longer form hollows in the pallets of the verge.

Balances which Beat and Overbank at the same time.

386. This defect embarrasses many workers; however it is easy to correct. It comes from the escape wheel not being placed horizontally on the plate, so that it takes more on one pallet than the other. By the pallet on which it takes more, it makes make a beat of balance; by that on which it acts less, it causes overbanking. You will correct these two defects by putting the verge escape wheel in a horizontal position by means of the domestic bird, N°. 309.

⁶⁷ I presume this is the tool shown in Pl. 12, Fig. 4.

The Pallets.

387. When you have a watch to disassemble, never neglect to examine the pallets of the verge, to be sure that they are of equal width. For that use the calibre compass and measure them carefully. If one is broader than the other, correct this defect. Remake the bevel, and smooth and polish the edge with oil stone and putty.

One often meets this inequality of the pallets when repairing, because lazy workmen or ignoramuses, to safeguard against butting, file the pallet on which the verge escape wheel butts. They get the watch to run, but they make the two levers of the verge unequal, and the verge escape wheel, operating sometimes on a broad pallet and sometimes on a narrow, makes the balance describe arcs of a circle more or less extended, which necessarily produces variations.

When you find butting, carefully inspect the holes of the verge, bush those which are too large, and examine the nose of the plug of the potence. If a burr has formed on the ends of the teeth of the verge escape wheel, remove it on the turns, and finish the verge escape wheel. See N°. 316.

Various Stoppages caused by the Chain.

388. The chain is the cause of several stoppages. If it is too large, it easily slips off its steps and is twisted on the fusee. If the links are too wide, it can touch the pillar which is between the barrel and the fusee, the back of the potence, or the stem of the center pinion. To correct these defects, choose a narrower chain and, if the case requires it, file the pillars or the back of the potence. If the stem of the center pinion is too large, reduce it on the turns.

Sometimes, to avoid these various frictions, the two holes for the barrel are bushed, moving it back on the side opposite the defect, which is corrected by this operation alone.

To Repair the Chain.

389. If the chain is broken, it is necessary to separate the two links from one broken end to remove the link in the middle of it. On the other end, it is necessary to remove the two external links and leave only the middle one, to then place it between the two links which were left on the other part of the chain. Pin these three links together, cut the pin on both sides, file it and rivet it with some hammer blows. A chain thus repaired will last as long as a new one. To take the pin out of the links of a chain, use a riveting clamp which you will fix in the vice. This tool is used so that it embraces the thickness of the chain. and a small punch is put on the pin to push it out with a hammer blow.

One can successfully use small screw pincers for the repair, which one puts in the jaws of the vice. After fixing the chain in it, leaving half of the link out of the jaw of the screw pincers, take a penknife and put the blade between the links, and with a hammer blow the blade is inserted, so that by drawing aside the link the pin is broken. This method is very convenient, especially when the chain is hardened too much; one is less likely to break several links, and consequently to shorten it to the point where it cannot be used.

Defects of Mainsprings.

390. When a mainspring has broken, do not waste your time repairing it, either by pinning the blades to each other or by tying them. A watch whose mainspring is thus repaired cannot have a uniform motion, because it is not possible to do this without forming considerable friction, and without the mainspring losing much of its elasticity. You should not hesitate to change it. However, if the spring is broken at its external end, it is sufficient to remake the eye there.

Whenever you change a mainspring do not forget to equalize it with the fusee, and to make the reference mark on the barrel arbor and the plate, No 299.

Agreement of the Turns of the Mainspring with those of the Chain.

391. To determine the number of turns that the mainspring makes, hang the chain from the hole in the barrel, roll it on this mobile and count the number of turns that it makes.

I suppose that the chain makes four turns on the barrel. It is necessary that the entirely wound up mainspring makes five and a half turns in the barrel. To determine the turns that the mainspring makes in the barrel, grip its arbor by the square with sliding ring pincers, that you will hold in one hand, and with the other tighten the barrel until it cannot move. Turn

the pincers to the left to wind the spring until the resistance which you feel, when the pincers can no longer turn, announces that spring is completely wound. Make a mark with the pincers, release them so that they turn gently in the hand, and count the turns which the spring makes.

The general rule is that when the chain makes four turns on the barrel it is necessary that the mainspring makes five and a half turns in the pincers. When put in and the chain mounted, the spring is set up three quarters of a turn. Thus there will remain three quarters of a turn of the spring which is not bent. This is necessary so that the mainspring is not likely to break at any moment.

And as in Province one cannot always get springs such as one wants, if it is found that a spring makes only one turn more in the barrel than the chain makes on the barrel, be satisfied to set up the spring half a turn, so that there remains another half a turn which will not be bent.

Method of Weakening a Balance Spring.

393. Take a glass plate, from five to six inches square, on which you will put a little Turkey stone dampened with oil. Put the spring on it and, while lightly pressing on it with a cork, move it in a circular motion. This is the way to make the spring as weak as you want it. To set up and to choose a balance spring, see No 277.

You can also use the above method to smooth and polish various steel parts, and to make them quite flat.

394. To avoid useless repetition, I warn my readers that when I speak about the defects in a part and I do not indicate the manner of correcting them, they must have recourse to what I have said on each part in the various articles in this work, and especially in finishing.

Chapter VII: Finishing the Watch.

N°. 395. After disassembling the watch, examine whether the gearing of the first wheel is good. If it is weak, rebush the hole to strengthen it. Enlarge the hole with a rat tail file, and move it towards the center. Then make a bush that you will turn on an arbor and, after driving it into this hole with force, rivet it on the side of the motion-work. If the gearing is too strong, enlarge the hole with a rat tail file, filing it towards the circumference of the plate, and bush it same manner. If you have made the wheel lean to one side or the other, bush the hole in the fusee bridge to put it as true as you can. For this, after plugging the hole, use the uprighing tool, enlarge the hole with a broach, and put the part free in the frame.

You will then put the center wheel, the first wheel and the barrel in the frame, and examine whether these first three mobiles have well distributed spaces. If you fear some friction, you will distribute spaces according to the circumstances. If there is not enough space on one side and too much on the other, raise or lower the barrel, to give these parts equal space. If, on the contrary, there is not enough and the barrel is too thick, see whether you can decrease the thickness of its base, by inspecting it with the figure eight calliper. If the lid is too thick, use a screw arbor to make it thinner. Also turn the snap of the barrel on the screw arbor, so that it is flush with its lid, and after smoothing these two parts, polish them.

If the center wheel rubs on the plate, and there is no recess, you can make one by placing the plate on a screw arbor. For this, make a square graver whose hook is rather long so that the pillars cannot touch it A, Fig. 3, Pl. 3. The recess made, you will be able to lower the center wheel and give it all the space necessary.

There are cases where you will be able to give space to the first wheel by lowering it a little, or by decreasing its thickness. If, however, you cannot do this, and all the parts of the watch are laid out so that you cannot give space to the barrel, make a recess in the top plate like that of the center wheel; this recess is also made with the screw arbor, and must be the size of the barrel. Make it flat and well smoothed. File the screws which protrude above the plate, round and polish the ends, and finish them in the screw plate so that their burrs does not wear the threads in the plate. If none of these methods can work, make another barrel.

When you give space to this part, check whether it turns exactly and centered on its arbor. It is necessary that the blade of the mainspring is a little narrower than the depth of the barrel. If it is too narrow, not only will the spring not have an elasticity proportional to the height of the barrel, but also its blades will have too much freedom between the lid and the bottom of the barrel, so that over time their elasticity will not act on the train in a uniform way. If it is too wide, the blades will be constrained between the lid and the barrel. In these two cases it is necessary to choose a spring whose blade is proportional to the depth of the barrel and according to the good or bad construction of the watch.

A work well finished requires a soft and pliant spring. A coarsely made watch requires an active and strong spring, so that it can drive the train more easily, and overcome the resistance of friction. Examine whether the lid and the bottom of the barrel are level, flat and without marks.

The First Wheel.

396. Put the first wheel true and free in the frame. Note that one never puts a part true and free in the frame without pinning the plates.

See if the collet of the fusee is true, if it holds the first wheel against the fusee with friction, if the click is good, if it is constrained or too free, if the spring of click-and-ratchet work is well made, if it is elastic without being too large. Correct the various defects which you find in these parts.

Clean the holes of the first wheel and put it in the frame. Set up the mainspring, giving it three quarters of a turn, and mark the reference mark on the plate so that you can tighten the mainspring to the same point every time you set up the train. Equalize the spring with the fusee. See N°. 259.

If the beak of the fusee touches the top plate and you cannot give it space, make a recess in the plate the size of the beak, as in the article above. Then you will no longer have to worry about friction.

The Center Wheel.

397. When this wheel does not turn centered and true, the pivots are not cylindrical and polished, and it is not true in the frame, correct these defects by rebushing the holes and reforming the pivots. Put the wheel in the frame. If, when turning it, you think that it touches the plate, make its recess deeper, or make one if there is none. For this repair one uses the screw arbor, on which the plate is fixed. If the center wheel does not turn true, strike the riveting on the side where it could rub, or straighten it by means of the arms. When the wheel is not round, turn its circumference, then round the teeth, and examine its gearing, remaking it if it is not good.

The Third Wheel.

398. If the pinion of this wheel is large, turn it and round it. Inspect its two pivots and make them polished and cylindrical if they are not. Form its gearing with the pinion of the contrate wheel. Bush the holes which are too large. See if there is any danger of it touching the beak of the fusee, the angle of the rim of the verge escape wheel, or its stem. Take the greatest care to make these parts safe from any friction and put them, one after the other, free in the frame.

The Verge Escape Wheel.

399. This wheel must be placed horizontally on the plate; if it is not it, use the domestic bird to make it true. It must turn true and centered. It should not be distorted nor blunted. After having repaired the wheel as in N°. 316, it is necessary to rebush the holes, if the case requires it, and then put the part in place true and free.

The Verge.

400. Examine whether the body of the verge runs smoothly, if the pallets are of equal width, if they are too open or too closed, if the pivots are round, cylindrical and polished, if the balance turns true and centered, and if it is the right weight. Then see if the balance spring collet can touch the verge escape wheel or the plate, if the friction of the collet is quite strong so that it is not likely to fall off or to put the watch out of beat. If the balance holes are too large they should be rebushed. Then see if the balance, when in place, has badly distributed

spaces. If, by its position, it can rub on the cock, the slide or the stud of balance spring, and if the overbanking pin is likely to touch the barrette of the contrate wheel. Use suitable methods to avoid these problems.

Give detailed attention to the drops of the verge escape wheel, if they are too small or unequal, see N°. 316 and 333.

The Motion-Work.

401. Inspect the motion-work to see if it is well laid out, if the canon pinion fits well on its stem, if it is pinned on, if its pinion gears well with the intermediate wheel, and if the pinion of that wheel gears well with the hour wheel. Make sure that the canon of the hour wheel is not too free or too tight, and that it does not have too much or not enough play under the dial. See if the hands are adjusted so that they cannot rub against each other and they cannot touch the square of the fusee. The watch having been examined carefully, clean it after correcting these various defects.

Chapter VIII: Method of Cleaning the Teeth of the Wheels, and of Repolishing the Fusee and other Parts.

No 402. Take a quarter of a hank of thread and soak it with rotten-stone dampened in water. Attach one end of this thread to the jaws of the vice and hold it tight with one hand while, with the other hand, you rub the fusee on this thread until it regains its polish, and its original gloss.

Take another bundle of thread, put on it a little dry Spanish whiting, and rub the fusee.

Use the same method to clean all the teeth of the wheels, which you rub lightly on the thread not to risk them breaking; they will regain their polish.

The teeth of the contrate wheel are cleaned in the same way. As for the rim, put a little rotten-stone on the second finger of the right hand and rub the wheel until it regains its polish. Polish and clean the verge scape wheel on the turns with spindle wood coated with wet rotten-stone.

Plates are degreased and the gilding revived using a small brush with two or three rows of hair and which is a little hard. Put Spanish whiting on this brush and then rub it on an ecu until no more Spanish whiting comes out. That done, rub the plate until it regains its gloss. If you put too much Spanish whiting on the brush and you do not take care to rub it off before you use it, you will clean the watch badly. While rubbing the brush on the plates, hold them in one hand with a cloth so as not to tarnish them.

Brush all the wheels and all the pinions, so that they are quite clean, introduce points of spindle wood into all the holes to remove the dirty oil, clean all the recesses, degrease the mainspring, and renew the oil. After cleaning the mainspring, put one drop of oil at each pivot hole of the verge escape wheel, and at the heel of the potence. If you do not want your watch to get full of dust, assemble it promptly.

Never use old cloths to clean the parts of a watch. When you assemble it, do not touch any part with the fingers; hold the plates with a cloth or a movement holder. The movement assembled, put one drop of oil in each of the pivot holes, to smooth their movement and to keep them safe from rust.



Chapter IX: The Development of the Watch and the Functions of the Train.⁶⁸

N°. 403. The frame is made up of two plates, Pl. 7, Fig. 1 and 2, and four pillars, Pl. 8, Fig. 36. When these pillars are riveted to the pillar plate, and the top plate is pinned on, there is between them a distance proportional to the height of the watch which one wants to make. It is in this space that the mobiles and the various parts of the movement are placed. It is necessary that the train is laid out so that its spaces are well distributed and none of its parts can rub against each other. This defect would cause the watch to stop or vary.

The pillar plate, Pl. 7, Fig. 1, has the head of the dial spring *G*, which is placed so that when one closes the watch in its case, the head is pushed by the spring 6, Pl. 7, Fig. 4, which enters a filet purposely made in the case to receive it. The movement is thus fixed, so that it can neither shake nor leave place, unless one pushes the head of the dial spring with a finger.

The barrette, Pl. 7, Fig. 10, is fixed on the side of the motion-work by two steady pins and a screw, which holds it firmly fixed to the plate. The barrettes enables the stems of the wheels to be as long as possible, and prevent them rubbing on any other part at any time.

The barrel, Pl. 8, Fig. 1, has a collar and a bottom (which are usually made of a single piece) that is recessed with a square graver. It is composed of a lid, an arbor, a click, a ratchet, a mainspring and a bridle.

The lid, Pl. 8, Fig. 2, enters the snap of the barrel with force. When these two parts are well fitted they form a drum, which leaves a large enough space between the lid and the bottom to hold the mainspring and the arbor of the barrel.

The mainspring, Fig. 7, is placed in the barrel in the shape of a balance spring. When this spring is wound, all its blades wrap around the arbor of the barrel, and act by their elastic force until they again take their original position on the outside of the barrel.

It often happens that the external eye of the mainspring unhooks from the barrel. This problem is overcome by making a bridle, Fig. 4, which, placed between the first two blades of the mainspring, is held by its shoulder *A* in the hole *B* of the barrel, and by its shoulder *B* in the notch *C* in the lid, Fig. 2. The bridle fixed, it holds the last blade of the mainspring against the hook of the barrel, so that the external eye of the mainspring cannot be unhooked.

The barrel arbor, Pl. 8, Fig. 3, has a square *B*, which protrudes above the plate about two lignes on the side of the motion-work, so that a ratchet can be put there by means of a square hole in the center of the ratchet, and when the arbor is turned this ratchet follows the movement.

The arbor of the barrel, Pl. 8, Fig. 3, has several shoulders. When it is finished, the end *B* exactly enters the hole *A* in the barrel, until it rests on the boss *A*, which is in the center of the barrel, Fig. 5. The center *B* of the lid is then put on the other end of the arbor, and is pressed until it enters the snap with force, so that, when these three parts are well adjusted, the barrel turns true and centered on its arbor. When the two pivots *A* and *B* are placed in the two holes of the plates, the barrel is supported there, so that it cannot touch the plates or any other part while turning on its arbor.

The small hook *D*, which is in the middle of the arbor, Fig. 3, holds the eye in the center of the mainspring. A hook *C* is made in the wall of the barrel, Fig. 5 to hold the external eye of the mainspring.

The click, Fig. 38, is fixed at end *B* to the pillar plate by a screw which allows it free movement; so that when one turns the square of the barrel arbor one way with pincers, to set up the mainspring, the click skips over the teeth of the ratchet, but prevents the arbor from turning the opposite way. These two parts are used to tighten or relax the mainspring, or to hold it fixed at the same point of tightening.

If you examine the end *A* of the barrel arbor, which enters the top plate, you will see a notch formed by a file stroke, and you will also see, close to the hole which receives the pivot, a small notch or a point which forms a reference mark; so that when the mainspring is set up

⁶⁸ This chapter should be at the beginning of the book.

and equalized with the fusee, one is sure that by setting the two reference marks opposite each other, the mainspring will always be set up to the same point of tightening.

The beak, Fig. 14, is fixed by a screw to the part *H*, Fig. 11, of the fusee, to stop the hand when the watch is sufficiently wound. The last step of the fusee has a small notch, in the middle of which is a pin which receives the hook of the chain.

The first wheel is made up of an arbor, a fusee, a beak, a toothed wheel, a click-and-ratchet work spring, a click, a brass collet, a recess and a steel collet.

The arbor, Fig. 9, is made so that the fusee can be soldered to it. It is in the shape of a truncated cone on which are steps in a spiral line, so that when the mainspring is wound and the chain winds onto the steps of the fusee, the fusee compensates for the force of the mainspring by its various levers. The arbor has two pivots *F* and *D*, one of which enters the pillar plate, and the other the top plate. These two pivots are made so that, when the fusee is fixed on the first wheel, this part is free in the frame and cannot rub on the plates or any other mobile.

The first wheel, Fig. 12, is turned round and of equal thickness. This part has a boss *L* which protrudes from the wheel on the side where it lies against the fusee. Part *I* is recessed with a square graver, so that the spring of the click-and-ratchet work and the click can be placed there. These two well fitted parts must be flush with the wheel, so that the spring *A*, Fig. 10, which is cut in the base of the fusee, can act on the click. If the whole is well adjusted, by turning the square of the fusee one way, the click pushed by its spring will enter the teeth of the ratchet, and will prevent the fusee from turning the opposite way. When the first wheel is fixed to the fusee, it is held by the collet *O*, Fig. 13, that is placed with force on the arbor of the fusee. This collet holds the first wheel against the fusee with friction, and does not prevent the watch being wound. The first wheel meshes with the center pinion.

The center wheel, Fig. 15, is made up of a wheel and a pinion. When this wheel is well riveted onto its pinion, these two parts seem to be a single body. This pinion has two stems *A* and *B*; stem *A* is used to put the wheel in the frame, which must be free and true on the two pivots *A* and *G*, and turn without rubbing on the plate or any other part. The long stem *B* receives the canon pinion, which is fixed with friction on this stem. A hole is bored at the end of the stem *B* for a pin which always holds the canon pinion in the same place. The center wheel meshes with the pinion of the third wheel.

The third wheel is made up of a pinion, a seat, and a wheel. The wheel is usually crossed with three arms. It is riveted onto its seat, so that when the two pivots *A* and *B*, Fig. 18, are finished and the part is in the frame, the wheel turns true and centered and cannot rub or touch any part of the watch. This wheel meshes with the pinion of the contrate wheel.

The contrate wheel, Fig. 21, is also made up of a pinion, Fig. 24, a seat *C*, and a wheel, Fig. 22, which is in the shape of a crown so that it can mesh with the pinion of the verge escape wheel, which is placed horizontally on the top plate. The pinion of the contrate wheel has two pivots *A* and *B*. When this part is in the frame, it must be about in the middle of the two plates, quite true in any direction, and turn freely without touching any other part of the train. This wheel, by meshing with the pinion of the verge escape wheel, moves it.

The verge escape wheel, Fig. 25, is also in the shape of a crown; see Fig. 26. It is fitted on and riveted to its pinion so that the two parts seem to be only one. The pinion has two pivots, one of which enters the hole in the nose of the potence *P*, Pl. 7, Fig. 2, and the other in the pivot carrier *E* of the counter-potence, the same figure. The potence *P*, Fig. 2, is of well hammer-hardened brass, and is made so that there is a notch with dovetail on the front; see Pl. 9, Fig. 9. This notch receives the plug *A*, Pl. 9, Fig. 10, which has the shape of the dovetail in the potence, and which enters the notch *B* in the potence exactly, free and with friction. This plug carries the nose *F* of the potence in which is bored a hole to support the pivot at the front of the verge escape wheel, at the end *P* of the potence, Pl. 7, Fig. 2, opposite to the nose of the plug. There is a screw which enters the end *D*, Pl. 7, Fig. 2. This screw has a round steel head which exactly enters a notch in the plug; so that by turning this screw, the plug moves in its notch, and enables the drops of the escapement to be made equal. When the escapement is made, one fixes the plug to the potence with its screw.

The steel plate, Pl. 9, Fig. 8, has the shape of the top of the potence; it is fixed there by the screw *H*. The end *B* of this plate supports the end of the pivot of the verge. The small steel blade *P*, which is at the other end and which protrudes from the potence, enables the plate to

be turned when one wants to clean the hole in the heel or bush it. The potence is fixed to the top plate by two steady pins and a screw.

The counter-potence *E*, Pl. 7, Fig. 2, is fixed to the plate by a screw *I*. It has a pivot carrier which rises from the plate about the height of the nose *D* of the potence. This pivot carrier has a steel plate against which the pivot of the stem of the verge escape wheel must rest. This plate has two screws, one of which is fixed against the pivot carrier, and the other is used for approaching or moving away the escapement.

To understand the positions of the potence and the counter-potence, see Pl. 7, Fig. 2. The verge escape wheel is placed horizontally on the plate, and is laid out so that it has free movement on its two pivots and does not touch any other part. This wheel is split in an odd number, so that when it drives the balance, it can, while being released from one pallet, meet the other, and give a continuity of vibrations, until the mainspring ceases acting on the train.

The top of the watch is composed of a barrette, part of the counter-potence, the fusee cock, the slide, the rack of the rosette wheel, the rosette, and the cock under which balance is placed and which is fixed by two screws. To more easily understand the functions of these various parts, see Pl. 9 and Pl. 10.

The barrette *Q* of the contrate wheel, Pl. 9, Fig. 1, is fixed on the plate by a screw and two steady pins, so that it cannot move from its place and so that the gearing with the third wheel and the pinion of the verge escape wheel are always the same. I have already stated the reasons which determine the positions of the barrettes on the plates.

Part *I* of the counter-potence fixes this part onto the plate by means of a screw. If you disassemble this part, you will see at the point *L* a small steady pin, which, by entering the plate, fixes the counter-potence so that when the screw tightens this part, it can no longer move. Without this precaution, the least accident to the counter-potence would disturb the escapement.

The fusee cock, Fig. 13, has a hole which receives the pivot of the fusee; this cock is fixed on the top plate with two steady pins and a screw. The slide *A*, Figs. 1 and 2, is fixed onto the top plate by two screws placed in the holes *C*, *C* of the ears of the slide. Before tightening these two screws, the rack *A*, Fig. 4, is put under the slide *A*, Fig. 1; the rack is encased in the thickness of the slide so that they seem to be a single part. The slide being fixed to the plate, the rack has a precise movement, so that it can be moved only by turning the hand of the rosette wheel.

The rosette wheel, Fig. 5, is placed at point *I*, under the rosette *B*, Fig. 3, which is fixed by the screw *F*. The teeth of this wheel pass under the slide, and mesh with teeth *A* of the rack, so that when the hand of the rosette is turned, the wheel meshes with the rack and moves it. The rack has a tail *B*, which has a slit which receives the outer blade of the balance spring.

The balance, Pl. 11, Fig. 5, is composed of a verge, a seat, a collet and a balance spring. The balance is a single piece; it has a circle on its circumference *B*, and a smaller one in its center joined by three arms *D*. When it is finished, it must be perfectly poised. Its weight controls its vibrations.

The verge has two pivots, one of which enters the heel of the potence and the other the hole in the coqueret. It has two pallets with which the verge escape wheel meshes to drive them alternately and to maintain the vibrations of the balance.

The seat is soldered onto the large pallet so that the balance can be riveted there. When these three parts are well made and well fitted, the balance, the pivots of the verge, its body, and the seat must be centered and true, as if the whole turned on the verge.

The balance spring collet, Pl. 8, Fig. 35, is fitted by friction on the seat of the verge; it rests against the balance. It is usually split, so that it is springy and its friction is weaker. It has a small hole to receive the inner end of the balance spring, which is fixed there with a pin. So that this spring functions well, it is placed on the collet so that it is quite true, and it does not rub on the balance or the plate.

The outer end of the balance spring is fixed to the stud *G*, Pl. 11, Fig. 6, by a pin, so that as the balance vibrates this spring, by its elasticity, speeds up the oscillations which are repeated faster or slower according to the weight of the balance and the force of balance spring. When one has a balance spring whose force is proportional with the construction of the movement, and when the watch is regulated, it is adjusted by the hand of the rosette. When this hand is turned to the side *A*, the notch *C* in the rack moves to the side *R*, p. 11, Fig.

6 and, by shortening the balance spring, speeds up the watch. Alternatively, if the hand of the rosette is turned to the side *R*, the fork, moving to the side of the stud *G*, lengthens the blade of the balance spring and consequently slows the watch.

The two ends of the rack, Pl. 9, Fig. 4, and part *A* of the rosette wheel, Fig. 5, do not have teeth, so that the rack stops and cannot leave the slide. Thus, while turning the hand of the rosette you will feel a resistance; do not force it or you might break the teeth of this wheel or those of the rack, and you could make the rack leave its place and stop the watch.

The cock, Pl. 10, Fig. 3, is of brass and the size of the balance; this part covers the balance to protect it from various accidents. The cock is fixed onto the plate by the two screws *C*, *C*; as it would be prone to shake a little, each ear has a steady pin which, entering with friction into the plate, gives it enough solidity. It is unlikely that the escapement will be disturbed when assembling or disassembling the cock.

The cock has two coquerets *D*, Pl. 10, Fig. 3; one is brass, and the other steel. The brass one receives the balance pivot; it is fixed onto the cock by two steady pins. The steel coqueret has a hole for a screw which fixes both coquerets onto the cock. The steel coqueret supports the end of the pivot of the verge.

When the balance is in place and the cock is fixed onto the plate by its two screws, the balance is supported on one side by the heel of the potence and on the other by the coqueret, as if in a frame independent from the rest of the movement, and the verge communicates with it by its two pallets, which mesh with the teeth of the verge scape wheel. The balance must be free in every direction, and it does not begin its vibrations until the train is set in motion.

The rim of the balance has a pin which protects it from overbanking, which would happen every time the balance described too large vibrations, or when it received some jolt. Then the banking pin strikes the ends of the slide and prevents this accident, which could blunt or break the teeth of the verge scape wheel.

The dial is usually made of enamel. It is divided into twelve equal parts. It is used to mark the hours and the minutes. It is held on the pillar plate by three feet that are pinned.

The dial work, which is also called motion-work, is placed between the dial and the pillar plate. The motion-work is made up of the canon pinion, the intermediate wheel, and the hour wheel.

The pinion of the canon pinion, Pl. 10, Fig. 2, is about half a ligne thick. It has a canon which is bored from one end to the other, which is used to put the canon pinion friction tight on the long stem of the center pinion. The part *B* of the canon is almost cylindrical, even and polished to receive the canon of the hour wheel, which must fit on it true and free. The part *C* of the canon is filed square to hold the minute hand. Pinion *A* meshes with the intermediate wheel and drives it.

The intermediate wheel is a wheel *A*, Fig. 6, which is riveted onto the pinion *B*. It has a hole in the center which is used to place this part on large plate, by means of a canon which enters a hole made purposely in the plate on which it turns true and free. One also fixes this wheel by a stud which is screwed into plate. This stud has a shoulder and a pivot shank which the canon of the intermediate wheel enters true and free. The pinion of this wheel meshes with the hour wheel.

The hour wheel *B*, Fig. 5, is riveted onto the canon *A*, which is bored so that it fits true and free on the canon *B* of the canon pinion. The canon of the hour wheel has two shoulders, one of which is used to hold this part under the dial, and the other holds the hour hand with friction.

Functions of the Movement.

404. Let us suppose that you have put the movement in the frame, Pl. 10, Fig. 1, that you have placed the chain on the barrel *A*, and that after hooking it, you tightened the mainspring three quarters of a turn. The chain is wrapped around the barrel and the train does not move. Turn the square of the fusee with a key, and in proportion to the winding of the watch, the chain will pass onto the steps of the fusee. After several turns you will feel a resistance which, by stopping your hand, informs you that the beak of the fusee rests against the chain guard and the watch is completely wound. The chain, while passing on to the fusee, has tightened the mainspring in proportion to the turns which it made on the barrel. Consequently, the mainspring makes an effort to be restored, until it has attracted onto the

barrel the same quantity of chain which was there before the watch was wound. Thus by its elastic force it turns the fusee *B*, to which the first wheel is fixed. The first wheel meshes with the center pinion and drives the center wheel *C*. The center wheel *C* meshes with the pinion of the third wheel *D*. The third wheel teeth communicate with the pinion of the contrate wheel *E*, and the contrate wheel with the pinion of the verge escape wheel *F*. This forms a succession of gears which communicate from one wheel to another. By this order and the effort which the mainspring makes to restore its original state, the chain which wraps around the fusee cannot return onto the barrel without making all the wheels move, and so the train runs until the mainspring has attracted the chain onto its barrel.

Let us also suppose that you put in the balance with its balance spring and you reassembled the watch. The train, which naturally wants to run, is intercepted by the pallets of the verge which hinder the passage of the verge escape wheel. The verge escape wheel operates the pallets of the verge, at the rate of the force which the mainspring communicates to it. This wheel, meeting a pallet of the verge which hinders to its passage, pushes it away and makes the balance describe a vibration. When the verge escape wheel is released from this first pallet, it meets the other, against which acts in the same way, and it moves the balance the opposite way and makes a second vibration. This reciprocating motion of the verge escape wheel on the balance, makes it describe a portion of circle, sometimes on one side, sometimes on the other, and maintains the vibrations the balance which, by its weight, slows down the movement so much that the center wheel makes only one turn per hour. But if you removed the balance, the train will run, in about half a minute, the thirty hours that it usually describes.

