Prize essay on

The construction of a simple but mechanically perfect watch

by

Moritz Grossmann

Translated by

Richard Watkins

Kingston, Tasmania, Australia

Published by the translator

August, 2002

Grossmann, Moritz, 1826-1885.
[Preis-Schrift Abhandlung über die Konstruktion einer einfachen, aber mechanisch volkommenen Uhr Glashütte in Sachsen]

Prize essay on the construction of a simple but mechanically perfect watch.

ISBN 0 9581369 0 4.

1. Clocks and watches. I. Watkins, R. P. (Richard P.). II. Title.

681.114

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Translator's preface

Karl Moritz Grossmann was born in 1826 and apprenticed to a watchmaker in 1843. He served in the army until 1852 and in 1854 he established a factory in Glashütte, making tools and watches. He was involved with the Glashütte watchmaking school from its start in 1878. He died in 1885.

Grossmann was an excellent watchmaker and a manufacturer of note. He was also one of the few nineteenth century horologists who was a thoughtful and competent writer. Paul Chamberlain (in *Its about time*) says he was inclined "to dig unremittingly into the basic reasons, which habit so distinguishes his writings and which places him among the great horologists".

His main work *Prize essay on the free lever escapement* is a classic. Grossmann, who was fluent in several languages, originally wrote it in English for the British Horological Society and then translated it himself into French and German.

On the construction of a simple and mechanically perfect watch is a superb analysis of watch design in the latter half of the nineteenth century. It was written in French in 1869, and later Grossmann revised this original essay, translated it into German and published it in 1880 together with *Über das reguliren der uhren mit tabellen* There were later printings in 1890, 1897 and 1903. The 1880 edition was reprinted in 1981.

In 1871 he was asked to translate the essay into English for the American Horological Journal, but I don't know if that translation was ever published. An English translation was produced in 1891 by Hazlitt and Walker in Chicago and this may be Grossmann's own 1871 translation, but it is extremely rare and I have not seen it. As a result, it almost impossible for English language readers to access this significant contribution to horological literature.

My translation is of Grossmann's 1880 revision. I was more concerned with expressing Grossmann's ideas than producing a literal translation and where I felt that the original could be advantageously re-expressed I have done so. Although Grossmann's writing is very clear, he sometimes used long and convoluted sentences. Consequently there were a few instances where I was not sure of his meaning and I have added some footnotes to his two original ones. However, most of the changes were simply to replace German technical terms by the corresponding English ones.

I am happy to receive feedback and suggestions for improvements. At the time of writing my contact address is watkinsr@netspace.net.au.

C. Mauch and H. Mauch "*Horological dictionary; Horologisches lexikon*" (Germany: Universitas Verlag Tubingen, 1984) was of considerable help in translating technical terms and I would like to thank my brother Andrew who gave up part of a holiday to help me interpret the obscure passages. I would also like to thank Don Holly and Alan Heugh for their suggestions.

Richard Watkins

Kingston, August 2001

Chapter I Introductory remarks

The construction of a good watch is undoubtably one of the most difficult tasks in the whole of practical mechanics. Not only the small size, but the necessity to place the mechanism within a space of a certain shape, the requirement of mechanical perfection and the need for external elegance, are difficulties which are probably not met to the same degree in other branches of mechanics.

Nevertheless, the acumen and skill of the practical watchmaker created many different designs of watchwork and there exist, particularly in Switzerland (the old centre of watch production), an infinite diversity of arrangements which are adapted to their purpose with more or less luck. If we examine these many different expressions of the same basic idea, then the attentive observer will not fail to come to the conclusion that a large number of them were only invented in order to bring out something new and original or possibly to serve fashion. Indeed some create the impression that a watch is an article of fashion and not a scientific instrument.

This was surely one of the main reasons why the Chamber of Commerce in Geneva opened a prize competition for the description of a simple and exemplary watch. Aware of the usefulness of a clear treatment of this matter (and after I had familiarised myself with the production systems in Switzerland, England, France and Germany) I decided to enter the competition, resulting in the satisfaction that my views were favourably assessed by the prize judges.

In 1871, when asked by the publisher of the American Horological Journal in New York, I translated this work (which was originally written in French) into English; and carefully examined and improved it, with some additions which particularly refer to English watches.

It is probably well known that watch production in the United States operates in a completely different way to that elsewhere. The scarcity of skilled manual work led to an expanded use of mechanical aids, which was satisfied to a high degree by the skill and discernment with which automatic and measuring machines were built .

The system of interchangeability, or identity of the parts of a movement, is certainly to be recommended and offers great advantages with large scale production. It was introduced a considerable time ago in some houses in Paris and Geneva, and the possibility of obtaining interchangeability within certain limits can no longer be doubted. But it seems me that this system should not be extended to the production of lever escapements, which should be regarded as individual components in carefully made watches. The cylinder escapement, in contrast, would permit an interchangeable treatment.

Watch production in Switzerland is, compared with the United States, organized in a very different way. In Switzerland ebauches (the frames, wheels and pinions, barrels and clickwork) are manufactured in a number of comparatively small factories. The watch manufacturer buys them and does the casing, dial work, escapement and jewelling, as well as finishing and adjustment.

He would not like to discuss the important principles in the construction of the ebauche, since he seems to be led more by the taste of his customers than by mechanical necessities. This organization causes many irregularities and inconveniences in manufacture; and different major houses, particularly in Geneva, were compelled to undertake the complete production of interchangeable ebauches for their own use in their own buildings, as happens in the watch factories of the United States.

Watch production in England follows the same general pattern so far the ebauche is concerned, but finishing is distributed over the whole country; in nearly every locality watchmakers, in addition to their repair business, construct some or many new watches so that comparatively little pure factory business is found after Swiss style. This system has the decided advantage of offering new work for fashion and important benefits for those who might want to implement a new escapement or something else. On the other hand, ebauche manufacture is at an uncomfortable distance from the influence and desires of most of its customers; and this, with other circumstances of which I will speak later, must be the explanation for some surprising imperfections in the production of high quality movements. Quite probably many English makers realise these disadvantages, but they are not able to force their opinions upon the ebauche manufactures. In the last fifteen years some ebauche manufactures have began to work using systems of interchangeability, but of their success I have learned nothing.

The English, Swiss and French ebauche manufacturers suffer from a common evil, the lack of generally recognized standards and of suitable measuring instruments. In France and Switzerland watchmakers retain outdated systems of units with uncommon tenacity, justified by the "Pied du roi", the foot of the king, although neither country has a king. This system is in total contradiction with the political structure as well as the measurement and weight systems of these countries, and with the normal practices of society. It is completely unsuitable for calculation and comparison, and also it is not appropriate for the size of measurements used in watch work. It should be abolished and be replaced by the metric system. If I am correctly informed, the metric system is already used in those factories in Geneva mentioned above.

The English factories use the English inch, which is as unsuitable for pocket watch work as the Paris line. But most parts are measured by their manufacturers using arbitrary size numbers, without any standard measure and without any guarantee that a certain size number of one manufacturer is equivalent to the same number of another. The disadvantages of this situation could not fail to attract the attention of the thinking watchmaker. Indeed, great inconvenience comes from the circumstance that watch production is spread over the whole United Kingdom, while ebauches and other parts are made only in the district of Lancashire. The manufacturer in London must get ebauches, wheels, pinions, hands and so on from a distance of at least 150 English miles; and it is easy to understand that, in the absence of a generally recognized standard measure, a major exercise is required to do this without committing frequent mistakes.

To change this the British Horological Institute issued a circular in 1861, by which suggestions for a good and practical system of units was requested; and it was expressly noted that it was not necessary that these suggestions should be based on the present English system of units. I submitted a detailed description of the system of units and the measuring instruments used in glasswork, which are based on the metric system. This was not published until two years later, but it was very warmly recommended by the special committee appointed for measurement and measuring instruments. No other reports were published later, except a so-called eccentric measure (which, by its nature, cannot have a definite relationship to a unit of measure), and I concluded that nobody had made any better suggestions. Regardless of the opinion expressed by the committee, there were no followers and English watch work is measured by inches and fractions of an inch to this day.

In my prize paper on the free lever escapement I detailed my opinions on this essay, examined the applicability of the metric standard to all aspects of watch work and also tried to demonstrate its importance.

It is to be deplored that the watch factories of the United States did not introduce the metric standard, which offers such great advantages, from the beginning. There was an opportunity to start afresh because these factories form, to a certain extent, a world by themselves.

Swiss watch manufacturers made their task unnecessarily difficult by creating a large number of sizes. Their regular sizes begin with 10 lines and go up to 21 lines, which results in 12 sizes. Meanwhile, an excessive willingness to satisfy even the most exacting requirements of their customers drove them so far as to implement intermediate sizes of half lines.

English watches have approximately 7 regular sizes. Even this I consider too many, because a gradation of a line (approximately 2.25 mm) is finer than would be necessary even for the most exacting requirements. If 6 sizes were used, which would differ from each other by around 3 mm, then production would be greatly simplified. The sizes would be 31, 34, 37, 40, 43 and 46 mm, which cover the whole range of 13-21 lines. Watches smaller than 13 lines or larger than 21 lines should not be made at all.

The manufacturers of the United States did not make such allowances for the different tastes of the public. It appears to me that they mainly make two sizes of watches, one for gentlemen and one for ladies. The egalitarian character of the republic probably assisted this and, as I am convinced, it has great advantages for the convenience of the watchmaker.

To these introductory remarks I want to add only this: to determine the individual part dimensions I consider it best to express their sizes, if possible, as simple fractions of the outside diameter of the pillar plate.

In my view the question is:

> **what arrangement is the best for the cheap production of a simple, but mechanically perfect and durable watch,**

to be best answered by studying the arrangements which have been used, which of them are advantageous and which are most to be recommended; or, where the current methods do not seem acceptable, by striving to produce new designs.

Chapter II The frame

1. We must begin with this part, because its design has the most substantial influence on the character of the work, all of its parts and even the form of the casing. A watch, and possibly other machines which consist mainly of turning parts, requires a frame to support both ends of each arbor, and this frame has to satisfy the same general requirements as in any other machine.

2. If we examine the frame of a number of different watches we can differentiate between three kinds of construction:

full plate,

three-quarter plate, and

the frame with bridges.

We first want to compare these three systems to select that which offers the greatest advantages for production and the best conditions for strength and good service of the watch.

3. Bridge work is used almost exclusively in Swiss watch production and we must realise that it is more than any other calculated to reveal the watch mechanism advantageously to the eye and to bestow a luxurious appearance to the works. ***(1)*** On the other hand, it is more complicated and cannot be produced and finished for the same price and in the same time as a full or three-quarter plate frame. The same can be said for taking apart and assembling, and it is probable that workers, both in production and repair work, would object to this system if it were introduced now, instead of it having been sanctified by practice over a long period.

4. The bridge frame for a cylinder watch requires 10-11 screws for the bridges, and 16 steady pins; the three-quarter plate frame needs only 7 screws and 6 steady pins. In manufacture, the preparation and fitting of the three pillars are to be balanced against the preparation and fitting of 3-4 screws and 9-10 steady pins; an undeniable advantage in favour of the three-quarter plate if we have cheap and rapid production in mind. Besides, 4 bridges have to be made instead of an upper plate, and the consideration for making and finishing these numerous parts shows a substantial saving in favour of three-quarter plate frames.

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1 *I believe the first of these two remarks relates to impressing the customer, despite the second in Art. 6 clearly referring to technical examination. Grossmann is not backward and openly voices his opinions, so this interpretation is perfectly reasonable. However, you may relate it to the observation of depths if you wish. [Trans]*

For the repairer the same inconveniences occur; the number of individual parts with bridge work is too large and necessarily requires a greater time to take apart and assemble.

5. The stability of the escapement and the uprightness of pinions is endangered each time a steady pin in a bridge movement is bent. For this reason some of the best Swiss manufacturers omit the bridge of the third wheel and place its hole on the centre wheel bridge; because this wheel, which is furthest from the surface of the plate, can suffer most from the last-mentioned danger. It is strange that the same causes did not lead to a complete change to the system.

6. It is stated that an advantage of bridge work is that it is simpler to take out certain parts, such as the barrel in the case of a broken mainspring. But often even this small advantage does not really exist because to take out the barrel, if its hole in the plate has little shake or when the steady pins of the barrel bridge are long, the centre wheel must be taken out first; and if there is little room it is often necessary to raise the bridge of the third wheel. Then 4 or 5 screws are to be screwed in, instead of the three screws of an upper plate. Therefore the only remaining advantage of the bridge watch is easier visual examination of the train. ***(2)***

7. Three-quarter plate work is very rarely implemented in Switzerland, but it is used more in England where, for about 20 years, it has enjoyed a clear advantage over the old full plate movement. It ensures the support and uprightness of the arbors better than the Swiss system and requires a smaller number of pieces and less time and trouble when repairing, with sufficient facility for removing escapement parts.

8. However, the layout of the train in these two frames is exactly the same, so that a three-quarter plate movement might possibly be converted into a bridge movement by removing the pillars and the upper plate and replacing them with a bridge for each arbor.

9. In contrast, the full plate movement requires a completely different layout of the train. It is the oldest frame for watches and it was always very much preferred in England. This kind of frame was also generally accepted by the United States watch factories.

10. It offers the opportunity of having a balance of larger diameter than is possible in the other frames, but this is a reason to which no special importance should be attached; it has long been known that an excessively large balance, since it approaches the effect of a fly, is not suitable for exact time measurement. It was probably the reduction in size of the balance which led English manufacturers to change to the three-quarter plate.

Anyway, it is not appropriate to set the balance near the centre of the plate in full plate watches; because when this happens each circular movement of a suspended watch exerts its full influence on the oscillations of the balance. If the balance is moved near the edge of the plate, this influence is minimised.

11. The full plate frame permits a far simpler and roomier arrangement of the train and, particularly in fusee work, the wheels and pinions can be made larger than in a three-quarter plate frame, which is certainly an advantage. But on the other hand, if we want to use a mainspring of the same width the full plate frame requires a substantially greater height for the frame and the case. This was acceptable when fashion required or permitted a case with a strongly curved bottom, but fashion now demands a nearly or completely flat bottom, and from this developed the need to abandon the full plate, since otherwise the case would be too thick.

12. Full plate work is undoubtably the simplest; it can be implemented with only two bridges, (for the balance) and with a work saving no other system offers to the same degree.

13. However, assembling a full plate watch is inconvenient and we can only make it bearable by habit and many years of practice. The bridge which carries the lower balance pivot must necessarily go over the end of the fork or, if it is a cylinder watch, the rim of the escape wheel; and the worker who takes off the upper plate without sufficient care inevitably breaks the lower lever

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2 *See footnote 1.*

pivot, or the lower escape wheel pivot in a cylinder watch. This very often happens to those repairers who take apart English watches without having previously studied the layout.

Indeed, if we want to avoid an accident of this kind the work must be assembled and taken apart on the upper plate, which is a very awkward method, particularly with fusee watches as we must reset the tension of the mainspring after each disassembly.

It is true that all these objections can be easily overcome if we omit the lower balance bridge and set the lower hole of the balance into the pillar plate. But this would not offer the same certainty of uprightness and endshake of the balance staff.

14. Also, examining the escapement of a full plate watch is not as easy as with differently laid out work. Likewise it is impossible to alter the escapement, to clean it or apply fresh oil without taking the whole movement apart.

15. After we compare the advantages and disadvantages of the three systems above, it is not difficult to draw the conclusion that the full plate movement is unsuitable for watches of our time; and of the two remaining arrangements, the three-quarter plate frame is to be preferred because of its greater firmness and cheapness of production.

16. A small saving in practical execution could be achieved by omitting the two lower bridges; the plate needs to be turned off only a little on the dial side in order to allow room for any unevenness of the dial. Spaces for the barrel and motion work, and even for the lever escapement, can easily be made by turning circular sinks on a lathe.

In the same way a small advantage could be obtained during manufacture of three-quarter plate frames if the pillars were omitted and the upper plate made of sufficient thickness to screw it directly onto the lower plate, whereby it would be secured in position by just three good steady pins. This method can even be recommended for flat watches, since it results in greater firmness. The sinks for the moving parts must be prepared on a lathe. Watches in thin gold cases and made with two full plates in this way would be heavier than if they were made with plates of the usual thickness. Also, setting jewels is not as easy as attaching them to bridges; but by means of suitably designed tools it would not be difficult to insert them directly into the plate.

17. The pillars should not be close to the edge of the upper plate. On the contrary, they will better serve their purpose if they are moved a little inward, because the plate can less easily distort when it is screwed on and the shoulders of the pillars are not precisely made or not exactly square. The two pillars close to the barrel should, if possible, be placed so that a straight line from one to the other passes near the centre of the barrel (Fig. 1 and 2); no matter what, the three pillars must be set the same distance from the centre of the work. The barrel is the container of the motive power, and therefore the frame must be designed so that it possesses the greatest rigidity near it.