Method of Disassembling a Watch.

405. If the watch wound, stop its movement by putting a hair or a piece of card between the arms of the contrate wheel; without this precaution the great speed of the train could break the verge or blunt the teeth of the verge escape wheel. Take the watch in one hand and a screwdriver in the other, and, after removing the two screws of the cock, remove it with tweezers, making sure to take only the cock; because if you take balance at the same time, you will risk bending or breaking the upper pivot of the verge. Remove the balance spring stud; you will easily separate it from the plate because it is held only by friction. Take care not to distort the balance spring; if you are not a craftsman, it would cause you great trouble, by the difficulty which you would have to rectify it. Remove the minute hand and the three dial pins to separate it from the pillar plate. If the mainspring is set up by means of a click and a ratchet, hold the square of the barrel arbor with the sliding ring pincers and move away the click so that it no longer hooks in the teeth of the ratchet. Then turn the pincers little by little in your hand until the mainspring is relaxed. This is the way to prevent, while letting down the mainspring, any jolt which might break or bend it. If there is an endless screw to tighten the mainspring, use an endless screw key with which you can set up or let down the mainspring easily.

Remove the four pins from the pillars and separate two plates. Remove the barrel and the first wheel. Then remove the third and the contrate wheels with tweezers and put the pieces under a goblet or in a box, so as not to risk damaging, breaking or losing them.

The center wheel is held on the pillar plate by the canon pinion, which is pinned to the long stem. Use a small punch to push out the pin; if it grips and you cannot make it leave the hole, take the pillar plate in one hand, and with the other tap the end of the stem with a hammer, to break the pin and separate the canon pinion from the center wheel.

To dismount the verge escape wheel, remove the screw of the counter-potence; this part removed, the verge escape wheel will leave its place. If the counter-potence is a type of pillar riveted to the plate, and bored so that it holds the pivot carrier of the verge escape wheel with friction, you will pull it out with pincers, and remove this wheel easily.

If you want to remove the slide, the rosette, the potence, the bridges, the barrettes, and the small springs, it is sufficient to remove the screws which hold each part on the plate.

To Reassemble a Watch.

406. When you want to reassemble a watch, after cleaning it as in N° 402, put oil in the hole in the nose of the potence, Pl. 7, Fig. 2, and in that of the counter-potence. Take the verge escape wheel, Pl. 8, Fig. 25, in tweezers, put the pivot at the wheel end in the hole in the nose of the potence, and fix the counter-potence to the plate with the screw *I*, so that this

part cannot move out of its place. By this arrangement, the verge escape wheel will be suspended by its two pivots, one of which enters the hole in the nose of the potence, and the other in that of the counter-potence. You will make sure this wheel is free in its holes, because if it were not quite free the watch would stop or vary.

Take the center wheel *C*, Pl. 10, Fig. 1, and put it in the center hole *C* of the pillar plate, Pl. 7, Fig. 1. Put the fusee *B* in the hole *B* of the pillar plate and put the barrel *A* in hole *A*. If it is an ordinary calibre, like Pl. 10, Fig. 1, the stem of the verge escape wheel could prevent you setting up or making the pivots of the third and contrate wheels enter their holes; in this case, put the pivots of these two wheels in the holes in the top plate. Then take the pillar plate in the left hand, and the top plate in the other; while doing this operation you will slightly press the thumb on the contrate wheel, to hold the pivot in its hole and prevent which it leaving its place. When you reverse the top plate onto the pillar plate to mount the frame, sit the two plates one on the other, so that each hole enters its pillar. Lightly press on the two plates with one hand while, with the small hook tool, Pl. 1, Fig. 27, in the other, insert each pivot into its hole. The train thus mounted, pin the frame. Test if the train is free by using a small wood point which you will press lightly on the first wheel. It is the way to be sure the train is free.

If the movement has a reversed calibre, the stem of the verge escape wheel will not constrain any pinion or wheel. You will place all the mobiles on the pillar plate, and, after putting on the top plate, you will insert each pivot into its hole, and pin the frame.

Fit the ratchet onto the square of the barrel arbor. After taking the end of the square in the loop pincers, hang the hook of the chain in the hole *L* of the barrel, Pl. 8, Fig. 5. By turning the pincers, you will wind the chain onto the barrel. Then hang the other hook of the chain on the pin which is fixed in the recess made in the last step of the fusee. Tighten the mainspring until the reference mark on the end of the arbor is opposite that on the plate. Wind the watch half a turn of the chain and let the train run to examine whether it is free.

Set up the slide and the rack and fix them on the plate with the two screws of the slide. Set up the rosette wheel and the rosette, and attach these two parts with the screw *F*, Pl. 9, Fig. 1.

Put the balance in its place and fix the stud of the balance spring in the plate. Pay attention when you turn the hand of the rosette, that the rack runs freely in the slide and does not obstruct the balance spring. After fixing the cock with its two screws, wind the watch, which will run after it has started vibrating.

Place the canon pinion with friction on the long stem of the center pinion. Put the intermediate wheel on its stud so that it meshes with the pinion of the canon pinion. Put on the dial, pin it, place the minute hand on the square of the canon pinion, and your watch is assembled.⁶⁹

When, for the first time, you make the chain which is on the barrel pass onto the fusee, take care to arrange it there from time to time, so that you do not have to fear that it slip from one step to another. This precaution once taken, you will be sure that the chain will not slip from one step to another when you wind it up.

Causes which usually Slow down Watches.

407. When a watch is cleaned, the train and balance having acquired a greater freedom, the balance will describe more extended vibrations, like lines *P* and *Q*, Pl. 11, Fig. 5. The balance, traversing most of a circle, takes more time (the action of the mainspring being the same) to traverse the line *P*, *Q*, than if it traversed only the lines *R*, *S*. From this it is easy to conclude that the balance, describing a greater portion of a circle, gives in the same space of time fewer vibrations, that by giving fewer vibrations the train goes more slowly, and the watch must necessarily slow down.⁷⁰

The Reason for Going Slow in Summer.

408. By the same reason, oils in summer being more liquid, the train and balance being freer, the vibrations are extended, and so the watch runs slow.

⁶⁹ Except Vigniaux has forgotten the hour wheel and hour hand!

⁷⁰ Vigniaux does not mention isochronism and this comment is misleading.

Causes which Advance Watches, when they need to be Cleaned.

409. When a watch needs to be cleaned, dirt makes the oil thick. The train being constrained, the balance then describes smaller portions of a circle, like the lines *R* and *S*, Pl. 11, Fig. 5. Traversing smaller spaces, it must, (the action of the mainspring being the same) give a greater number of vibrations in the same space of time, which necessarily makes the watch run fast.

The cold condenses oils during the winter and numb the train and the balance. The balance describes smaller vibrations and, by increasing the number in the same space of time, the watch runs fast.

Method of Advancing or Slowing a Watch with the Hand of the Rosette.

410. When the watch advances, it is necessary to turn the hand of rosette backwards; that is, in the same direction that you turn the minute hand to retard the watch. If, on the contrary, the watch runs slow, it is necessary to turn the hand of rosette ahead, that is, in the direction of the hours. Take care each time to turn the hand of rosette only half of a division of the small dial, unless the watch makes a large variation in twenty-four hours, like four or five minutes; then one can proportionally turn the hand of the rosette for the variation which it makes.

Set your watch right every eight or ten days, by means of a good clock or a meridian which you can easily trace; see N°. 415. If your watch deviates only one minute per day, content yourself with setting it right; if its variations are greater, use the hand of the rosette.

You use a key to turn the minute hand, which will drive the hour hand, and continue to turn the minute hand until your watch agrees with the clock or the meridian. For that, you can turn the minute hand forward or back.

The Care which a Person must take with his Watch.

413. If you have a good watch, look after it like an invaluable jewel, and do not entrust it to anybody if you do not want to risk it being damaged. Carefully avoid dropping it, because it is the worst accident which can happen. Only one drop is enough to shake the plates, or make all the parts lose their horizontal position. This accident can also distort the wheels and pivots, and it is almost impossible to return them to their original state. Though these defects are sometimes almost invisible, they necessarily make watches vary or stop, until the parts which were distorted by dropping are remade.

Never place your watch in a wet place. Wind it about the same hour; by forming the habit of doing it before you sleep, you will be certain not to forget it.

414. Do not trust clocks to adjust your watch; if you have several portable ones you will well aware of their inexactness. These pieces are prone to great variations, because there are few clocks which are made according to the rules of the art; perhaps because they are usually placed in bell-towers where they feel the effects of the air to which they are exposed.

If you indifferently adjust your watch by all sorts of watches, pendulums or clocks, you will never succeed. On the contrary, you are sure to succeed by using a well adjusted seconds clock or a good meridian; see N°. 415. You will also be able to successfully use the rising or setting of the sun.

Method of Tracing a Meridian by Corresponding Heights.

415. Raise the style *A L*, Pl. 9, Fig. 11, on an exactly horizontal surface; its height must be about one third the length of the stone on which it is fixed. This style is given various forms; there are some like a pyramid, and others are like that represented in Fig. 11, which we will take as a model. This style is attached to the point *L* of the stone, by a screw and a nut which fix it immovably. The upper part of the style is finished with a plate of three or four inches, in the center of which is a hole about a ligne in diameter. When you are sure the stone is exactly level, use a plumb line to mark the point *C* perpendicular to the hole *A*. With this point taken as the center, with a compass trace the arcs *D*, *E*, *F*. In the morning, observe the moment when the point of light from the sun lies in the middle of one of these arcs. If it is possible, in the morning mark the points on all the arcs which you have traced. Make the same observation in the afternoon, and mark points on each arc, like *M*, *N*. Trace a line from the middle *F* to the point *C* and you will have the meridian. Note that the best time to make an exact meridian is that of the solstices.

Equation for Pendulum Clocks, by Mr. Vidal.

416. A clock, whose movement is uniform, cannot mark the same hour every day as a sundial, because of the inequality of the movement of the sun. April 14th, June 15th, August 31st and December 13th are the only days of the year when it marks the same hour as a sundial, if it is regulated for mean time. (One distinguishes two kinds of time, true time, and mean time. True or apparent time is measured by the movement of the sun from east to west, such as sundials measure it. Mean time is that which one conceives to run in an always equal way. It is the mark of a good, well regulated clock which, set to the hour of the sun on a certain day of the year, will no longer agree with this star at a similar day of the following year; from which it follows that natural days are not equal. One understands by a natural day, the duration of an apparent revolution of the sun from east to west, such as we see it from midday until midday of the next day.) In between these times, a clock is in advance or behind. Its greatest variations are on February 10th, when it is in advance 14 minutes 40 seconds; on May 14th, when it is behind 4 minutes 1 second; on July 26th, where it is in advance 6 minutes 2 seconds; and on November 2nd, where it is behind 16 minutes 14 seconds.

The following table indicates for each day, how many seconds a clock must be advanced or retarded on the previous day. For example, if one set a clock to the time of the sun on the first of January, it will have advanced 28 seconds the next day. Similarly, if one has set it to the time of the sun on the first March, it is 13 seconds behind the next day. (The letter *A* means advance and the letter *R* means retard.) So having set a clock right and it is compared to sun several days later, it will be necessary to take into account the differences for each day, by adding them, if they are of the same type. For example, from the first of January to the 12th, it must advance 4 minutes 50 seconds. But if the type changes, as from February first to the 15th, one will find that it initially advances 27 seconds from the first to the 10th, and then it retards 11 seconds from the 10th to the 15th; so that from the first to the 15th it should advance only 16 seconds.

The differences which one will find between the hours marked by a clock, and those which result from the table, will indicate how much it deviates. One can adjust a watch like a clock, but one should not expect same exactness from it.



Table of the Equation.

TABLE DES ÉQUATIONS.												
JOURS DU MOIS	JANVIER.	FÉVRIER.	MARS.	AVRIL.	MAI.	JUIN.	JUILLET.	AOUT.	SEPTEMB.	OCTOB.	NOVEMB.	DÉCEMB.
	A	A	R	R	R	A	A	R	R	R	R	A
1	28	"	"	18	"	"	12	4	19	19	"	"
2	28	6	13	18	7	9	11	4	19	18	A	24
3	27	5	13	18	6	10	11	5	19	18	1	24
4	27	5	14	18	6	10	11	6	20	18	2	25
5	26	4	14	18	5	10	10	6	20	17	3	25
6	26	3	15	17	5	11	10	7	20	17	4	26
7	25	2	15	17	4	11	9	8	20	17	4	27
8	25	1	16	17	4	11	9	8	20	16	5	27
9	24	R	16	17	3	11	9	9	21	16	6	28
10	24	0	16	16	2	12	8	9	21	15	7	28
11	23	1	17	16	2	12	8	10	21	15	8	28
12	22	2	17	16	1	12	7	10	21	14	9	28
13	22	2	17	16	1	12	7	11	21	14	10	29
14	21	3	17	15	A	13	6	11	21	13	10	29
15	20	4	18	15	1	13	6	12	21	12	11	29
16	20	5	18	14	1	13	5	12	21	12	12	30
17	19	5	18	14	2	13	5	13	21	11	13	30
18	18	6	18	14	2	13	4	13	21	11	14	30
19	18	7	18	13	3	13	4	14	21	10	15	30
20	17	7	18	13	3	13	3	14	21	9	15	30
21	16	8	18	12	4	13	3	14	21	9	16	30
22	15	9	18	12	5	13	2	15	21	8	17	30
23	14	9	19	11	5	13	2	16	20	7	18	30
24	14	10	19	11	6	13	1	16	20	7	18	30
25	13	10	19	10	6	13	R	16	20	6	19	30
26	12	11	19	10	7	13	0	17	20	5	20	30
27	11	12	19	9	7	12	1	17	20	4	20	30
28	10	12	19	9	8	12	1	18	19	4	21	29
29	10		19	8	8	12	2	18	19	3	22	29
30	9		18	8	8	12	3	18	19	2	23	29
31	8		18		9		3	18		1		29



Vocabulary of the Terms of Watchmaking.⁷¹

Accelerate (*Accélérer*): Movement whose speed increases at every moment.

It is also said that a movement uniformly accelerates when all the vibrations are equal and they are not intermittent.

Adjusting Rod (*Levier*), Pl. 9, Fig. 18: The tool used to equalize the mainspring with the fusee.

Angle (*Angle*): The meeting of two lines at a point.

Anneal (*Recuire*): To redden steel to be able to file it more easily. One also reheats brass to soften it.

Anvil With Two Beaks (*Bigorne*), Pl. 6, Fig. 4: A tool made in the shape of anvil, on which one forges, and where various parts are riveted. It has a round beak which is used to form collets or to give the curve to certain springs and other works, which you will use according to the circumstances.

Arbor (*Arbre*): The arbor is a round or square piece of steel which is finished at each end with a point.⁷² In watchmaking, the words arbor, stem, verge, are about synonymous.

There are various arbors such as: turning arbor, Pl. 1, Fig. 17 and 31; screw arbor, Pl. 1, Fig. 10; and eccentric arbor, Pl. 1, Fig. 6. The principles which I give will easily explain their use.

Arms (*Croisées*): Rays of a circle, which go from the center and end on the rim of a wheel, and support it. See the arms of the center wheel, Pl. 8, Fig. 16.⁷³

Assemble (*Remonté*⁷⁴): A movement is assembled when, after setting up all the parts, the top plate is pinned.

Balance (*Balancier*), Pl. 10, Fig. 4: It is a steel or brass circle which, once riveted onto its verge and put to weight, regulates and moderates the movement of a watch.

Brass balances are preferred, because they are not prone to rust or being magnetized. These two defects cause watches to vary.

Balance Spring (*Spiral*): A spring whose blades are folded into a spiral, Pl. 6, Fig. 9. The end *B* is fixed by a pin to the collet, which is fitted with friction on the seat of the verge. The other end *A* is fixed to the stud which is on the plate, so that when the balance is moving, the balance spring speeds up or moderates the vibrations of it.

Banking Pin (*Étoquio, Étoteau or Étoto*): A banking pin is a small pin riveted onto the balance to prevent it from overbanking.

Barley Grain (*Grain d'orge*): It is the shape of a leaf of a pinion, whose side is a little fat and well rounded, and whose end comes to an almost acute peak.

Barrel (*Barillet*), Pl. 8, Fig. 1: A type of case or drum in which the mainspring is put, and on which the chain is placed.

⁷¹ Additional entries are in italics.

⁷² This definition refers specifically to turning arbors, which see.

⁷³ See also *Barrette*.

⁷⁴ Strictly speaking *re-assemble*, to assemble the parts after finishing.

Barrette, Bridle, Arm (Barrette)⁷⁵: Several parts have this name. There is the bridle or brace in the barrel, Pl. 8, Fig. 4, fixed between its base and the lid to hold the last blade of the mainspring against the barrel, so that the eye of the mainspring cannot be unhooked.

There are also barrettes on the plates. These barrettes enable stems to be made with long pinions, which is a great advantage in a watch.

The arms of a wheel are lines from the center to the circumference. They need to be worked delicately without losing their solidity.

Bastard (Batarde): It is a file of which the cutting edge is neither fine nor coarse.

Beat (Battement): There is a beat when the banking pin strikes the slide. That usually happens when the balance describes most of circle.⁷⁶

Bench (Établi): A type of table where a vice is attached, and on which the watchmaker puts his tools.

Bevel (Biseau): One gives this name to an inclined part which is formed on the edge of various tools or on any part of a watch; instead of being turned or filed square it has a gentle slope to its end. A bevel frees a part without it losing its solidity.

Blade (Lame): A plate of steel of an unspecified length. One says blade of a saw, blade of a balance spring, blade of a mainspring. When the mainspring is in the barrel, one regards the turns that it makes as the number of blades.

Blow-Pipe (Chalumeau), Pl. 2, Fig. 11: It is a pipe whose small end is curved. It is used to blow the flame of a candle onto a part which one wants to harden or solder.

Blue (Bleuir): A steel part is blued, after hardening it, by heating it sufficiently to give it the colour blue. By this operation a spring is not prone to break and becomes softer and more pliable.

Bluing Pan (Revenoir): A piece of tinplate or extremely thin steel on which one places a steel part that one wants to temper after hardening it. The part is usually heated in the flame of a candle until it takes the colour which one wants to give it.

Borax (Borax): Borax is a fossilised salt, which comes from India and Persia, and which is used when one wants to solder metals to each other. The best for soldering is the yellow. Before using it, it is calcined, so that while boiling it does not move the solder away from the place where one wants to solder the part.

Bow (Archet): It is an elastic rod of steel, whale bone, or wood, which is used to tighten a gut cord or a hair to drive a part in the turns.

Bridge (Pont), Pl. 9, Fig. 13: It is a part which is used to support the pivots of the wheels of a watch, so that they do not roll in the plates.

Bridle: See *Barrette*.

Broach (Alezoir): A rod of steel filed slightly tapered. To be good it must be hardened, well rounded and well polished.

Broach (Équarrissoir): A steel rod with several equal faces and which finishes in a point. It is used to enlarge holes. The best usually have five sides.⁷⁷

Broach (Équarrir): To enlarge a hole and make it round with a broach.

Broach, Ream (Alezer): To smooth a hole and make it uniform and polished using a broach that one puts in it and turns several times.

Burnish (Brunir): To give a brilliant surface to metals such as steel or brass, with a tool in the shape of file which is well hardened and rubbed on wood coated with emery. It is called a burnisher.

Burnish a Pivot (Rouler un pivot): After turning it to about size, to place it in the turns and pass a file over it to remove the large marks, and to then polish it with a burnisher.

⁷⁵ Vigniaux uses the one word *barrette* for all three meanings.

⁷⁶ The definition is obviously wrong; Vigniaux is describing overbanking.

⁷⁷ But Vigniaux prefers ones with four faces; see N°. 81.

- Bush** (Bouchon): A piece of brass which is riveted in the plates of watches when one wants to plug a hole. One makes smooth bushes for large holes. For small holes it is better to plug them with a screw, because the work is more solid.
- Butting** (Accrochement): When a tooth of the verge escape wheel presses on a pallet before that which is opposite to it has left the other pallet; it causes a stoppage that is called butting. It results from the escapement being too exactly or badly made, or from too long use, which has enlarged the holes of the balance pivots and those of the verge escape wheel. Sometimes these stoppages also result from the points of the teeth of the verge escape wheel having burrs formed over a period of time.
- Calibre, Gauge** (Calibre): There are several types and several sizes. By this word one means a plate of brass, Pl. 7, Fig. 3, on which the sizes of the wheels and their respective positions are traced. It is, to be strictly accurate, the plan of a watch.
One gives the name calibre compass or pinion calibre to a small compass, Pl. 2, fig 8, which is used to measure pinions and teeth. One says to gauge a pinion, to gauge a wheel.
- Canon** (Canon): The canon A, Pl. 10, Fig. 5, is a small brass pipe which cylindrical and is bored through all its length. There is the canon of the canon pinion and that of the hour wheel.
- Canon Pinion** (Chaussée), Pl. 10, Fig. 2: It is the canon which carries the minute hand on one end. The other end has ten or twelve leaves which, by means of two wheels, moves the hour hand.
- Cap** (Calotte): It is a type of case which covers the movement of a watch, to guarantee it is free from dust and all that could fall in it.
- Cap** (Chapeau): A conical piece of steel with a screw which is used to fix a wheel on the wheel cutting machine.
- Center** (Centre): It is the point which, in a circle, is equally distant from all the points on its circumference.
- Center Punch** (Pointeau), Pl. 3, Fig. 17: A steel punch pointed at one end and flat at the other, whose point must be sharp and well hardened. This tool is used to mark holes on brass or steel parts.
- Chain** (Chaîne): An assembly of small, similar links, bored at each end and fixed one to the other with pins, which are riveted on both sides.
- Chain guard** (Guide-chaîne), V, Pl. 7, Fig. 2. A small lever which stops the beak of the fusee when the watch is sufficiently wound.
- Chamfer** (Chanfrein): A small conical recess made by a cutter or a drill formed with four or six sides on one of its ends. To chamfer or bevel a hole mean the same thing.
- Click** (Cliquet), Pl. 8, Fig. 37: A piece which has the form of a comma, where one end is riveted with friction onto the first wheel and other is pushed by a spring. The click, entering the teeth of the ratchet, prevents the fusee from turning backwards.
- Click-and-Ratchet Work** (Encliquetage): The machinery used so that a wheel cannot turn in opposite directions.
- Cock** (Coq), Pl. 10, Fig. 3: The part which supports and covers the balance.
- Collet** (Chaperon): A round plate which has a canon which fits with light friction on a stem. A collet is driven with force onto a stem to fix it, so that they seem to be a single part; Pl. 6, Fig. 10 and 11.⁷⁸
- Collet** (Goutte), Pl. 8, Fig. 13: A small, round steel plate which has a hole bored the size of the arbor of the fusee, on which one forces it to hold the first wheel by friction against the base of the fusee.
There is also a collet which is small, round, convex on one side and concave on the other, that is placed on the square of the fusee.

⁷⁸ These illustrations are not of a collet, but of a piece to repair a verge pivot; see N°. 355.

A tallow-drop, dome or button-head screw (*vis en goutte de suif*) is one whose head has the shape of a cone. It is so formed so that enters a countersink.

Collet (Virolle): It is a small brass canon which is put on the handles files so that they are more solid.

There is also the collet of the barrel. It is this part which forms the circumference of the barrel and which gives it depth, where the mainspring is placed.

One also calls the small part which is adjusted with friction on the seat of the verge the collet of the balance. This collet is used to fix, by means of a pin, the inner end of the balance spring.

Collet Punch (Poinçon à enfoncer les gouttes), Pl. 3, Fig. 15: It is usually made of brass. It has a large hole which fits freely over the square of the fusee. One gives this tool a hammer blow to tighten the collet against the first wheel.

Compass (Compas), Pl. 5, Fig. 3: Instrument with two arms and a spring or hinge, known to everyone. There are various forms of them, according to their different uses. Watchmakers normally use spring compasses.

Coqueret (Coqueret), Pl. 9, Fig. 6: A type of bar, fitted on the cock by two steady pins, to receive the pivot of the balance. There is another coqueret of steel of the same form as the brass one, fitted on the former, with a screw which fixes both coquerets to the cock. The brass coqueret contains the pivot of the verge, and the steel coqueret supports the end of the pivot.

Counter-Potence (Contre-potence), Pl. 7, Fig. 2: This name is given to the piece which supports the pivot of the long stem of the verge escape wheel.

Counter-Sink (Fraisier): It is to make a recess suitable to recess the heads of screws. For that one uses certain drills whose heads are made according to the form which one wants to give to the hole. See Pl. 1, Fig. 4 and 5.

Cutter (Fraise), Pl. 12, Fig. 7 and 8: It is a steel wheel whose circumference is cut in the shape of a saw, and which is put on the wheel cutting machine, to divide the teeth of wheels.

There is also a cutter to make a small notch in the last step of the fusee to receive the chain hook.⁷⁹

Dancing master (Maitre-a-danser, inside-outside callipers), Pl. 4, Fig. 1: An instrument which is used to determine the height that stems must have in the frame.

Depthing File (Dossier), Pl. 3, Fig. 1: It has two plates of steel between which is fixed a file to determine the depth which one wants to give to teeth, and to be sure that, when one has used this tool in all the teeth of a wheel, they will all be of equal depth.

Dial (Cadran): It is the piece on which the hours are traced. In the past some were made of gold and silver. Currently almost all are made of enamel, because they are more pleasant to see and the hours are more easily distinguished.

Dial Work (Quadrature or cadrature, motion-work): This name is given to all the parts placed between the dial and the pillar plate. In a simple watch it is the train which is between the dial and the pillar plate; it is arranged so that while driving the minute hand it also drives the hour hand.

Dividing Plate (Plate-forme): A round brass plate filled with concentric circles on which the numbers which are needed to divide the teeth of wheels are marked. It is part of the wheel cutting machine.

Dovetail (Queue d'aronde or queue d'hironde): A small slide formed in the thickness of a part in which one inserts a plug of the same form.

Drawn Steel (Acier tiré): It is a small steel bar passed through a grooved draw-plate, which is used to make pinions. There is also round steel of any size and steel to make clicks and verges.

⁷⁹ Pl. 1, Fig. 16.

- Drill** (Foret), Pl. 1, Fig. 1, 2, 3: A tool which workers use to bore various materials. It ends with a drill tip (mèche). After flattening and hardening it, it is tempered yellow and sharpened. They drive a ferrule on the other end, around which they pass the cord of a bow.
- Drill Guides** (Jeu de fraises), Pl. 12, Fig. 4: Five or six drills of various sizes and various forms, with cylindrical bodies, which one fits in a canon to make a recess exactly at the place where it is needed.⁸⁰
- Drive In** (Chasser): Said of a pivot or a stem which is inserted into a seat or any other part with the blows of a hammer, for fixing it as if they were soldered.
- Driving Force** (Force motrice): It is the power which is delivered to and maintains the movement; such as the mainspring.
- Drop** (Chute): The movement that the verge escape wheel makes when it falls onto a pallet of the verge. It is a second drop when the opposite tooth falls on the other pallet and strikes it.
- Ears of the Cock** (Oreilles du coq), Pl. 10, Fig. 3: The two feet, which are used to fix this part on the plate with two screws, are called the ears of the cock. The slide also has two ears which are the two feet used to fix it to the plate by means of two screws.
- Elastic** (Élastique): A spring is more or less elastic according to the degree of hardness given it, and that its blade is more or less thick on its length.
It is said that a spring has lost its elasticity when it loses its force while functioning, which usually occurs when a spring is badly hardened, or it has been tempered too much.
- Embistage** (Embistage): Means the respective positions of the two plates of a watch.⁸¹
- Emery** (Emeri): A stone which is found in iron mines that is reduced to a powder, and to which one gives various degrees of smoothness. It is used to remove file marks from steel. It is also used to maintain burnishing files.
- Enarbor** (Enabrer): To mount a wheel on an arbor and rivet it. For a wheel to be well enarbores, it must turn true and centered on its arbor or its pinion.
- Endless Screw** (Vis sans fin): It is used for setting up or relaxing the mainspring of a watch. Its threads mesh in the teeth of a wheel with hard friction, so that one can neither advance nor retrogress the wheel unless one turns the square of the endless screw with an endless screw key.
- Engage** (Quotter): This means when the tooth of a wheel meets the leaf of a pinion before the line of centers. By touching the point of the pinion it makes an effort which infringes on the force of the train and sometimes stops it.
- Equalize** (Égalir): It is to make the teeth of a wheel equally thick with an equalling file, and to give them the same depth.
It also means to put the action of the mainspring in agreement with the various steps of the fusee.
- Escapement** (Echappement): The escapement the machinery which, by means of the verge escape wheel, communicates the movement to the balance. The balance describes more or less extended vibrations in proportion as the verge escape wheel is more or less close to the body of the verge, or according to the width of the pallets, or according to whether they are opened or closed.
- Eye** (Œil): It is the hole made in each end of the mainspring, one of which is for the hook on the arbor, and the other for the hook in the barrel.
- Faces** (Faces) The two sides which finish the thickness of a pinion. For a face to be well made it must be flat and brilliant.

⁸⁰ Although drawn too large, I presume the six unnumbered tools are to be used with the guide in Fig. 4.

⁸¹ See N°. 144 and 153.

False-Plate (Faussee-plaque): A brass circle fitted on the pillar plate by means of three pillars.⁸² It supports the dial and is high enough to contain the motion-work. Formerly false-plates were put on French watches. One compensates for them by making thicker plates and recessing them enough to place the dial work in them.

The English always use false-plates on their watches.

Ferrule (Cuivreau), Pl. 1, Fig. 15: A small steel or brass pulley which is fitted to pieces that one wants to turn with a bow.