18. It is not absolutely necessary to give the plates a particular thickness, but the pillar plate should be thick enough to provide a safe grip for good strong screws, and so that the anchor and escape wheel can be placed a little below the surface of the plate. Also, the upper plate must be turned off to take in the centre wheel, so that it lies with its internal surface level to the plate, and additionally it must provide a solid bearing for the upper pivot of the centre pinion.

According to these requirements a good rule is to make the thickness of the pillar plate in a three-quarter plate frame 0.06 of its diameter. The upper plate should be approximately 0.035 of its diameter. Naturally these conditions refer only to watches of average height (approximately 0.16 or l/6 of their diameter).

A flat watch, which has a weaker mainspring and therefore exerts less pressure on the frame and on the centre pinion pivot, can bear a reduction of these thicknesses.

19. The material of which the frame is made also deserves some remarks. A certain degree of elasticity and hardness is necessary and, in addition, it should oppose the smallest frictional resistance to the movement of pivots and the greatest durability against wear resulting from friction.

20. For this latter reason steel cannot be used. Besides, we could not protect it sufficiently from rust and magnetism would be likely to seriously effect the running of such a watch. However, I want to note here that years ago I saw a good watch which had been made in Leipzig by a clever watchmaker known as Zachariae senior, before jewel holes could be obtained easily and cheaply. He screwed steel bushes into the plate for all the pivots, not excluding the escapement, and these steel holes, which were well hardened and polished, showed no wear and the oil kept remarkably well in them after more than 50 years of service.

21. Brass perfectly fits all the requirements for making the frames of good watches, if it is brought to its greatest hardness and density by sufficient hammering or rolling. If possible, hammering is to be preferred to rolling because the latter method stretches the metal, an effect which is not wanted and does not improve its condition. Rollers of small diameter stretch the material more than large rollers, and I undertook a lengthy set of experiments in order to find the best way to get brass of the greatest density possible. For this purpose I had constructed a small tilt hammer ***(3)*** of approximately 3 pounds weight, which made 5-6 impacts in a second and was adjusted exactly parallel to the anvil. I found that a strip of brass worked with this hammer did not show the slightest increase in width or length, proof that the considerable amount of mechanical work done on it had acted exclusively in the desired and useful direction. By comparison, I found a strip which had been reduced by this perpendicular hammering from 1 mm to 0.9 mm thick, equal in elasticity to that of a strip which was reduced from 3 mm to the same thickness by rollers. The latter was stretched to 2.5 times its original length.

From this it unquestionably results that the majority of the work which is done by rollers is used to lengthen the metal, and only a small fraction of the work serves the real purpose. This stretching is a source of great damage to the quality of the metal, not only for the reason that it brings out flaws at the edges of the strip, but also because it causes the smallest faults (blisters or casting holes) to expand two or three times; while perpendicular hammering squeezes them together and minimises these faults. I could not continue my tests on a larger scale, because these were the largest pieces which could be managed by my small tilt hammer driven by a man with a foot wheel and I did not have bigger machines available. But the result led me to the conviction that the normal method for achieving the necessary density and elasticity of brass is completely wrong. I would prefer rough bridges and other parts to be punched out by a stamping press from the usual hard-rolled sheet brass which we buy in shops, and left approximately 10 percent thicker to allow for compression by perpendicular hammering. Then each part would be put on a flat anvil and subjected to the heavy impacts of a drop hammer set exactly parallel to the surface of the anvil. Such a method would have yet another advantage; it would make the two sides of the punched-out piece completely smooth and flat so that it would not require as much finishing as it would if it were rolled in the usual way.

For production on a large scale, a press of the kind used for minting large coins is much to be recommended. If we consider the perfection with which coins and medals are shaped, such a press would probably have no difficulty in making pillar plates, including their sinks and the shoulder for the case, with such perfection that they would require no finishing.

22. The plates of English watches are usually very soft, due to the bad practice of the gilder exposing them to a high degree of heat; I don't know why and, indeed, I know that a very good gold plating can be obtained without any heating. In addition, their upper plates are usually too thin; the screwed jewel settings, where the screw heads are sunk into the plate, give the repairer great trouble because of the low strength of the metal holding the screw threads.

23. For many years there has been an increasing demand for so-called nickel movements. These are mainly made of the alloy German silver which is given the incorrect designation of nickel. There is no doubt that German silver is an excellent metal for watch work because of its elasticity and hardness; about which the reader will find further details in the comparative study which I published in chapter 14 of my prize essay on the free lever escapement. Beautifully smoothed and polished German silver makes a pleasant impression on the eye, and its surface resists atmospheric influences very well, while brass must be protected by gold plating. However, if we

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3 *"Schwanzhammer", literally a tail hammer. [Trans]*

handle such work carelessly with sweaty fingers ugly black marks form and it is less resistant in this respect than gilded brass.

In all other aspects German silver does not offer any advantage over brass, and it must be said that it is harmful to the eyes of those who are continually occupied with the completion of these shining, polished works. Anyhow, brass, if it is well worked, is so similar to German silver in physical characteristics that the demand for the latter for watchwork might be regarded as merely a matter of taste.

It must also be mentioned that German silver is somewhat sensitive to magnetism, which does not speak in favour of its use for watches.

Further, experience has taught us that screw threads do not hold as well in German silver if they are not lubricated with grease or oil during repair. Hence we usually find rougher screw threads in good German silver work (deeper and with a stronger upward gradient). Also, in many of these watches the barrel hook and even the barrel cover are made of brass, from which we may deduce that the use of German silver for these parts was unsatisfactory.

Chapter III The barrel and mainspring

24. An examination of how this section of the watch is implemented by modern manufacturers must lead us to the conviction that due care is not given to a part of such importance. This fact is all the more surprising as these days a large number of cheap lever watches are produced whose pinions and escapements are so badly made that they can be brought to a reasonable vibration only by an excess of power.

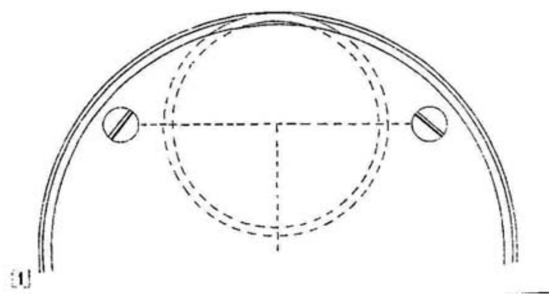


Figure 1. Barrel size.

25. When designing the barrel of a watch, the manufacturer should be driven by the principle that the width and thickness of the mainspring should be limited only by the height and diameter of the watch. It is of extreme importance that the barrel be made as high and wide as the size of the watch permits. For this purpose a good rule for the diameter of the main wheel is to multiply the outside diameter of the pillar plate by 0.47. This gives a main wheel with the largest diameter the size of the watch will allow.

It is even possible to go beyond this size by putting the toothed part of the barrel a little lower than usual, so that this largest part of the barrel is located in the hollow area of the case body where there is enough space, provided the case springs are arranged in an appropriate way in hunter watches.

In this case the diameter of the plate can be multiplied by 0.485 in order to find the diameter of the barrel.

26. The height of the barrel in three-quarter plate watches is the sum of the height of a pillar and the thickness of the pillar plate, from which we take off only a sufficient amount for free movement between the upper and lower faces of the barrel and the plates, and the necessary thickness of the bearing for the bottom pivot of the barrel arbor.

27. We can readily understand that a watch whose escapement and pinions are incorrect, and which is made without any care, will require a strong mainspring, while in a carefully made watch this excess is avoided. Further, by the astute use of the area available for the barrel, a long and thin mainspring can be used, which results in fewer breakages because of its pliancy; and, because of the number of turns which it makes in the barrel, it offers the advantage of being able to select the middle turns of the spring for daily running and so attain a greater uniformity of power.

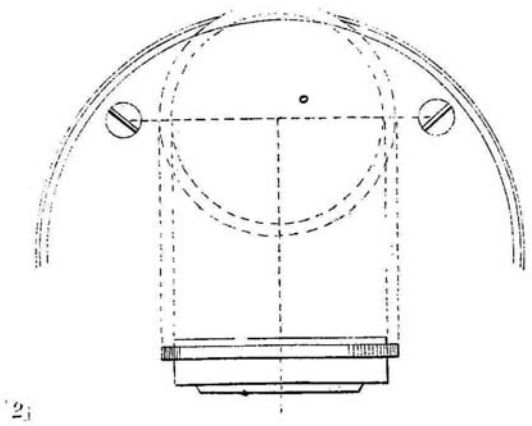


Figure 2. Barrel size.

28. It is also advisable to limit the width of the toothed edge of the barrel to the smallest required by the length of the teeth. We often see a watch whose barrel is too small and which has a toothed edge of excessive width, so that too much of the area available to the spring is lost completely. It is apparent that a barrel of this kind loses power in two ways. Not only must the spring be thinner and weaker than we could otherwise make it, also the internal radius of the barrel (which defines the force lever) is smaller, while the radius of the toothed part, which is the resistance lever, remains the same. The same point shows that the wall of the barrel should be just thick enough to attach a solid hook.

29. If the barrel meets all these conditions, as it should, then a spring of a thickness equivalent to 1/80 of the internal diameter of the barrel is completely sufficient to produce a lively oscillation in a watch whose escapement and pinions are carefully made. Such a spring, if the core of the barrel arbor measures 1/3 of the internal diameter of the barrel, develops more than 6 turns, from which the middle ones can be reserved for the daily running of the watch.

30. The way in which the barrel arbor is constructed shows tremendous variations between different production countries. I want to openly express my disapproval of the Swiss system generally used in watches. In the greater number of these, the lower end of the barrel arbor has no bearing or support and the barrel is held in place only by the ratchet wheel, which is in one piece with the barrel arbor. This system shows clearly that the favour which it enjoys can be attributed essentially to blind habit. It offers neither saving of time in production or repairing, nor a better distribution of space in flat watches, but it is mainly from the point of view of firmness and durability that it is to be rejected. In all watches, both in the well made and in those of inferior work, the barrel arbor should be supported at both ends; in the former because of the greater firmness and additionally in the latter because of cheaper production.

31. There are two main ways to make the hanging barrel arbor. In the first the ratchet wheel forms a part of the barrel arbor, and it is recessed into the upper side of the barrel bridge and held in place by a cap secured with 3 or 4 screws.

These screws, which have just 3 or 4 threads in the metal of the bridge, are the only means to stabilise the barrel. Every repairer must know from repeated experience that this arrangement is an inexhaustible source of annoyance and that, if oiling the rubbing surfaces is neglected or the teeth of the ratchet are not rounded off at their points, the internal surface of the cap or the barrel bottom is rapidly worn by daily winding. The consequence of this wear is an increased shake of the ratchet and the barrel. Every error of this kind is very serious, because the barrel and the centre wheel are the largest mobile parts of the train and necessarily lie with their surfaces very close to each other.

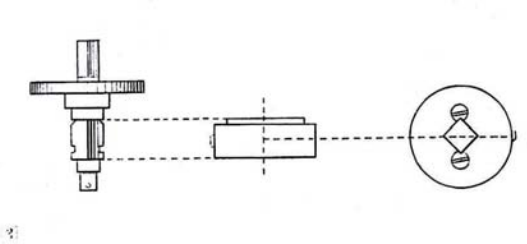


Figure 3. Barrel arbor and ratchet wheel parts.

32. With the other method of construction, the ratchet wheel is attached by 3 screws to a shoulder which is formed on the part of the barrel arbor above the barrel.

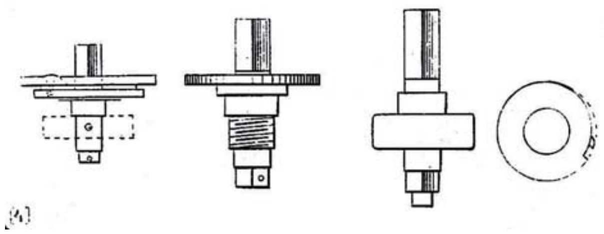


Figure 4. Different kinds of barrel arbor.

This system is, from all points of view, even worse. There are only two narrow circular surfaces which hold the barrel. The top of the barrel arbor and the face of the ratchet gradually wear away the surfaces of the barrel bridge, and the screws are often loosened by the countless small impacts of the click when the watch is wound.

Besides, the ratchet wheel is exposed to faults during hardening and its ability to hold is weakened because the three holes with their sinks for the screw heads must be very near the edge. In these two cases the core of the barrel arbor is a separate piece which is screwed onto the arbor or, and we must watch out for this, it is held by a pin which goes through both parts. The stop finger has a square hole and is pinned on by a transverse hole bored through the end of the barrel arbor.

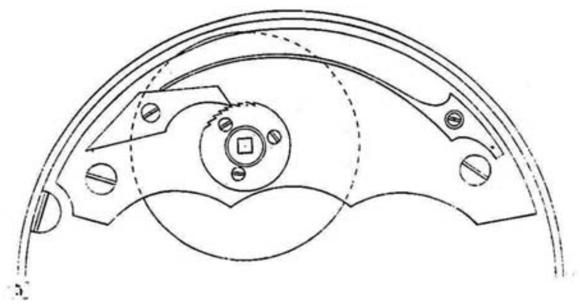


Figure 5. Barrel parts of old design.

33. The best method for the manufacturer and the repairer, and no less for durability and good service, is to make the barrel arbor with two pivots which run in holes. A barrel arbor of this kind is very easy to make. The ratchet wheel must fit onto the square of the arbor, and this is easier to achieve than fitting the core of the Swiss barrel arbor. In addition there is no necessity to make a hole in the lower end of the barrel arbor to hold the stop finger in place, because this is done by the barrel bridge.

A barrel of this kind is much easier to take apart and assemble than a Swiss hanging barrel; we only need to remove the cover of the barrel and everything is done. But with the other the pin of the star finger must be taken out and, after opening the barrel, the pin which fastens the core to the arbor must be removed, or the core unscrewed, before we can clean the parts or put in a new spring; and afterwards these parts must be re-assembled.

34. In a frame whose pillar plate is turned off only 0.2 or 0.3 mm on the dial side, there will be a sufficient gap to attach a thin steel bridge which can take the lower pivot of the barrel arbor. The same space would be also necessary to accommodate the locking pin of the star finger if we wish to avoid the deplorable characteristic of so many flat watches, in which it is almost impossible to remove or insert these pins without splitting the end of the barrel arbor. From this we see that no saving of space worth mentioning is gained.

Chapter IV Clickwork

35. Clickwork is a necessary accessory of the barrel and mainspring; its purpose is to prevent the spring unwinding after winding up has ceased. Since this task is not directly related to the other parts of the mechanism, it is not surprising that a large variety of designs can be found; all of which serve the same purpose with greater or lesser ease of manufacture, or with different degrees of elegance.

36. If simplicity and practicality are required, but mainly if the clickwork is to be sunk into the upper plate, then it seems that a round fitting is preferable.

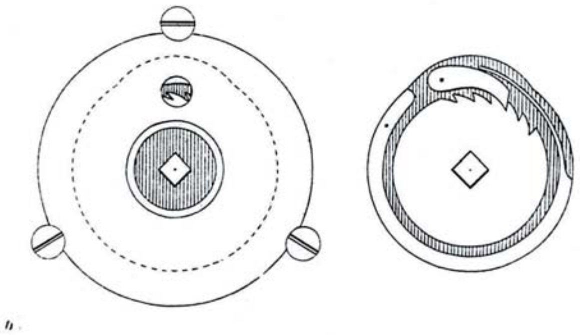
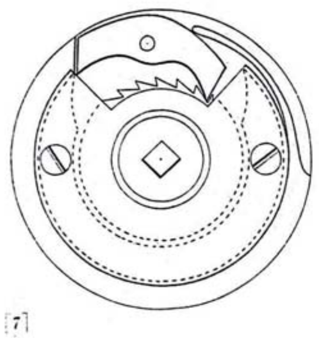


Figure 6. Simple clickwork sunk into the upper plate and completely covered by a cap.

The simplest clickwork of this kind consists of a ratchet, click and clickspring (which is circular and surrounds the ratchet) that fit into a sink in the upper plate, with only the necessary gap for free movement of the parts.

The click should move on a stud set in the sink, or between two pivots. The whole arrangement should be covered by a cap screwed onto the plate, which can be easily put in position by the aid of a shallow sink around it. A small hole bored in a suitable place on the cap would be useful so that the click could be pushed out when it is necessary to let down the mainspring. It would be hardly possible to make clickwork more simply and more cheaply than this, and it is also totally reliable in operation.