There are broken steel ferrules, Pl. 1, fig 26, that one fixes on the part with two screws, and others which have only one of them.

Figure Eight Compass (Huit de chiffre), Pl.5, Fig. 5: This is a compass which has the form of a figure eight. It is used to measure the thickness of parts.

File (Lime): It is a hardened steel tool whose faces are cut in several directions. The files, Pl. 2, are the tools used to give metals the form which one wants.

Watchmakers need a great number of files of different forms. Such as:

Hand files (main).

Carrelet (or carrelette) files, Pl. 2, Fig. 3.

Knife edge files (couteau).

Crossing out files (feuille de sauge, sage leaf), Fig. 2.

Hinge files (charnière).

Rounding-up files (arrondir), Fig. 4.

Thinning files (efflanquer), Fig. 1 and 5.

Pivot files (pivot), Fig. 6.

Equalling files (égalir), Fig. 7.

Plug files (lardon, dovetail).

Barrette files (barrette, cant).

Notching files (entrée).

Rat tail files (queue de rat).

Square files (carrées).

Verge escape wheel files (roue de rencontre).

Depthing files (dossier), Pl. 3, Fig. 1.

This name is also given to plates of iron, steel, tin or brass which are used to smooth and polish steel.

Fillet (Filet): It is a piece of projecting material which one leaves on certain parts.

Finisher (Finisseur): The workman who takes a rough movement and forms the teeth, the pivots, the gearing, the escapement, and delivers the movement of a watch.

Foot of the Chain Guard (Pied de guide-chaîne): A small square pillar, placed between the barrel and the fusee, to which is attached a small lever called the chain guard. It stops the hand when the watch entirely wound.

Fraise: See *Cutter*.

Frame (Cage): The frame consists of the two assembled plates fixed by their four pillars.

Freedom (Liberté): A part has freedom when it can be driven, and it does not rub against any other part.

Friction (Frottement): It is the resistance which a body experiences when driving another.

There are also parts which are fixed by strong friction; such as the first wheel, which the collet holds with friction against the fusee. It is said two parts are safe from friction when there is enough space between them so that they do not touch each other.

Fusee (Fusée), Pl. 8, Fig. 11: A cone whose circumference is cut in the shape of snail, and on which the chain is wrapped when the watch is wound.

⁸² Or held by key screws.

Fusee Cutting Machine (Outil à tailler les fusées), Pl. 11, Fig. 1: It is composed of several parts placed on a brass base in the form of a “T”, which is approximately five lignes thick. On this is fixed the square plate *V V*, which enters the slide *R R*, made purposely to contain it, exactly and with light friction.

This plate which is about nine to ten inches long and an inch and a quarter wide, carries a tilted piece of brass *H H*, made in the form of a rule, which crosses the plate from one end to the other. It is fixed by a hinge at the end *S*, and by the screw *K* at the other end, so that one can increase or decrease the tilt of the rule.

This brass part also carries a strip of the same metal on which the teeth *D* are formed over its length; so that when the pinion *B* is turned by the crank *A*, the plate *V V* comes and goes in its slide.⁸³

This tool has two headstocks *F F*, which have at their bases *X X* two holes, one of which is used to hold the runner *G*, and the other the pivot of the pinion *B* which carries the jaw *G*.

The part *E M T*, is a type of bent steel arm, which is fixed by a hinge at the point *T*, and at the point *M*. The arm *E* exactly enters a slide which is formed on the ends of the two headstocks *F F*.

The small lever *Y* has a point under it which rest on the rule of the inclined plan, because it is always pushed by the spring *L*. This lever is fixed by a hinge on the arm *E M T*, and it controls the movement.

Carriage *Z* is placed on the arm *E* exactly and free with friction. When it is positioned so that the square graver is opposite the fusee, it is fixed on the arm *E* by a screw.

There is a hole in the middle of this carriage *Z*, which receives and holds the cylinder *C* with friction. *C* carries a square graver at its end *O*. Fixed on the same carriage and behind the cylinder *C* is a screw *O*, whose higher end is connected to the cylinder by a steel part, stops it and determines the distance by which it protrudes from its hole.

The part *P* is a wheel which has five eccentric cavities, to which one gives various forms which correspond to the heights of fusees and to the form that one must give them. So that when one is cutting a fusee, and the end of the screw *O* touches the hollow of the wheel *P*, it, by giving the form of the fusee, determines the depth of its steps.⁸⁴

When you want to cut the fusee, fix its two pivots between the runner *G* and the jaw *G*. Place the square graver so that it is opposite the part where you want to begin the first step of the fusee. Turn the crank, and count the turns which it makes; you will lengthen or shorten the inclined plan until, by turning the crank, the square graver traverses on the fusee the number of turns which you need.

Your tool thus set up, turn the crank *A*, and at the same time press on the cylinder *C*. The arm *E M*, running between the two headstocks, will give the means of cutting the fusee in the shape of screw. You will continue the same operation, by making the crank go and come until the end of the screw *O* touches the hollow of the wheel *P*. If the steps are not deep enough, turn the screw *O* to shorten it, and continue to cut the fusee until the steps are rather deep.

Gauge: See *Calibre*.

Gearing: See *Mesh*.

Hammer (Marteau), Pl. 2, Fig. 9: Watchmakers have several different sizes and forms. The ordinary ones are of hardened steel, with a flat head and a round peen. There are also ones with round heads. The sharp hammer is used to straighten distorted parts. Ivory or wood hammers are used to correct watch cases.

⁸³ *H H* controls the lateral movement of the fusee cutter. By changing its angle, the number of turns of *A* required to traverse a given distance changes and hence the number of steps on the fusee can be varied. The crank *A* also rotates the fusee.

⁸⁴ To pre-empt the following, the fusee machine is set up by turning the screw *O* so that the cutter touches the end of the fusee when the screw touches the end of a hollow on *P*; *P* is drawn incorrectly in that the five hollows should be different shapes to suit different fusees. By turning the handle *A*, the carriage will move transversely and the position of the cutter will follow the curved surface of *P*, forming the conical shape. A set of guides *P* would be required, one for each fusee height.

- Hands** (Aiguilles): They are used to mark the hours and the minutes on the dial. They are usually made of gold, steel, or brass. A hand must be light, simple and of a beautiful form.
- Harden** (Trempe): It is the operation by which, after reddening a steel part, it is thrown into water to harden it so much that a file cannot bite into it. The part is prone to break easily if care is not taken to temper it.
- Heel** (Talon): It is the part of the potence on which the end of the pivot of the verge of the balance presses.
- Hook** (Crochet): Used to hang one part from another. There are several types of them: the hook of the chain, that of the fusee,⁸⁵ that of the barrel and that of its arbor.
- Horizontal** (horizontal): All that is level; that is, in a position parallel to the horizon.
- Horologist** (Horloger): It is the name given to those whose role in life is to make clocks, pendulum clocks, and in particular watches. One distinguishes the true horologist who, practices his art joined to the knowledge of the sciences which are relevant to him, from he who only has practice and routine.
- Lead** (Menée): This word means the space which the tooth of a wheel traverses from the moment when it drops on the leaf of a pinion until it is released.
- Leaves** (Ailes): This name is given to the teeth of a pinion. For a leaf to be well made, its face must be a straight line from the center to the circumference.
- Link** (Maillon): A small oval piece, bored at each end, of which several are fitted to each other to form the chain of a watch.
- Meridian** (Méridien): It is a large circle of the globe, and is called this because it is midday at all the places located on this circle when the sun passes over.
- Meridian Line** (Méridienne): It is a line which indicates the hour of midday. See Pl. 9, Fig. 11.
- Mesh**, Gearing (Engrener): It is said of a wheel whose teeth enter the leaves of a pinion to drive it.
- Microscope** (Microscope): It is a glass which enlarges objects, which watchmakers use to examine small parts and discover defects which would otherwise escape the sight.
- Mobile** (Mobile): All that has movement. In watchmaking one distinguishes the first and last mobiles. The barrel, first wheel and center wheel are the first. The last are the third wheel, the contrate wheel, the verge escape wheel and the balance.
- Movement** (Mouvement): It is the assembly of springs and wheels which compose a watch.
The rough movement (mouvement en blanc) is that whose parts are only roughed out.
It is also said that a movement is finished in white (fini en blanc), when the finisher done the last of the hand work, rubbed it with water stone, to smooth all the parts, and the watch runs.⁸⁶
- Movement Holder** (Main, hand), Pl. 5, Fig. 11. A tool to hold the plates, which is used in order not to tarnish their gilding when a movement is assembled.
- Nose of the Potence** (Nez de potence): It is the part of the potence in which the pivot on the pivot shank of the verge escape wheel runs, Pl. 9, Fig. 10.
- Notch** (Coche): It is a small slit or notch formed on a part, such as the notch in the rack which receives the balance spring, and that which is made in the plate to receive the counter-potence.
- Notching Teeth** (Crânage): I have not come across the term *crânage* before and it may have been more common in clocks than watches.
Crâner is defined as: “faire des entailles au bas des dent d'une roue.” (E.O. LAMI, “Dictionnaire encyclopédique & biographique de l'industrie & des arts industriels”, tome

⁸⁵ I use the word *beak* for what Vigniaux calls the *fusee hook*.

⁸⁶ At this point the movement is finished but not gilt. After it has been gilt, it is cleaned, checked and reassembled.

III, Paris: Librairie des dictionnaires, 1883, p. 1083.) That is, to make notches at the base of a tooth of a wheel. (This information was provided by Karla Vanraepenbusch, Center d'études Institut l'homme et le temps, Musée international d'horlogerie.)

Crânage was discussed on a message board at <http://www.horlogerie-suisse.com/forum/viewtopic.php?f=2&t=15638>. It does not appear to serve a useful purpose and was probably done for reasons of aesthetics, although it was suggested that it could affect the way a tooth would fracture on being given a jolt.

The tool mentioned by Vigniaux is described by "Sulren" as "a curved tool called 'notching file' which one strikes as a chisel and which notches the two sides of the tooth at the same time." (This means a number of these tools would be required for different tooth and space sizes.) Jean Claude Sulka provided the following photograph of *crânage*:



Number (Nombre): Number is the quantity of teeth which a wheel has on its circumference.

Oil Stone (Pierre à l'huile): It is the hard stone with a fine strong grain which is used to sharpen various tools. Those from Turkey are preferred.

Oiler (Porte-huile), Pl. 1, Fig. 28: An extremely thin tool, the end of which is flattened with a hammer blow. It is used to take a small drop of oil to put on the pivots of wheels.

Overbanking (Renversement): It is a defect which takes place when a balance describes too wide circles by leading the pallets of the verge too far, and they catch the teeth of the verge escape wheel. To cure this defect, one usually places a banking pin on the rim of the balance which, by striking the two ends of the slide, prevents the balance from describing arcs which are too large, and keeps the pallets of the verge arranged so that the verge escape wheel operates on one pallet sometimes, sometimes on the other, without risking a similar defect.

Pallets (Palettes): These are the two levers of the verge against which the verge escape wheel strikes, and by means of which this wheel maintains the vibrations of the regulator.

Pea of the Hammer (Panne de marteau): It is the part of this tool whose end is round and flat.

Pendant (Pendant): It is the part of a watch case to which one usually attaches a cord.

Pillars (Piliers), Pl. 8, Fig. 36: These are four small columns which are riveted to the pillar plate and support the top plate at the height that one wants to give to the movement.

Pin (Goupille): A small piece of round iron or brass made in the shape of pin, and used to fix plates to pillars.

Pin (Goupiller): To put the pins in their holes.

Pincers (Tenailles): There are several kinds of them, such as: screw pincers, Pl. 4, Fig. 2; loop pincers, Pl. 5, Fig. 1; and cutting pliers, Pl. 4, Fig. 6. In general, it is a tool which watchmakers use to hold a part. These tools enable it to be filed in the form which is needed.

Pinion (Pignon), Pl. 8, Fig. 17: A piece of turned steel on which one makes stems to raise pivots. The leaves are divided according to the numbers of the train. A pinion is usually moved by a wheel whose circumference is larger. Drawn steel (pinion wire) is used, which can be found of any number and any size at the tool merchants.

Pinion Wire: See *Drawn Steel*.

Pivot Shank (Tigeron): It is a small, short, strong stem which extends from the shoulder of a pivot to the wheel or pinion.

Plate (Platine): It is a brass plate of a some thickness. There are two of them for each watch: the pillar plate on which the pillars are riveted, and the top plate that is fixed onto the pillars by four pins.

Play (Jue): A hardly noticeable movement that a wheel must have between the two plates when it is set up in the frame. If the pivots are obstructed, one gives them play by enlarging their holes with a broach.

Pliers (Pincés or pincettes), Pl. 4, Fig. 3, 4 and 8: Tools which are used to hold and place various parts.

Plug (Lardon), Pl. 9, Fig. 10: This name is given to the small part which fitted on the nose and the heel of the potence. The plug runs in a dovetail slide.

Polish (Polir): To make a metal part smooth and brilliant. The pivots, pinions, wheels and all the parts of the escapement must be polished with great care.

Post or Stud (Piton or Tenon): A small part which is used fix some other part solidly to the plates. Studs are usually fixed on plates with hard friction.

Post (Tenon, stud): It is a part which is used in the assembly of horological pieces; such as the stud which fixes the balance spring to the plate.

Potence (Potence), Pl. 9, Fig. 9: The part which is fixed perpendicularly on the top plate by a screw. It holds the verge of the balance. Its plug supports the pivot in front of the verge escape wheel.

Press (Étamper): To give to a part or a hole the shape of a press tool, by making it enter with blows of a hammer.

Press Tools (Étampe), Pl. 3, Fig. 16: Pieces of hardened steel about an inch and a half long, formed round, square, or any other shape. They are driven into a hole to make it take the shape of the tool.⁸⁷

Rack (Rateau), Pl. 9, Fig. 4: Part of a toothed wheel which, fixed in the slide, is driven by the wheel of the rosette. It is used to lengthen or shorten the balance spring.

Raise A Pivot (Lever un pivot): It is to turn the pivot of a pinion cylindrical, centered, and proportional in size, and to form a shoulder. After filing the part round, to cut it with the point of a graver, and to burnish it.

Rat Tail (Queue de rat): A round file exactly in the shape of a rat's tail which tapers toward the point and cut on all sides.

Ratchet (Rochet), Pl. 8, Fig. 6: It is a flat wheel whose teeth have the shape of a rack. It is used to set up the mainspring and to form the click-and-ratchet work.

Ream: See *Broach*.

Recess (Creusure): This name is given to hollows formed in the plates; such as the recess for the center wheel, which one sinks into the thickness of the plate to provide greater space for the other mobiles.

Smaller recesses are also made in watches in order to have longer stems, which give them more solidity.

⁸⁷ Most of the tools in Pl. 3, Fig. 12 to 19, are not mentioned in the text and some are clearly not punches.

- Recoil** (Recul): The escapement with recoil is, for example, that of the verge escape wheel. If you examine the contrate wheel in its motion, it has a movement forwards and another backwards. This movement is communicated to it by the effects that the verge gives to the verge escape wheel.
- Re-entrant Number** (Nombre rentrant): Watchmakers thus call the number of pinions when they are aliquot with the teeth of the wheel in which they mesh; that is, that the pinion which gears in a wheel traverses the number without any remainder.
- Regulate a watch** (Régler une montre): To set it right. To retard or advance the hand of rosette according to how slow or fast the machine runs.
- Regulator** (Régulateur): One understands by this word the balance and the balance spring which regulate the movement of a watch. The balance slows down the speed of the train, and balance spring speeds up or modifies the vibrations, according to whether it is more or less elastic.
- Retain** (Encliqueter): The way in which a click is driven when, by its spring, it enters the teeth of a ratchet.⁸⁸
- Rivet** (River): To drive back, with hammer blows or with a punch, a piece of brass or steel, to fix it to any other part.
- Riveting** (Rivure): It is usually the part of a seat or the edge of a pinion which must enter exactly the hole of a wheel. The riveting is folded back onto the wheel with hammer blows, or with a punch, so that these two parts are fixed to each other.
- Riveting Clamp** (Presse à river), Pl. 6, Fig. 5: A tool with two sprung jaws which is placed in the vice to rivet certain wheels.
- Riveting Punch** (Poinçon à river), Pl. 3, Fig. 19: A small tool which is used to rivet wheels onto pinions.
- Riveting Stake** (Banc à river), Pl. 5, Fig. 9: It is a piece of steel or brass which has several holes of different sizes. Stems, pinions and canons are placed on this tool to rivet wheels to them. When this operation is done it must be fixed in the vice.
- Riveting Stake** (Tas): It is a small anvil which is fixed in the jaws of the vice. There are several forms of them.
- Rosette** (Rosette), Pl. 9, Fig. 3: A type of dial which is placed beside the slide. It is divided and numbered. It has a hand which is turned to the side *A* to advance a watch, and to the side *R* to retard it.
- Rough Out** (Ébaucher) A part is roughed out when it is filed to about the thickness and size which it must have. If it is a part which is to be turned, it is after marking its center and making a compass line on it, and filing to this line. To trim (dégrossir) is a synonym.
- Round** (Arrondir): One means by this word the shape that one gives to the ends of the teeth of a wheel and the leaves of a pinion. A wheel is quite round when the curve is well formed, the teeth are quite smooth on their sides, and their circumference is perfectly equal.
- Screw** (Vis): It is a cylinder fluted in a spiral, which enters a hole that is called a nut (écrou), the interior of which is also formed in a spiral. The separation of the filets of the screw are not named. The force of the screw increases in proportion as it is larger, and as its threads are multiplied.
- Screw plate** (Filière), Pl. 5, Fig. 7: A plate of hardened steel, which has tapped holes of several sizes to form the threads of screws.
- Seat** (Assiette): The seat is usually a piece of brass on which one rivets or fixes a wheel, after soldering the seat onto the arbor and turning it, like the seat *B*, Pl. 8, Fig. 20.
- Set-up** (Bande, Tour de bande): It is the number of turns that the mainspring is tightened when the chain is put on the barrel and hung on the fusee, and before the watch is wound.

⁸⁸ There is no English equivalent, but *retain* is near enough.

- Shoulder** (Portée): It is a small surface larger than the pivot. It is usually the size of the stem. It is turned round and flat, and it is polished. It keeps the wheels true and free between the two plates.
- Side** (Pan) This name is given to the faces formed with a file on a cylinder. There are four, five, six sides, etc.
- Slide** (Coulisse), Pl. 9, Fig. 2: It is a half circle under which is placed the rack to shorten or lengthen the blade of the balance spring.
- Smooth** (Adoucir): One smooths a part by filing it with a smooth file, or by using it with various substances such as emery, oil stone, pumice stone, and water stone.
The first two are used to smooth steel, and the latter two to smooth brass.
- Snap** (Drageoir) A type of groove made in certain pieces and recessed on the turns, to fit a lid to it by friction; such as the snap of a barrel.
- Solder** (Soudure): It is a mixture of various metals and various salts which is fused to make two metal parts adhere together. See the various types of solder, Part One, Chapter IX.
- Space** (Jour): It is the space between all the various parts which make up a watch. To be well made, their spaces must be distributed so that there is no risk of friction between one and the other.
- Spring** (Ressort): The mainspring, Pl. 8, Fig. 7, is a blade of steel hardened and tempered to blue, contained in the barrel and rolled up on an arbor. This spring, through its elasticity, gives movement to the watch.
A movement has several springs; such as the balance spring, that of the click-and-ratchet work, that of the chain guard, and that for the head of the dial spring.
- Square Graver** (Échoppe), Pl. 3, Fig. 2 and 3: A type of graver flat on the end, of which all the angles are finished in bevel, and which is used to form the recesses in plates or to recess the barrel, the contrate wheel and the verge escape wheel.
- Steady Pin** (Pied, foot): Small cylindrical pieces of brass or steel, which are usually fitted on parts that one wants to attach to a plate, such as barrettes and the feet of springs.
- Steel** (Acier): It is a quality of refined iron which acquires various degrees of hardness by the various degrees of heat treatment that one gives it.
- Stem** (Tige): This name is given to the arbor of a wheel or a pinion; such as the stem of the verge escape wheel.
- Step** (Pas): This name is given to each turn of the fusee, on which the chain is wrapped when a watch is wound.
- Stoppage by the Finger** (Arrêt au doigt): When one presses a thumb on the contrate wheel until the balance has stopped, and after raising this finger the watch does not start again. This inaction is called stoppage by the finger.
- Stud** (Broche): A small steel piece which is tapped at one end to fix it to a plate. The other end is formed into a cylindrical pivot and a shoulder. A stud holds the canon of the intermediate wheel pinion.
- Swing** (Branle): It is the space which the action of the verge escape wheel makes the balance traverse. For a watch to be exact, it is necessary that each vibration traverses only half of a circle. If it traverses a greater space, the escapement being too forced, the watch will not have a uniform rate. It is what is called to swing by halves.
- Teeth** (Denture): It is all the teeth of a wheel. So that the teeth are good, it is necessary that they are all well equalized, quite round, of the same form, and equal in length.
- Temper** (Renevir): To temper a part. After hardening it, it is put on a bluing pan to make it take a suitable colour for the degree of hardness that it is needed.
- Thin** (Efflanquer): It is to hollow out a pinion with a file and to decrease the thickness of its leaves, to give it a pleasant form.
- Threads** (Pas des vis): Small filets formed in a spiral on a piece of cylindrical steel. A screw has more or less threads, according to whether it is more or less long, or the steps are more or less large.

Train (Rouage): One understands by this word all the wheels and all the pinions acting one upon the other.

Trim (*dégrossir*): See *Rough Out*.

True And Round (Droit et rond): When one says to turn a part true and round, one means that it should be turned flat on both ends and round on its circumference, so that it is square in all directions and of equal thickness.⁸⁹

Tweezers (Brucelles), Pl. 2, Fig. 10: Small grips which are sprung and used to hold delicate parts.

This tool is also used to widen and tighten balance springs. For that purpose, one point is made hollow and the other is rounded.

Turning Arbor (Branche): Pieces of steel about an inch and a half long, on which one fits a ferrule to turn it. A screw turning arbor is a turning arbor to make balance spring studs and others.

Turns (Tour), Pl. 6, Fig. 1. A watchmaking tool which is used to turn the parts of a watch and which is proportioned to their size.

Unclick (Décliqueter): To unclick a ratchet is to release the click from the teeth of the ratchet, which are formed into a peak and are sunk in the base of the fusee. This wheel turns with friction in one direction, and when one wants to turn it in the other the click, which enters the bottom of the teeth, stops it.

Unriveter (Dérivoir), Pl. 3, Fig. 15: A tool used to unrivet wheels. It is similar to a small punch, whose end has a small and rather deep hole the size of the stem, so that the bottom of the tool cannot touch the pivot.

Unriveting Punch (Poinçon à dériver), Pl. 3, Fig. 13 and 14: It is a small tool whose end has a hole deep enough to hold the stem of the part that one wants to unrivet. With a hammer blow a pinion can be unriveted from a wheel without danger of spoiling either the wheel or the pinion.

Uprighting Tool (Planter or outil à planter): See Part Three, Chapter IV and Pl. 11, Fig. 4.

Verge (Verge), Pl. 8, Fig. 34: It is a steel stem, soldered onto a seat which is riveted to the center of the balance of a watch. It has two pallets, against which the teeth of the verge escape wheel strike. It has two pivots, one of which enters the hole in the heel of the potence and the other in the hole of the coqueret, to hold the balance suspended in equilibrium.

Vibration (Vibration): It is the part of circle which each tooth of the verge escape wheel makes the balance describe, by operating on the pallets of the verge.

Walls (Paroits, paroi): The walls are the sides of the holes in which one puts the pivots of a wheel.

Watch (Montre): A machine or small portable clock, which marks the hours and the minutes. It is the only thing that is treated in this work.

Wheel (Roue): In watchmaking, a piece of brass turned true and centered, and divided on its circumference into a given number of teeth.

Wheel Cutting Machine (Outil à fendre), Pl. 12, Fig. 1: It is composed of a frame in the shape of triangle, in which the arbor *A* is so skilfully adjusted that it turns exactly and free in this type of frame. It carries a bass plate called the dividing plate (*plate-forme*), which is fixed immovably to the base of the arbor so that these two parts turn in unison. Surface *B* of the dividing plate has several divided and numbered concentric circles of different numbers, in order to give a wheel the number of teeth which it needs. The part *K*, called the alidade, is a steel arm which springs. One end is fixed at the point *N*, on one of the pillars of the frame. It carries a pointed screw *L*, which enters the divisions of the dividing plate and holds it fixed at this point. The carriage *F* slides on the arm *O* of the frame, on which the carriage can come and go by means of a screw which moves it towards or away from the arbor *A*, according to the size of the wheel. Fixed on the carriage is a hinge *Q*, which holds a toothed wheel, mounted on an arbor, on the

⁸⁹ I also translate this as *true and centered* when appropriate.

end of which the crank *I* is placed. This wheel meshes with a pinion *P* which carries a steel wheel cut in the shape of file, called a fraise or cutter. So when the crank *I* is turned, the wheel turns the cutter *R*.

Let us suppose that you want to split a wheel. Enlarge the hole until it enters the pivot of the screw *H* and fix it there with the nut *M*. Then place the alidade on the line of the plate N°. 60. Approach the carriage of the wheel little by little, to be sure that the teeth of the wheel will be neither too long nor too short. Then fix the carriage by means of the lock screw *E*, and turn the crank while pressing the hinge *Q* lightly against the wheel. The cutter, by filing the wheel, will split a tooth. That one split, change the alidade point to split another, and continue until you have made a full turn of the dividing plate.

Whip (Fouetter): An arbor or stem whips when it is long and thin. It follows the action of the graver or the movement of the bow.

Window (Fenêtre): An opening made in a plate, opposite a pinion, to examine the gearing and to know the precision or defects of it.

The End of Practical Watchmaking.

In conforming with the Decree of the National Convention of July 19th, 1793, year 2 of the French Republic, I reserve to myself the exclusive property of my work. I will sign all the specimens of it on the first page, so that nobody believing himself true can print and distribute *Practical Watchmaking* without having obtained permission from me to do so. Vigniaux.⁹⁰

Approval.

I have read, by order of Monseigneur the Keeper Of The Seals, a manuscript having the title *Practical Watchmaking* and I have not found therein anything that can prevent the publishing of it.

Toulouse, on February 7th, 1787.

Villeneuve.

General Privilege of the King.⁹¹

LOUIS, BY THE GRACE OF GOD, KING OF FRANCE AND NAVARRE:

With our friendly and loving Advisers, the People upholding our Courts of Parliament, Masters of the ordinary Requests of our Hotel, the Great Council, Provost of Paris, Bailiffs, Seneshals, their Civil Lieutenants, and others of our Dispensers of Justice: GREETINGS. Our friend Sieur VIGNIAUX stated to us that he would wish to impart and give to the Public *Practical Watchmaking*, of his composition, if it pleased us to grant to him our necessary Letters of privilege. WITH THESE SUITS, wanting to treat the Exhibitor favourably, we allow him and permit by these Presents, to print the aforementioned work as many times as will seem good to him, and to offer it, make sales and spread it throughout all our Kingdom:

We desire that he enjoys the effects of this Privilege, for him and his heirs in perpetuity, provided that he does not reassign it to anyone; and so however he would judge in connection with making a transfer of it, the act which will include it will be recorded by the Employers' Federation of Paris, with the penalty of nullity, as well of the Privilege as of the Transfer; and then, by the fact alone of the recorded Transfer, the duration of this Privilege will be reduced to that of the life of the Exhibitor, or that of ten years, as from this time, if the Exhibitor dies before the aforesaid expiry of ten years; the whole in accordance with Articles IV and V of the Judgment of the Council of August 30th, 1777, covering the Regulation of the duration of the Privileges of Booksellers. LET US MAKE prohibitions with all Printers, Booksellers, and other people of quality and condition, to introduce any foreign impressions into any place under our obedience; to print, or to publish, offer, sell, retail or to counterfeit the aforementioned Work, under any pretext, without the express permission in writing of the aforesaid Petitioner, or of he who will represent him, on penalty of seizure and confiscation of the counterfeited specimens, of a fine of six thousand pounds, which cannot be moderated, for the first offence, and a similar fine and forfeiture in the event of repetition, and all costs, damages and interests, in accordance with the Judgement of the Council of August 30th, 1777, concerning counterfeits: WITH the RESPONSIBILITY that these Presents will be recorded all and at length in the Register of the Company of the Printers and Booksellers of Paris, within three months of the date thereof; that the printing of the aforesaid Work will done in our Kingdom and not elsewhere, on beautiful paper and in beautiful characters, in accordance with the Regulations of the Booksellers, on penalty of forfeiture of this Privilege; that before placing it on sale, the manuscript which will have been used as copy for the

⁹⁰ My copy is signed at the end of the preface.

⁹¹ The following translation is rough, for which I apologise.

printing of the aforesaid Work, will be given in the same state when approval has been given into the hands of our very Dear and loyal Chevalier, Guard of the Seals of France, Sieur HUE DE MIROMESNIL, Commander of our orders; that there will then be given from them two specimens to our Public library, one in that of our Louvre Castle, one in that of our very Dear and loyal Chevalier, Chancellor of France, Sieur DE MAUPEOU, and one in that of the aforesaid Sieur HUE DE MIROMESNIL: the whole on penalty of nullity of the Presents; OF THE CONTENTS of which SUMMON and order you to enjoy the aforementioned Exhibitor and his heirs, fully and peacefully, without allowing them any distress or hindrance. LET US REQUIRE that the copy of the Presents, which will be printed at length at the beginning or the end of the aforesaid Work, is held for due notification, and that with the copies collated by one of our friendly and loving Counsellors Secretaries, trust is added as to the original. LET US ORDER with our first Bailiff Sergeant on this demand, to make, for the execution hereunto, all required and necessary acts, without asking any other permission, and notwithstanding the clamour of Haro, Charte Norman, and contrary letters. Because such is our pleasure. GIVEN at Versailles, the twenty-eighth day of March, the year of our grace one thousand seven hundred and eighty-seven, and of our Reign, the thirteenth year. BY THE KING IN HIS COUNCIL. THE STAMMERER.⁹²

Registered in Register XXIII of the Royal Room, with Syndicale Booksellers and Imprimeurs of Paris, No 1009, folio. 212, in accordance with the provisions stated in this Privilege, and with the responsibility of giving to the aforementioned Room the nine specimens present by the Order of the Council of April 16th, 1785. In Paris, on April 13th, 1787.

KNAPEN, Syndic.

⁹² I do not know the reason for the appellation “The Stammerer”. All sources I have seen state that Louis The Stammerer was Louis II (846 - 879) and not our king, Louis XVI.

PRACTICAL WATCHMAKING

Part Five.

Chapter One: Functions of the Pieces of the Dial-Work.⁹³

Amateurs and apprentices who, after making and finishing rough movements, wish to know the functions of the repeater, will do well have the dial-work under their eyes. They will more easily manage to understand its mechanics, and will conceive without trouble what I will show them.

I will not, especially in this part, avoid repetition, because all the parts of the dial-work have so great a relationship between them, that to explain the functions of one it is necessary to speak about the effects that it has on the others. You will also see that when I repeat myself I do it briefly, because I imagine that a worker, with whom I have already spoken, has need only for a few words to understand me.

I have abstained, as much as it is possible, to put letters in the course of this work, because they usually obstruct the reader. Consequently I have placed beside the figures the names of each part, which appeared simpler to me to make the functions of the dial-work and the names of all the parts understood.

This small work being written only for amateurs and apprentices, I hope that by explaining to them the functions of the various parts of the dial-work, I will manage to render it comprehensible to them.

Article One: The Collar.

The collar is a well forged plate of brass, turned true and round, and sufficiently recessed to be able to contain the parts of the dial-work in its thickness. It has a bevel which enters the pillar plate exactly. When one turns the key screws *b c*, Pl. 14, Fig. 2, their ends enter the two notches which are made in the collar, and fix these two parts in an invariable way.⁹⁴

One usually keeps two ears on the collar which are same part; one ear holds the hinge. They both have holes which receive the two feet of the dial, so that it cannot shake when it is fixed by its screw.

Article II: The Mainspring.

The mainspring which gives movement to the train, drives the dial-work at the same time.⁹⁵ Its blade is a spiral. It has a hole at each end which are called eyes; one is held by the hook on the arbor, and the other by the hook placed on the external circumference of the barrel. When spring is placed in the barrel and the train is set up, if one turns the square of the arbor to the left the spring is tightened, in proportion to the turns which one makes with the arbor. The spring, having been wound, moves the train by its elastic force, which makes the dial-work function and sound the hours.

⁹³ A better explanation of the continental quarter repeater will be found in Watkins *The Repeater*. The labels on Plate 14, and references to them in the text, are sometimes incorrect. I have changed both where possible.

⁹⁴ There are actually three key screws, *b*, *c* and *Y*.

⁹⁵ Vigniaux is referring to the small train (the repeater train) not the going train of the watch.

Article III: The Small Springs.

There are several springs in a repeater and each one usually has its own particular function. These springs are fixed to the plate by a screw and a steady pin; their force must be proportional to the efforts which they make to give movement to a part of the dial-work. Their durability, their force, and the facility with which they drive the levers on which they act depends on their form and their hardness.

Since the dial-work has been simplified, there are four types of springs, Pl. 14.

N^o. 1, is a spring in prolonged curve.

N^o. 2, is a straight spring.

N^o. 3, is a spring and jumper at the same time.⁹⁶

N^o. 4, is a spring with a double action.

These springs are given a form and a length as the other parts of the dial-work allow it.

Article IV: Springs with a Double Action.

One makes springs with a double action, such as the spring *W* which drives the star wheel. On the end *c* it has a jumper which is one with the spring. At the same time it functions as a spring and a jumper.

The double action spring *Æ* was invented to drive the hour pallet and the quarter pallet. Although these springs simplify the work, they are prone to several defects, as we will see.

Article V: The Barrel.

The barrel is recessed in its thickness to contain the mainspring. It has two ears which, protruding from its diameter, are used to fix it to the plate by means of two screws. The spring is lodged between the top plate and the bottom of the barrel. As this spring is very narrow, and prone to unhooking when the hook is placed in the interior of the barrel, the hook is put on the outside, and a slit is made in the body of the barrel; so the end of the spring passes through this opening and held by the hook which is placed on the circumference of the barrel.

Article VI: The Barrel Arbor.

The barrel arbor is held between the two plates by two pivots and two shoulders. It has a hook which enters the eye in the center of the spring. It also has a ratchet *I*, Pl. 13, Fig. 1, which is usually part of the arbor; its teeth are very fine so that, when the winding rack is pushed, the click-and-ratchet work is as soft as possible. The ratchet *R*, Pl. 13, Fig. 1, which is used to sound the hours, is also turned equally thick. It is fixed onto the ratchet of the click-and-ratchet work by two screws. It has twelve teeth which are cut on half of its circumference; they are used to sound the twelve hours. The other half is filed round and level with the feet of the teeth. The arbor carries a pivot which protrudes above the plate on the side of the dial-work by about a ligne and a half. It is square in order to receive and hold the chain pulley and the quarter rack gathering pallet, which makes the hours and the quarters sound.

Article VII: The Small First Wheel.

The small first wheel *G*, Pl. 13, Fig. 1, is recessed for half its thickness. This recess contains the ratchet, the spring for the click-and-ratchet work and the click. The spring and the click must have a very soft movement, so that they do not oppose a great resistance to the winding rack when it is pushed. The wheel is held against the ratchet by means of a steel collet which fits on the arbor *D* with friction. Although the wheel *G*, Pl. 13, Fig. 1, rubs against the ratchet *I* of click-and-ratchet work, the arbor *D* can turn without obstructing the wheel *G*. So when the button is pushed, the winding rack turns the small pulley and winds the mainspring, which makes the train run.

⁹⁶ Pl. 14, Fig. 1 *W* uses this form. Pl. 14, Fig. 2 *W* uses a separate jumper.

Article VIII: The Push Piece.⁹⁷

The push piece, Pl. 14, Fig. 1, is composed of two parts. One part *b* is of gold or silver, pierced and turned cylindrical. At the end of this part is soldered the button *a*. The other part *c* is of turned, cylindrical steel and of the same size; it carries a type of stem which enters the canon exactly. When these two parts are fitted to each other, and are pinned at the point *e*, they form the push piece which must enter the canon in the case exactly and freely so that it can be driven without experiencing resistance.

If you examine the steel part *c* which is inside the case, you will see that it is notched to half its thickness; this is done in order to be able to place the steel plate in the case. The plate is supported against the push piece and held in its canon so that it cannot turn. When the steel plate is adjusted to the push piece, it is fixed to the case with two screws *r* and *r*. The end of the push piece carries a fillet of material *d*, called the heel, which is a little larger than the cylindrical part *c* so that when the button is withdrawn, the push piece is held in its canon, although there is free movement.

Article IX: The Winding Rack.

The winding rack *C* is a plate of flat steel filed equally thick. It has four parts, of which the form and the levers answer to the various functions that it must do. The part *f*, Pl. 14, which is used as a fulcrum, is held on the plate by the stud *l*, Pl. 13, Fig. 1, or by a screw. Part *n* is a heel which, being attached to the winding rack by a screw, receives the impulses of the push piece *P*, Pl. 14, Fig. 1. The arm *m*, by resting on the various degrees of the snail, determines the number of hours that the watch must sound. The end of the arm *O*, which is near the large pulley, is formed to receive and fix one end of the chain by the means of a screw or a pin.

Article X: The Chain.

The chain *B* is attached to the end *O* of the winding rack, and the other end is pinned to the small pulley *H*. When the button is pushed, the chain, by running over the large pulley *A*, drives the small pulley *H*, and consequently turns the arbor *D* of the small first wheel. It turns more or less, according to the depth of the step of the snail *N* on which the arm *m* of the winding rack rests. When the button is released, the train runs. In proportion to which it sounds the hours and the quarters, the chain is again wrapped on the small pulley *H* which remains inactive until the button is pushed again.

Article XI: The Pulleys.

The dial-work has two pulleys. The large pulley *A* is placed on a stud beside the arm *O* of the winding rack. It is turned true and round, and is placed free and exactly on its stud. The pulley receives the chain *B* in its thickness. The small pulley *H* is also turned true and round. It has a square hole in its center, which fits on the square of the arbor *D* of the small first wheel. This pulley receives the chain *B* in its thickness, which is fixed there by a pin. It is thus arranged to wind the repeater every time the button is pushed. See the article above.

Article XII: The Star Wheel.

The star wheel *E*, Pl. 13, Fig. 3, is a wheel of brass or steel divided into twelve equal parts. The ends of its rays *u*, which are pointed, correspond with the twelve steps of the snail *N*, Fig. 2. The surprise piece *S*, Fig. 6 and 10, makes it jump a tooth on each turn of the minute hand. The star wheel is riveted onto a steel canon, whose end enters a hole made in the plate. The other end receives the stud *h* of the all-or-nothing piece; so that when it is in position, the star wheel and the snail are held between the plate and the all-or-nothing piece, as in a type of frame where they must have free movement.

Article XIII: The Hour Snail.

The hour snail *N*, Pl. 13, Fig. 1 and 2, is divided into twelve concentric steps, which determine the number of hours that the repeater must strike. It makes more or less hours sound, according to whether the steps of the snail are more or less deep towards the center.

⁹⁷ In the following, only *b* and *c* are shown on Pl. 14. The plate and its two screws *r r* are drawn but not labelled.

It has a hole in the middle which exactly fits the canon of the star wheel *E*, and two screws fix these two parts together so that one cannot move without the other.

Article XIV: The Quarter Snail.

The quarter snail *L*, Pl. 13, Fig. 6, is a steel wheel turned round and of uniform thickness. It is divided into four equal and concentric steps. These four steps, 1, 2, 3, 4, by their different depths, determine the number of quarters which the watch must strike. The snail is riveted onto the pinion of canon pinion *O*. For its effects see the article on the quarter rack.

Article XV: The Valet or Jumper Spring.

The valet or jumper spring, Pl. 14, *W* has a hole at one of its ends which is used as a fulcrum. This hole fits on a stud attached to the plate. The other end is inclined in the shape of an elongated V. The jumper spring has a notch or a pin close to its fulcrum, which receives the end of its spring.⁹⁸ The spring, by its elastic force, presses on the jumper and makes it drive the star wheel at each change of hour, and then holds it at its point of rest until the button of the surprise piece makes it move again.

There are springs or jumper springs which are a single part; see springs with a double action.

Article XVI: The All-Or-Nothing Piece.

The all-or-nothing piece, Pl. 13, Fig. 4, is a plate of steel filed flat and uniformly thick. It is placed on two pillars which are fixed by screws onto the plate. The pillar *g*, Pl. 14, is bored, and the other *i* has a pivot jutting out from its shoulder. Part *Z* of the all-or-nothing piece carries a stud *g*, which enters the hole in the pillar which is used as a fulcrum. At the opposite end *T*, it has a hole *e* which is placed over the pivot of the other pillar. So when the plate *Z* of the all-or-nothing piece is placed on its two pillars, it forms a type of frame which contains the star wheel *E*, and the snail *N* by means of the stud *h*, which fixes them so that they are true and free in their frame.

The plate of the all-or-nothing piece is held in place at one end by the key screw *Y*. As, when pushing the button, the other end could lift up, causing the functions of the repeater and the effects of the all-or-nothing piece to miss, someone thought of making a spring which is fixed to the all-or-nothing piece by a screw close to the fulcrum *g*, and the other end *e* enters a notch made in the pivot of the pillar *e*. By this means the all-or-nothing piece is firmly fixed onto its two pillars and retains the freedom to function.

The hole in the plate in which is placed the pivot of the canon *p* of the star wheel *E*, Pl. 13, Fig. 3, is a small oval. So when the winding rack *C* is pushed, and the arm *m* of it touches the snail *N*, the all-or-nothing piece makes a small movement which gives freedom to the quarter rack to disengage and fall on its snail. When the hours and quarters have sounded, the beak *r* of the quarter rack passes in front of the part *i* of the all-or-nothing piece and pushes it until it has passed over the beak *T* of the all-or-nothing piece to lock on it, and remain there at its point of rest until the winding rack is pushed again. It is the detent of these two parts at the ends *r* and *T* which forms the all-or-nothing action.

Article XVII: The Surprise Piece.

The surprise piece *S*, Pl. 13, Fig. 10, is a steel plate which has about a quarter of its circumference. It has a hole in the center which enters exactly and free on the canon of the canon pinion. The surprise piece is held against the snail by a collet which goes on the canon pinion with friction and so that the surprise piece *S* has free movement, though it is held against the snail *L*. This movement is controlled by a pin which is placed on the snail. It enters an oval hole *n* made in the surprise piece to receive it, to control the movement of the surprise piece. It also has a button *t* underneath, which is used to drive the star wheel. When the motion-work runs, the button *t* passes into the rays *u* of the star wheel and changes its place; and at the same moment the impulse of the jumper spring drives the surprise piece out beyond the first step 1 of the quarter snail. This movement forward is necessary, because if first step 1 of the snail were as large as the others, the arm *a* of the quarter rack would

⁹⁸ Plate 14 shows two different jumper springs; the first is a single piece, and the second, being described here, is in two parts

engage with the first step at the time when the surprise piece is about to make the star wheel jump.

Article XVIII: The Quarter Rack.

As the functions of the quarter rack Q are very difficult to understand, it will be good to have a repeater to look at, to make it function several times, and to examine its various operations attentively. It is made of a steel plate Q , and is filed uniformly thick. It has a hole in the center d , which is tapped the same as the canon, and when a screw is put tightly in the canon in the center d of the quarter rack, these two pieces are united together in an invariable way. The canon enters a stud which is used as a support. A pin e is put in the center of the quarter rack about a ligne away from the canon. The quarter rack spring is placed so that its end rests against this pin; this spring makes the quarter rack drop onto its snail when the button is pushed.

The arm a of the quarter rack is used to determine the number of quarters which the dial-work must sound; it sounds more or less quarters according to the depth of the four steps of the snail on which the arm a of the quarter rack falls. The pin c , which is close to the three teeth 1, 2 and 3, is used to raise the quarter rack a moment after the hours have sounded; then the quarter rack gathering pallet V , Fig. 9, meets the pin c , moves it, and makes the quarters sound.

When the quarters have sounded, the arm r , which communicates with the all-or-nothing piece, passes in front of that piece's arm i , which it pushes back until it has reached the end T . Then the all-or-nothing piece, pushed by its spring, locks the arm r of the quarter rack to hold it at its point of rest. At the same instant the arm k presses against the stud u of the pallet F and pushes back the lever u of the pallet F . By this means the end of its lever x is reversed, so that if you do not push the winding rack far enough to move the all-or-nothing piece, the train will slip by without striking the hours. If you push the winding rack far enough to move the all-or-nothing piece T and r , at that moment the hour pallet F , having gained its freedom, will be reversed by its spring so that the ratchet R meets the end of pallet x and will sound the hours.

Suppose the winding rack is pushed. When the arm m of the winding rack touches one of the steps of the hour snail N , the pressure of the winding rack will make the all-or-nothing piece T move, and the quarter rack Q will drop onto its snail L . And by dropping, the two ends y , which are in the shape of a ratchet, will push past the two pallets U and X , which will immediately be pushed back by their springs to their point of rest, so that they can strike the hammers when the quarter rack gathering pallet V raises the quarter rack.

Push the button again, the quarter rack Q is released from the all-or-nothing piece T , and will obey the impulse of its spring. If the arm a of the quarter rack drops on the first step of its snail L , the teeth of the two ratchets will be a little further away from the pallets, and when the quarter rack gathering pallet raises the quarter rack it will sound the hours without quarters.

Turn the snail so that the arm of the quarter rack drops on the second step. By its impulse it will retrogress the two pallets U and X , which will be placed between the first and second teeth of the two ratchets. When the hours sound, the quarter rack gathering pallet, while raising the quarter rack, will actuate the two pallets U and X which will give a blow of the hammers rapidly and distinctly one after the other, which indicates that the repeater has sounded a quarter.

If the arm a of the quarter rack drops onto the third step of the snail, the dial-work will repeat two quarters; and if the arm a of the quarter rack drops onto the fourth step of the snail, all the teeth of the two ratchets will reverse and pass the two pallets U and X , and when the quarter rack gathering pallet raises the quarter rack it will sound three quarters.

Article XIX: The Quarter Rack Gathering Pallet.

The quarter rack gathering pallet V , Pl. 13, Fig. 9, is a small lever which is a straight line from its end to the center of the pivot of the arbor D , of the small first wheel, Fig. 1. The quarter rack gathering pallet has a square hole t so that when it is placed on the arbor it cannot make any movement unless the arbor turns. When the pulley H and the quarter rack gathering pallet V are put on the same square of the arbor, they are fixed by a pin. If you push the winding rack, the chain will turn the quarter rack gathering pallet backwards, which then being turned by the running of the train, will meet the pin c of the quarter rack

and make it sound according to the depth of the step of the snail on which the arm a of the quarter rack has fallen.

Article XX: The Entries.

Three holes are made beside the pivot which juts out from the large hammer. These allow the three posts, which are used to sound the hours and the quarters, to pass through to the side of the dial-work. These three holes (which are called entries) are bored on a compass line which follows the contour of the hole of the large hammer. These entries must be wide enough to let the hour pallet and the two posts of the hammer pass freely.

The stem of the small hammer has a pivot which passes through the plate on the side of the dial-work. This pivot receives the quarter pallet. An entry is also made close to the hole for the stem of the small hammer; this entry lets the post of the small hammer pass freely, which gives the pallet X the means of striking the quarters.

Article XXI: The Hour and Quarter Pallets.

The hour pallet F , Pl. 13, Fig. 1, has on one side the lever x , which passes close to the small first wheel. On the other, it has a post u or type of lever which, passing through its entry, rests against the hammer. When the train runs, the ratchet R moves the lever x of the pallet. Then the hammer, moved by the post u of the pallet, rises into the frame until the ratchet, ceasing to catch, frees the hammer and it, pushed by its spring, sounds the hours.

The quarter hammer also has a pallet X which is in the form of a comma. When ever the quarter rack rises, the pallet is pushed by its spring back to its point of rest. When the two pallets X , U are raised by the quarter rack, they each strike a blow one after the other. These two distinct and rapid blows announce that the watch has sounded a quarter.

Article XXII: The Silencer.

The Silencer s , Pl. 13, Fig. 11, is a steel plate bored in the center, and held on the plate by a screw a . Its two ends $c d$ are contoured so that one rests against the post of the large hammer, and the other against that of the small hammer. It has a square, flat arm b which goes through the collar and which protrudes from it by about a ligne and a half. It is set up so that when you push the winding rack and the watch sounds the hours, if you press a finger on the arm b , the two ends $c d$ will rest against the posts of the hammers, and this pressure will prevent them from striking against the bell.

Examine the bezel of the case and you will see opposite the arm b of the silencer a small spring which is fixed there by a screw. It holds a button inside the bezel which emerges from the case. After closing it, make the dial-work function, and at the same time press on the small button of the silencer with a finger. You will distinctly feel all the blows which the hammers strike and be able to count the hours without hearing the bell. And when you no longer push on the small button the hammers, having been freed, will strike against the bell.

Article XXIII: The Bell.

The bell, of which everyone knows the form and effects, is fixed by its center to a boss which is soldered in the bottom of the case. A screw holds it there so that it cannot touch the case or any part of train.



Chapter II: Repairing the Dial-Work.⁹⁹

The repair of dial-work is very difficult. It would be preferable that all workmen who intend to do this work had spent some time making them. They would acquire from the experience of hand work a full understanding of dial-work, which would give them the means of correcting the defects to which it is prone.

The various functions of the dial-work are so complicated, and have many relationships where they combine, one with the other, that one cannot take too many precautions to preserve them in their original state.

When you repair a repeater, especially take care to avoid tempering, forging or filing the various parts of the dial-work. You will often get into great trouble, and will make it almost more defective than it was before passing through your hands.

To avoid similar faults, make the dial-work function at various times. Examine with great care the various movements of all the parts, and when you are sure you have found the defect or the stoppage which you seek, employ the methods which I shall give.

It would be impossible for me to speak about all the defects which can make a repeater miss strike or stop. I will speak about those which experience has made known to me, and give you the methods for correcting them.

Article One: Stoppages caused by the Collar.

The collar can cause many defects in the dial-work. Several parts and most of the springs are placed around the collar, so that if they touch it, just this friction will make the effects of the dial-work miss. In this case, it is necessary to give space between the collar and the springs with a square graver. If it is not possible to do that, it is necessary to change the position of the springs or, by changing their form, make sure they do not touch the collar.

Sometimes the pallets pass so close to the collar that they touch it or butt on it. If this defect is difficult to find, and you cannot catch the part at the stop, nor know the place where it touches, wet a little rouge with a drop of oil and put it on the pallets. By making the dial-work function, they will mark the places where they touch, and the defect once known will be easy to correct.

The silencer can also make the hammers miss if it is constrained in its notch. When you are sure of it, file the notch with a smooth file, and you will easily give it freedom.

Article II: Stoppages caused by the Mainspring.

If the mainspring is soft, it will pull the train badly and lose its elasticity quickly. If it is too hard it will be prone to break. If it is too stiff or its blade is uneven, it will pull too much at the start and too little at the end. If it has these defects, it is necessary to choose a spring whose blade is flexible, uniform and of good hardness.

When the mainspring is constrained in the barrel, or it rubs on the plate, give it freedom by recessing the bottom of the barrel or the top plate. See the article on the small barrel.

Sometimes it happens that the hook on the arbor cannot hold the eye in the center of the mainspring. You will usually succeed in making it hold by introducing a piece of brass between the first and second blades of the mainspring. While you turn the arbor with one hand, put the brass piece in its place with the other, which will make the arbor hold the spring.

If this method does not succeed, it is necessary to disassemble the piece and to arrange the first turns of spring so that they follow the contour of the arbor. If the hook of the arbor is too thick to enter the eye easily, thin it.

It happened to me that I could disassemble and assemble a repeater several times without being able to make the arbor hold the spring. Wearied by this problem, I made a hole the size of a watch hand in the top plate, a little beyond the last turn of the spring. I then made a small hook at the end of a hand, which I introduced between the first two blades of the spring and, while I pressed one hand on the spring, I turned the arbor of the barrel with the other;

⁹⁹ Another discussion of faults will be found in *Crepe Essay on Repeater Watches*.

by this means, I easily made my arbor hold it. Thus one must endeavour to overcome problems, without deteriorating the watch.

If you cannot assemble the train, because the last turns of the mainspring are, (being in its barrel) a little to one side, or that it is a little closed and the size of the arbor prevents the pivot from entering its hole, put a bevel on the end of the head of the arbor. While opening the first turn of the mainspring, it will give the facility to put in the pivot. If this method does not work, do it as follows.

To be sure that the small mainspring will not prevent the pivot of the barrel arbor from entering its hole, make two holes in the top plate opposite each other, that are size of a watch hand, and a little away from the center of spring. Put two pins in the plate from the side of the cock, whose points protrude about a ligne from the part which forms the bottom of the barrel. Then use pincers to place the last turn of the spring beyond these two pins which, holding it more open than the size of the arbor, will let you assemble the train easily. When it is assembled, pull out the pins.

Article III: Method of making small Springs.

When you have to remake a spring, before doing anything see if it is well placed according to the principles. If it is not, find the best position according to the positions of the other parts and so that it does not obstruct the dial-work. Give this spring a consistency proportional to its length. A spring which is a little long acts with less violence and is not prone to break. Take care that its width tapers slightly toward the point; it will make it springy throughout its length, and will keep it elastic for a long time.

As far as you can, make your springs in a straight line *K*, or an elongated curve *R*, Pl. 14, unless the position of other parts of the dial-work prevents it. One gives them a form according to their circumstances. Fix them to the plate with a steady pin and a screw, so that they can be assembled and disassembled when necessary, and you will be sure to always replace them in the same position, and so that they will have the same amount of bending. Your spring roughed out, harden it and touch it with a file to test if it is hard from one end to the other. Whiten it with pumice stone. Take care, when doing this, not to press too hard on the part; if it is not flat it will break like glass. It is necessary to temper it blue, and set it in place. If it acts with too much strength, file its width, always tapering it slightly from the foot to the point, until it is of a force proportional with its function, and easily leads the part that it drives.

If it is not bent enough, take a square piece of brass filed flat and fix it in the vice. Place the spring flat on it and strike it with the round peen of a hammer on the side which you want to bend. Strike it smartly and firmly according to the consistency of the spring. To succeed more easily, it is necessary to strike at the bottom of spring as far as you can. Never fail to temper your springs, at least to deep yellow, after correcting them (which many good workmen call to stop a spring); you will be sure that, though they take much care, and you filed or polished them, they will not lose their elasticity. However, if you neglect to temper them, they will easily revert, and you will have the nuisance of repeating the operation shortly after finishing and setting them up.

You can smooth and polish springs on glass or an iron plate. To use glass, spread a little oil stone crushed with oil on it. Place your part on the glass, take a quite level bottle cork, and after sitting it on the spring, move it on the glass in a circular pattern, and continue until it is flat and without marks. Then smooth the sides of the spring with an iron file coated with oil stone. Take care to make several iron files of various sizes; ones that are flat, and others like crossing out files. One uses these tools according to contours of the part which is to be smoothed.

Before polishing the spring, clean the glass very well so that no oil stone or dirt remains on it. Take another clean bottle cork, put putty or rouge on the glass, and move the part in a circular pattern, until it takes a beautiful polish. If the part is so delicate that you fear breaking it, use the second or third finger to move the spring on the glass; this method succeeds wonderfully.

There are workmen who polish springs and flat parts in another way. They have several iron, copper, brass and tin plates which they give the shape of a hand file. The iron files are always used to smooth with oil stone, and the others to polish. See N°. 103, 104.

When you have difficulty in getting a black polish, which happens because the rouge or putty is not fine enough, take a quite smooth riveting stake and crush your compounds with oil until they become black; by just this means you will polish the part more easily.

One uses cork to smooth and polish because it follows the movements of the hand, and will smooth and polish flat. Take care to use cork which is quite smooth, because if there were hard spots it would make marks on the piece. It is better is to wrap the cork in cloth, and still better in a little skin. That done, you will place it in the vice.

Article IV: Stoppages caused by the Spring with Double Action.

By inventing the spring with double action, the repeater was simplified. This spring made carefully, well laid out, and well fitted, functions wonderfully without being prone to any disadvantage.

The double action spring, by its structure, its form, and the various functions which it does at the same time, can give much trouble to the workmen, when it is a question of placing it, making it function, and preventing or correcting the defects to which it is prone.

When the quarter rack drops on its snail, the train, while sounding the hours, draws aside the pallet so far that only the movement of the hammer makes the quarter pallet retrogress, so that when the teeth of the quarter rack bring back the pallet it then butts against the teeth of the quarter rack, making the quarters miss strike, and stops the watch. This defect occurs because the stop that is made by the double action spring is not close enough to the pallet to prevent it from retrogressing. If the hour pallet is moved too far by the head of the spring, file it a little. By this means it will deviate less, and will prevent the quarter pallet from being reversed.

If this method does not work, it is necessary to make another pallet in which the notch against which spring acts is prolonged, or a spring of which the stop is closer to the pallet. When repairing one can correct this defect by placing a pin in the plate which prevents the pallet from retrogressing more than it should; this method, though very simple, generally works.

There is sometimes so little space between this spring, the pallet and the silencer, that there hardly remains the thickness of a card from the post which is used to hold the pallet which drives the hammer. For the little play that the spring has, or that it raises the pallet, it will act against the post of the hammer and will prevent the hours sounding. It is necessary, in this case, to fix the spring well, or to make another which holds the pallet well, so that when it leads the hammer it cannot be raised, leave its place, or exceed the stop of its spring. When the head of the pallet is small and the surface on which spring acts is not prolonged enough, the spring will not have enough support to push back the pallet briskly. It will sometimes butt against the angles of the pallet and will make the repeater miss. The quickest solution is to make another pallet whose head (being larger) will have a longer surface on which spring will act more easily.

The effects of this spring are so sensitive that, although it is fixed to the plate with a steady pin and a screw, if you loosen or tighten the screw a little you will make the quarters miss strike. This spring is so difficult to handle that, while trying to correct one defect, it is replaced by another more embarrassing, because of the difficulty which the spring has to drive the hour and quarter pallets at the same time. The hour and quarter pallets are not prone to these problems when each pallet has its own spring. In the case that one of these springs has suddenly missed, it can be fixed more easily because, the movement of each pallet being given by its own spring, you will cure the defect of the one without being prejudicial to the other.

If the pallet retrogresses too much at the time the quarter rack drops, and if it does not then return to its point of rest while waiting for the quarter rack to strike the hammer, it will often be enough to prolong the notch of the pallet on which spring operates a little, or to bend the spring a little. If that is not enough, it is necessary to make a spring which is of a force and form proportional with those of the pallet.

Article V: Defects of the Arbor of the Small First Wheel.

If the hook on the arbor is placed too high or too low it should be moved, because it would make the blades of spring rub against the barrel, or it would prevent the hook from holding the eye of the mainspring. This would give much trouble, and would prevent you from

reassembling the watch. If the hook is too thick, thin it, which is generally enough to make the arbor hold the mainspring.

When the arbor is small the spring is prone to break, or it will not act with enough strength. It must be one third of the diameter of the barrel. If it is small it will be necessary to make a steel or brass collet (called a jacket). After turning it and reducing it to a third of the barrel, drive it onto the arbor and put a hook on it.