37. For watches where greater elegance is desired, the click and clickspring can be visibly attached by leaving a small circular ring standing around the sink in which the ratchet wheel sits, and screwing the cap onto this. The spring fits into a circular sink outside so that it is only partly covered by the cap, in order to hold it in its place (Fig. 7). The thinner acting part of the spring can be easily turned in an eccentric chuck on the lathe.



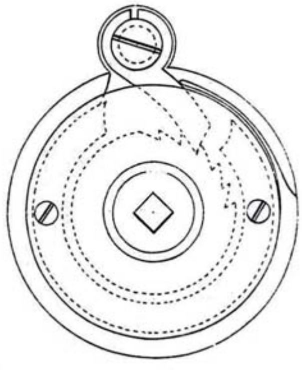


Figure 7. Figure 8.
Clickwork sunk into the upper plate; figure 7 with visible parts.

The click is held by means of a shoulder screw, whose head is on the lower side of the plate. Since such a screw might break off or loosen, it is recommended that the click sits on a stud in the sink and the screw simply holds it in place (Fig. 8). The cut in the click is for disengaging it when letting down the mainspring.

38. A simplified clickwork has the click and the spring made from one piece, but they break more frequently and then the replacement of the piece causes more trouble.

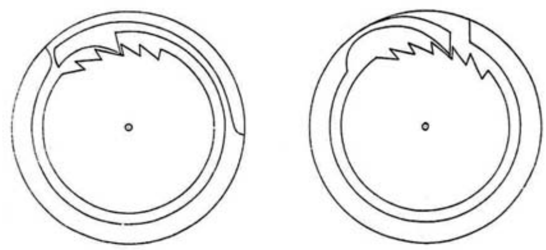


Figure 9. The one-piece round clickspring and click; two types.

39. The material from which the clickwork should be made is hardened and well tempered steel, for the ratchet wheel and click anyway. The spring can be made equally well from another metal which has the necessary springiness, but steel springs are preferable because their polished surface gives the work a brighter appearance.

The form of the ratchet teeth is important. We can give them greater strength if the back is not flat but somewhat curved. The working corner of the click will have to be thinner, but it is very easy to relieve it if there is wear.

The front face should always be somewhat under-cut so that the back of the adjacent tooth has a sharp corner, and consequently the working surface of the click rests, if possible, on the whole tooth surface. The durability and safe operation of clickwork depends substantially on the good execution of these points.

For the safe operation of clickwork is it important that the centre of the click to the point is a straight line tangential to the ratchet wheel circle, or, which is the same thing, that it stands perpendicularly to the radius of the wheel at the point of contact. If we deviate even a little from this direction then it should be only inwards if the click is pushed, so that the angle is more obtuse. However, the reverse is true when the click is pulled.

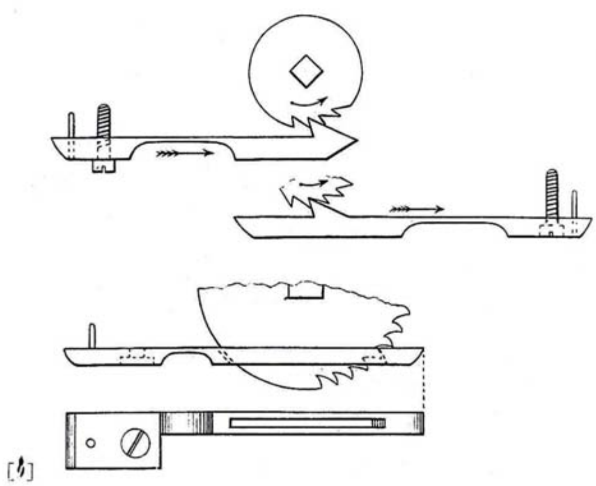


Figure 10. The straight one-piece clickspring and click; three kinds for barrel bridge mounting.

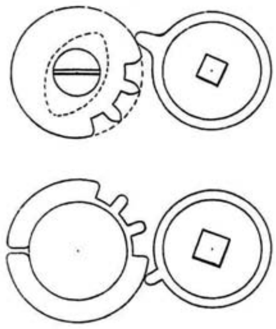
Fig. 10 shows different straight clickworks that are often used in Swiss watches and against which no objections can be raised if they are well and prudently made.

Chapter V Stopwork

40. The last of the barrel accessories is the mechanism to control the tension to which the mainspring is subjected when winding and to limit the turns which are used for daily running. This part of the watch has been the subject of a variety of opinions as to the best way to implement it. We find stopwork designed in the most diverse ways, from its complete omission to the most complicated and ingenious stopwork in some Swiss and French watches.

41. If we try to compare the advantages of different constructions then our judgement must be based on an important criterion. This is friction, and we can object to all stopwork whose parts move under the control of frictional resistance; because friction, as small as it may be, results in a useless loss of power. By the way, in all stopwork of this kind only one tooth or finger stops winding by pressing against the full part of the star wheel. This tooth or finger is in danger of breaking off under the force which is put on it by the careless way in which some people wind their watches.

42. With frictional stopwork, which is not seen very often in watches, a wheel with 3 or 4 teeth is usual, while the remainder of the wheel is left uncut. This wheel is screwed onto the plate by a shoulder screw and the end of the barrel arbor carries a finger or tooth, which meshes with the wheel teeth; and with each revolution of the barrel arbor it rotates one tooth. At the start and end of winding the finger presses against the full part of the wheel and prevents further movement of the barrel arbor in that direction. It is apparent that the wheel is not held during the whole time between two rotations of the finger, and an outside vibration could make it turn around on its axle if its freedom to move were not controlled by a spring washer producing sufficient friction. Sometimes the stop wheel is turned off to a thin rim and slit opposite the teeth, so that it can be sprung onto a slightly under-turned stud on the barrel cover, where it will hold itself without a screw or a spring.



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Figures 11 and 12.

43. To the same class belongs a kind of stopwork with a type of internal gear. An eccentric circular groove is turned in the barrel cover and is undercut at its outside edge. This groove contains a circular spring on whose internal edge some teeth are cut, into which the stop finger meshes; when the stop finger comes into contact with the uncut parts of the spring, winding stops. The friction of this spring in its groove prevents unwanted movement. This arrangement has the same problems as the previous.

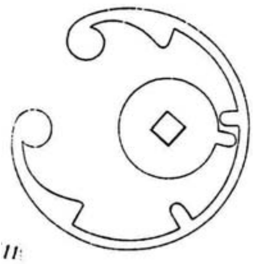

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Figure 13.

44. Of the other class of stopwork, which works without friction, a very clever design should be mentioned here, which we frequently find in the best Swiss and French watches of about 50 years ago. It consists of two wheels with identical teeth which mesh into each other; the one on barrel arbor having more teeth than the other, so that the same teeth of both wheels meet again only after a certain number of rotations determined by the winding. On the upper side of both wheels a stop piece of steel is well fastened and these two stop pieces, if they meet together, halt the movement by coming into contact at right-angles.

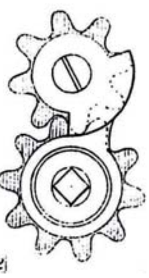

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Figure 14.

The mechanical perfection and reliability of this stopwork are without doubt; the only disadvantage is that it requires a greater height for the stop pieces, which sit over both wheels, and it follows that the width of the mainspring must be reduced by the same amount.

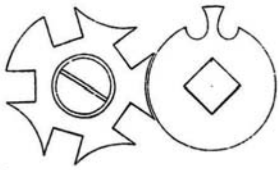

Figure 15.

45. Stopwork with a Maltese cross, Fig. 15, is the most frequently used and preferred for watches. It is so well-known it does not need to be described. It is true that careless execution of this stopwork, which we very often find in inferior grades of watches, is a source of annoyance and trouble for the repairer and the owner. Do not be mistaken, Maltese stopwork will not stand poor execution or carelessness; but if it is well made it has the strength to withstand any test. With well designed tools its correct production is not difficult.

46. However Geneva stopwork, no matter how well built, is always a necessary evil; because it makes the mechanism more complicated, is always exposed to different kinds of disorders and errors, and because it takes up some of the space which otherwise could be used to increase the mainspring width.

For this reason it is not surprising that the question was seriously studied, whether it would be feasible to completely omit stopwork without endangering durability and normal running, and without a mainspring of a disproportionate strength. This question requires a careful discussion, because the advantages which we may get from the omission of stopwork cannot be underestimated. It will thus be necessary to examine whether these advantages are counterbalanced by serious drawbacks.

47. The omission of stopwork was tried in various ways. More than 20 years ago a mainspring for this purpose was suggested, to whose outer end a piece of the same spring was riveted, about as long as a third of the internal diameter of the barrel. This piece was fastened backwards to the direction of the spring and its free end supported against a hook in the barrel of the usual kind. This arrangement allows the spring to completely roll up to its outermost end, and the short piece riveted to it rises in a diagonal direction against the hook and prevents further winding.

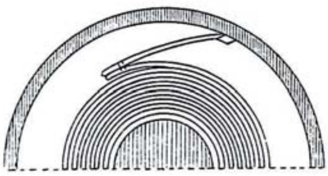

Figure 16.

This system is to be preferred to the simple omission of stopwork because the spring is far more protected against breaking; but it does not protect the other parts of the movement against the sudden force which results from imprudent winding. This is, however, a fault which occurs with all of the stopworks previously considered.

This method looks rather grotesque but it should not be summarily rejected. At the time I wanted to arrive at a correct judgement of its value, and about 24 years ago I installed barrels of this type in two small ladies watches, as these are intended to be very flat. These watches are in continual use by people who often work with me, and so I had them under observation during the whole time; they were satisfactory in their running and, up to now, have not broken a mainspring.

Many years ago I saw some American watches whose barrels were designed in exactly the same way; the only difference was that the piece riveted to the end of the spring had two pivots at its free end which sat in holes in the bottom and the cover of the barrel.

48. More than 10 years ago a system was invented for omitting stopwork and it was completely free of the disadvantages just mentioned. This is the free spring of A. Philippe. An investigation of its advantages and the objections raised against is appropriate here.

This free spring is made in such way that it is held in the barrel without the usual hook, but instead by the greater tension and strength of its outermost coil which is left, for this purpose, approximately double the thickness of the working coils of the spring. The comparative thickness of these two parts of the spring must be arranged in such a way that the outside coil, gripping the barrel by friction, can follow the winding action, but slip if the spring suffers a certain higher tension. In this way the tension of the spring cannot go beyond this highest amount, even if winding were continued for a long time.

49. Springs of this kind are made in two different ways. With one the thicker part of the spring is in one piece with the rest; while in the other a spring of the ordinary kind is purchased with a special piece of greater strength, whose length equals the circumference of the barrel; it forms a flexible brace for the mainspring and is attached to it by a hook.

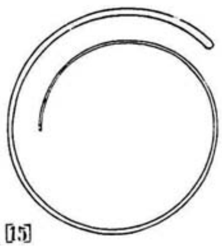

Figure 17.

The effect of both systems is naturally the same.

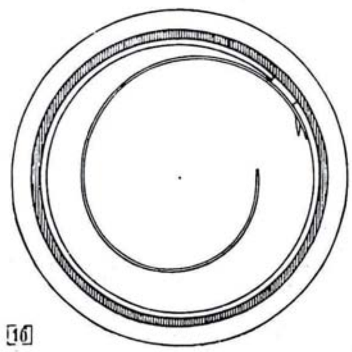

Figure 18

50. It is not easy to give an opinion for or against free springs in a few words; because if we judge their advantages fairly then we must also consider the disadvantages and the objections made by watchmakers and repairers, and weigh them against the advantages which can be expected. The latter are:

1) Larger height of the barrel that allows, in a watch of the same size, a wider and thinner mainspring which is therefore less exposed to accidents and results in a more even rate.

2) Savings with the production of the barrel. However, this advantage is balanced to some degree by the higher price of the free spring; but this price would be very much reduced if the free spring became a regular commercial product.

3) Complete removal of all disturbances of the watch which come from faults and disorders of stopwork.

4) Protection of the work against damage which can result from imprudent and rough winding.

5) An extended running period in one winding, because the free spring is usually made in such a way that it produces 6 rotations or more.

These advantages, especially those of 3 to 5, are of great importance; and in particular the full importance of 4 has not yet been determined.

51. The disadvantages of the free spring are:

1) The lack of a clear indication that the end of winding has been reached. This objection can be overcome by making 3 or 4 vertical cuts on the inside wall of the barrel and giving the end of the spring a weak outward bend, so that it penetrates a little into one of these recesses. When the highest tension is reached the end of the spring is no longer held back by the recess and it slides into the next, making a quiet but audible noise indicating that winding should cease. At the same time this sudden small movement can be felt.

2) The large inequality of rate, which must necessarily occur between the two extremes of the spring development. At first sight this objection seems to be serious because the watch, if it is not wound regularly, continues to run until the tension of the spring is exhausted, and there can be no doubt that in the last hours of running the watch will show some deviation in rate from that which it has with regular winding. But it also must be said that we cannot expect a perfect rate from any watch if it is treated carelessly. In addition, we should ask what the consequences of irregular winding would be if stopwork were provided? Then the watch would simply stop, a very unpleasant occurrence for travellers, and it is at just these times that it is most likely we will forget to wind the watch. In such a case the owner of a watch with a free spring must realise how advantageous it is for his watch to continue to run, even if with a deviation of a quarter or half minute; which however is hardly likely to occur with a good watch, even under such unusual circumstances.

52. It seems that these two main objections against the free spring are of no importance. But there are probably practical difficulties which make most watchmakers averse to their use. So, to be added to the weight of the above are the inconveniences of having to stock an assortment of free springs in addition to the usual supply of springs (in case of breakages), and the higher price of the free springs. In contrast, springs of the usual kind are easy and cheap to get.

These circumstances got me thinking, whether it is possible to enjoy the indisputable advantages of the free spring without having to forego the ease with which we can replace a broken spring in a conventional system. It seems to me that I found a method that can be used at least in an emergency. I take an ordinary spring of suitable width and thickness for the barrel and break a piece off the end, long enough to go round once inside the barrel.

At the end of this piece I file a hook, into which the spring is hooked in the usual way, so that the loose piece extends backwards in the direction of the length of the spring. (4)

This arrangement causes the pressure of the piece against the inside of the barrel to increase with the tension of the spring, whereas with Philippe's method winding the spring decreases the friction of outside piece; and this is why in his method the outside piece must be stronger than the spring. With the changes just mentioned a piece of the mainspring is adequate, and its resistance

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4 *If Grossmann was the first person to propose this then he is the inventor of the mainspring used in all automatic watches. [Trans}*

can be increased by recesses in the barrel and a protuberance punched in the end of the tension piece; on the other hand, the resistance can be reduced if the tension piece is shortened. I believe that a spring made in this way would quickly win friends because it offers all the advantages of the free spring without its difficulties for the practical repairer. Anyhow, it provides the means to repair a watch in which a free spring has broken with a suitable new spring, without having to increase the stock of springs.

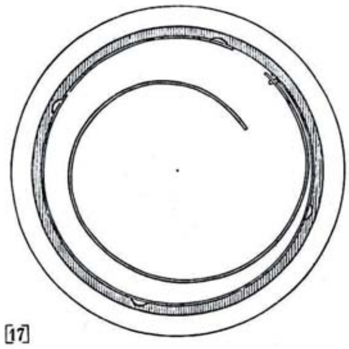

Figure 19.

Chapter VI The train

53. The first requirement for the watch train is to make it as large as the diameter of the movement permits. The very limited area allowed by the dominant taste for a portable timekeeper is an obstacle to reaching a higher degree of perfection in gearing; if it is possible to manufacture the wheels and pinions of a pendulum clock with satisfying accuracy then it will be increasingly difficult to do this as the space in which we have to build the watch decreases. If we had simpler means to examine the accuracy of the division and the cutting of small pinions, even of the best manufacturers, then we would soon arrive at the conclusion that these qualities necessarily decline with the size of the pinion. The inequalities and deformations caused by grinding and polishing are nearly the same with large pinions as with small, but small pinions suffer relatively much more from them. This refers only to the production of pinions; but before a pinion runs in the train it goes through the hands of the pinion turner. First he has to determine whether it runs completely true and then to set it true if necessary. With all operations of this kind the worker has to rely on his eye to determine if the condition of the piece is satisfactory. The eye however, like all human senses, is reliable only within certain limits, and if a good worker says a pinion is round then we must not understand this mathematically; it only indicates that an experienced eye cannot see any deviation from the round. There are thus small errors which escape the sharpest eye and their absolute size is approximately the same for large pieces as for small. For example, if a careful worker turns a pinion of 3 mm diameter he cannot tell if it is out of round by less than a hundredth of this size, 0.03 mm. This error is the smallest that can be differentiated by the eye, and with pinions of 1 mm diameter it will be not one hundredth but three hundredths of the diameter; and therefore it is relatively of three-times greater importance with small pinions. The same argument can be extended to the accuracy of wheels and it is clear that it is of the greatest importance to have as large a train as the diameter of the watch allows.