Place the arbor true in the frame. If it is tilted, the small first wheel will rub against nearby wheels or the potence, or obstruct the pallet. All these defects will weaken the effects of the driving force or will cause stoppages. If the arbor is not free in the frame, the mainspring will not move the train uniformly and will often cause it to stop.

Article VI: Defects of the Small Barrel.

If the small barrel is not well recessed or it has marks inside, it is necessary to place it on the turns in the air, to remove the marks with a square graver, and then smooth it with pumice-stone or water stone which is given the shape of a square graver. If the bottom of the barrel is the plate, then it is necessary to put the plate on a screw arbor, and to operate as above.

When the barrel is so narrow that spring is constrained in it, it is necessary to recess the plate a little to give the spring the necessary freedom, or to put in a wider blade.

If the small barrel is so thin that, for little that you can touch it, it obstructs the blade of spring, another well hammer-hardened barrel should be made, that will give you the facility to turn it quite thin and give it consistency necessary. In this case it is necessary to polish the barrel and not gild it; it would become soft and have the same defect.

When the teeth of the contrate wheel touch the barrel and it is not possible, because of the other parts of the repeater, to change the gearing, put a little rouge on the ends of the teeth of the wheel, put it in the frame, and drive it. By this means the rouge will mark the barrel where the teeth touch. This part will have to be filed or cut with a square graver to remove the material until the wheel no longer touches it.

Article VII: Defects of the Push Piece.

If the button of the push piece touches the canon, so that the push piece cannot be pushed in enough to make twelve hours sound, it is necessary to lengthen the cylindrical part *b*, Pl. 14. If you cannot alter it, file a little off the end of the canon until the push piece is long enough to push the winding rack against the twelfth step of the snail to sound twelve hours.

When the repeater, after sounding the hours, misses the last quarter, that often means that the heel of the push piece is obstructed by the winding rack and the case. If the last quarter sounds when you open the case, it is proof that the stoppage comes from the push piece. One can also, when last quarter does not sound and one realizes that the push piece is obstructed, pull out the button with effort. If by just this movement the piece sounds, you will be sure to have found the defect. Then disassemble the plate of the push piece and file the end, or use a square graver to shave the hole of the canon in the case; after touching it a little, the quarters will no longer have this defect.

When the push piece has too much play in its canon, it can move the heel of the winding rack aside instead of pushing it in a true line, or it can touch the large barrel, which would make the action of the dial-work miss. Make another push piece or another canon.

A push piece which is too tight in its canon makes it difficult to push the button. If you do not take care to withdraw it after pushing it, it will obstruct the motion of the train, and will make the hours or the quarters miss. Sometimes this defect comes from rust which has formed between the end of the push piece and the plate which holds it. It is necessary to remove the rust, rub the part and coat it with one drop of oil.

When a push piece is too free in its canon, and it sometimes engages there, it is a defect which can come from the pin which links the two parts of the push piece. If this pin becomes free in its hole, it will rise a little and will engage in the canon. Rivet or file it, or change the pin.

Article VIII: Stoppages caused by the Winding Rack.

It is necessary that the winding rack lies flat on the plate, and runs freely between the plate and its bridge. If it is constrained, file the end of the bridge until the winding rack has the necessary freedom. If the end of the arm which drops on the snail scrapes or if it makes marks on the plate, smooth it with oil stone.

When the chain is fixed to the winding rack with a pin or a screw which protrudes from the end of the winding rack, just this defect will stop the functions of the repeater. It is necessary to file the pin or the end of the screw flush with the arm of the winding rack.

The winding rack *C*, Pl. 13, Fig. 1, is fixed to the plate by the post *l* which is used as a fulcrum. If it is constrained in its hole, or if it makes the winding rack touch against the plate, or the arms *m* and *O* rise, which can cause several defects, correct it by enlarging the hole of the fulcrum, until the winding rack no longer touches.

If the hole is larger and the post shakes at its fulcrum, the arm *m* of the winding rack will vary in its direction, will sometimes move in one direction, sometimes in another, and will miscount the hours. If it moves against the nearest angles of the snail, the repeater will sound less hours than it should. In these two cases it is necessary to bush the hole of the fulcrum, or to make a post which enters the hole exactly.

When the arm of the winding rack, while dropping on the snail, touches the collet which holds the surprise piece, the winding rack will be obstructed by the collet or will butt on it, and make the hours miss. If the collet is rather thick, decrease the diameter of it. If it is so thin that you risk making it defective, file the back of the winding rack until it passes beside the collet without rubbing on it. I have seen repeaters stopped by just this friction, which stopped the movement of the train.

Push the button. If you see that the star wheel has a retrograde movement, that usually means that the end of the arm *m* of the winding rack touches the angle of the next step of the snail. File the end of the arm of the winding rack, because this defect would miscount the hours.

When the arm *m* of the winding rack is thin and it is not held well by its bridge, or the snail has the same defect, the winding rack will slip over or under the snail, which will make the dial-work miscount. It is necessary to fix the bridge on the winding rack so that it is true and free. If this does not work, it is necessary to make a thicker winding rack.

If the winding rack, though thin, has a good form, you should remake it immediately. To do this, bore a hole in a steel plate which is same size as that of the support *f*. Pin these two parts together. Make another hole in the plate opposite that of the hole in arm *O* which receives the chain, and put in a pin which crosses the steel plate and the old winding rack. That done, just follow the lines and contours of the old winding rack with a file, and when it is well roughed out remove the two pins. File the part flat and uniformly thick. Fit the post *l* at its fulcrum and the chain on the arm *O* of the winding rack, and make it function. Then it is necessary to harden it, blue it, smooth it, polish it, and set up it. Workmen who are not familiar with dial-work will do well to use this method when they have to remake some part.

If the end of the arm *m* of the winding rack is rounded a little or bevelled, it can slip over or under the snail, which will stop the dial-work. File the end of the arm *m* of the winding rack straight; then take care to use oil stone on an iron file to remove the burrs. The part set up and performing well, polish it; see N°. 105.

Article IX: Stoppages caused by the Chain.

Choose the best chains that it is possible to get for the dial-work. They should be well hardened and as wide as the grooves in the pulleys will allow. It is necessary that the links are quite free, and that the chain is equally thick to prevent it binding in the grooves. Also, a chain will break more easily in the hands of its owner who, not knowing the danger, pushes a repeater with force without realising that there are sometimes obstacles which hold the push piece.

If the chain breaks, rejoin it carefully, file the pin flush with the chain, and pass oil stone and then a burnisher over it. When a link is broken or lost, it is necessary to add as much as is missing. The chain being rejoined and the pulleys and the winding rack set up, if when pushing the button the watch sounds more hours than is needed, it is proof that the chain is too short. When it sounds less, it is too long. It is necessary in these cases to lengthen or shorten it. If you do not have links exactly the same as those which were broken or lost, you

can manage to lengthen the chain by filing the hole in the ring which fixes the chain to the winding rack a little oval, or by making a longer ring. If you want to shorten it, make a shorter ring.

When the chain is bad and prone to break, do not waste time on it. Use the old one to determine the length of a new one, fix one end to the small pulley and the other to the winding rack. If it is too long, follow the method above.

If the chain is too short to use, turn the bottom of the groove in the large pulley, which will decrease its diameter. By this means the chain will acquire the necessary length. To turn the bottom of the groove in the large pulley, make a square graver which enters the pulley exactly. It must be well smoothed, and square on the bottom. Harden it, temper it deep straw, and grind it with an iron file coated with oil stone. While recessing the pulley, put it in place now and then to test if it works correctly. When it works well, smooth and polish it. It is essential that the chain is not constrained in the pulley; this defect alone would make the functions of the dial-work miss. If the pulley is so hard that the square graver cannot bite into it, temper it, and when it works well, harden and polish it.

When the chain is too long, so that the repeater sounds one hour less than it should, and while pushing the button you realize that the pallet is almost at the point to escape from the ratchet, that shows that just a little correction will make sound exactly. It will then be enough to file a little from the end of the arm *m* of the winding rack. Before doing it, examine whether the winding rack and the push piece can drop far enough to reach the twelfth step of the snail. Several causes can prevent the push piece and the winding rack dropping on the twelfth step of the snail. If the winding rack touches the bridge, it should be filed. The other defects are caused by the action of the push piece; see the article on the push piece.

Before putting in the chain, make sure that it moves freely in the grooves of the pulleys, and make the links and the ring free; without this care the chain, by binding in the pulleys, will make the repeater miss. If the pin or the screw which fixes the chain to the winding rack protrudes, file it close to the winding rack. That could make it miscount the hours or stop the action of the dial-work.

Article X: Stoppages caused by the Pulleys.

Take care that the large pulley is true on its stud; because if it is tilted on the side of the winding rack, it will rub against plate or will butt against the arm *O* which holds the chain, and it will miss the last quarter. If it inclines to the opposite side, the side *e* of the pulley will rub against the chain, will prevent it from running freely in the groove, and will make the hours miscount. Also, when the ring does not enter the groove easily, the arm *O* of the winding rack, by butting against the part *e* of the pulley, will make the last quarter miss; it is necessary to turn a bevel inside the groove of the pulley, then the ring will enter the pulley freely, and the winding rack will do its duty. There are cases where the diameter of the pulley *e*, being too large, prevents the winding rack from moving far enough to make the last quarter sound, it is enough to turn the circumference *e* of the pulley until the winding rack no longer touches.

When the small pulley is not well adjusted on its arbor and it shakes, it can rub on the plate or the quarter rack. The best thing to do is to make another whose square is exactly the size of the arbor, so that one can remove and put back the pulley easily.

If the pin which fixes the chain to the small pulley protrudes underneath, and it makes a mark on the plate, that can cause the hours to miscount or make them sound sometimes rapidly and sometimes slowly. If this pin protrudes from the pulley and touches the quarter rack, the rack, being obstructed, will miss its action. It is sufficient to strike the pin a few times with a hammer and to file it close to the pulley. When the pulley is so thin that it can be distorted when putting it in place, it can prevent the chain from developing easily, and so miscount the hours. Sometimes the pulley obstructs the chain so much that it can no longer develop, which stops the dial-work. In these two cases it is necessary to make another pulley.

When space between the quarter rack and the plate is so small that one cannot make a thicker pulley, make a recess in the plate a little larger than the pulley; the thickness that you have removed from the plate will enable you to make a thick enough pulley and not risk a similar defect.

Article XI: Defects of the Star Wheel and the Hour Snail.

Make sure that the star wheel and the snail are well fitted to each other, and they turn true and centered. If the snail binds to its post, either by the effect of rust or other causes, remove the dirty oil or rust, or enlarge the center of the hole until the star wheel and the snail are free in the frame.

Sometimes the canon which links the star wheel to the snail is so long that it obstructs them in their frame. If the shoulders are too tight, turn them on the side where the space is larger. If the snail is too far away from the star wheel, file it accordingly as the case requires. Sometimes the star wheel is not well riveted to its canon, so that it can touch the plate of the all-or-nothing piece, or butt against the surprise piece, or it cannot obey the impulse of the jumper spring. Rivet the star wheel to the canon until it turns true and centered.

When you are obliged to separate the snail from the star wheel, before removing the screws make a reference mark on the star wheel and the snail. Without this precaution you could change their place: this change would make the hours miscount, especially if the hole in the snail is a little larger than the canon of the star wheel.

If the heads or ends of the screws protrude from the star wheel or the snail, they will rub against the plate or the all-or-nothing piece; file them flush with the star wheel and the snail and then polish them.

The square of the arbor of the fusee sometimes passes so close to the star wheel that it butts on the ends of its rays, and makes the repeater miscount or stop. After marking the place where the star wheel touches the square of the arbor, place it in the turns and make a rather broad and deep groove, so that the star wheel can no longer touch it.

When the dial-work misses on a step of the snail, guard against filing it, because you would be obliged to file all the other steps, and if this defect came from another part, the snail would be degraded so much so that it could no longer be used. Thus never touch the snail unless you are convinced that the defect comes from the inequality of the steps, and they were not filed properly concentric.

It is the practice of repeater makers to trace on the snail twelve concentric lines which determine the form and the depth that the steps of the snail must have. When the snail is incorrect and the marks are not traced on it, place a point of a compass in the center of the snail, and with the other point make a line on the steps which miss, and file them while scrupulously following the marks.

Let us suppose that your repeater sounds every hour correctly. When the star wheel and the snail are at the point of rest and, at the moment when the surprise piece will change the position of star wheel (which happens from 55 to 59 minutes), the part sounds one hour too few, it is proof that the step was not well filed to its concentric line. Then it is necessary to do as above. If the part sounds one hour more that it should, lengthen the chain by a link, or made a ring a little longer, or turn the bottom of the groove of the large pulley, until the step sounds correctly. All the other steps which miss are corrected until the snail is equalized.

Article XII: The Quarter Snail.

I have often spoken, in the course of this work, of the defects to which the quarter snail is prone and I believe it would useless to repeat them. I will restrict myself to saying that when you turn the minute hand and realize that the canon pinion does not turn evenly, or that it clings, or that the quarters do not agree with the minute hand, it is proof that the snail is not well riveted onto the canon pinion. It is necessary to turn the snail on the canon pinion until the surprise piece jumps the star wheel at sixty minutes. And then rivet the snail until it is well fixed onto the canon pinion, and it turns true and round.

If the snail passes close to the star wheel, if it butts or hangs there, take care to correct these defects, and especially pin the canon pinion onto the stem. Because if the canon pinion lifted up, you would risk the arm *a* of the quarter rack, while dropping onto its snail, passing under and not resting on it, which would stop the dial-work and the movement.

When the star wheel does not jump at the time when the hand is over sixty minutes, and you risk spoiling the pinion of the canon pinion by unriveting it, the only option is to enlarge the hole in the minute hand. Make a collet with a punched square hole and fit it in the hole of the hand. When the star wheel moves at sixty minutes, remove the hand and rivet the square that you put there.

Article XIII: Defects of the Jumper Spring or Valet.

The jumper spring, or valet, must be exact and free on its post. If it is too tight, it will be constrained so much that its spring will not be able to make the star wheel function. The star wheel, remaining half way, will obstruct the surprise piece, and sometimes it will butt and stop the watch. It is necessary to clean the holes, or to enlarge them if they are too tight. If the spring which controls the jumper is not strong enough, bend it, or make another strong enough to drive the star wheel.

If the jumper locks on the ends of the rays of the star wheel, and if its points have a small square flat or some burrs, round the ends with a smooth file, and pass a burnisher over them as if you wanted to round them. If the jumper has too much play, if it passes over or under the star wheel, it can be easily cured by bending the spring so that the end always presses on the valet (or jumper spring) and holds it on the surface of the star wheel.

When the valet and spring are a single part, if the spring is weak and its head is badly formed or too thin, the jumper will pass over or under the star wheel or will slip between the snail and the star wheel, against which it will butt and stop the dial-work. If spring is too thin, it is necessary to make another, and to keep all the length of its blade as broad as you can; this width will give it enough strength to prevent the jumper from leaving its place. If the head of the jumper is too thin, make a thicker one. If the head is round or bevelled, repair these defects with an iron file coated with oil stone, which you will pass over the front of the jumper spring until its angles are flat. If the spring is not well placed, it is necessary to raise or lower the end of the jumper spring until it acts fully in the star wheel, so that in no case can it leave the rays.

Article XIV: Defects of the All-Or-Nothing Piece.

The all-or-nothing piece, though very simple in its action, is prone to several defects. If the spring which moves the star wheel and, at the same time, the all-or-nothing piece is not enough strong to make these two parts function, try to bend it; and if that is not sufficient, it will be necessary to make another with a stronger blade.

If the post of the fulcrum is constrained by rust, (which will cause the action of the all-or-nothing piece to miss) remove the rust. If the hole of the all-or-nothing piece which enters the pivot on the pillar is not large enough, and the plate of the all-or-nothing piece touches the pivot before the all-or-nothing piece can be released, enlarge this hole and give the all-or-nothing piece the freedom to obey the pressure of the winding rack.

If, when pushing the winding rack, the end *T* of the all-or-nothing piece rises, it is proof that it is not held well in its frame. Tighten the key screw *Y*, which sometimes is enough. If the defect remains, it is necessary to examine whether the spring which enters the notch of the pivot of the pillar is well supported against the pivot. If not, the spring should be bent; some taps of a hammer will be enough. When the notch is not deep enough, and it lets the spring slip, it is necessary to deepen the notch with an equalling file and bend the spring. If there is no spring which holds the all-or-nothing piece to the pillar *i*, put another key screw there, or bore a hole in the pivot of the pillar close to the plate of the all-or-nothing piece and put a pin in it.

I suppose that the release of the all-or-nothing piece does not take place when the winding rack reaches a step of the snail, although the arm *r* of the quarter rack is ready to be released. That shows that the detent is too strong. It is necessary to file the front of the all-or-nothing piece little by little, until the all-or-nothing piece is released and obeys the impulse of the winding rack.

If, when pushing the button, the all-or-nothing piece drops before the winding rack reaches the snail, and if the dial-work sounds one hour less than is needed, it is proof that the all-or-nothing piece was not well formed. To correct this defect, place the quarter rack and the all-or-nothing piece at the point of rest. With a compass, divide in two equal parts the distance from the fulcrum *g* of the all-or-nothing piece to the point of detent *T*, and mark on the plate of the all-or-nothing piece the center of this division. Place one of the points of the compass on the point marked, and with the other point made a line on the end of the all-or-nothing piece, and file exactly to this line. Then the beak *T* of all-or-nothing piece will be round, and the arm *r* of the quarter rack will be hollow. When these two parts form their detent, they will be safe, and will no longer be able to release until the winding rack will rests against the snail. If you do not follow this method, and you file the all-or-nothing piece by

sight of eye, you will risk seeing it often missing, and if you succeed it will be the result of chance.

Article XV: Stoppages caused by the Quarter Rack.

The quarter rack is the most difficult part of the repeater. It requires great exactness in its making, and also requires great care to repair its defects. When the quarter rack is not free, because the hole of its fulcrum is tight, enlarge it with a broach. If it is caused by dirty oil or rust, it is sufficient to work a point of wood coated with oil in the hole, until it is free from marks, dirty oil and rust.

If the post for the quarter rack is not well fixed onto the plate, the quarter rack will tilt, sometimes in one direction, sometimes in another, and will butt against nearby parts, so much so that it will stop the movement and the dial-work. It is then necessary to tighten the screw of the post in the plate, and if the screw is not good, another post should be made.

When the post is not firmly fixed in the plate, if it causes the quarter rack to tilt on the side of the large hammer, the pallet will escape a long time after that of the small hammer, which will give a too large an interval between the two quarters. It will also happen that the quarter rack, returning the hammers too far, will cling to the ends of the pallets; or the quarter rack, by entering into the pallet more than necessary, will make the large hammer traverse too much space. When the hammer drops it will move too close to the bell, and cut off the sound. The same defect will happen if the quarter rack inclines on the side of the small hammer.

When the quarter rack is tilted on the side of its snail, the arm a , which must rest on the snail L when the quarter rack drops, will pass under it and will cling to it. If the arm is tilted in the opposite direction, it will lodge between the snail and the hour wheel, so that it will make the action of the dial-work miss and stop the movement. From this it is easy to conclude how essential it is that the quarter rack is placed horizontally on the plate, and the post is fixed so it cannot move. If the part of the plate which receives the post for the quarter rack is so thin that the screw of the post cannot be firmly fixed there, make a rather long barrette so that it creates a thicker part on the plate, and fit it with two steady pins and a screw. The barrette in place, bore the hole which must receive the post; to do it exactly, put the drill in the old hole. Then adjust the quarter rack so that it makes its actions well.

If the arm a of the quarter rack is too thin, and instead of falling on the snail it passes over or under, it will cling and stop the movement. Cure this defect by an addition; that is, attach a small steel plate i at the end of the arm a of the quarter rack, which you will fix with a screw. Then file this small plate little-by-little until the length of the arm suits the depths of the steps of the snail perfectly, and keep it thick enough to be able to file the end of it as the situation requires. This small addition will not degrade the quarter rack, since the parts are best treated the same way.

When the end of the arm a of the quarter rack is not large enough to be able to attach an addition with a screw, after tempering the end of the arm a , make a square hole at its end, and a piece of steel in form of a "T". Rivet it and file it to the contour of arm a . By this means you will succeed very well, without harming the cleanliness of the work and the solidity of the part.

If the hole in the canon of the quarter rack is too large, it will shake on its post, and will cause the actions of the dial-work to miss. It is necessary to make a larger post or a canon with a smaller hole, so that the quarter rack is exactly and free on its post, and it is horizontal.

Many repeaters have trouble striking the quarters, and some stop on the third quarter. You will not be surprised, if you consider the number of actions which the mainspring has, to drive the train and to make the various part of the dial-work function. It has to overcome the force of the of the quarter rack drop spring, which always pushes it towards the center, to make it drop onto its snail. It drives the hour pallet and the two quarter pallets, each one of which has its own spring. It also has to overcome the force of the two hammer springs. And add to that the action of the two springs which drive the star wheel and the all-or-nothing piece.

All that I have just said makes clear the effort that the mainspring makes when it operates the quarter rack, as well as the other parts of the dial-work, and especially when this driving force is at the end of its run and it has lost most of its elasticity.

When the spring of the quarter rack is so strong (which frequently happens) that it presses too hard against the quarter rack post, it will obstruct it or stop the functions of it, and will often make the last quarter miss. Decrease the end of this spring until it no longer obstructs the center of the quarter rack. If it is too weak to make the quarter rack drop onto the steps of the snail, it is necessary to see if this defect comes from the screw, which is not well tightened, or from the spring, which is not bent enough; in which case give it some hammer blows near the foot of spring. That will usually be enough to give it the necessary elasticity. But if, in spite of that, it does not have enough force, it is necessary to make another.

When the spring of the large hammer is so weak that it cannot make it strike strongly, another spring should be made. If it is too strong (which often happens) it will prevent the last quarter from functioning. Do you want to be sure that this defect comes from the stiffness of spring? When the quarter rack cannot make the last quarter sound, take a point which you will press lightly against the spring. If you realize that the last quarter sounds with the little that you touch it, it is proof that the spring is too stiff. It should be weakened by filing it its thickness, and especially by tapering it slightly from the foot to the point.

Some times marks or burrs have been left at the end of the quarter rack drop spring, or the pin which is placed in the center of this part. It also happens that the pin is not true, cylindrical, or polished. All these defects, to which one pays attention, can make the quarters miss. If the spring is so long that its end touches the canon of the quarter rack, you will file a little from the end of this spring and round it. Take care to not shorten it too much, if you do not want to risk it escaping from the pin which it must always operate without touching the canon. If it escaped it would cause the functions of the quarter rack to miss.

Article XVI: Defects caused by the Quarter Rack Gathering Pallet.

The quarter rack can often be constrained by the quarter rack gathering pallet or the pulley, because the quarter rack is placed between these two parts, and it generally has very little space there. An intelligent workman must examine whether the squares of the pulley and quarter rack gathering pallet are true on their arbor. If they are too free, it is necessary to make new ones. If the pulley and the quarter rack gathering pallet, by their thickness, obstruct the movement of the quarter rack, they should be filed as the case requires it, and then polished.

If the quarter rack gathering pallet cannot bring back the quarter rack, and this defect comes from the front of the quarter rack gathering pallet which presses against the pin *c* of the quarter rack, Pl. 13, Fig. 5, it is necessary to round the front of the quarter rack gathering pallet in the shape of the pin. You will generally succeed in curing this defect by changing the position of pin *c*, moving it closer to the center *d* of the quarter rack.

If you are obliged to remake a quarter rack gathering pallet, after having roughed it out and set it up, examine the positions of the quarter rack gathering pallet and the pin. When the quarter rack is at rest, draw a line from the front of the quarter rack gathering pallet which passes the center arbor and finishes exactly against pin, because it is essential that when the quarter rack gathering pallet has finished raising the quarter rack, it rests well against the pin.

Sometimes, when repairing, it is necessary to use other methods, according to the circumstances. One must shape the front of the quarter rack gathering pallet little-by-little until it agrees with the force and shape of the other parts.

Article XVII: Defects of the Hammers.

When the movement of the small hammer is too rapid, and the two pallets escape almost at the same time, do not shorten the pallet of the small hammer; because if this defect comes from a pallet which is already too short, it will not be able to make the small hammer strike the bell, or the blow will be so light that the bell will give little or no sound. The same defect would happen if the pallet of the large hammer were shortened. They should be shortened only when one is quite sure that they are too long.

There are cases when the large hammer strikes its blow much too long after that of the small hammer. Sometimes it happens that the pallets cannot escape, though the post of the quarter rack is well fixed to the plate. Make the quarter rack function. If, when the arm *a* has fallen on its snail, the teeth of the quarter rack make the hammers move too far, if the pallets have trouble escaping, if at times they butt on the end of a tooth, it is proof that they

are too long. Smooth the ends of the teeth with an iron file coated with oil stone, so that the point is round. Do not go too quickly in this work; it is necessary to do this operation little-by-little, and to check from time to time if the quarter rack does its actions well; if you do not take this precaution, you will be obliged to remake the quarter rack or the pallets.

When the drops of the hammers for the quarters are not equal, that proves that the teeth of the ratchets of the quarter rack are unequal, either in distance apart or in length. To determine the distance, use the calibre compass to equalize the teeth. To determine their length, put a point of a compass in the hole at the center of the quarter rack, and with the other point make a line on the ends of the teeth, which will show you those which are not equally long. Shorten those which are long. Never file the teeth of the quarter rack unless you are sure that they are too long; because if they are already short, it would then be necessary to make another quarter rack, or to make new pallets whose levers were longer.

Shorten the pallets only when they make hammers rise too much, or they cling to the neighbouring teeth, which would make the hammers move back, and would cause a dissonance.

When the hammers escape together, and the pallets are short, it is necessary to lengthen the arm of the quarter rack so that its teeth enter the pallet of the small hammer rather more. Do this by striking the edge of the arm which drives the pallet with a sharp hammer. The closer to the center *d* of the quarter rack that you strike, the more easily you will lengthen it. Continue to strike until you have adjusted the movement of the quarter rack with that of the pallet, so that each blow of hammer makes the bell sound distinctly. If this defect occurs on the opposite side, do the same for the large hammer as you did for the small one.

Article XVIII: Stoppages caused by the Hammers.

When the hammers are not quite free in the frame, and the pivots are constrained in their holes, enlarge them with a broach. If when the stems are too long, and they are obstructed by tightening the pins, use a cutter to give them freedom. But before doing it, examine whether the hammers have their spaces well distributed, and give play on the side which will be most advantageous for the watch. When you are obliged to rebush the holes for the hammers, always have regard for the arrangement of the other parts, and especially take care, when rebushing them, that they cannot rub against any other part of the watch.

If the pivots of the stem of the large hammer are too free, the hour pallet *F* will be driven back by the action of the teeth of ratchet *R*. The ratchet, catching sometimes more, sometimes less on the pallet, will give unequal blows of the hammer.

When the stem is not quite tight in the large hammer and in consequence makes it free, it is necessary to disassemble the train to forcefully screw the stem into the hammer. Because if you are satisfied by tightening the stem against the hammer with pincers when the watch is assembled, the other parts will prevent you from tightening it forcefully, and in a while you will have the same defect to correct.

When you finish a repeater, take care to assemble the train, and to make the parts of the dial-work function. If the holes for the pallets are too large, they will make the hours or the quarters miss, and then you will be obliged to make new posts or new pallets. When the hour pallet or the posts of the hammers are constrained in the entries after gilding plates, one has forgotten to remove the gilding which forms a thickness. Enlarge the entries so that the posts are no longer constrained.

If a repeater, after having sounded the hours well for some time, has trouble repeating them, that often comes from the spring of the hammer rubbing against plate. File this spring on the side that touches, or raise it so that it no longer touches. If the piece always has the same defect, operate the repeater while pressing lightly on the end of the spring with a point. If you feel a little resistance when sounding the hours, it is proof that spring is too strong. File it over its width; for the little that you weaken it, the mainspring will move the train, and will make the part of the dial-work function well. This defect can also come from a mainspring which does not have enough force, or which has stretched; it is necessary to put in another of good quality.

Article XIX: Defects of the Hour Pallet.

Sometimes dirty oil or rust forms in the hole of the hour pallet, which obstructs it so much so that it can no longer function. Clean the stem, and work a wooden point coated with one drop of oil in the hole of the pallet, until you see no more dirty oil; that will often be enough to make it free.

When the canon of the hour pallet is too tight on the stem of the hammer, it is necessary to put the stem in the turns and rub it with oil stone until the pallet is exact and free on its stem. When you have good reason not to decrease the stem, it is necessary to enlarge the hole in the pallet, but you will not be able to do this with a broach, because the pallet and the canon are usually very hard. Enlarge this hole by taking an iron wire about six inches long and attaching one end to the vice. Hold the other end by pincers in one hand, while with the other hand move the pallet back and forth on the iron wire coated with oil stone, until the pallet enters freely on its stem. While doing this operation, test from time to time if the hole is large enough; because if you increase it too much the pallet would make the actions of the dial-work miss. If the small first wheel rubs against the hour pallet it will lose its freedom and will make the dial-work miscount. If the space which the stem of the hammer has in the frame makes it possible for you to raise it without fearing obstructing some part of the train, the defect will be cured. You can also give space to the pallet by thinning the small first wheel when it is thick. When the lever of the pallet is thicker than necessary, decrease its thickness on the side which rubs on the wheel; do this with a file or, if it is too hard, use oil stone, and then polish it.

Take care that the top of the beak of the pallet does not touch the contrate wheel; this defect alone will stop the movement.

If the hole in the pallet is too large, it will happen that during the running of the train, the ratchet will enter the lever of the pallet sometimes more and sometimes less, and will cause unequal blows to strike. Moreover, the pallet could touch the entries. The quickest solution is to make another pallet, or another stem for the hammer, which is larger and enters exactly and free in the pallet.

A pallet whose end is not quite round can butt on the teeth of the ratchet. If the ratchet has the same defect, round its teeth and the end of the beak of the pallet.

When the pallet has escaped and, instead of returning to its place after each blow which the hammer strikes, it drops onto the following tooth of the ratchet, it interrupts the sound of the bell. Sometimes this defect can be cured by means of the counter spring screw. If, after the last hour has sounded, the pallet, being retained by the teeth of the ratchet, releases the hammer, it will touch the bell, which will give little or no sound. In this case it is necessary to shorten the pallet. If the same thing happens with the quarter pallets, it is necessary to fix it as above, and use the counter spring screw to move the hammers nearer or further away from the bell. If the pallets sometimes rub against the collar, file the place where they touch.

If the repeater sounds the hours well without the dial, but after putting it on the hours have trouble sounding, or they sometimes miss, that comes from the pallet touching the dial. As it is impossible to see where this defect comes from, it is necessary to take the dial and pass it over the flame of a candle, so that the concave side becomes a uniform black. Put on the dial with its screw and operate the repeater. If the pallet touches the dial, it will remove the black from where it rubs, and you can see the defect. Scrape the enamel or file the end of the pallet. You can use the same method whenever another part of the dial-work misses.

Article XX: Stoppages caused by the Quarter Pallets.

When the two quarter pallets have trouble disengaging from the teeth of the quarter rack, and these pallets butt at the ends of its teeth, round the ends of the pallets and the teeth of the quarter rack a little.

If you have a dial-work which, after sounding the hours well, misses sounding the third quarter, examine all the projecting parts which are close to the pallet. If you think that it butts against one of these parts, but it is not possible for you to see the defect, mix rouge with one drop of oil, put it on the pallet, and operate your piece. The pallet, while striking the hours, will mark the place where it touches and it will be easy to cure this defect.

When the holes of the pallets are obstructed by dirty oil or rust, it is necessary to fix it as I have already explained. If they are too large, so that pallets have too much play on their stems, the quarter rack will enter the pallet sometimes more, sometimes less, and produce

unequal blows. It is necessary to remake the pallets or the posts. When the hammers touch the bell, and you have made them return too far by the means of the counter spring screws, and so you have obstructed the pallets, it is enough to turn the screws in the opposite direction until the piece sounds well. If the counter-springs are not well fixed to plate, they will cause the bell to sound badly; tighten them strongly against plate.

Article XXI: Stoppages caused by the Silencer.

When the silencer does not lie flat against the plate, and by raising its ends it makes the pallets retrogress, they remain reversed and butt against the teeth of the quarter rack. The quarter snail continues its rotation and will cling to the arm *a* of the quarter rack, which forms a double stop of both the dial-work and the movement. It is necessary in this case to tighten the screw of the silencer, so that it is true and free on plate. If the arms of the silencer are still raised, it is necessary to give them some blows of a hammer to make them flat against the plate. When, after this operation, you realize that the two ends *c* and *d* of the silencer are too thick, they should be filed so that they can no longer obstruct the pallets.

It often happens that the silencer works well before the movement is put in its case, and misses afterwards. This results from the arm *b*, jutting out from the silencer, rubbing on or engaging with the collar or the case and raising the ends of the silencer so much that it can no longer do its duty. File the collar or the case until the arm jutting out of the silencer no longer touches.

When the silencer moves the hammers too far, they sometimes remain butted against its ends *c d*, especially when they are short; this makes the action of the dial-work miss. Make a stop by placing a pin on the plate close to the end of the arm *d* of the Silencer. This stop will prevent the arm from resting on the posts of the hammers more than is necessary. This simple repair will fulfil your goal.

Article XXII: Defects of the Bell.

The bell when set up should not touch any part of the movement or the case; the little that it touches causes it to lose its harmony. If the bell, by its height, touches the case or the silencer, it is necessary to place the bell on the turns in the air and to fix it with sealing wax. While the cement is hot, make the bell turn true and centered, by resting a piece of wood on it, which you will press lightly with one hand, while driving the bow with the other. When the sealing wax is cool, turn the edge of the bell until it no longer touches the movement or elsewhere.

When the bell is too large, the hammers, not being able to drop far enough to reach it, it will give little or no sound. It is necessary to get a smaller bell or to make another. If the bell is a little too small, and it is thick, place it on the turns in the air and turn the inside with a graver or a square graver until no parts can touch it. There are circumstances where the bell touches the case, the cock, the counter-potence or another part of the movement. It is very difficult (the case being closed) to know which part it touches and interrupts the sound.

After removing the movement from the case, light a candle and reverse the case, so that the bell is very close to the flame, and hold the case thus until the smoke has formed a layer of black inside the bell. Then put the movement in the case. It is necessary to pin it, open it and close it several times, and to operate the dial-work. The part which touches the bell, by removing the lampblack, will show the defect which you seek. Cure it as above and according to the circumstances. Especially take care to degrade nothing.

A contrate wheel which touches the bell, interrupts the vibrations of it or stops the watch. It is necessary to move the contrate wheel further into the frame, and to remake the gearing of the third wheel with the pinion of the contrate wheel. Then it is necessary to remake the gearing of the contrate wheel with the pinion of the verge escape wheel.

If it is the cock which touches the bell, correct this defect without degrading the gilding. If there is no other way, lower the bell a little by decreasing its shoulder or that of the case. When the friction is light, it is often enough to give some hammer blows to the bottom of the case. But take care not to decrease the shoulder too much, because then the bell would touch the bottom of the case or the hammers will no longer reach the bell.

When the push piece passes so close to the bell that it produces only a little or no sound, you can lower the bell or make a notch opposite the push piece. That will not degrade the bell and the sound will not be interrupted.

Every time you remove a bell, make, with the point of a drill, a reference mark which is usually put opposite the push piece. It is the way to always replace the bell true. This precaution is essential, because if you change the position of the bell it would sound poorly, or not at all. If you neglect to make a reference mark, it is necessary to change the position of the bell until you find its true place.

If the bell shakes in its hole, though the screw is tight, and the sound is not clear, put a little paper or card under the screw. That can be enough to fix the bell well. If the bell moves too far from the hammers, put the bit of card under the bell. If, when you put the card there, the hammers rest against the bell, file the card to half thickness on the side where the hammers touch the bell. That will incline the bell and prevent that the hammers resting on it.

When the bell is broken or split, you can solder it with tin. Put all the parts as close together as possible, and bind them with wire after putting a sufficient quantity of rosin and tin on the joins. Place the bell on the fire and when the solder runs remove it and let it cool. If you were careful, the bell will be almost as sound as it was it before it was broken. You will not be surprised that I have gone into meticulous details about the bell, when you discover how difficult it is to make it sound.

When a bell is broken so much so that you cannot solder it, it is necessary to get a new one, or make one yourself. For that take rather thick tin, which you will turn on the turns in the air until it has the size, height, and shape of the bell. Give this model to a founder, and when the bell is cast, trim it with a file, or rub it on sandstone, until it is uniform. Especially file the sprue until it is detached from the bell; because if you strike it with a hammer, the consequence will be the bell will break or lose sound. Then place it on the turns and turn true and centered in every direction until it is the thickness, height and size necessary, and finally polish it.

The bell finished, do not tear it off the wax with force; it should be softened on a fire to separate it from the bell without fearing breaking it.

If you have a finished bell which is not bored in the center, lay it on its back on a quite flat piece of wood. Then place one point of a compass on the edge of the bell and the other approximately in the center. Then trace four lines which give you a small square and bore in the center of it. You will square the hole with a square file until it is of the necessary size.

Note that when one gives a founder a bell from which to cast another, the model must be a ligne larger than that which one needs; because after it has been cast the bottom becomes a ligne smaller than the model.

Article XXIII: Method of making Ground Gold.¹⁰⁰

When one wants to gild with ground gold¹⁰¹ it should be made, and for this get fine gold, such as separated gold¹⁰² or gold ducats. Separated gold is the most convenient to use, because, being reduced to powder, one can use it immediately to make ground gold.

For lack of separated gold, take a gros of gold ducat,¹⁰³ or such other which is of the same standard, and forge it until it is as thin as foil. Cut it with scissors, and make pieces as small, narrow and thin as you can. Then put the gold in a new crucible, place it on burning coals, and liven the fire with bellows until you see the gold, which was red, becomes whitish; this tells you that it is ready to be fused. Immediately throw in one ounce of mercury for each gros of gold. Stir this composition with a stick or a piece of brass for about two minutes. As the mercury will evaporate and it could go to your head, take care to move as far away as you can. And during all this time, put a handkerchief in front of your face to prevent you breathing this dangerous vapour. Then throw this ground gold into water, and place it in a box to use when needed.

¹⁰⁰ Articles XXIII, XXIV and XXV on gilding should appear as the last chapter of Part 3.

¹⁰¹ *Or moult.*

¹⁰² *Or de separ.*

¹⁰³ *Gross:* One eighth of an ounce.

Article XXIV: Gilding with Ground Gold.

To gild with ground gold, it is necessary to have the following articles, that one lays out on a table to have them at hand.

1. Take a piece of copper an inch and a half long, file it in the shape of a sage leaf file and put a handle on it. This tool is called a buff and is used to spread the ground gold on the piece which one gilds.

2. A small vase in which there is a little nitric acid.

3. A hare's foot which is used to spread the ground gold on the part that one gilds, and to make it as even as it is possible.

4. A flat glazed pot in which one puts good vinegar or urine.

5. A scratch brush, which is a type of very fine copper wire brush. If the wire were large, the scratch brush would make marks on the pieces being gilt.

6. A small box of ground gold.

7. A flat glazed pot large enough to hold the part being gilt. As for the ground gold which falls to the bottom of the pot, it is thrown into clear water to wash it, and then put back in the small box with the other ground gold.

8. A stove with a fire covered with ashes, which is used to evaporate the mercury.

9. A pot of common water.

10. A small pot of good olive oil.

11. Two cloths. One is used to handle the part being gilt, while the mercury is mixed with the gold; and the other to handle and wipe the part when mercury has evaporated.

Everything being laid out, take the copper file (called a buff), dip it in the nitric acid and then in the ground gold which will stick to it. Rub it on the plate until you have put a sufficient quantity of ground gold on it. Take the hare's foot and spread the ground gold until the plate is very white. Place the plate on the fire and, when you see the ground gold start to bubble, quickly withdraw it and lightly rub the hare's foot over it to spread the ground gold. Repeat the same operation until the ground gold is quite even.

Then put the plate on the fire. Little by little the mercury will evaporate, and the piece will become a matt russet-red. One usually puts two or three layers of ground gold on it. With each layer, one follows the process exactly as above.

When you want to test if the part is well gilded, it is necessary to throw it in the olive oil, and to put it on the fire. If the part is gold colour when oil has evaporated, it is proof that it is well gilded; if some black spots remain, it is necessary to put on another layer of ground gold.

After the second or third layer, put the piece on the fire until the mercury has completely evaporated. If it does not have any white spots, it will be a matt gold colour. Take it with pincers and throw it in the urine or vinegar.

Take the piece in the left hand, while with the right hand pass the scratch brush over it, always rubbing in the same direction; that is, one should not move the scratch brush back and forth on the part. It is necessary to scratch from left to right and each time the scratch brush is passed over it, lift it up and go from right to left, and always continue in the same direction. When you have started scratching the position should not be changed; because if you scratch the plate sometimes in one direction, sometimes in another, you will make marks on the plate. Put the piece on the fire, throw it hot in the urine, and then into common water. If you have to gild several pieces, in proportion that you scratched them, throw them into common water; and when you finish gilding them, rub them with a clean cloth, put them on the fire, and test them.

After the first or second layer of gilding, you need to know the degree of heat to give to the part before throwing it in the urine or vinegar. Take an extremely thin bit of spring, whiten it, and put it on the piece which you put on the fire; when the steel starts to turn red purple, throw your piece in the urine. You can also test the degree of heat by using a thin piece of paper; place a bit of it on the piece which you want to heat, and when paper becomes yellow, take your piece from the fire, and immediately throw in the urine.

Article XXV: Gilding with Gold Leaf.

Those who only have to gild cocks, counter-potences, bridges, bars, or other parts of little consequence, can do it in the following way. Put on a table the same tools and articles as for ground gold gilding. Instead of ground gold, it is necessary to get double gold leaf, which comes from Paris; instead of double leaf, one can use that which the gilders employ.

Dip the buff in nitric acid, then in mercury and rub the cock until it becomes very white; also spread it with the hare's foot as well as you can. Cut a sufficient quantity of double gold leaf so that covers the whole piece. Sit this sheet on the cock, which in a moment will become white, subside, and incorporate itself into the mercury. Place the piece on the fire; the mercury will evaporate and the cock will become a matt colour. If you realize that certain parts are not well gilded, put on a second layer as above. After evaporating some mercury, throw the cock into the urine or vinegar, and scratch brush it well, etc.

Instead of double leaf, take a booklet of the leaf which gilders use. Cut enough leaf to be able to double and triple it. Place it on the mercury coated cock, and after putting it on the fire, throw it in the urine, scratch it, etc. If the piece is not well gilded, it is necessary to repeat the same operation, and to follow the same processes as used to gild with ground gold.

Chapter III.

Article One: How to Disassemble a Repeater.

A repeater watch requires more care to disassemble it than an ordinary watch, because it has a greater quantity of wheels and springs which make it up, and it is necessary to avoid, while disassembling it, breaking, distorting or losing them. To prevent these accidents, get a case which has several boxes, and put the various parts of the repeater in it. If you remove several springs from the dial-work, take care to put each screw beside its spring; because if you place the screw of one spring on another (which is easy, since the screws of springs have the same form, and are tapped in the same hole of the screw plate) you will cause errors which will cause you great trouble.

Before disassembling a repeater, take care to stop the movement with a piece of card or a broach, which you will place between the arms of the contrate wheel. When you remove the two screws of the cock, remove it and the balance and allow the movement to run until at the end of the chain. Slacken the mainspring of the movement, and that of the repeater train. Without this precaution, when you separate two plates, the mainspring, by releasing very rapidly, would break a pivot, and make the wheels jump in the air. To avoid these accidents, remove the pin which is on the quarter rack gathering pallet, and after having separated the quarter rack gathering pallet from its arbor, remove the pulley from its place with pincers. The small train will run as long as spring acts with enough strength. If you doubt that the mainspring is completely relaxed, move the small first wheel with a point, and push on it lightly until spring is no longer tightened.

Remove the pin of the canon pinion, and separate it from the stem of the center pinion. Remove the pins of the pillars, and separate the two plates. Then take all the wheels in tweezers and put them in a safe place.

When one cannot pull out the pin of the canon pinion, it is necessary to take the pillar plate in one hand and, with the other, give some hammer blows on the end of the stem. By this means you will easily succeed in driving out the stem which will separate from the canon pinion. Remove the screw of the counter-potence, and then remove the verge escape wheel and all the parts of the train, which you will put in the box.

The hammers being disassembled, take care to remove the two quarter pallets and put them in the box, because these two parts are not held on their pivots and you could mislay them. Finish disassembling the dial-work. Move the end of the quarter rack drop spring and make it pass underneath; and if you cannot do this, or you fear some accident, remove the screw of the spring and you will remove the quarter rack easily. To remove the all-or-nothing piece, turn the key screw the wrong way until it no longer touches, release the end of the

spring which enters the notch of the pivot, and which holds the all-or-nothing piece. Remove this and also remove the star wheel and the jumper spring. To remove the collar, turn the two key screws which fix it to the plate to the left, and separate these two parts. Remove the screw of the bridge, and remove the winding rack. As for the other small springs, remove them one after another and put each one with its screw in the box.

Article II: Finishing the Repeater.

Put the first three mobiles in the frame, distributing the spaces so that they cannot rub against each other or to touch the plate or any other part. Put each wheel in the frame one after the other, taking care to put the four pins in the pillars. Drive the wheels to be sure that they have neither too much nor too little play, and that they have the necessary freedom. Rebush all the holes which are large, especially those of the plug of the potence and the balance. Do not give the verge escape wheel too much play, which usually causes butting. Carefully examine the gearing. Make the escapement so that there is, between the verge escape wheel and the verge, neither too much nor not enough drop, and follow the principles that I have given in N°. 396. Remember that many small defects that one allows in a simple watch are of great consequence in a repeater, as you will see in the two following articles.

In a simple watch, if the center wheel is a little too free in the frame, if the two holes are a little large, if the wheels have enough space between them so that there is no fear of rubbing, you will be able to leave these mobiles in this state, without having to fear that the watch will stop. But in a repeater, the least friction will make the watch stop. If the two holes of the center wheel are too large, the quarter snail loses its horizontal position, sometimes in one direction, sometimes in another, and the arm *a* of the quarter rack will butt against the snail and make the watch stop.

If the contrate wheel is too free in the frame, if it rubs against the hammer or the hour pallet, or if the ends of its teeth touch the small barrel, the watch stops. If the holes of the pivots of the contrate wheel are not right, your piece will be likely to stop. These two examples prove how carefully you must to distribute the spaces well, and put the mobiles true and free in the frame.

Distribute your spaces, gauge your pinions, and remake those whose size could harm the gearing. See that the wheels turn true and centered; burnish all the pivots which have marks or which are not cylindrical; and if, after this operation the holes are too large, rebush them and remake the gearing. Especially take care of that of the contrate wheel, it is better that it is strong rather than weak, because the contrate wheel being always driven on its pivot by the pinion of the verge escape wheel, the shoulder over time will wear the brass, will give play to the wheel, and the gearing will be perfect.

Equalize the mainspring with the fusee. Take care to poise the balance and make it free so that it cannot touch the cock, the slide, or any other part. If the ends of the pivots of the verge scrape on an angle, if they have recessed the steel plate of the heel of the potence or that of the coqueret, it is necessary to put the verge on the lunette runner, round the ends of the pivots and polish them. Erase the holes which have formed on the steel plates. Because if you let these defects remain, you will never be able to adjust the watch.

As for the train of the repeater, it is necessary to put each wheel free in the frame one after the other, to see whether the spaces are well distributed, if the wheels rub against each other or against any other part. Examine the small first wheel; take care that it does not obstruct the hour pallet and does not touch the potence; these frictions would stop the train, or would make the watch sound sometimes quickly, sometimes slowly.

If the small train is too slow or too rapid, you will generally cure it by turning the small square of the delay, which is beside the cock. The bushing of the delay wheel being eccentric, turn it to the right or left to increase or slow down the speed of the train. Observe that beside the ear of the cock, there is a type of dial engraved on the plate, on which several divisions are marked and engraved with the two letters *V* and *L*, so that by turning the small hand on the side of the letter *V*, you will speed up the running of the train, and if you turn the hand to the side of the letter *L* you will slow it down.¹⁰⁴

¹⁰⁴ *L*: *lent* or slow; *V*: *vita* or quick.

When the train goes too quickly, and the method above does not slow it down, make a brass seat, drive it onto the pinion of the delay, and turn it so that it cannot touch the pillar; this small weight is sometimes enough to slow down the train.

If this method does not succeed, make another pinion of greater number; instead of six use seven, eight or ten. It is a sure way to arrive at your goal. This change of number has another advantage. The larger the number of the leaves of the pinion, the more the train will sound the hours uniformly. Just this change will cure the defect of repeaters which sound too quickly at the start and too slowly at the end.

Set up the two hammers. It is necessary that they are true and free in the frame. If they touch some part of the train, correct this defect. When the end of the hammer touches the fusee, file it until it can no longer butt against this part.

If the hour hammer touches the rim or the arms of the contrate wheel, if the gearing of this wheel is good and if the arms are too thick, put the wheel in the turns and decrease its thickness. If the hammer has too much space in the plate, remove the stem of the hammer, place it in the turns and, by decreasing the shoulder a little, you will lower the hammer; which will stop it from touching the contrate wheel.

When you have to temper a steel part to repair it, after having cured the defect, retemper it and repolish it. Avoid, as far as possible, filing the wheels, and even less the plates. If you are forced to, take care to repolish them. If a part does not have enough play in the frame, use the set of cutters.¹⁰⁵ It is the way to preserve the gilding and not degrade the plates.

If a repeater has a broken pivot, do not make another on the same stem; you would be forced to place a nipple on the plate, which would prevent you from setting up the train, or would expose you to breaking some part, by the difficulty that there is to insert the pivot in this nipple. It is then necessary to remake the pinion and to remove the nipple. If your part does not have a oil sink, use the set of cutters to make one. Then pass through each hole a broach, and put the part free in the frame.

Take care that the canon pinion is not too tight on its stem because, while turning the hands, you could distort some teeth of the wheels of the movement or break them. If it is too free it will not move motion-work, and consequently the hands. It is necessary that it has neither too much nor too little friction.

If you suspect that the motion-work obstructs or stop the watch, it is easy for you to check this. Put the center wheel in the frame, pin plates and, after setting up the motion-work and fixing the dial with its screw, turn the center wheel slightly. Examine whether the motion-work turns freely. If it is obstructed under the dial, it is proof that it touches, or the canons are too tight, or they do not have enough play. If that comes from the gearing, and the wheels are the right size, bring the gears closer, or remake the pinions which are not the right size. If you are not to risk seeing your watch stop, never forget to put a pin in the canon pinion, and if the stem does not have a hole one should be made.

Article III: Method of Cleaning a Repeater.

Before assembling a repeater, it is necessary to clean the wheels, teeth, fusee, and the holes in the plates, (see N°. 402), and to work wood points in them until you see no more dirty oil. You will also clean all the parts of the dial-work, and place them under a glass. Remove all the springs from the plates which, by their delicacy, are likely to be distorted. Then rub them with a cloth and a brush until the plates again take their gloss. Also brush the hammers. Clean the posts and the holes which they enter. When these holes are quite clean, take another spindle wood point soaked with oil and work it in all the holes. These precautions are essential, so that the posts do not rust in their canons. Clean the holes of the balance and those of the verge escape wheel, and put a drop of oil there. And if the brass coqueret and the heel of the potence are not filed in the shape of lens, do it.

Article IV: Method of Assembling the Train of a Repeater.

The plates, the various parts of the train and the dial-work being clean, do not touch them; the prints of your fingers would tarnish the gilding and the polish of the brass and steel. Besides, there are workers who have sour perspiration, so that just the impression of their hands makes steel rust. To avoid this, use the movement holder (Pl. 5, Fig. 11) or a

¹⁰⁵ These are presumably the tools used with the guide, Pl. 12, Fig. 4.

white cloth which is not too old, because it would charge your piece with a type of soft hair. Hold the top plate with this cloth in one hand and fit the springs that have been removed. Put a drop of oil on the nose and the heel of the potence, and put in the verge escape wheel; turn it in order to be sure that it is free. Tighten the plate of the heel of the potence, so that it is well fixed. Without this precaution, the plate would touch the center pinion or another part, and would prevent you from setting up the train or would make the watch stop. Put the top plate under a glass.

In the same manner take the pillar plate and fix the springs that were removed. Set up the center and third wheels of the movement, and the small center wheel and the small first wheel of the small train. Then put in the first wheel of the movement, the barrel, and the two hammers, the ends of whose springs must rest against their posts. Put in the other wheels, the delay pinion, the hour pallet, and the contrate wheel. By this means all the parts will be laid out on the pillar plate. Then take the top plate in tweezers and insert the four pivots in the holes of the pillar plate. Then, while you press the top plate against the pillar plate with your left hand, with the small hook, Pl. 1, Fig. 27, insert each pivot into its hole. When you feel that all the pivots of the movement are in place, put a pin in the pillar which is between the first wheel and the contrate wheel. It should be done this way, so that when you want to insert the pivots of the small train into their holes, those of the movement cannot leave their places. If the pivot of the small barrel does not easily enter its hole, take an endless screw key and put it on the square of the arbor; by turning it in your fingers, you will manage to get the pivot into its hole. Then take the hook tool (Pl. 1, Fig. 27) and guide the wheels one after the other until the pivots enter their holes. Put a pin in the pillar which is opposite the small train and then put in the other pins. Put the chain in place, and set up the mainspring according to the reference mark on the arbor and the plate. Turn the key on the fusee square and let the movement run. Turn the square of the arbor of the small mainspring, and check that the train is free. Then set up the slide, the rosette, the balance spring stud and the balance, and put on the cock. If you have done this well, the watch will give equal vibrations, and will run for a long time.

I taught (Chapter 8, N°. 402), the way to repolish the fusee, wheels and teeth. You will give them more brilliance by putting dry rotten-stone on the cord, with which you will restore their original gloss.

If you want to degrease the gilding, take sheep bones and calcine them; it will form a type of lime which you will rub on a buffing brush and then rub it on the plate. This method is preferable to using Spanish whiting.

Article V: How to Assemble the Dial-Work.

After assembling the train and pinning plates, set up the hour snail and the all-or-nothing piece, so that the post *h* enters the hole of the star wheel, and tighten the key screw *Y*. Insert the end of the spring on the all-or-nothing piece into the notch in the pivot of the pillar. Check that the all-or-nothing piece *T* has free movement and its spring acts with enough force to drive it.

Put the valet, or jumper spring, on its post and put the end of its spring in the notch in the back of the jumper *c*. Check that it is free on its post, that the spring *W* has enough strength to make it function, and that it holds the jumper at its point of rest.

Put the post *l* of the winding rack in the hole which is used for its fulcrum and, after setting it flat against the plate, pass the chain over the large pulley. Stop the train with a little rolled paper or a pivot broach, which is put between the wheels. Take an endless screw key, turn the square of the small first wheel to the left, and set up the spring at least one turn. Take the small pulley *H* and, after wrapping it with one turn of the chain, put it on. Turn the star wheel so that it presents the first step of the snail *N* to the winding rack. If, after pushing the winding rack, the repeater sounds more hours than it should, block the train again, remove the pulley, and change its position on the square. Push the winding rack again; if it sounds one hour on the first step of the snail, it is proof that the pulley is in its correct place.

There are mainsprings which it is necessary to set up a turn, and others a turn and a half. Experience, and the way in which the spring drives the train and strikes the hours will indicate the degree to which you must set it up.

If, after pushing the winding rack on the twelfth step of the snail, the piece sounds fewer hours than it should, or that, at the end, the train has trouble actuating the hammers, it is

necessary to remove the pulley and set up the mainspring with more turns, which, acting with more force, will drive the dial-work as is needed. If the train goes too quickly or too slowly, slow down its rate by turning the delay hand towards the letter *L*, and speed it up by turning the hand towards the letter *V*.

Put in the bridge for the winding rack and fix it with its screw; check that the winding rack is exact and free under its bridge. Put the quarter pallet on the stem of the large hammer and fix the spring of the pallet on the plate, so that it returns to its point of rest. Also put on the pallet of the small hammer and give it the necessary play so that, after putting in its spring, it also returns to its point of rest, and it is always within reach of acting when the quarter rack is raised by the quarter rack gathering pallet.

Put the quarter rack on its post. Make sure that it is well fixed on the plate, that it does not shake, that it has free movement, and that it can act without touching any other part of the dial-work. Put in its spring and make its end rest on the pin *e* of the quarter rack, which you will lead with a point until the quarters have sounded, and that the end *T* of the all-or-nothing piece has locked the arm *r* of the quarter rack. At this moment it is necessary that the quarter rack gathering pallet rests against the pin *c*, which is beside the teeth of the quarter rack.

When you want to set up the quarter rack gathering pallet *V*, push the winding rack a little, which, by turning the quarter rack gathering pallet, will give you the room to insert it until it rests against the pulley. Put the canon pinion on the long stem with friction. Make sure the surprise piece is free and, for that, give it play by turning the collet, or by removing any dirty oil which can numb it. Do not give it too much play, because it would touch the bridge of the winding rack or the rays of the star wheel. Put each spring in its place. And if some part does not do its particular function, and does not contribute to making the others function, correct its defects, as I explained in the repairing of dial-work.

Set up the collar and fix it to the plate by the two key screws. Pin the quarter rack gathering pallet, which could slip off the top the arbor and cause the repeater to miss its effects. Push the winding rack and see that, in proportion as the arbor *D* turns, the teeth of the ratchet *R* make the beak *x* of the pallet *F* retrogress. The pallet, pushed by its spring and obeying the impulse of the ratchet, will place itself between the teeth of the ratchet as soon as you push the winding rack *C*.

Let go the push piece and when the train runs, the teeth of the ratchet *R*, meeting the beak *x* of the pallet, will make the hammer strike a blow for each tooth which meets the beak *x* of the pallet. The train continuing to run, the quarter rack gathering pallet *V* will meet the pin of the quarter rack and will make the quarters strike.

Never forget to put the pin in the canon pinion. When there is no hole at the end of the stem of the center pinion, make sure to bore one. Because if the canon pinion is not pinned, the hour wheel would press against the dial or would obstruct the motion-work. Or the quarter rack would pass under its snail and stop the watch. Adjust the minute hand until the surprise piece makes the star wheel jump at sixty minutes.

Table of the Citizen Arlaud.

Experience shows that watches which give about 17000 vibrations per hour are the easiest to regulate. They are less prone to the variations of the seasons, and more easily cope with the various jolts to which they are exposed. These reasons have persuaded me to add to this work the table of Mr. Arlaud, of Geneva, which has been approved by the better artists. You can use the calculations, either when you make movements, or when you occupy yourself with repairing.

This table has four columns of figures. The first indicates the number of teeth of the center, third and contrate wheels. The second gives the number of leaves of the pinions of the third, contrate and the verge escape wheels. The third gives the number of teeth of the verge escape wheel. And the fourth gives the number of vibrations which the watch makes in an hour.¹⁰⁶

I	II	III	IV	I	II	III	IV
68 52 48	6	11	17287	62 42 42	6	17	17215
66 52 49	6	11	17128	60 46 40	6	17	17377
66 48 45	6	13	17160	60 42 39	6	19	17290
64 50 45	6	13	17330 (17333)	58 44 39	6	19	17520 (17510)
64 45 43	6	15	17200	80 60 56	7	11	17240
62 48 42	6	15	17360	80 58 56	7	11	16666
80 54 52	7	13	17004 (17028)	90 66 66	8	11	16745 (16845)
76 58 52	7	13	17375	88 64 60	8	13	17160
74 52 50	7	15	16828	86 64 62	8	13	17329
72 56 50	7	15	17632	86 60 58	8	15	17535
72 50 50	7	17	17842	84 60 58	8	15	17128

¹⁰⁶ The table is approximate, with the vibrations per hour rounded.