54. Another matter of great importance is the even transmission of power from the barrel to the escapement by the train. This uniformity can only be obtained by good gearing, and there is sufficient evidence that gears with pinions of high leaf numbers are more perfect; it is advisable that centre pinions are never given less than 12 leaves, 3rd and 4th pinions 10 and escape pinions should have at least 7 leaves. The difference this has on production costs is so insignificant that it should be no problem to use pinions with highest possible number of teeth in inferior watches. ***(5)***

The centre pinion will then have more fragile teeth and be more exposed to damage from sudden impacts, which come from the mainspring breaking or the pressure of rough winding. The teeth of the barrel, which must also be thinner, will be more exposed to buckling from the same causes; but these dangers are partly remedied by the circumstance that almost two leaves of pinions of 12 work into two teeth of the barrel at the same time, while in pinions of smaller count only one tooth leads with a larger movement angle. Consequently, the force of any sudden impact from the barrel will be distributed over two teeth of a pinion with a high leaf number, significantly reducing the apparent danger of breakage. Besides, there is a better transmission of power with fine teeth and so a weaker mainspring can be used, with which there is a less violent impact if it breaks.

55. One of the chief requirements for good and even transmission of power is a correct and suitable form for the teeth of wheels, and it is amazing to see in what an indifferent way this important matter is treated by many people. It is a well-known fact that wheel teeth, in order to work appropriately, must have an epicyclic form, and no machine-maker would accept any other for his spur wheels. About a century ago Berthoud treated this matter in the most detailed way, and Reid and others also explained the principles of the design of wheel teeth in the clearest manner; but in vain. It seems that most of our professional colleagues decided to regard the form of their teeth as a matter of taste. The wheels of most English and other watches have, with very few exceptions, teeth which scorn the rules of Berthoud, Reid and other masters; a form of which nothing can be said other than that it looks quite good in the eyes of the makers and users. When the late Adolph Lange had the courage, at the beginning of his production, to give the teeth of his wheels the theoretically correct form it was met with hostility in Germany and ridiculed on all sides. I knew a watchmaker who did not want to buy his watches because they had this “horrible” tooth profile. It is difficult to argue against such reasons and I heard a respectable and good watchmaker explain that he could not understand epicyclic teeth. Fortunately times are now different; in particular, thanks to our specialised journals, there are among our watchmakers a proper recognition and a striving to achieve the best possible, and there is now hardly a watchmaker who would not know what a well-formed tooth should look like.

56. The reciprocal ratios of the train wheels should also have a certain harmony, which can be attained by a regular distribution of the wheel diameters and the fineness of the teeth.

57. With regards to the escape wheel pinion for larger watches, I would recommend at least 8 leaves with a 4th wheel of 75 teeth and an escape wheel of 16 teeth. The last gearing, which is the most sensitive to any irregularities of transmission, will be significantly improved.

58. The following are the sizes of a train for a watch of 43 mm or 19 Swiss lines, which would correspond exactly, in my view, to the above conditions:

Diameter of the Barrel = 43.0 x 0.485 ***(6)*** =	20.85 mm
Centre wheel	15.40 mm
3rd wheel	13.00 mm
4th wheel	11.80 mm

The tooth numbers for this are:

Barrel	90,	Centre pinion	12,
Centre wheel	80,	3rd pinion	10,
3rd wheel	75,	4th pinion	10,
4th wheel	75,	escape pinion	8,
Escape wheel	16.		

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5 *Or small watches. Grossmann uses “geringen” for two purposes. Usually he means “small”, but sometimes he means “inferior” or “lesser grade”. A few instances are ambiguous and I have footnoted these. [Trans]*

6 See Art. 25.

The tooth pitches would be:

Barrel	0.345 mm
Centre wheel	0.30 mm
3rd wheel	0.27 mm
4th wheel	0.24 mm

It is easy to see that this distribution is quite regular.

For watches 43 mm or larger in diameter a train with 12-leaf pinions is excellent, but provided that the gears are planted and laid out with the greatest care. Then the train will be:

Barrel	105,	Centre pinion	14,
Centre wheel	96,	3rd pinion	12,
3rd wheel	90,	4th pinion	12,
4th wheel	80,	escape pinion.	8.
Escape wheel	15,		

from which the following tooth pitches result:

Barrel	0.30 mm
Centre wheel	0.24 mm
3rd wheel	0.22 mm
4th wheel	0.216 mm

59. The train should be laid out in such a way that the seconds circle comes on a suitable part of the dial. This circle must be as large as possible to have clear divisions, but not so large that it completely covers the VI of the hour circle. A good arrangement I can recommend is to set the centre of the seconds circle exactly half way between the centre of the dial and its edge. If this rule was generally observed it would be a decided step towards regularity of construction; it would make things much easier for dial manufacturers and dealers, and would make dial replacement much simpler for the repairer.

A still larger seconds circle could be obtained by shifting its centre nearer the centre of the dial, but this minor advantage would be too expensive and detrimental to the layout of the train.

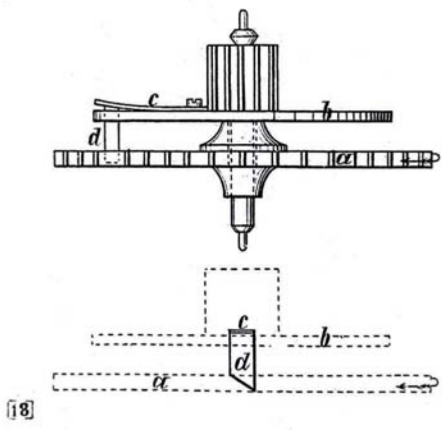
60. The length of the arbors should only be limited by the height of the frame. The larger the distance between the bearings of a pinion the better for its safe guidance and operation. The same quantity of side shake necessary for free movement will affect the depthing of a long pinion less than a short one.

The generally accepted construction rules for machines cannot be used for the diameters of pivots in watch work, because if we tried to set their size by theoretical relationship to the power which they must handle, then we would get pivots so small that they would be very difficult to manufacture; and the cross section of such a pivot might come into a disadvantageous relationship with the molecular structure of steel. Besides, we must always remember that the pivots of the train must not only be proportioned to handle the mainspring force with safety, but also the violent force which comes from breaking a mainspring or rough winding. Consequently, very few can object to the diameters of pivots which are normally used in pocket watches.

61. It remains to say a few words about a new improvement. It has been mentioned (Art. 54) that the centre pinion and the barrel are in continual danger of having their teeth bent or broken by the sudden impact of a breaking mainspring.

These accidents are so annoying that a number of small inventions have been made in order to avoid them. It will not be redundant to say a little and express my views about them in order to find whether they actually do what they promise.

62. One of these safety mechanisms consists of a kind of flexible transmission on the 3rd wheel. This wheel ***a*** (see Fig. 20) sits loosely on the arbor which carries a disk riveted onto the pinion. On this smooth disk a spring ***c*** is fastened with a vertical pin ***d*** which projects into the space between the spokes of the 3rd wheel. In this way it turns the wheel while the watch is going. The end of the pin has a chamfer and it is assumed that, if the mainspring breaks, the force of the impact slides the tapered end over the wheel spoke. I could not advise the use of this safety device because I believe that it will be made ineffective by the inertia of the parts lying between the 3rd wheel and the mainspring. The destruction caused by a sudden jerk will be completed before the power of it reaches the 3rd wheel; in the same way that explosive powder, in a hole bored into hard rock and stopped up with loam, will burst the rock by its sudden effect before it has time to remove the soft loam plug.



Figures 20 and 21. Safety mechanism on the third wheel for mainspring breakage. The 3rd wheel ***a*** is loose on the arbor and is turned by the pin ***d***. The arrow indicates the direction of rotation of the wheels.

This mechanism, if it is to have any chance of success, must presuppose an exact adjustment of the mainspring so that it does not give way to the force of the mainspring when fully wound, but a force beyond that causes it to slide. If this is not the case, then the safety of the centre pinion is not ensured and an excessive force from rough winding, when the stopwork comes into effect, will probably overcome the spring ***c*** and thus cause the hands to advance. I am of the opinion that the watch owner would regard such an irregularity in its rate as a serious defect, rather than a random accident unconnected with its time keeping and which cannot be eliminated by the watchmaker, however careful he is.

63. Another invention promises more, because the controlling resistance lies in the centre pinion. This has a rather large hole and is fitted onto the arbor on which the wheel is riveted. The pinion is held on the arbor by a nut and a spring washer. When the pinion is set in motion it works like a one-piece pinion because of the friction which holds it on the arbor and which is a little more than the force which is exerted by the mainspring. However, an increase of this force causes the pinion to rotate on the arbor and so absorb the power without damage to other working parts.

It is easily understood that this arrangement protects the centre pinion and barrel teeth, not just against the sudden impacts of a breaking mainspring, but also against excessive force when winding; and without causing a change in the time indicated by the watch (Art. 62).

However, this invention also has its disadvantages. The centre pinion with its large hole, particularly if it has less than 12 leaves, has too little space between this hole and the base of its teeth, and thus the durability of it is endangered. This mechanism can be used in a watch whose hands are set from the front, but it appears questionable for the hollow centre arbors which are used in watches whose hands are set from the rear.

64. I recently had in my hands a somewhat similar safety centre pinion of English work; it had an arbor onto which the pinion was screwed by three turns. This thread was cut into the hole of the pinion and into the arbor, and it has to be a right-hand thread if the centre wheel is over the pinion (a left-hand thread is required in the other case). While the watch is running this screw thread is tightened by the mainspring. If, however, an impact in the opposite direction occurs, then it unscrews itself and so avoids the harmful effects. This method, although it appears very effective, is also subject to serious doubts. The greater force at the end of winding is not avoided and will, in fact, screw the pinion on more firmly; so that it may not unscrew or it may break, considering that it is rather fragile because of the large hole. By the way, and this is the main objection, we cannot be sure in which direction the impact of a breaking mainspring will take place. If the mainspring breaks close to its outside end then the impact will take place in the direction of normal rotation and this safety device will be of no use at all; on the contrary, the pinion, weakened by the large hole, will be endangered. The device will be effective only in the case that the mainspring breaks at its inner end.

65. It is a general need to secure the centre pinion against accidents, and all thinking manufacturers should seriously consider this matter. It seems that up to now no good solution has been found. The best method is the pinion fitted onto a round but slightly conical arbor and held by a nut and a spring washer, but the decreased strength of the pinion is a problem.

66. Nevertheless, I have never attached such a safety pinion to a watch of my manufacture because I believe that I can obtain the same purpose in much simpler way. Firstly, a substantial step in this direction can be attained if the above-mentioned principles concerning the barrel and the train are observed, and a mainspring of comparatively greater length and smaller strength is used. In the case of a break the impact which follows is less harmful; and when winding the stop of the stopwork is more easily noticed than with an excessively strong mainspring. Also a thin and long mainspring which develops more than 6 turns, of which only 4 are used, is much less likely to break.

Briefly, I consider it very desirable and practically easy to strengthen the teeth of the centre pinion and the barrel by giving them a more suitable form. If one of these teeth is found broken then, without exception, the break took place at the base where the tooth is thinnest and has two sharp corners (as the taste of the majority of watchmakers require it). A change of this form, from the dotted line at ***a*** in Fig. 22, would approximately double the strength of the tooth without any disadvantage resulting. I feel convinced that the general use of this form for the teeth of the barrel, centre pinion and centre wheel would fulfil the discussed purpose very well, although we cannot be assured that complete safety from breakages would result from it. However in this respect the other mechanisms are at least equally dubious.

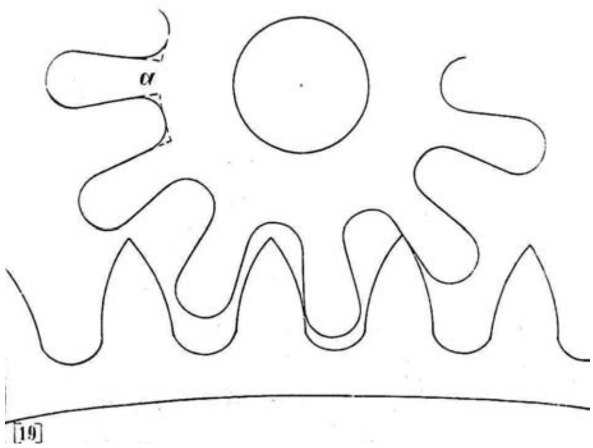


Figure 22. Wheel and pinion with round bases, which better resist the shock of a breaking mainspring.

Chapter VII Motion work

67. About the construction of this part of the movement not much needs to be said, because it is fairly independent of the design of the train. In Swiss watches the motion work is usually much smaller than it is necessary to make it. However, there is some advantage when using a free mainspring (Art. 48) in having very small motion work, because then the barrel cover does not need to have a shoulder for the hour wheel, so leaving the room required for such a mainspring.

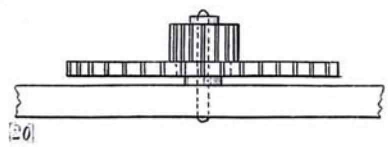


Figure 23. Minute wheel mounted on a steel pin.

68. There are nevertheless some small points in motion work which permit improvement. In English watches, even of the best class, the minute pinion usually runs on a brass stud which is driven rather carelessly into the pillar plate, a construction which is completely unworthy of the character and the generally careful execution of these watches. In contrast, all Swiss watches, including the inferior ones ***(7)***, have a screwed-in stud on which the minute pinion fits. These studs are not easy to make, difficult to screw in and unscrew, and by cutting the screw hole into the plate they offer far less certainty of exact depthing than a round hole which can be drilled on depthing circles. I believe the solution lies between these two, one which is more easily executed, is firm and decreases friction. A hole is bored for the minute pinion in the pillar plate. A finely polished pin of hard of steel, rounded off at both ends, is driven into this hole so that it is flush with the inside of the plate and projects on the other side close to the dial. The minute pinion has a small projecting pipe which is left standing beyond the rivet and serves to hold the minute wheel a small distance above the plate; the other end of the minute pinion also has a small pipe which is turned down so that it has just the necessary shake under the dial.

69. Still another aspect could be improved easily. It is the way the minute hand fits on. In nearly all Swiss watches the hand fits on the end of the hand arbor ***(8)***, and we must support the square of the hand arbor or it may squeeze out of the pinion with the pressure. This is not the case if the hand fits onto the end of the cannon pinion, which must have a shoulder for this purpose. Besides, this arrangement has the advantage that the end shake of the hour wheel can be adjusted between the front surface of the cannon pinion and the lower end of the minute hand pipe so that it does not require the small spring washer which we normally use to hold the hour wheel in place.

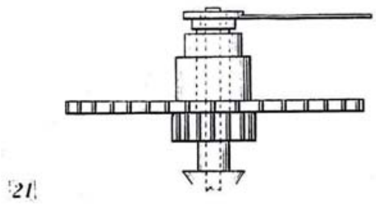


Figure 24. Arrangement of the minute hand on the cannon pinion.

70. It remains to say a few words about hand setting which is usually done from the back, particularly with Swiss watches. Setting the hands from the dial is an inconvenience which is inevitable with full plate frames, while in bridge and three-quarter plate watches there is simply no necessity for it. Gradual replacement of the old-style fixed dome (double back) case, whose movement is only accessible from the dial side, also led to the demand to change the method of hand setting.

71. The dial of the watch, although made from a material which is difficult to work, is not open to much improvement. The possibility of damage to the enamel face led to many efforts to replace it by a more suitable material. But the main requirement of a good dial, clarity, has not yet reached such perfection in anything other than the enamel dial. A completely white surface with jet black figures on it cannot be excelled for this purpose. Silver dials, with which we have tried to replace

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7 *Or small ones. [Trans]*

8 *The taper pin running inside the hollow centre arbor. [Trans]*

enamel dials, can be nearly the same white colour, but they are prone to blackening by oxidisation or imprudent treatment. Gold dials have also been tried, but they are far less clear unless viewed under very bright light and cannot be recommended for persons who do not have good eyesight. It is strange, as we very often find with English watches, that a gold dial is used with gold numbers and gold hands.

For this reason the enamel dial, despite its fragility and greater thickness, is still in use and it will remain so with those who keep its main function in mind. But it cannot be denied that the invention of a suitable metallic or other material possessing the necessary characteristics would be a great improvement for the practical watchmaker.

There was a time when dials with a yellowish-grey colour were preferred in England and elsewhere. Naturally these are not as suitable as a white dial. In the same way a matt surface is regarded by some as a great improvement, since we can look at the watch from any direction without being disturbed by the reflections which a shining dial throws back. This is a strange mistake; because if the dial of a watch does not reflect light then the glass over it will surely do so; and anyway, it is very easy to look at a watch without disturbing reflections.

72. The attachment of the dial is done by pins or screws. The dial should not be fastened by two small screws ***(9)*** for which holes must be bored in the plate, because the dial is very easily damaged by the slightest side pressure when closing the case (since the holes are very close to the edge of the dial). This method of fastening the dial used to be preferred by the best Swiss and French makers and some beautiful dials were spoiled in consequence.

Another kind of fastening is with dial feet and pins, which is completely effective and has no risks; therefore it was preferred for English watches and, if the movement is accessible, nothing can be said against it. However, with today's movements, the majority of which cannot be opened by a hinge, attachment with pins would probably be quite cumbersome, because to remove the dial it would be necessary to take the movement from the case.

With all movements fitted in this way, the dial feet should be held by dog screws which allow the dial to be removed without taking the movement out.

73. A very good method of fastening a dial is to mount it on a thin rim of silver or gold which fits exactly onto the outside edge of the pillar plate.

74. In order to be clearly seen, the hands should be made a dark colour and blued steel is used for this purpose in preference to gold. The numbers and hands should be thicker than present taste prescribes. The most suitable form for hands are those of the so-called poker and spade; the Breguet and fleur-de-lis hands cannot be seen as clearly.

75. The seconds circle should have a longer and stronger line at each fifth second in order to facilitate reading off seconds.

In the past all dials had flat seconds, but for about thirty years sunk seconds have been generally used, even for inferior ***(10)*** watches. There is some advantage in flat watches because space for the seconds hand is obtained; but importantly the dial is weakened at the same time. This probably explains why some manufacturers make the sunk seconds bit smaller and paint the seconds divisions on the surrounding part. The seconds hand is then shorter and moves in the sink.

The dial should never be made larger than the pillar plate.

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9 *From the front. [Trans]*

10 *Or small watches. [Trans]*

Chapter VIII The escapement

75. It is outside the scope of this work to describe the different escapements or to discuss their comparative advantages. We are concerned only with the external parts of the movement which serve the escapement and which hold it rigidly in place.

76. We begin with the cylinder escapement. It always seemed to me that the adjustable bridge (chariot) is a nearly redundant addition. If the distance between the cylinder and escape wheel are correctly set then it is desirable to maintain this invariably, and the mobility of the chariot is a danger for the good operation of the watch. Also, nobody thinks that the correct setting up of a cylinder escapement is a difficult task, but the duplex escapement rarely has a chariot even though it requires greater accuracy because of its fragile nature. Besides, the cylinder escapement is more suitable than other escapements for interchangeable manufacture and we should take advantage of this.

The complete omission of the chariot would make the movement simpler and easier to make, because the lower balance bridge can then be omitted and the balance hole and escape wheel hole, when on the bridge, can be set in the plate. The need for a chariot is just a bias which developed from habit and blind imitation. If a cylinder escapement is correctly set then it will remain that way for all time and no inexperienced hand will be able to change this set-up; with regard to those escapements which are incorrectly set up, they should not have passed examination without being corrected.

77. The cylinder escapement does not require as much area as the lever escapement. Thus the movement is not pushed for space and an advantage is that a better train can be made with a higher numbered centre wheel than in a lever watch of the same diameter (Art. 53).

78. In all countries, France perhaps excepted, the cylinder escapement has been nearly displaced by the lever escapement, and some remarks need to be made about it.

The lever escapement permits a greater diversity of layout and we must firstly consider the question, whether it is to be set in a straight line or at right angles. The latter has been recommended because it saves space or, which means same, it allows a more convenient arrangement of the parts. Thus with it we could make the escape wheel, lever and fork larger in a movement of the same diameter. This may appear advantageous for the reasons I have given for the size of wheels and pinions (Art. 53), but for escapements other aspects must be taken into consideration. In the first place, we must remember that during the interrupted running of a resting or free escapement the inertia of the wheels has to be overcome with each oscillation, and this inertia should be minimised. Over and above this, the sliding friction of the escape wheel on the pallet surfaces is, by its very nature, different from the rolling friction of teeth and it becomes considerably larger as the surface area increases. For these reasons the escape wheel, lever and fork should not exceed certain limits and should be made as light as possible without adversely affecting their strength. The length of the fork must also be limited. I do not want to repeat here what I have already detailed in my prize essay on the free anchor escapement (chapter IX, page 62). The action of the fork and roller is more robust, so that we can make them relatively larger in order to observe their action more easily. ***(11)***

For the same reasons it is not advisable to make the wheel and other parts of the escapement from gold, whose density would be disadvantageous.

79. As we have seen, there is no benefit in terms of saving space from using a right-angle escapement, unless in very complicated work where the available room is limited by other parts of the mechanism. The use of one or other of these two layouts must be considered as little more than a matter of taste. As far as friction is concerned, there appears to be a small difference in favour of the right-angle escapement; however this difference, which was discussed in the prize essay mentioned above, is of no great importance. All straight line escapements must have jewelled lever holes, because the bushing of a lever hole is more vital with the straight line

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11 *This sentence makes little sense to me in either language. [Trans]*

escapement than with the other. The reason is that any deviation from the correct centre distances necessarily causes not only an error in the action of the escape wheel and pallets, but also in the fork and roller.

80. In view of the previous arguments, the diameter of the escape wheel in a lever watch should not exceed 1/5 of the diameter of the pillar plate. A good ratio will be then obtained by making the acting length of the fork, i.e. the distance from the lever centre to the working corners of the fork, equal to the radius of the wheel or 0.1 of the diameter of the plate.

With these conditions the centre of the lever will lie within the circumference of the balance, if the balance is not disproportionately small.

81. We could obtain a slight saving by setting the escape wheel and lever under the same bridge; but then we would have to make do without the advantage of a short fork or we would have to make the escape wheel arbor as short as the pallet arbor, which should be under the balance. We should avoid this, because the stability of the escape wheel pinion is greater if the pivots are further apart (Art. 60); therefore the small amount of work and expense which result from using a separate bridge for the escape wheel should not be regarded as a major obstacle.

82. The depth of the 4th wheel in the escape pinion should not be too great; because otherwise the correct operation of the gear, which by its nature is the most sensitive and least perfect of the whole train, is endangered by the smallest change in the steady pins of the escape wheel bridge.

For the same reason this bridge should be set so that a straight line between the pivot hole and the screw hole passes through the centre of the 4th wheel, or not far from it, because the depths will then be less affected by a bent steady pin.

83. The balance cock, in the normal course of production and repair, must be removed and replaced frequently; and it is important to make the steady pins very carefully as much trouble and damage can result if they are badly made. A well fitted cock, especially that of the balance, should slide easily into the steady pin holes to a distance of some tenths of a millimetre from the plate, stand firmly in its place and at the same time hold in such a way that the escapement can be tested safely without screwing the cock on. This can be only obtained by using slightly tapered steady pins.

I cannot recommend the English method of screwing in the steady pins, because they are not easy to make and do not give the same certainty of exact fitting as a pin which is driven into a round hole. For doing this I have always found the following method very good. I take a piece of wire, somewhat thicker than the hole, and file its length slightly tapered (the same as a broach) until it goes approximately half way into the steady pin hole of the pillar plate. Then I take a sharp polishing file ***(12)*** and, with the pin in a pinvise resting on a suitable notch in a filing block, I work on the end of it with the polishing file so that somewhat more of its length than amounts to the thickness of the plate is tapered. If this done in the right way the conical part of the pin will fit into the hole of the pillar plate. Then I take a good broach and broach the appropriate hole in the cock until the prepared pin goes in so far that its end is flush with the lower surface of the cock ***(13)***. However, this must be left to experience because much depends on the comparative hardness of the cock and the pinwire, as well as on the shape in which the wire has been filed. Then it is cut off leaving a just sufficient length protruding above the upper surface of the cock. Then, after the bottom of the cock has been put on a flat piece of steel with a hole only little larger than the pin, I drive the pin in firmly, frequently testing it in the hole of the pillar plate, until the pin holds the cock firmly. The other pin is made in the same way. A cock which is fitted according to this method goes completely easily into the holes until the pivot is in the jewel hole, and then with the last pressure, which can now be applied safely and without danger for the jewel hole, it holds securely. These conical steady pins offer the further advantage that if they are slightly bent the position of the bridge is not significantly affected; because, due to their conical form, they gain

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12 *Presumably a pivot file [Trans].*

13 *The hole goes right through the cock and the pin is inserted from the top. [Trans]*

their secure footing in the plate only by the part closest to the bridge, while those parts most likely to be bent are free in the hole.

84. If the pins are well fitted then two are perfectly sufficient and much better than three made in the usual careless way, with which a cock fits tightly at first but nevertheless has shake when it is close to the plate.

The steady pins should not be too long, because they are very easily bent otherwise. Their length may not exceed twice their diameter, and the pinwire should always be drawn as hard as possible. If the steady pins are to do their service in an effective way then they must be placed as far apart as the foot of the cock allows.

85. The balance is a part which has very different relative sizes in different watches and without undertaking a more extensive description I will limit myself to stating that a good value for the diameter of the balance is to multiply the diameter of the pillar plate by 0.4, or to take 4 tenths of it. For a work of 43 mm diameter the balance would then be 43 x 0.4 = 17.2 mm.

86. If the work is to have a compensation balance, great care must be exercised to ensure that the inside and outside of the rim have plenty of room. I have seen many cases where inexperienced workers were driven nearly to despair by watches which were apparently in good condition and went very well, but at the start of the cold season stopped every night. If one was examined, which naturally happened in a warm room, it resumed its usual running without showing the least problem, until it was found that the expansion of the balance caused it to come too close to a bridge or another part.

Chapter IX Case fitting

87. The way to fit the movement into the case changes significantly with the design of the case; therefore we must, in order to speak about it, decide which is the best design.

First we have the old English case with a fixed dome. It must be opened and the hands set from the front (i.e. from the dial side). In a case of this kind the movement is fastened by a hinge at XII and is held in place by a locking bolt at VI, which is pushed in by the thumb-nail. This method certainly results in a strong case, but it is very inconvenient for the owner who must open the back to wind it and must open the bezel to set the hands. A still worse fault of this design is the use of a bolt; if the thumb-nail slips over it the seconds and minute hands can be broken off. A case of this kind is meant to be used with a full plate movement, where the hands have to be set from the dial side, but a three-quarter plate or bridge movement should always have the hand setting square at the back (Art. 70).

88. For the latter types of watch the modern form of case is more suitable, where the movement is fastened into the case by means of a steady pin and one or two screws. Two screws are better. Swiss watches usually have three pins at the edge of the pillar plate at some distance from each other. The middle one is the thickest and in the form of a square; it goes partially into a small filing in the body of the case (whereby it prevents the movement rotating) and the upper side of the outer end is cut down sufficiently to fit under the case rim, as are the two side pins.

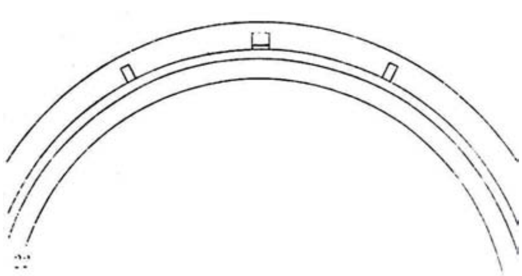

Figure 25.

This method of attaching the movement, usually with only one dog screw, makes taking out and inserting the movement more difficult, particularly with the very thin cases which are used on so many Swiss watches.

89. Therefore I propose another plan, which is very easy and simple to make if the pillar plate and its shoulder fit exactly into the case. A hole is drilled into the rim of the case surrounding the pillar plate and into the plate. A pin is driven into the hole in the plate and shortened so that it enters the hole in the case without projecting on the outside; the pin both holds the movement in place and prevents it rotating. The attachment is completed by two dog screws, 120° from each other and from the pin, which lock onto two shoulders soldered into the body.

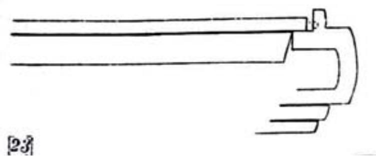

Figure 26.

90. If possible the pin should be attached near the balance so that this most precious and delicate part of the movement is placed in position first and not exposed to any force that may be used to press the movement into the case. It is very important to carefully fit the movement to its case so that it goes in gently, without pressure and without clearance; because otherwise, particularly if the case is strong and the plate thin, the plate can easily bend enough to change the end shakes of the pinions.

91. I do not recommend attaching the dog screws onto the upper plate so that they lock above the case band, because this plate is too thin to give the screw threads enough hold, and if the screws are tightened firmly this fairly thin plate is likely to bend. The pillars form the pivotal points for movement and when the screws strive to lift the outside edge of the plate the internal part will pull downward by the same amount and the end shakes of the pinions will decrease.

92. In the modern case the movement can be accessed from the rear by opening the back and the hands are set from this side, so the owner of the watch need never open the bezel. With this kind of case the dial should be fastened with dog screws and not with pins, otherwise it would not be possible to remove the dial without first taking the movement from its case.

93. Recently Swiss watches have been made which have the heads of the case screws under the dial. This method does not offer any obvious advantage and causes unnecessary trouble for the repairer, who has to remove the hands and dial before the movement can be taken from the case.

94. Just like the winding square, the hand setting square should have a pipe to prevent foreign particles hanging on the key from entering the movement. We must take care that this pipe reaches up to the inside of the case back but not further; because then, in a strong case, a pressure would develop on the upper plate when the case is closed and this pressure is often sufficient to stop the watch by decreasing the end shakes of the arbors.

95. Cases in which the movement hinges offer an advantage for exact adjustment of the watch because the adjusting screws on the balance are more accessible; however this advantage is of no great importance.

96. It remains to say a word about the devices whose purpose is to protect the movement, or parts of it, against any dust which enters the case. The most perfect dust cap is that of the old English full plate watch, because it covers the whole movement without any exception. These caps are usually very well made and serve their purpose excellently. It was attempted, with some success, to protect the movement of the three-quarter plate watch in the same way; but the dust cap requires a higher case which is not entirely compatible with the modern watch. It was absolutely necessary to use it with the old watches which opened and closed by springs, and therefore were definitely not dust proof. However, through gradual progress in casemaking, cases now close more tightly than before and dust caps can be completely omitted. If they are made with some care, the case snaps are tight but can nevertheless be closed and opened very easily. For this purpose the snap must not be deeply undercut. The edge should be rounded off a little upward, so that the closing corner of the other part goes easily past its highest point (see Fig. 26). The better kinds of English case are usually made with much care and insight.

97. The circular dustcap, which surrounds the frame in full plate movements, avoids the problem of needing a higher case but it is also less effective. Why use it to protect the train against dust if, at same time, the balance, the balance spring and the oil-sinks on the upper plate remain exposed?

Chapter X Jewelling

98. The use of jewels is a recent improvement in watchmaking. It is clearly a significant advance to use a material for pivot holes that cannot be destroyed by friction, is unaltered by chemicals and will take the highest polish; and at the same time obtains the stability of the gear depths ***(14)***, the fluidity and purity of the oil, and ensures the reduction of friction to the smallest amount.

99. All jewel holes must be carefully examined before they are used. If a jewel hole is not carefully polished or the corners are cracked, it is worse than a metal bush and very rapidly wears out the pivot.

100. In my view, movements should be fully jewelled. The price of a pair of jewel holes is not so high that it should be an obstacle to their use, and the lever holes should not be left without jewels. It is true that the angular movement of the lever is very small, but experience teaches us that a reciprocating movement is most effective when sharpening something, and the wear of a pivot in its hole is just the same as a very gentle sharpening process. Besides we can expect a reduction of friction by using jewel holes for the lever pivots and this is very important in the lever escapement, with which inertia and frictional resistance have to be overcome anew with each tick of the watch.

101. For similar reasons the 4th and 3rd wheels should also have jewel holes, if the quality and the intended value of the watch permit.

102. The use of end stones for the escape wheel and lever is more a matter of taste than of practical usefulness. However, the balance has a fast movement over about 450° and it is extremely important to avoid the increased friction which would come from contact of the arbor shoulders with the surfaces of the jewels; and so we cannot omit end stones from the balance. On the other hand, it is obvious that the lever and escape wheel work under very different circumstances. In watches of normal design the lever makes an angular movement of 10-15° with each oscillation of the balance; and the escape wheel, if it has 15 teeth, covers 12° of one revolution in the same time. Besides, we cannot assume their weight exercises as much pressure in the upright position, because they are actually light and work under continual and significant side pressures. But the greatest difference is that the escape wheel and lever are made as light as possible while the balance is and must be much heavier.