In addition to a few major errors, there are a few discrepancies; for example, entry 4 in the second column actually gives 17509.556 vibrations and not 17520. Correct values where there are significant discrepancies are given in parentheses; note that an error of about 50 is equivalent to an error in rate of about 10 seconds per hour or 2 hours per month. These discrepancies do not matter much in practice, because the balance and balance spring are chosen to suit the train, whatever its rate; see N°. 277 and 339.

More interesting are vibrations per minute for vibrating balance springs.

Vigniaux Practical Watchmaking

I	II	III	IV	I	II	III	IV
70 52 48	7	17	17319	82 56 56	8	17	17076
70 49 46	7	19	17480	80 58 56	8	17	17255
68 50 46	7	19	17337 (17327)	80 54 64 (54)	8	19	17313
90 68 64	8	11	16830	78 58 52	8	19	17459
60 64 50	7 7 6	13	16978	64 52 46	6	11	15592
62 50 48	6	13	17758 (17911)	64 52 50	6	11	16951 (16948)
60 64 50	7	15	16800 (16793)	72 60 60	7	11	16610 (16625)
70 58 56	8 8 6	15	17760 (17762)	84 58 54	7	11	16874
84 64 60	8	13	16380	80 58 56	7	11	16666
66 52 50	6	11	17710 (17478)	80 60 58	7	11	17842 (17856)
75 52 44	6	11	17468	96 64 64	8	11	16896
75 50 45	6	11	17182 (17188)	75 50 46	6	11	17544 (17569)
64 50 50	6	11	16396 (16296)	64 56 40	6	13	17190 (17256)
60 46 54	6	13	17940	72 48 42	6	13	17472
60 52 48	6	13	18018 (18027)	70 56 56	7	13	16640
64 48 46	6	13	17009	70 56 54	7	13	16142
68 48 44	6	13	17286	74 54 54	7	13	16354
54 51 51	6	13	16906	82 64 64	8	13	17056
54 56 48	6	13	17552 (17472)	84 64 62	8	13	16926
60 48 50	6	13	17316 (17333)	88 64 62	8	13	17732
58 50 50	6	13	17447	80 64 64	8	13	16640

Vigniaux Practical Watchmaking

I	II	III	IV	I	II	III	IV
60 46 52	6	13	17290 (17276)	84 64 61	8	13	16120 (16653)
60 50 48	6	13	17333	70 58 56	8	19	16872
74 64 66 (60)	8	15	16650	54 48 48	6	15	17280
72 64 64	8	15	17280	60 48 45	6	15	18000
78 62 62	8	15	17550 (17568)	64 45 43	6	15	17200
80 64 60	8	15	18000	72 54 52	7	15	17723 (17683)
84 58 58	8	15	16556	84 62 56	8 8 7	13	16926
86 56 58	8	15	16365	72 60 60	8 8 6	13	17550
88 62 56	8	15	17962 (17902)	72 62 58	8 8 6	13	17524
88 58 56	8	15	16747	73 60 60	8 8 6	13	17750 (17794)
70 50 (58?) 50	7 7 6	13	17832 (17952?)	70 56 56	8 8 6	15	17150
74 60 58	8 8 6	13	17420 (17436)	70 58 56	8 8 6	15	17760
74 60 54	8 8 6	13	16204 (16234)	80 60 60	8 8 6	11	16720 (16500)
100 82 78	10	13	16614 (16630)	80 64 62	8	13	16120
96 70 68	10	19	17366	66 58 54	6	9	17226
76 80 80	10	17	16524 (16538)	60 48 48	6	13	16640
66 54 50	7	17	17646 (17664)	66 52 50	6	11	17468 (17478)
60 50 50	7 7 6	17	17340	60 51 48	6	13	17680
60 48 48	6 6 8	17	16320	72 56 56	7	13	17108 (17115)
84 64 60	8	13	16380	76 64 64	8	15	18240

I	II	III	IV	I	II	III	IV
60	7	17	17986	64	7	17	17782 (17814)
56				52			
54				54			
110	12	21	17094				
82							
78							

The numbers below are applicable to the 5 wheels of the small train of repeater.

Pinion of :	6	7	8
1	42	48	56
2	36	40	46
3	26	31	35
4	26	31	35
5	26	31	35

A tooth more or less on each of these 5 wheels will change the number of revolutions of the last pinion as follows:

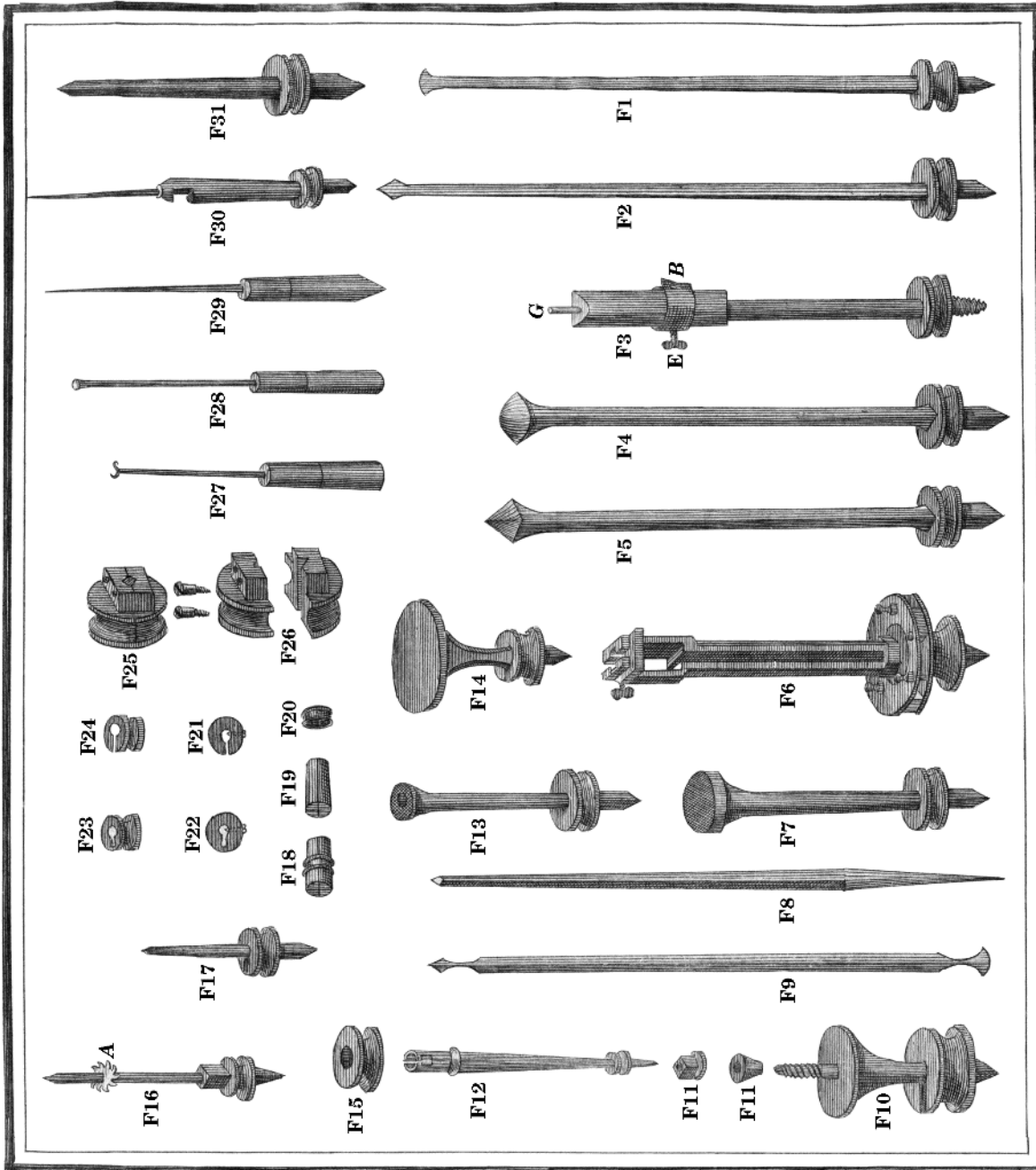
Pinion of :	6	7	8
1	76	70	60
2	94	85	73
3	124	109	96
4	124	109	96
5	124	109	96

When a watch is brought to you to be repaired and it is missing a wheel, do not make it with a number taken randomly. It is necessary to multiply one mobile by the other, as I explained in N°. 247, because if you increase the numbers of the wheels or pinions, the watch will go too quickly; and if you decrease them, it will go too slowly, and it will not be possible to regulate it.

To prove what I say, suppose that an ordinary watch with a verge escape wheel of fifteen teeth, gives you 17280 vibrations per hour. If in place of the fifteen teeth which the verge escape wheel must have, you make one of thirteen, the watch will give 14976 vibrations. Making the subtraction, the watch will give 2304 vibrations less per hour. This example proves how essential it is to calculate the numbers of the wheels and pinions, by following the method which I gave in N°. 247. The table of the citizen Arlaud is even quicker and simpler and you will do well to use it, either when you make new watches or when you deal with repairing.

END.

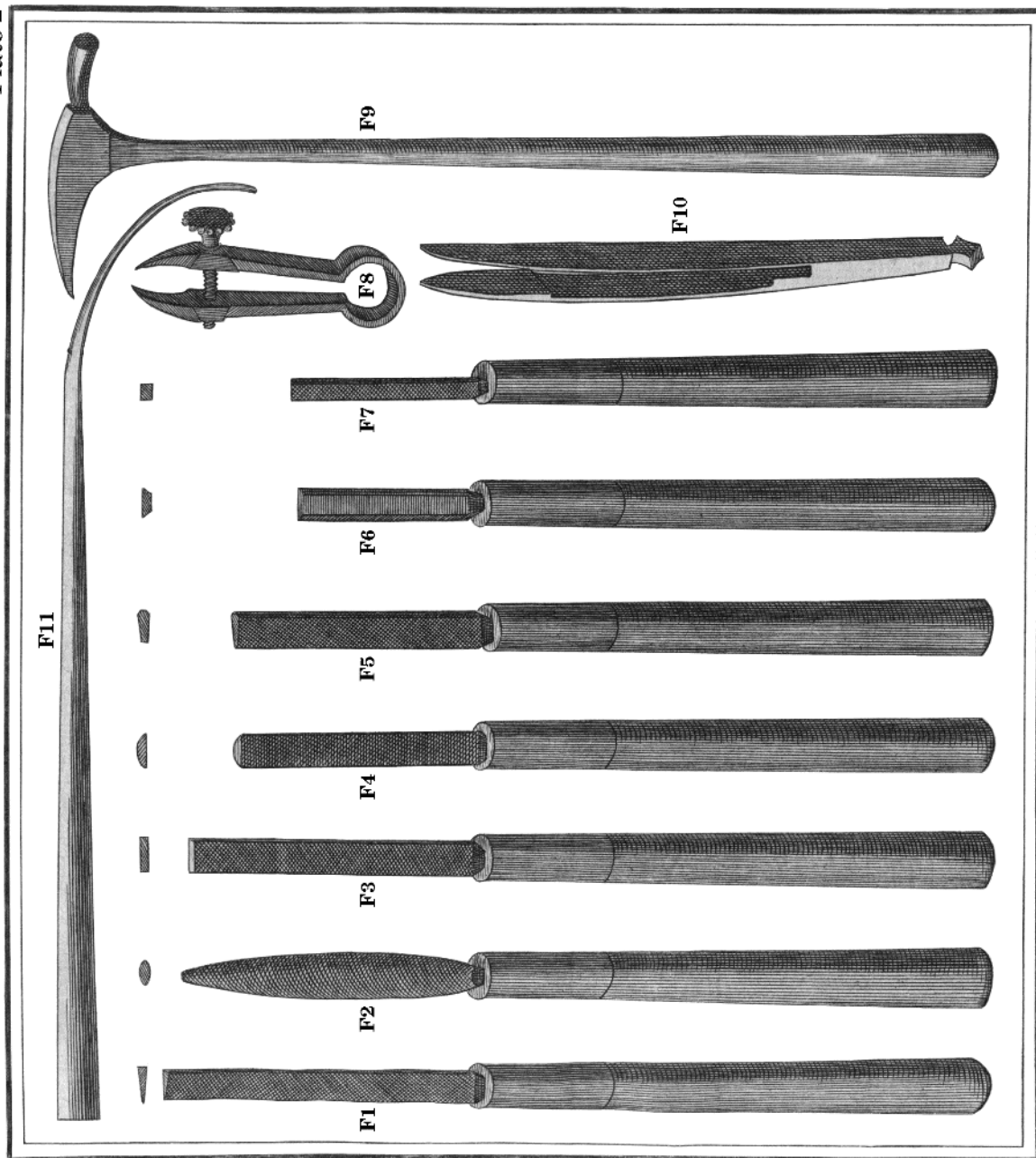
Plate 1



Watchmaking Tools

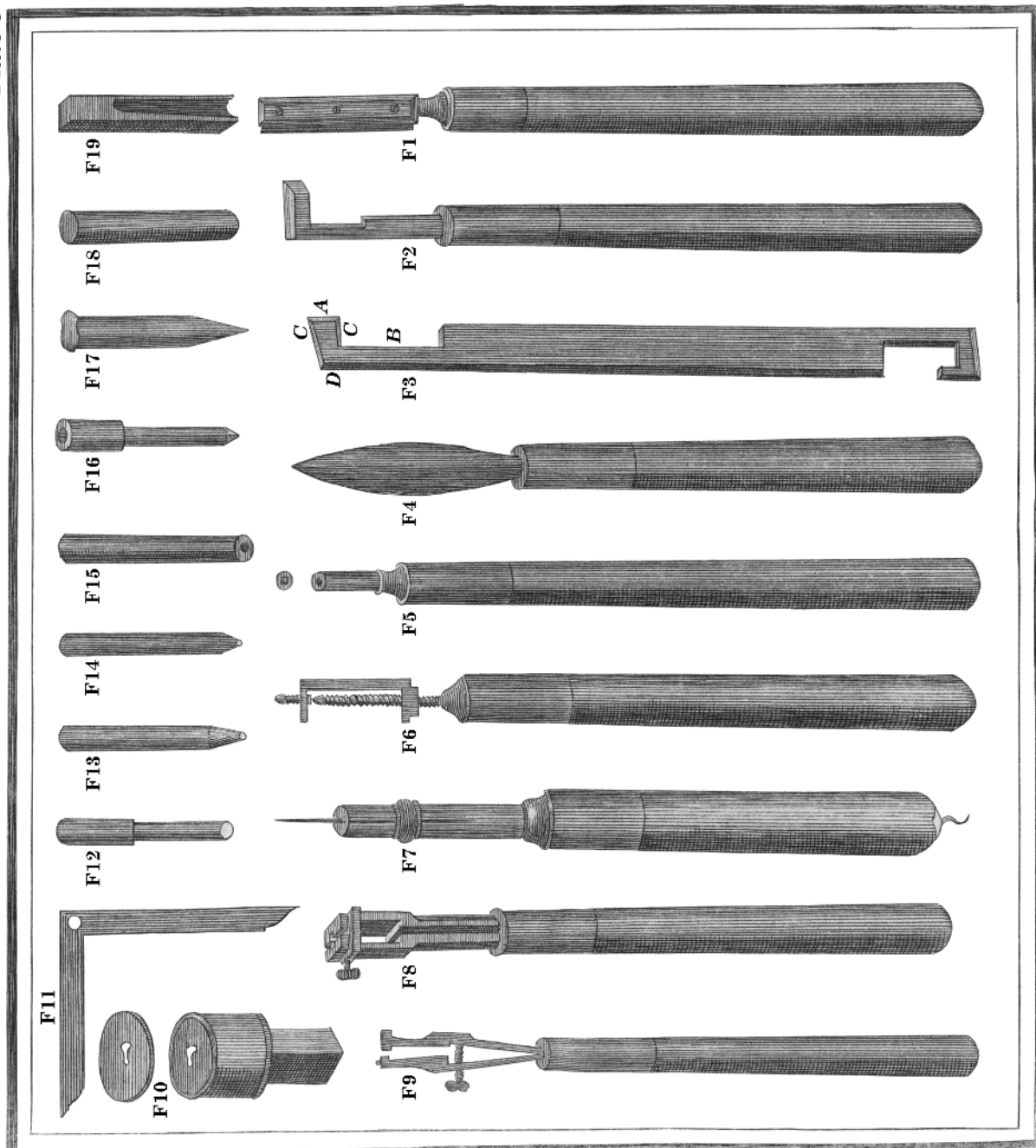
Schneider-Sculp.

Plate 2



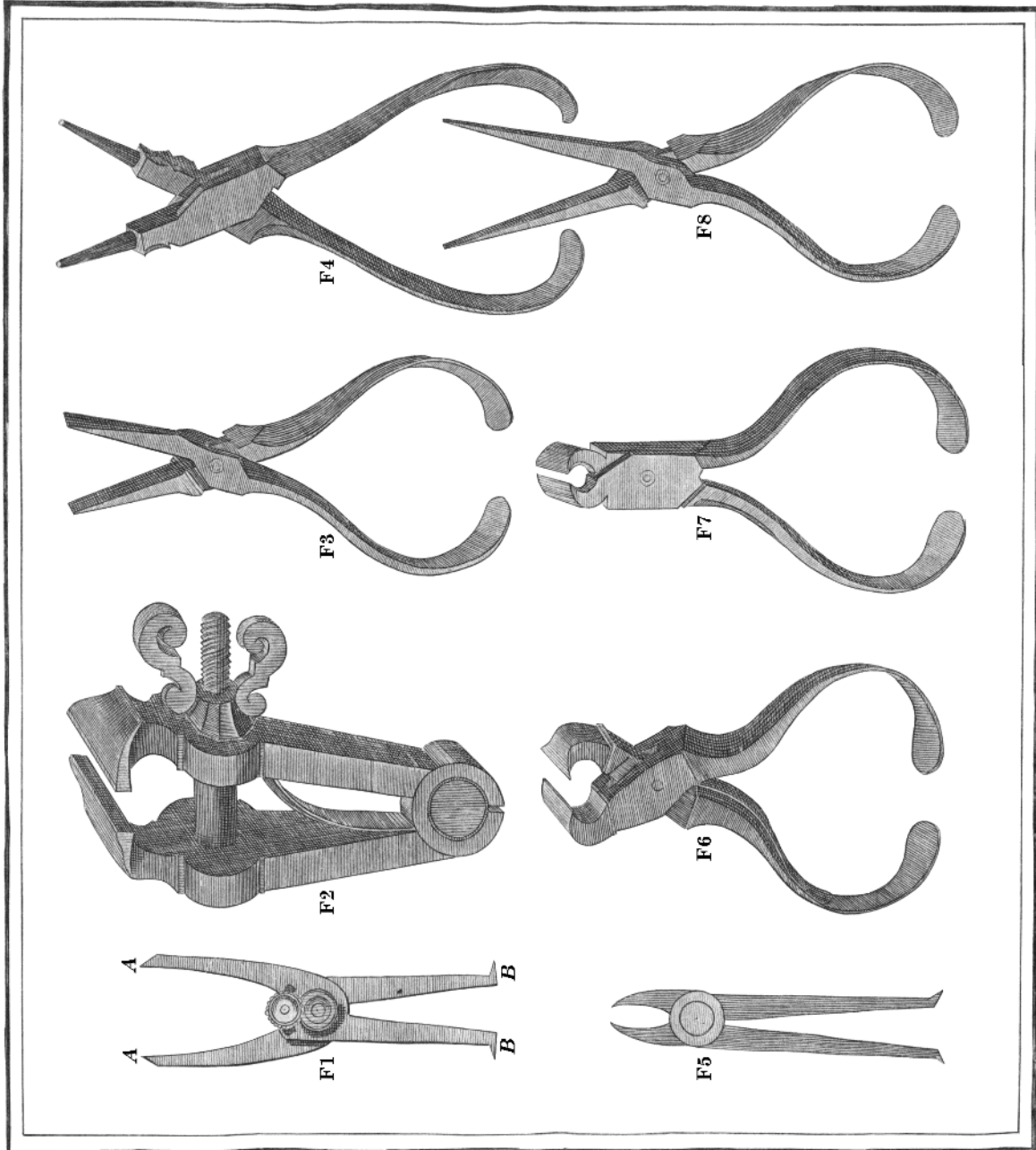
Watchmaking Tools

Plate 3



Tools

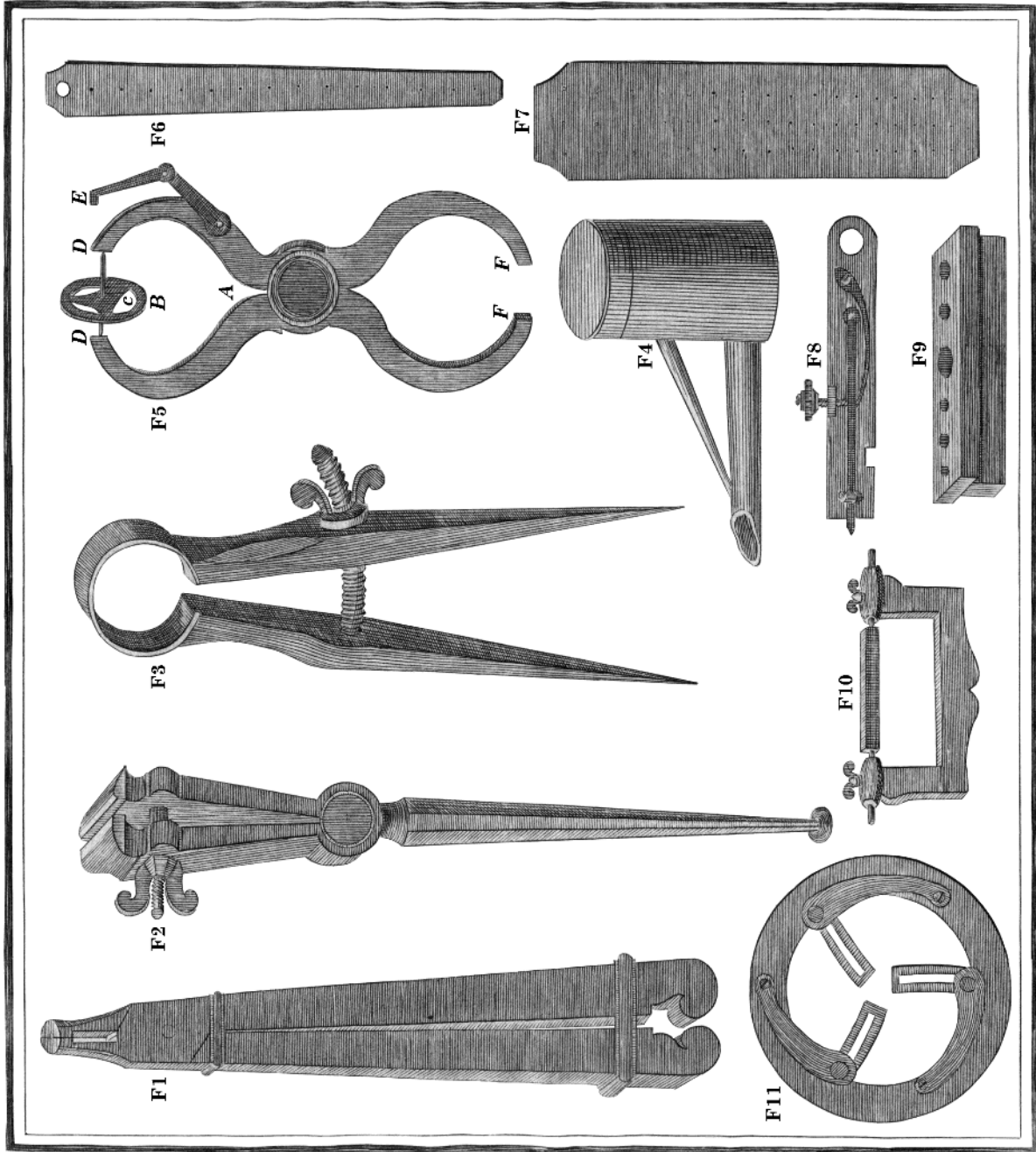
Plate 4



Schuder. Sculp.