103. The difference between the friction of a simply set pivot and one with end stones is extraordinarily small. According to the generally valid law of mechanics, that the magnitude of friction at equal pressures is independent of the surface area of contact, this difference should be zero. However, in our case adhesion must be considered, particularly because oil must be applied to the pivot. But the friction of a pivot provided with caps will only be smaller in relation to the difference in the contact surfaces, and the difference between the surface of the end of the pivot and that of a shoulder reduced in size is small. However, with an angular movement 30 times larger than those of the escape wheel and the lever it assumes a greater importance with the balance. And therefore the balance must have end stones. I agree that a small saving of energy

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14 *"…die Stabilität der Wirkungen …" is literally "the stability of the action". I think Grossmann means the stability of the gear depths. [Trans]*

can be obtained by putting end stones on the escape wheel and lever, but I believe this very slight advantage is usually overrated. The fact that a number of best English watches are without end stones on the escape wheel suggests that English watchmakers understand the matter roughly in the way described above.

104. The use of diamond for the end stone of the upper balance pivot is probably recommended because, if the watch operates in the usual horizontal position, the balance rests with its whole weight on the end of the upper balance pivot and the friction and wear on it are reduced to the smallest amount by the extraordinary hardness and fine polish of the diamond surface. But we must use great care when selecting diamonds, because we will occasionally find badly polished pieces amongst those which we buy from shops, and they will contribute to the destruction of the pivot instead of protecting it.

I want to report one case which occurred in my own business and caused me to avoid using diamond caps if they were not expressly required. I supplied a pocket chronometer, which went to the great satisfaction of its owner; but after 6 or 7 months I learnt that its rate had become irregular and that in certain positions it was noisy. When it was sent to me for examination I found the upper balance hole was oval. With the help of a strong microscope I discovered a tiny fault in the surface of the diamond cap and could now understand it. I made a new jewel hole, put on another diamond cap and repolished the pivot a little, although this had not noticeably suffered. The watch went as before, but I got it back 6 months later with the same complaint. My investigation showed that the jewel hole was again oval. I believe this could only be explained by a microscopically small fragment of diamond sticking to the pivot and which may have been pressed into the surface when it was repolished. Now another balance hole and a new balance staff were made. Since then the watch has gone for many years without problems. This shows how carefully diamond caps must be selected and that a strong loupe is not sufficient for this purpose. The difference of friction between a good ruby or sapphire cap and one of diamond is very small and I do not recommend exposing a watch to such dangers if the profit which can be obtained from it is not more important.

105. The exact and careful execution of the balance holes is the most important part of the jewel work of a watch. They must not only have, as all other jewel holes, an error free polish, but also be rounded in a suitable way, in order to make the friction in the upright and horizontal positions completely equal or as equal as possible.

[24]

Figure 27.

106. It is a good plan to make the balance holes with a conical sink in order to give them more strength and to help the pivot enter the hole when putting on the cock. But its form is very important or adhesion will increase. Besides, if the cock has its steady pins made in the way described above (Art. 83) there will no difficulty in putting on the cock without damaging the jewel hole.

[25]

Figure 28.

107. Setting jewels is done in different ways. In some, including the better class of English watches, the jewel holes are set in brass or gold bushes which fit into sinks and are fastened by screws; part of their heads are sunk into the setting and part into the plate so that they lie flush with the surface, with the thread cut in the plate.

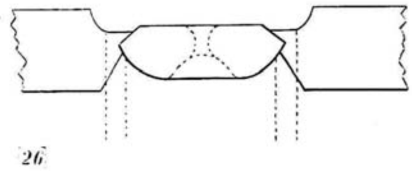

Figure 29. Jewel hole setting.

108. The advantage of setting jewels in this way is that it is easier to replace a damaged or broken jewel without having to re-gild the bridge or the plate. However this is not very important, because if we have a good supply of jewels in stock then it will be simple to find one which fits into the old setting; and even if this is not possible we can set the new jewel into a piece of brass wire of a suitable diameter. This wire, after it is turned slightly tapered and exactly concentric with the jewel hole, is turned until it fits into the hole in the plate, and then cut off so that it remains a little longer than is necessary. The setting is driven carefully into the hole in the plate until the right amount of end shake is obtained. Then the plate or bridge is put on a cement chuck ***(15)***, centred to the jewel hole and the chamfer is turned. When the brass setting has been turned to a suitable size, then is it easy to ensure that the chamfer is cut a little larger into the plate; if this is carried out well in a simply set watch, then replacing a jewel in the way just described will be barely visible afterwards.

109. A work with simply set jewels is in no way inferior to one with screwed settings even in the rare cases where a jewel has to be replaced, provided it is done as explained above. Work with screwed settings has a higher reputation, but if it is not implemented with understanding and great care it results in a large increase in work during production and still more during repair. In order to clean a watch carefully we have to take out and then replace the screws and jewels, and the small depth in which the screws are held is a large source of annoyance for the repairer; particularly in English watches with their thin upper plates of brass made completely soft by gilding and their screws with rather rough threads (Art. 22). Each loose screw must be replaced by another of a larger diameter, and this will have less chance of holding securely because of its greater thickness, so that it is often necessary to drill new holes in fresh places. If screwed settings offer the advantage of easier replacement of broken jewels without leaving any noticeable traces, then we can say that this small advantage is offset by the disadvantages mentioned above.

110. However, we can change the screwed setting in such a way that these problems are eliminated. There is not the slightest necessity to sink the screw heads into the upper plate. They could, without any disadvantage, have a flat head which only serves to hold the jewel in its place, and then the whole thickness of the plate is available for the thread. A screwed setting can also be provided with marks so that it is always inserted the same way into the sink, which is not unimportant. If it is necessary to ensure the position of the jewel when careless repairers ignore the marks, then this can be easily done by drilling a small hole in the bottom of the sink and putting in a pin, which enters a small cut made for it in the setting.

Chapter XI The fusee

111. In the age of the recoil escapement the invention of the fusee was unquestionably the most important step for achieving good time keeping by watches. The old verge watch was so influenced by changes in mainspring power that it hardly deserved the title of a timekeeper unless it was provided with a mechanism to counteract these irregularities. The verge escapement was replaced

15 "flachen Aufsatz", literally a flat chuck or a surface chuck. This could be a face plate (mandrel) or a cement chuck. I have oscillated between the two and have chosen a cement chuck because "flat chuck" has been used in this sense in English.

by the resting escapements, particularly the cylinder escapement. One of the main characteristics of the latter is that the lock and lift take place at the same distance from the centre of the balance; therefore the locking friction is considerable and happens during the greater part of the oscillation. These circumstances mean that an increase of locking friction goes hand in hand with an increase in mainspring power, and this friction works in a correcting way if the escapement is well designed. Then irregularities in power affect the rate by a surprisingly small amount. The duplex escapement works in a similar way; while the free escapements, which do not have a correcting friction, achieve their high independence from power variations only by a prudent adjustment of the balance spring.

112. From the time when these facts were clearly understood the leading watchmakers in the various centres of watch production followed very different approaches. The French and Swiss, with their practical gift, took immediate advantage of this changed state of affairs and simplified the work by eliminating the fusee and its associated parts. This step, together with some other circumstances, formed the basis on which Swiss production greatly expanded, because it was able to manufacture a cheap watch of convenient and even delicate design which, nevertheless, was sufficiently accurate for civil use.

113. In contrast, the English retained the fusee in these greatly changed circumstances; and even though an equal number of voices in favour of the going barrel have arisen amongst them of late, the majority hold to the faith that the fusee is an indispensable characteristic of a good English watch. The consequence of this conservative attitude is a well deserved superiority of time keeping in their better watches, but a gradual decrease in demand for their lesser grades, which indeed have slowly ceased to be marketable.

114. These are the practical and commercial results of the retention and omission of the fusee in modern watches, as shown by experience in the old production countries. It is surprising that the famous invention of Graham, the cylinder escapement, was little used by his compatriots; they rejected the idea merely because the nature of the new escapement makes it necessary, or at least desirable, to change the layout the movement. The Swiss, by adopting the latter approach and introducing a far-reaching division of work, succeeded in manufacturing a watch with good time measurement, of elegant style and size, and at a marketable price; and so their production greatly increased.

115. There is no doubt that the fusee, with its compensatory effect, secures a higher uniformity of rate in watches of the best class; but the degree of superiority which is achieved is greatly overrated, and for ordinary use there is no difference of practical importance between the rate of a fusee watch and that of a going barrel watch. Even if, between the first 6 and the last 6 hours of the mainspring, there was a difference of 10 or 20 seconds in the rate of a going barrel watch (which is a very much larger deviation than can occur from this cause in a good watch), then this is no obstacle to the general reliability of the watch; because the error repeats itself every 24 hours, and it would only be necessary to wind the watch in the most regular way possible.

116. The use of the going barrel permits a larger train, a roomier barrel and a less restrained layout of the moving parts. It avoids the frictional resistance of the two large pivots of the fusee, and has the great advantage of not being exposed to the many accidents involving fusee work, not only the danger of breaking a mainspring, but also that of the chain breaking. Work with a going barrel, if it is designed in an appropriate way so that it has a long and thin mainspring, can have a total development of at least six turns with the middle ones reserved for running, and such a mainspring is not as prone to breaking as the thick and short spring used for fusee work.

117. However, the greatest advantage of all is that going barrel work, with its greater abundance of motive power, is more suitable than fusee work for fast oscillations of 18,000 per hour. This fast oscillation makes a watch more suitable for exact time measurement, particularly if it is carried by a person who drives and rides, or it is exposed to continual outside vibrations in other ways. It is apparent that the much greater momentum of a quickly oscillating balance will be far less subject to the influence of such disturbances than another balance which oscillates a fifth more slowly. This increased activity of the mechanism, with 3,600 more oscillations in an hour, will naturally require a greater motive power, and in this situation fusee work has no advantage, unless it has a greater height and diameter, or unless it has a very light balance.

118. The above points can be combined into the following conclusion:

The use of a fusee is recommended for all watches from which the most exact time measurement is expected. However, the going barrel should be used for all watches which do not belong to this class, and particularly for the use of people who require their watch to be as little affected by disturbances as possible; such as travellers, soldiers and so on.

119. This criterion was probably understood by the first watch manufacturers in the United States when they dropped the fusee from their movements and, in my view, herein lies a very substantial part of their success.

120. Having stated the situation in which the application of the fusee is useful, it is not redundant to say something about the best design for strong and well proportioned fusee work. Here I must say that I do not think the old English fusee work deserves to be regarded as the perfect arrangement, because it cannot use a mainspring whose width is in relationship to the height of the frame. This, as I will prove by designs and numbers, is to be attributed mainly to the fact that the centre wheel is not favourably positioned in such movements. When I worked in London, I had a number of conversations on this point with very good watchmakers who, in the most determined way, advised me against any attempt to change the construction of fusee work. I sketched a design in which I could not see any mechanical faults and which was certainly complete, but at that time I lacked the means to implement it. However I found an opportunity later and the test confirmed my first opinions totally. I give here the design and description of my fusee work with numbers showing its comparative advantage over English work, in hope that it might be useful to the reader.

As will be easily seen, the greatest change in this work is to transfer the centre wheel from its usual place under the barrel to the opposite side of the frame, over the barrel and fusee. The centre wheel can be sunk very conveniently into the upper plate so that it lies flat with the lower surface of the plate; then the fusee can come close to the upper plate as in English work. However, the barrel cannot go through the upper plate, as is usually the case in English work, but it can reach down almost to the dial, with the exception of the thickness of its lower bridge. In English work the centre wheel is an absolute obstacle to the greater height which could be made available to the fusee and barrel, and the whole height of the frame between the centre wheel and dial is completely lost for these important parts.

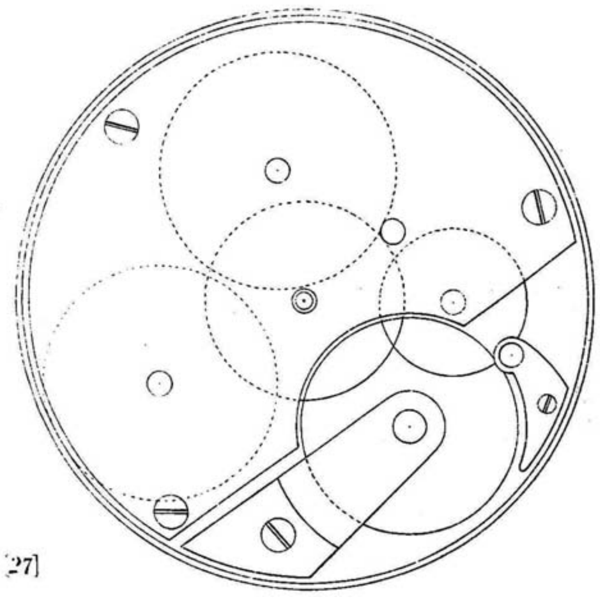

Figure 30. Improved arrangement of fusee work (view from the upper plate).

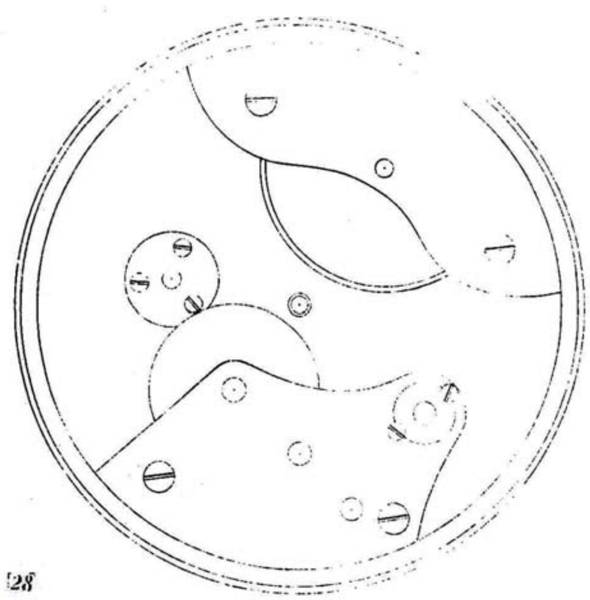

Figure. 31. Improved arrangement of fusee work (view under dial).

In order to show more clearly the advantages which follow from this layout, I give the following comparison.

I have a good English three-quarter plate movement; diameter 44 mm, overall height of the frame 7.2 mm, the height of the fusee 3.2 mm and the height of the Barrel 2.65 mm.

My work with the changed layout has a diameter of 46 mm, its height is also 7.2 mm, the height of the fusee 3.8 mm and that of the Barrel 3.9 mm.

Since the height of the frames are the same in both cases, the apparent advantage is clearly due to my arrangement.

	Height of fusee	Height of barrel
In my fusee work	3.8 mm	3.9 mm
In English fusee work	3.2 mm	2.65 mm
Difference in favour of the first	0.6 mm	1.25 mm

Compared with the English work with the centre wheel over the fusee, my design increases the height of the fusee by 19 percent and the width the mainspring by 47 percent.

This latter is an increase of almost one half and I believe it is a very substantial improvement in fusee work. From the description of my design the reader can see that this gain was not bought by losses in the durability of the other parts of the movement.

The 3rd wheel in work of this kind must go on the dial side of the pillar plate under the fusee wheel, in all other details there is no difference from the usual arrangement of the parts.

121. The positions of the fusee and barrel is not correct in English work and they should be turned around. This latter position of the fusee saves a large amount of friction on the pivot without causing any loss or disadvantage.

The pressure on the fusee pivot in English work is greatly increased by this constructional defect. Fig. 32 shows the positions of the fusee and centre wheels. To determine the pressure on the pivot we assume the point of contact between the wheel and pinion at ***f*** is the fulcrum of a lever, at whose other end ***g*** the force is transferred by the chain. It does not require a proof that the pressure on the fusee pivot at ***c*** is nearly double the pressure exerted at ***g***.

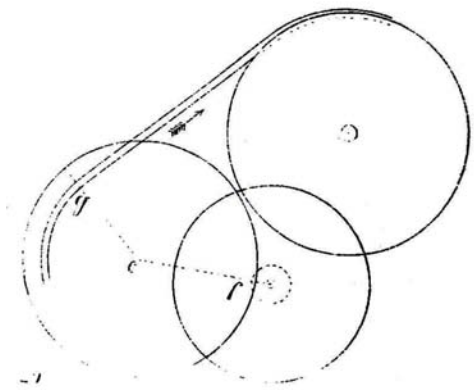

Figure 32. Usual position of the fusee and barrel.

In the other arrangement, shown in Fig. 33, the fulcrum is still at ***f***; the force acts very close to it and the pressure at the pivot ***c*** is approximately 1/4 of the pressure exerted at ***g***.

The difference of the pressure in these two cases is about 8 to 1, and since friction varies with pressure, the advantage which can be obtained by the change is significant; although we should note that the difference between the pressures is largest in these two cases, and when the chain runs on the lowest part of the fusee it will be reduced, but it will still be about 4 to 1.

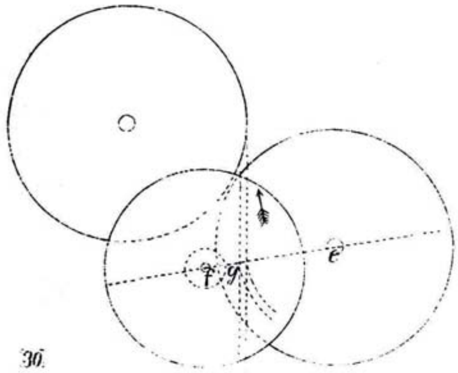

Figure 33. Improved position of the fusee and barrel, after Julien Leroy.

It is surprising that this design (which is undoubtably of great advantage and for which we must thank Julien Leroy) did not find followers in England, the mother country of fusee work, although it was endorsed by Mudge. In contrast, it has been adopted most enthusiastically by German and French chronometer makers.

122. Stopwork is absolutely necessary with fusee work. Its omission is not possible because, on the one hand, the chain could not find space on the barrel and fusee if it had a surplus of length; and on the other hand because further winding, for which there would be no limit apart from the excessive strain of the spring, would necessarily unhook the chain from the barrel.

The common stopwork for fusee watches is too well-known to need description here. When well executed its action, which happens at right angles, is as strong and safe as we could wish.

123. The stopwork for the arrangement described in Art. 121 must necessarily be different, but at the same time it becomes simpler and better. Instead of the usual stopwork which is pushed, it is pulled at the moment of stopping. It consists of a foot ***a*** with the spring arm ***b*** lying on a tangent to the circle of the fusee beak. At ***c*** it has a wide shoulder, against which the beak acts, with an extension ***d*** going in a straight line beyond the chain which, as Fig. 35 shows, is filed thinner and somewhat rounded.

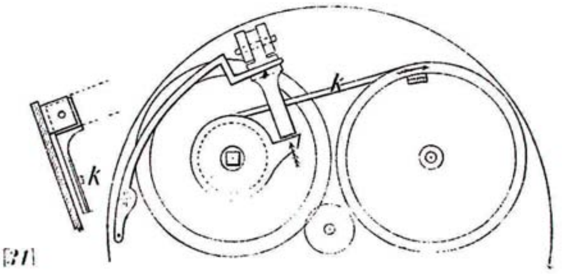

Figure 34. Common fusee stopwork.

Now, if the chain is completely wound on the fusee it pushes the spring arm towards the upper plate until the beak meets the shoulder at ***c*** and further winding is prevented.

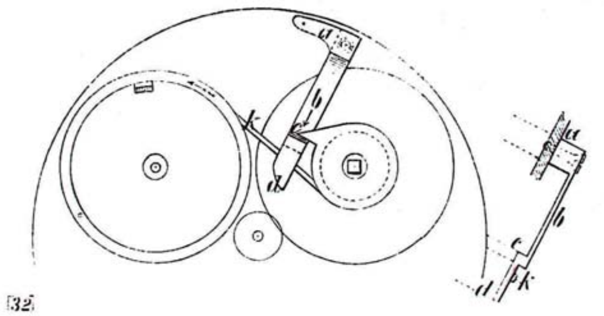

Figure 35. Fusee stopwork after Julien Leroy.

124. Another kind of stopwork, which is rarely seen, would be suitable for both arrangements of the fusee work and is very solid.

It consists of a narrow steel slide ***a***, which fits firmly in a groove in the upper surface the fusee but can slide in this groove. It lies level with the upper fusee-chain groove and may not extend below it. By means of a weak spring ***b***, which is pivoted in the upper surface of the fusee, the slide is pushed back so that its rear end stands out from the upper fusee groove somewhat. When winding, the last turn of the chain takes up its proper position in the highest groove and it presses the slide inward, whereby the other end of the slide ***c*** leans against a screw or a strong pin and further winding prevented. Naturally this does not require a fusee beak; instead a round plate is screwed to the fusee which holds the slide and spring in their place.

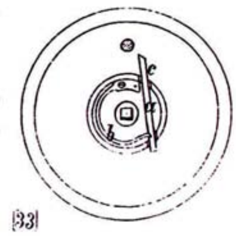

Figure 36. Fusee stop work with slide.

125. The stopworks illustrated in Fig. 11-15 are also applicable to fusee watches, but then the stop wheel must be fastened to the plate.

Whichever kind of stopwork we use with a fusee watch, we should never forget to protect the more delicate parts of the work from the damage which can result from centrifugal rotation of the free end of the chain when it breaks; either by prudent planting of the frame pillars or by mounting a thin separating wall close to the edge of the barrel.

Chapter XII Keyless winding

126. This accessory of the modern watch is now very much desired and, it must be granted, so useful and pleasant that it has acquired much general favour; even though considerable sections of the public still distrust it, particularly in England where many respectable watchmakers do not yet endorse watches with pendant winding. However, it is important to say something about its construction and finishing.

Pendant winding is more than a plaything or a convenience for the owner; it is useful in many ways. Firstly it offers the possibility of winding a watch and setting the hands at any time and in any place, because these operations do not require opening the case. Winding or setting with an ordinary watch must be carried out when the watch is held still, and therefore cannot be done in a carriage or on horseback or while walking. Likewise we can only attempt this when we are under a roof and in a place which is free of dust, whereas we can adjust a watch with pendant winding in the open air without being afraid of rain or dust. All this is more than a mere convenience, because it ensures continuing operation during a journey, when the owner rarely finds a quiet moment to wind his watch or has forgotten to bring its key; it is generally recognized that a watch is of double importance to the traveller.

127. Yet another benefit can be expected from keyless winding and I would regard this as an important advantage as well. The turning movement, which is necessary for winding up a keyless watch, takes place perpendicularly or at right-angles to the balance. This offers complete protection against the harmful effects of the bad, but very frequent habit of watch owners who move the watch as well as the key when winding. It is easy to see that this habit results in a fast circular movement of the watch level with the balance, and it is repeated 10-12 times until the winding is finished. If, in the best case, this casual treatment does not damage the escapement, then it at least causes deviations in rate by violent over-banking; this irregularity, for which it is difficult to find an explanation, lowers a watch in the opinion of its owner, who often attributes it to a lack of skill or care by the repairer to whom the watch was entrusted.

128. A very important consideration with pendant winding is the greater durability of the case and the better protection from damage and destruction. In a watch with key winding, repeated opening of the case wears out the rim and hinge and additionally, it is necessary to have a case that does not close too tightly. This is not the situation with a pendant wound watch whose case can close better and provide far more protection against dust entering.

129. The necessity to open the case of a key wound watch at least once a day permits the direct entrance of dust. The key is also a very eager mediator for the introduction of fibres and impurities of all kinds, particularly with the bad habit of carrying the key in a vest pocket which nobody thinks to clean.

130. In order to understand and compare the different keyless mechanisms it will be necessary to group them; otherwise the great diversity of designs could not be conveniently considered.

Nearly all keyless watches can be divided into two main classes.

1. Those where hand setting is done via adjustable parts on the stem.
2. Those where this is done by means of a rocking bar.

131. The last mentioned class, which must be used for fusee watches, is delicate and requires very careful execution. For this reason the first type is more common, particularly in Swiss watches. If we examine this class of keyless mechanism then we can easily subdivide it by differentiating between those which set hands by pulling the crown out, and those which have a pusher to engage hand-setting.

132. In most cases the latter kind uses what is known as Breguet clickwork; if the crown is turned to the right the mainspring is wound and if the crown is turned the other way nothing happens. This has the advantage that an awkward attempt to turn the crown in the wrong direction cannot damage the mechanism. Breguet clickwork is, however, not an essential part of this kind of keyless mechanism.

133. In most keyless watches the crown is connected (by a square or other fitting) to a stem which goes through the pendant to the winding pinion within the case body. In this arrangement the barrel arbor stands perpendicularly to the pinion and these two parts must be connected by a bevel gear. In most keyless watches this gear consists of a straight pinion and a straight crown wheel. However these give very imperfect power transmission because the teeth of the crown wheel, which are cut towards the centre, can coincide with the direction of the pinion leaf only at that point in the action where the side of the tooth is located on the line of centres. During the part of the action which takes place before and after the line of centres, the pinion leaf works against the outside or inside corner of the tooth, which is certainly of no benefit for either gear. With a pinion of small leaf number, the destructive effect of this type of gearing is considerable because the leaves work at a greater angle. Anyhow, the teeth of the straight crown wheel must be tapered from the outside and inside in order to minimise this fault.

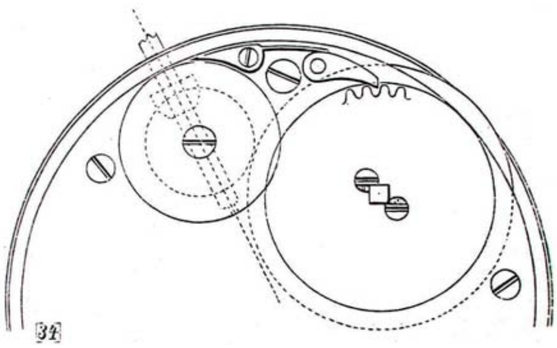

Figure 37.

134. For these reasons a conical gear is preferred and it offers the best conditions for a regular and gentle transmission of power and for durability. Besides, a conical pinion can be made much stronger than a straight one. It is actually very difficult to construct a conical wheel and pinion with theoretically correct tooth profiles; however, when they are made in the usual way they are completely satisfactory for what they are intended to do and have considerable advantages over straight pinions.

135. One of the best keyless mechanisms, because of its simplicity and durability, is the following: The barrel arbor (Fig. 37) has the usual square at its upper end and on this is fitted a large wheel, as big as the size of the upper plate allows, or, what is approximately the same, almost as big as the barrel. This wheel meshes with another wheel which is about 2/3 of the diameter of the first and which is concentrically joined to a conical wheel underneath the upper plate. The latter wheel is set in motion by a conical pinion whose arbor goes through the case pendant and carries a milled crown outside the pendant. At the same time, one of the two flat wheels on the upper plate serves as a ratchet by means of a suitable click with a spring. These are the fundamentals of the oldest watches with keyless winding, but since then many improvements have been made.

136. For the purpose of hand setting the most diverse mechanisms can be added. The oldest of these is the following: The stem (Fig. 38) can move along its length and, if the crown is pulled out a little, the winding pinion moves out of mesh with the conical or crown wheel and a lever pushes a small crown wheel on the stem into gear with the minute wheel, or a wheel connected to it. The small crown wheel is mounted by a pipe onto the internal end of the stem, which is either squared or left round but with its sides flattened for approximately 1/4 of their thickness. In the latter case the pipe has a fixing pin which is screwed into it sideways, so that it protrudes a little internally and thus has a sufficient grip on the flattened side of the stem to prevent the wheel rotating but still allows it to slide along the arbor (Fig. 38 shows the position of the parts when the crown is pulled out).

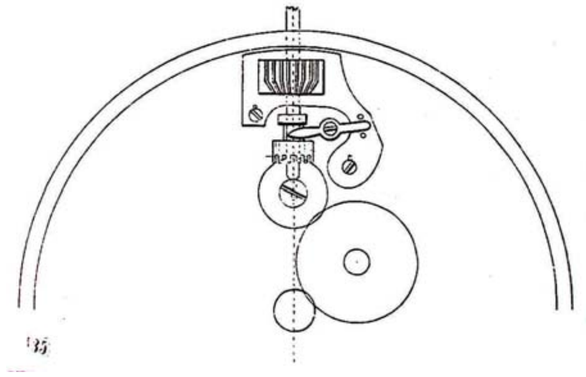

Figure 38.

137. Another method is the following: A small pinion is fitted on the round part of the stem, on which it turns freely. The minute wheel meshes into a similar wheel of steel, which is provided with crown teeth, and these teeth are constantly in mesh with the small pinion on the stem, so that these two parts rotate with the motion work while the watch is running. The small pinion, which is held in place by a bridge, has a short pipe projecting towards the base of the stem which is cross-cut at its end so that four small recesses are formed, deep and wide enough to accept a pin which fits in a hole drilled through the stem. When the crown is pulled out, together with the winding pinion, the motion work pinion is activated by the pin fitting into one of the cross-cuts. If the crown is pushed back into its earlier position the motion work is disengaged and the winding pinion engaged again, as before.

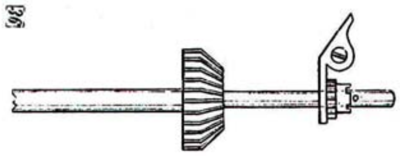

Figure 39.

138. This kind of hand setting is certainly very simple and reliable, but it is criticised because the crown, after being pulled out to adjust the hands, is often left in that position by careless people and the watch often stops; because the winding mechanism operates with considerable friction and the watch is unable to cope with this additional task. This problem substantially contributed to the distrust which developed against pendant wound watches; and eventually the designs where the crown is pulled out to adjust the hands were completely discarded.

Figure 40.

139. Another arrangement of hand setting was better designed, and we can probably say that it fulfils the function completely. The winding parts are exactly the same except that that the winding pinion sits loosely on a round arbor whose end, extending beyond the winding pinion, is squared. On this square a small steel tube with a square hole is fitted, free enough to move easily on the square. The front face of the winding pinion and the appropriate face of this pipe are cut with ratchet teeth which fit exactly into one another. A spring, which operates in a groove cut in the pipe, holds both parts together so that the winding pinion rotates with the stem.

140. When it is necessary to set the hands, a small button or pusher (protruding from the case near the pendant) is pressed and this causes the pipe to slide inward on the square by means of the spring mentioned above. The internal face of the pipe has fine crown teeth which come into mesh with the minute wheel or another small wheel connected to it. At the same time the ratchet teeth of the pipe go out of mesh with those of the winding pinion so it no longer rotates with the stem. When hand setting is finished the button, if we do not continue pressing on it, lets the spring return and the pipe moves into its previous position, ready for winding.

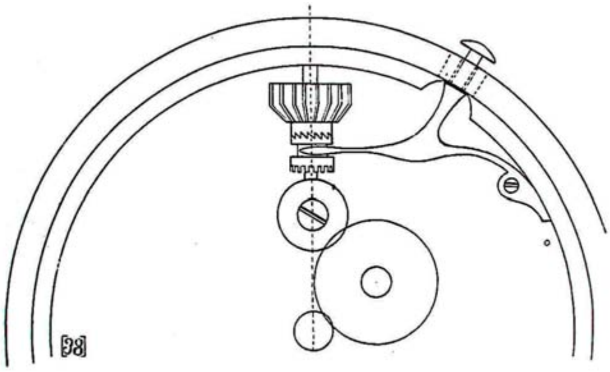

Figure 41.

141. An advantage of this arrangement is that if someone should turn the crown in the wrong direction damage to the winding parts and clickwork is prevented; because in this case the two ratchet wheels have the effect of Breguet clickwork.

142. Nevertheless, objections were raised against this system, because the opening in the band for the button was regarded as a opportunity for dust and so on to enter the movement, and because the projecting button could be pressed in accidentally while the watch was carried in a pocket. For these reasons much effort and thought were put into finding other methods for hand setting.

143. One method is a rather complicated arrangement of the case bow, which engages the motion work when the bow is turned down. The advantage which we may expect from this invention is very dubious, because the bow can be pushed down by accident when carrying the watch, which naturally brings it to a stop. Besides, many people have the praise-worthy habit of always turning down the bow when they put their watch flat on a table, in order to avoid scratching the polish or engraving. This would naturally have the same consequences.

The simplest and safest arrangement for hand setting, which is now generally used, omits the button and has a small pipe extending from at the edge of case which surrounds the pusher pin; this pipe has a cross-cut wide enough for the thumb nail of the left hand to push in the pin while the right hand turns the crown to set the hands.

144. Other mechanisms were devised for keyless hunter watches where the pusher protrudes from under the bezel but is inside the hunter cover of the case. This pusher, when pressed in, shifts part of its spring to the outside edge of the bezel where it is held securely, and the motion work is engaged with the stem and remains so from then on. The position of the spring and pusher is released when the case is closed and each part goes back to its earlier place. This arrangement is in every respect of great utility, but if the hands are set without closing the case afterwards, as some people do when they come home or go to bed, then the watch will stop.

145. From the preceding discussion we can arrive at some conclusions about the mechanism of hand setting, and I am of the opinion that these parts should always be designed so that they are based the following criteria:

1) It must not be possible to engage the motion work accidentally; on the contrary, it must be designed in such a way that the owner has to make a decided act of will to engage the motion work.

2) After hand setting, the mechanism must go out of mesh with the minute wheel without requiring any action by the owner.

These two principles are of extreme importance for the good and reliable operation of a watch, because a watch inevitably stops if the winding mechanism engages or remains engaged with the motion work at the wrong time. Any design which requires even a very small amount of care, which not all watch owners use with their watches, must be regarded as defective, so long as we can create other mechanisms which do not have these errors.