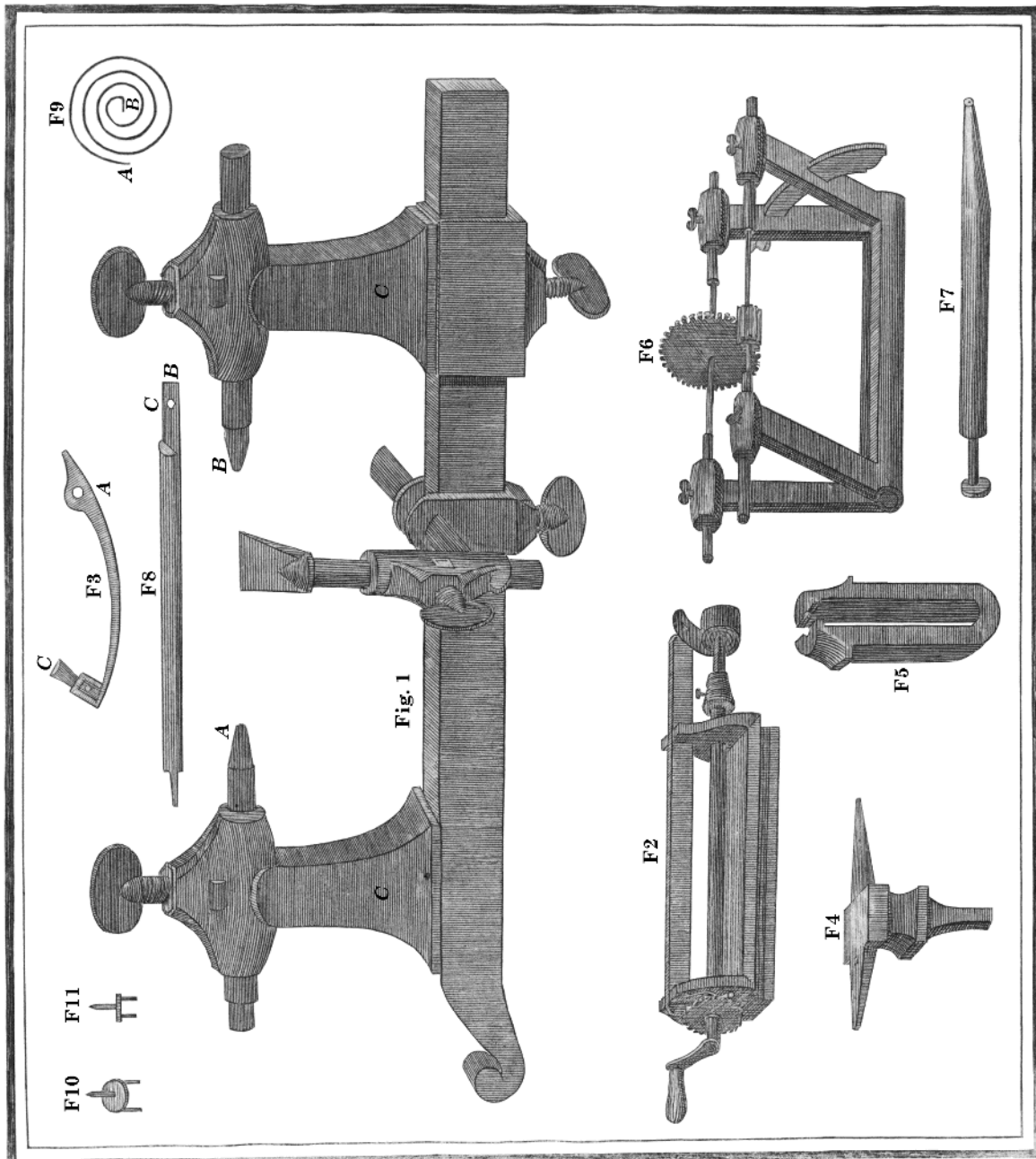
Watchmaking Tools

Plate 5

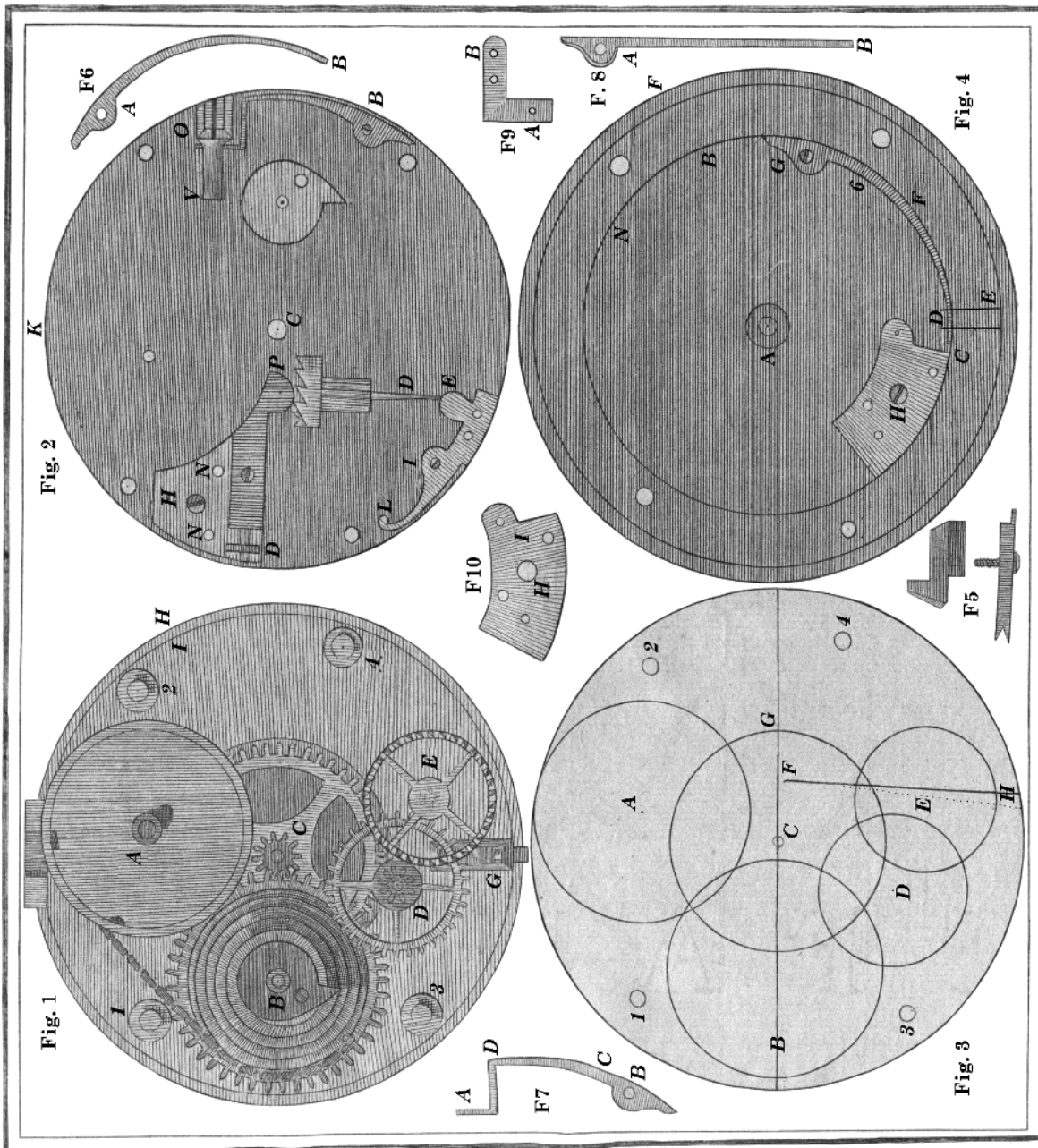


Tools

Plate 6

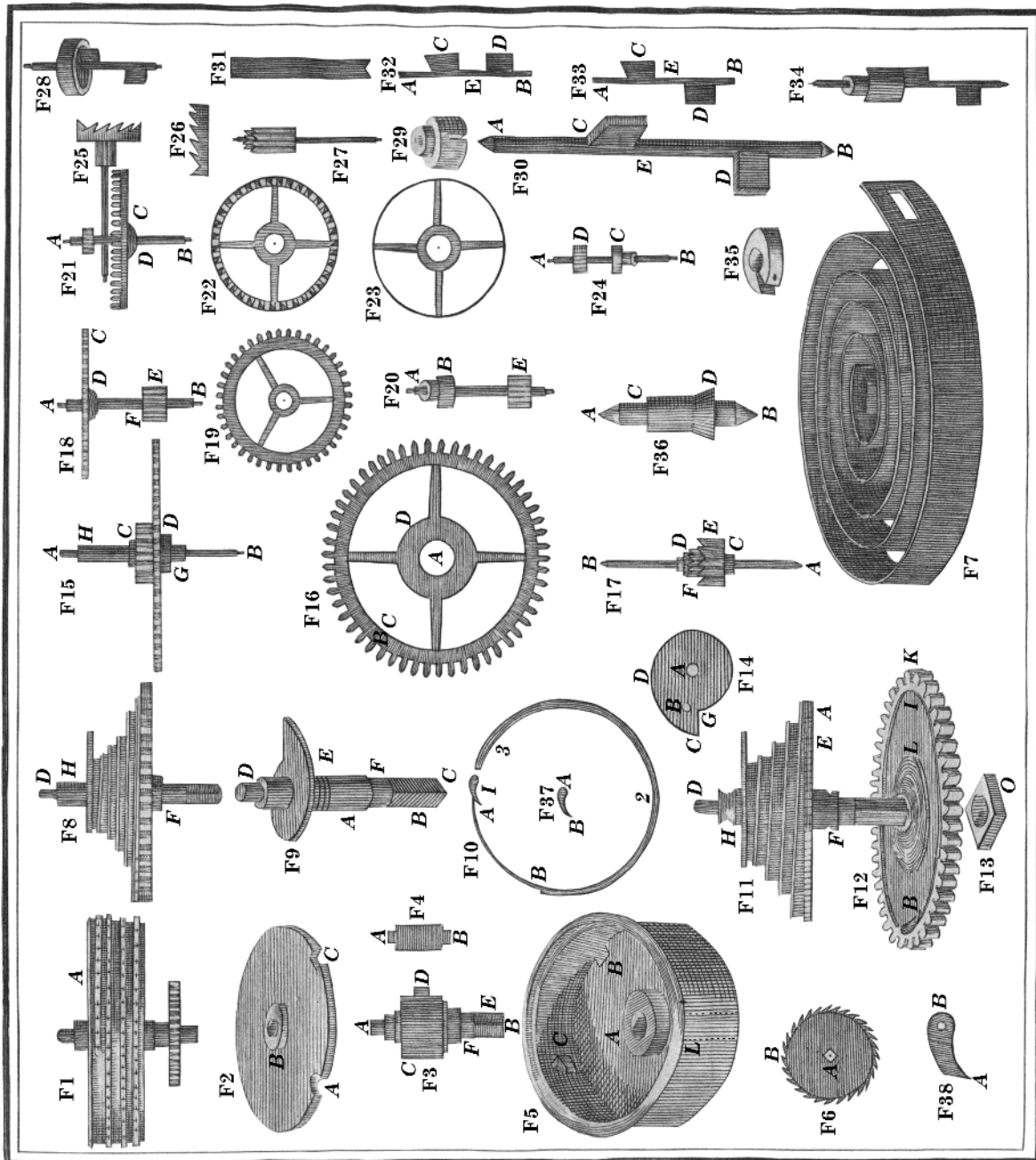


Watchmaking Tools



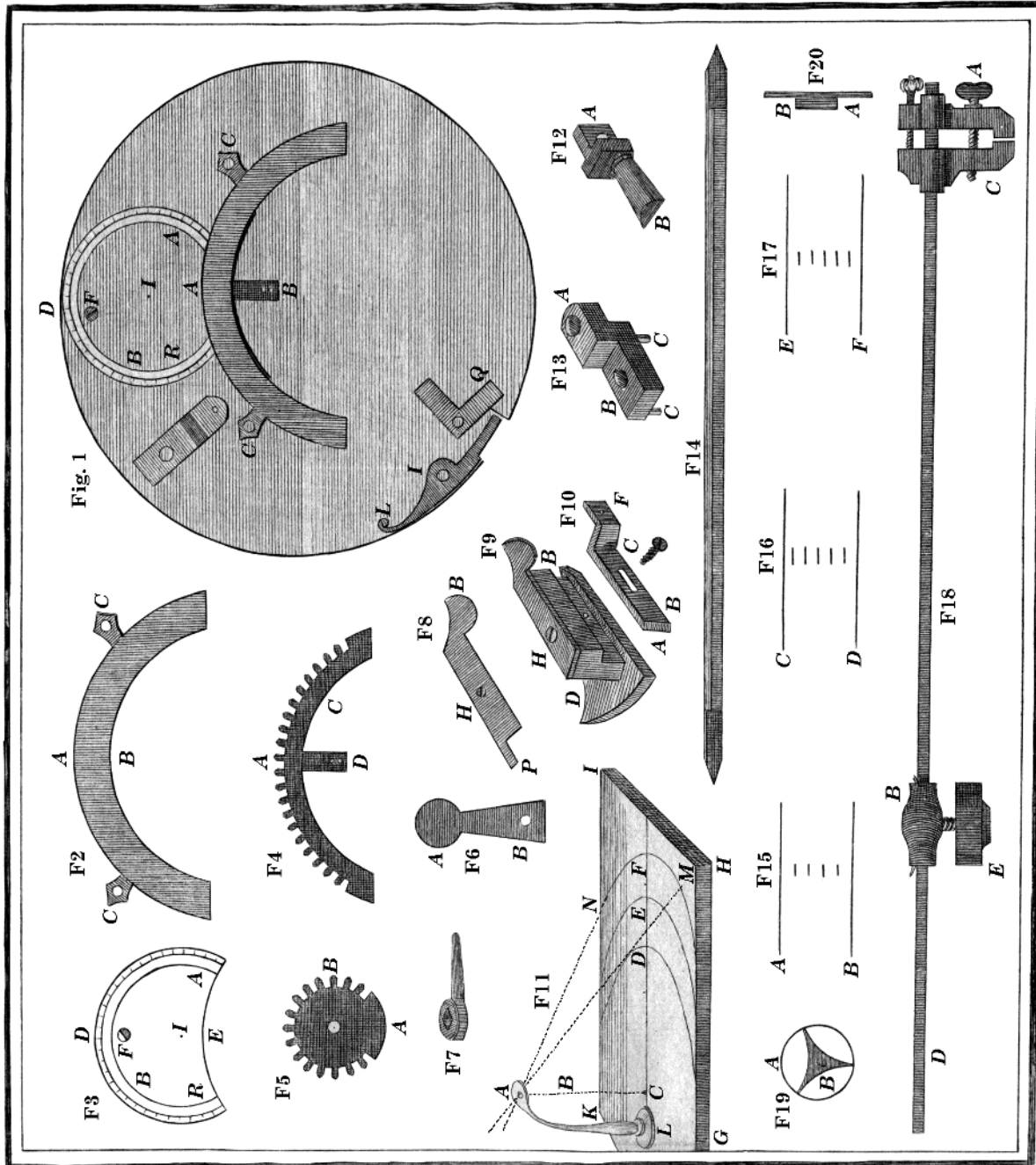
Calibre and Plates of the Watch

Plate 8



Parts of the Verge Watch

Plate 9



Further Watch Parts, Various Tools

Plate 10

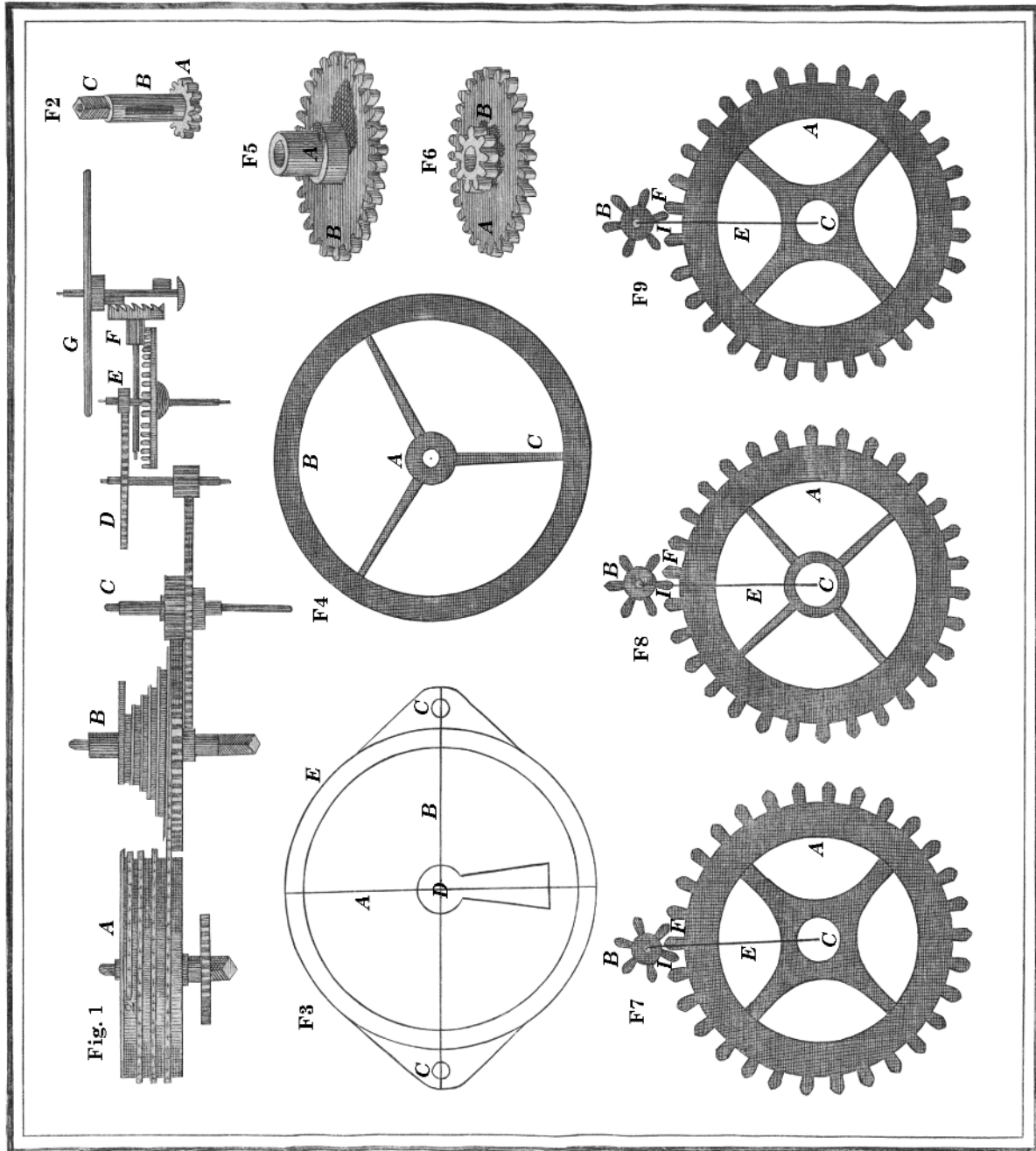
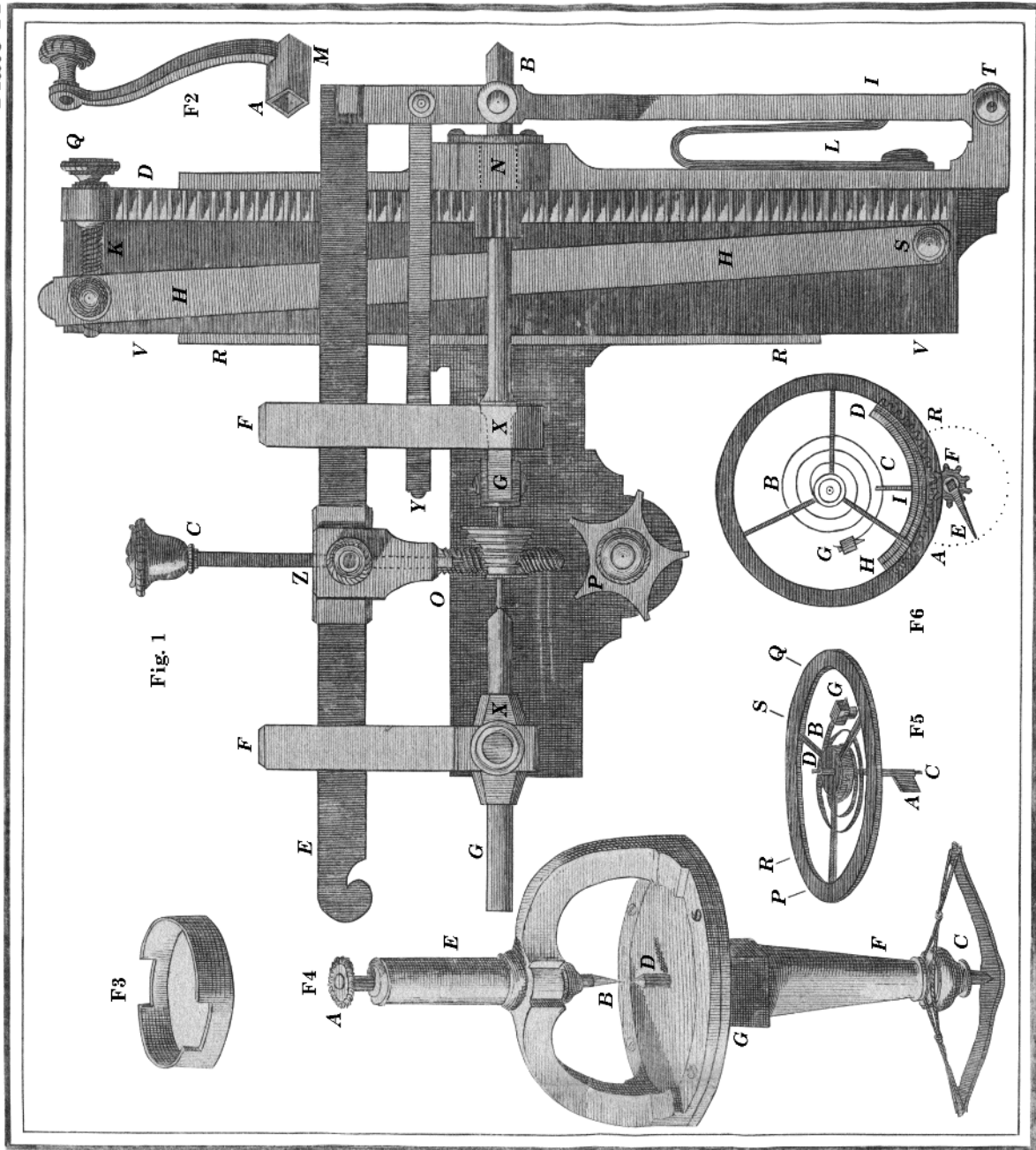
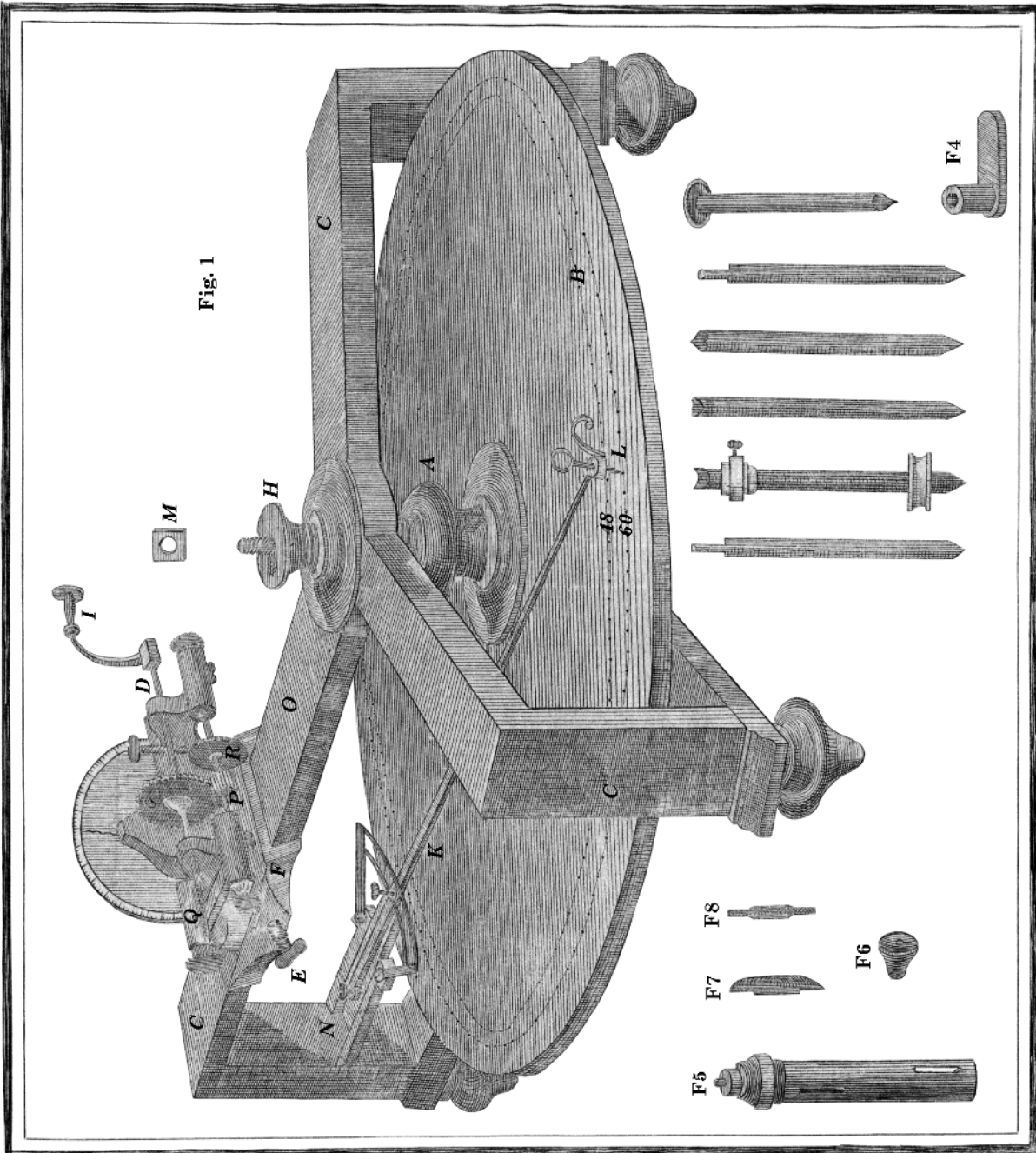


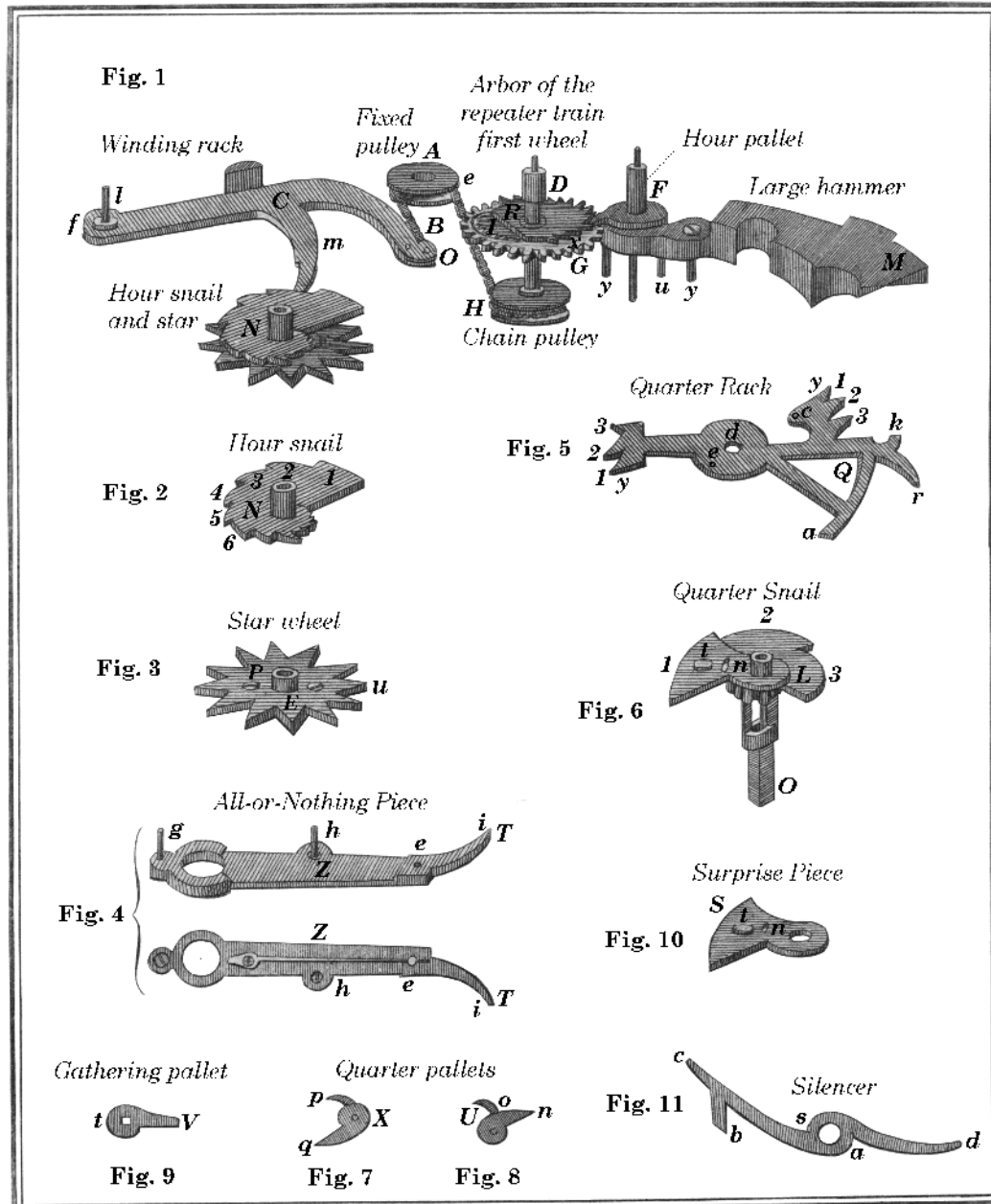
Plate 11



Machine for Cutting Fusees



Tools to Cut the Wheels of Watches



Repeater Watch

Plate 14

Fig. 1

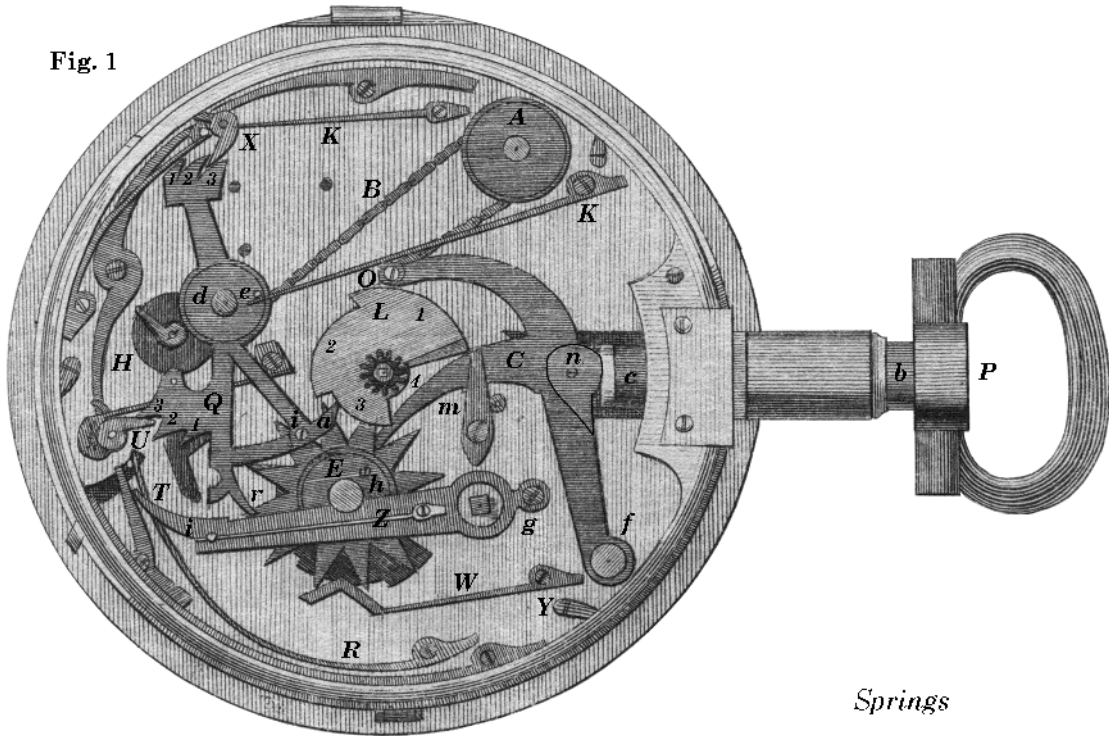
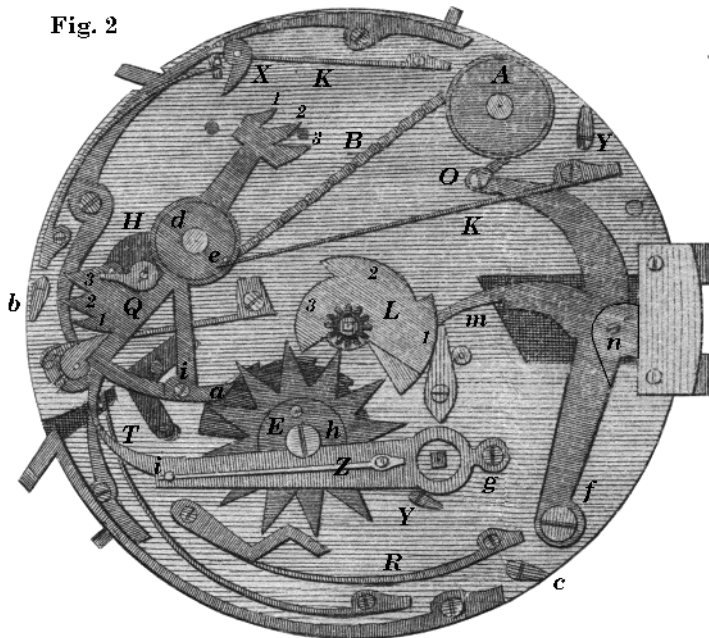
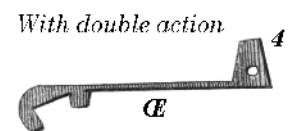
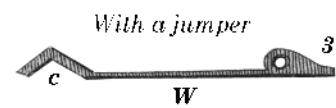
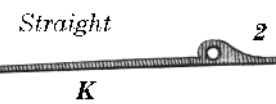


Fig. 2



Springs



D. et G. par Mercadier.