146. The kind of hand setting where the motion work is engaged by turning down the bow offends against both of these principles. Those mechanisms which require pulling the crown out and those by which the pusher is held fast until the case is closed commit errors against the second of the rules above.

147. There is an arrangement which is completely free of these faults, and it can be used for both open-face and hunter watches. With this the pusher protrudes from under the bezel and is flush with the outside of the case. The thickness of the pusher, approximately 1 mm or a little more, permits it to be pressed in by a nail without difficulty. The bezel of an open face case or the front cover of a hunter case must be filed through so that the end of the pusher just fits into it.

It is apparent that there is no opening for the entrance of dust, no pressure can affect the pusher from the outside, and that the original free position of the hand setting mechanism will be instantly restored by the pusher spring as soon as hand adjustment is completed. The only inconvenience of this method is that an open face watch of this kind requires the bezel to be opened to adjust the hands, which is not necessary with a projecting pusher. However, hand setting occurs only occasionally with a well adjusted watch, and it is a small inconvenience of no great importance on such rare occasions.

148. The other main group of winding mechanisms, those with a rocking bar, also deserve to be discussed. They offer several very important advantages, particularly for fusee watches in which the fusee arbor is always rotating and requires (like the barrel ***(16)*** of a watch with a going barrel) absolute independence from the winding mechanism at all times other than at the instant of winding up. Therefore, with a fusee watch the wheels must be on a rocking bar which is held in a neutral position by a spring, so that they affect neither the fusee wheel nor the minute wheel.

149. Most of these winding mechanisms have three wheels on the rocking bar, the centre one incorporating the conical wheel which meshes with the winding pinion. The stem does not have to extend into the movement and in many watches the whole of it is in the pendant. However this is not acceptable, and the magnitude of the lateral pressure produced by bevel gears emphasises the necessity of providing the internal end of the stem with a support on the edge of the pillar plate, which can be done very easily. A stem supported in this way allows the bevel gear to be examined with the movement out of its case, a convenience which is useful. The rocking bar is fastened so that its centre of rotation is also the centre of the conical wheel, for then the wheels on both sides remain in mesh with it whatever the position of the bridge. One of these wheels is constantly in gear with the barrel wheel, which sits on the square of the barrel arbor and transmits the winding movement. The other wheel stands sufficiently far away from the teeth of the minute wheel so that it does not mesh with them unless the wheel on the other side of the bridge is shifted completely out of mesh with the barrel arbor wheel. The rocking bar is held at this distance from the minute wheel by a spring.

150. For hand setting the position of the rocking bar must be reversed by pressure on a pusher. For this procedure see the remarks made in Art. 142-147. The pusher changes the position of the bar and puts the other wheel on this bar into mesh with the minute wheel while a stop pin, when

16 *Grossmann actually wrote "like the barrel arbor". [Trans]*

it is necessary for a safe depth, prevents further movement. After the hands are set the spring moves the bridge back into its previous position.

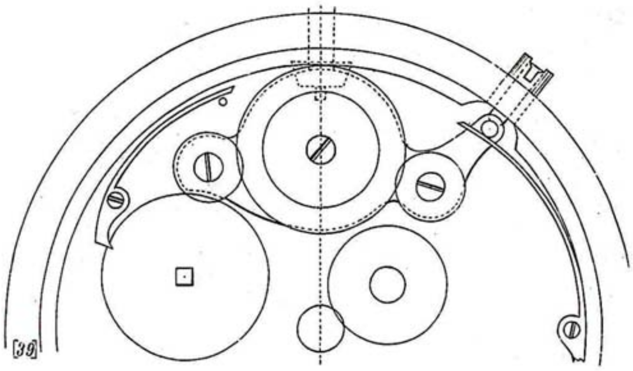

Figure 42.

151. This mechanism also incorporates Breguet clickwork; if we attempt to turn the crown the wrong way the clickwork prevents the barrel arbor rotating in this direction and the rounded-off parts of the wheel teeth on the bar slide over those of the barrel arbor wheel, so that no damage to any other parts of the mechanism can occur.

152. In fusee work, as explained already, this mechanism requires yet another arrangement in as much as the wheels of the rocking bar must rest in centrally between the winding and setting positions; this is done by an appropriately attached spring. It is not necessary to use a pusher to bring the rocking bar into contact with the fusee wheel. Here we see one of the surprising effects of friction, which is otherwise a persistent enemy of watchmakers. ***(17)*** When the crown is turned in the right direction the friction of the small intermediate wheel on the bar causes the bar to move around the centre of the conical wheel in reaction to the pinion rotating. If this friction is not sufficient to guide the wheel into mesh with the fusee wheel with the necessary certainty, then a small spring washer is inserted under the intermediate wheel in a recess on the lower side of it. If the crown is turned in the wrong direction the wheels freely turn on the rocking bar without any effect, since Breguet clickwork is not used in a fusee watch. For hand setting we use the normal pusher.

153. Beautifully designed rocking bars are made by Mr. V. Kullberg, one the best London watch manufacturers. These have only two wheels and the movement of the bridge results from the very astutely chosen action of the friction of the engaged wheels. The only objection to it is the necessity for a straight pinion and crown wheel, because the bar does not move around the centre of the crown wheel. Mr. Kullberg described his mechanism in the April 1869 issue of the British Horological Journal.

154. After the preceding remarks on the nature of these two main classes of winding mechanism and their essential operation, it remains to say some words about how they are attached to the movement.

The movement drawn in Fig. 43 permits the addition of keyless winding to hunter watches without the any change in the layout of the work, except that the pillars are set somewhat further from the edge of the plate so that the pillar screws are free from the large winding wheels. The lower pivot of the 3rd wheel must be set into the pillar plate and not into a bridge, because the space is used for the minute wheel.

If the winding wheels are to be flush with the upper plate it must be left that much thicker. This is recommended because the increased thickness necessary for the winding wheels can be used to

17 *Grossmann is ignoring the necessity for friction. Without it screws would undo, nails fall out of wood and all machines and buildings would fall apart! [Trans]*

give the arbors of the train greater length (Art. 60). In other respects the layout of the movement and the size of its parts are the same whether the watch is key or pendant wound.

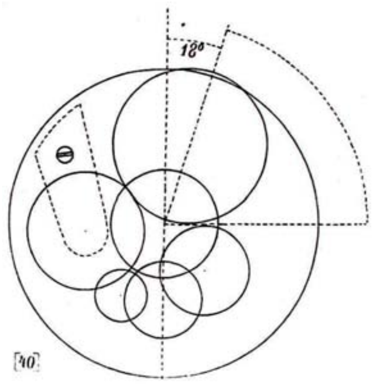

Figure 43.

155. The pendant is the most suitable place on the case for winding, but if it is to be used in an open-face watch then the layout presents some difficulties. The pendant of an open-face watch always corresponds to XII on the dial. If the watch is to have a seconds hand on an eccentric seconds dial, which is the general rule for watches of our time, then the position of the barrel in relationship to the pendant can only be changed within very clearly defined limits, if we want to avoid substantial deviations from the valid principles for the layout of the train (Art. 53).

156. Different methods were adopted in order to avoid this difficulty; and no other aspect of the watch shows, in such a clear way, the need for the manufacturer to subordinate his better judgement to the tastes and habits of the public. If we want to make an open-face keyless watch without seconds, then the problems immediately vanish, because the position of the barrel can be chosen with complete freedom. But the public requires watches with seconds.

In well laid out movements (Fig. 43) the angular distance between the pendant and the barrel centre is approximately 20°, while with the same movement in a hunter case (whose pendant is at III on the dial) this angle is 90° - 20° = 70°, so that a very convenient space for mounting winding wheels results, whereas 20° is much too small for this purpose.

For a long time attempts were made to arrange the dial in another way and the seconds circle was placed, for instance, at VIII or IX; but public taste rejected these changes, although they completely satisfied construction criteria. Symmetry of the dial was an absolute necessity.

In this difficult situation some manufacturers had the ingenious idea of artificially correcting the symmetry of the dial by adding a day hand, whose circle took up a symmetrical position with the seconds circle; but the increased cost of the dial and the additional motion work, for which there was no substantial need, were significant objections to it.

Others provided the train with an extra 4th pinion which only served to carry the seconds hand. This system created sufficient space between the pendant and the barrel for keyless work with the seconds dial in its usual place; but we must complain all the more, as it not only loads the train with a further arbor, but also increases friction because of the small spring which this pinion must have in order to avoid jerks of the hand caused by tooth shake.

157. It is possible to somewhat increase the angle mentioned above by using substantially smaller train wheels. With the common models of Swiss production this angle is often increased up to 30° or even 35° by using much smaller wheels than should be the case for the space made available by the proportions of the frame. A further increase could be achieved if we brought the 3rd wheel closer to the barrel, so that it runs under the toothed edge of it but just far enough away that it does not affect the cylindrical part. But with all these different efforts and the constructional faults contained in them, it is not possible to obtain sufficient space for the winding parts.

158. In order to attain this aim it was necessary to take a step of great boldness which, although it offended against the principles of a good and clean design, was considered satisfactory by watchmakers and manufacturers in the absence of a more favourable solution.

It consists of mounting the 3rd wheel and its arbor against the barrel, whereby the necessary space for the 3rd wheel must be found over the centre wheel. The disadvantages of this layout are apparent. The increased height of the frame required by placing the wheels on top of each other, and the cramped accommodation of three of the largest mobile parts, one over the other, are certainly very serious doubts. But a watch is, more than many other articles, dependent on the dominant taste and its construction must be subjected to the tyranny of fashion; and this fact explains why nearly all open-face keyless movements are laid out in this way (Fig. 44).

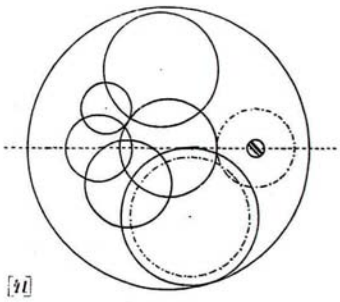

Figure 44.

It must be said in favour of this method that all parts of the winding work are unchanged and can be used in open or hunter watches, and that all parts of the train can be made the same regular diameter, as in a watch of the same size with key winding.

159. To overcome the difficulties in the design of open-face keyless watches we must look for a solution using another method of transmitting the winding force. So long as flat, conical and crown wheels are used, the difficulty can only be got around by designs which are just as incorrect as the above. The application of an endless screw with one or two bevel gears seems to allow a greater freedom of arrangement, but up to now I have not seen an acceptable design of this kind. It seems that the idea has not been sufficiently studied.

The problem with it lies in the following circumstances:

If winding is to be implemented with a moderate number of revolutions of the crown, then a very small wheel must be used on the barrel arbor in order to take up the effect of the screw; but then room for this screw must be found over or under the barrel, and the height of the work necessarily increases. If, in contrast, the wheel on the barrel arbor is large enough that the screw can mesh outside the extent of the barrel, then winding becomes so uncommonly slow that it requires gearing up.

160. Some time ago I made a number of keyless movements which had a more convenient layout of the train by using a rocking bar under the dial. The pendant is located at an angle of 45° from the centre of the barrel and the train wheels are of completely normal size. The 3rd wheel is fastened to the lower end of its arbor by a collet and moves in the area between the barrel cover and the lower barrel bridge. The gap is quite sufficient to have the barrel and the 3rd wheel completely free from each other. The centre wheel is attached in exactly in the usual way on the other side of the barrel. A work on this plan is not much higher than a key wound watch with a mainspring of the same width.

161. I still have to mention some other designs of keyless winding where the power is not provided at the pendant. There were some old watches which were wound by turning the case bottom. However, this was not followed up because of the impossibility of dust proofing such a case and because there is no method for hand setting in the usual way, i.e. with a key.

Other inventors had a circular rack operated by a slide protruding from the exterior of the case, and the watch was wound by moving the slide up and down. Still others used the action of opening the front cover of a hunter case to wind up a small part of the mainspring each time, and supported their idea with the fact that a hunter watch is definitely opened a certain number of times and so continues to run. It is not difficult to determine the value of mechanisms that justify their effectiveness by such statements. They are very similar to the old self-winding watch, which was wound by the movements made by the owner, and required him to walk or give it a prolonged shaking each day to keep it running. ***(18)*** .

162. When designing a keyless mechanism it is essential to specify the relationship between the number of turns of the crown and those made by the barrel arbor. In the majority of carefully designed keyless watches each revolution of the stem causes about a 1/3 rotation of the barrel arbor. This is a relationship from which we should not depart too far in either direction. If a greater speed were given to the winding then it would be too difficult, especially for delicate fingers. If, in contrast, winding is divided over many rotations, then it will be very easy, but at the same time it will put too much power into the hands of the winder which could be fatal for the working parts if it is not used with the circumspection. Particularly at the end of winding there is danger for the stopwork, barrel teeth, centre pinion and so on. With a rocking bar the relationship between the number of rotations is simply the ratio of the tooth numbers on the winding pinion and the wheel on the barrel arbor, because there is direct transmission, tooth on tooth. In the other group of keyless mechanisms, which have gearing because the flat wheel is on the axle of the crown wheel, the relationship between the numbers of these two must be included in the calculation. For example, if the winding pinion has 12 teeth, the crown wheel 24, the spur wheel 40 and the barrel arbor wheel 60 teeth, then the ratio will be:

$$(12 \times 40) / (24 \times 60) = 1/3$$

and a revolution of the pinion causes a one third rotation of the barrel arbor.

163. There is still another danger which comes from roughly winding a watch that has a winding wheel with large and fine teeth in which the click operates. The excessive power which is often used for winding is suddenly halted by the stopwork. The stopwork is usually at the lower end of the barrel arbor so that a certain amount of torsion or coiling of the barrel arbor occurs and a further tooth of the wheel is forced past the click. From then on the watch runs under the influence of the full strength of the completely wound mainspring, increased by the reaction of the torsion which is transferred by the stopwork; the watch begins to overbank violently and often continues doing this for several minutes afterwards. This is accompanied by considerable danger to the escapement and, if no continuing damage is caused to the watch, then at least a major deviation in rate occurs. So a good keyless watch can show an excellent rate when well treated, but came into disrepute because of the irregular rate resulting from rough treatment when being wound.

164. A very simple means of overcoming this fault was probably first used by A. Lange. It consists of giving the click a certain amount of shake on its screw or stud. The recoil which comes from this shake is sufficient to reduce a torsion stress of the kind described above. Strangely, this mechanism was patented in the past year in England, when it had been used here for at least 15 years and put into circulation in many thousands of watches.

Occasionally I have made keyless watches with special clickwork under the large winding wheel on the barrel arbor and which fulfils this function well. The ratchet wheel is the same size as in a normal key wound watch but with rather wide teeth; the recoil caused by it is likewise sufficient to reduce the tension. There is plenty of room for this ratchet wheel and, if the tail of the click is made long enough, the mainspring can be let down without removing the barrel arbor wheel. Clickwork of this kind never annoys by getting in the way when fitting the movement into the

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18 The inadequacies of these old watches were remedied by A. v. Loehr of Vienna in very satisfactory way, so that they now begin to vie with the other winding systems. The details of them are given in my German translation of the great text book by Saunier.

case; whereas clickwork which is at the level of the winding wheels and on the edge of the largest one can create serious difficulties in getting it freely past the dome of the case.

165. If it can be avoided, the movement of a keyless watch should not be overloaded by the friction of redundant parts. Some watches are forced to drive one or two intermediate wheels and occasionally another pinion, and these are arranged in a way that does not reduce friction to a minimum. If their shoulder screws are overlooked when the repairer oils the movement, the friction will cause the watch to stop, particularly if the screw heads fit tightly in their sinks. All these parts should come into action only at the time of hand setting and afterwards move away in order to leave the motion work completely free. We must ensure that the hand setting wheel moves toward the centre of the minute wheel when it is brought into mesh. In addition, the teeth of this wheel should be cut thinly and pointed to avoid a sudden movement of the hands occurring when the wheels mesh and the points of two teeth meet.

166. The tooth profiles of winding wheels and pinions can be divided into two classes. One has the normal symmetrical profile while the other, which the Swiss prefer, has ratchet like teeth for the spur and bevel gears. There is no objection to the latter if they are well made, since these teeth act only in one direction, and the shape of the non working side of the teeth is arbitrary except in as far as it affects their strength. This form is necessary with the extremely thin winding wheels of many Swiss watches, but the front side of the teeth must be an involute and the back must be hollow only to the extent that it allows free movement of the meshed wheels. However, many of these wheels have such strangely formed teeth that it seems as if taste or fashion determined them.

We can make winding wheels with normally shaped teeth of appropriate thickness without fearing breakage. In this case the teeth should not be too fine and the flank and base must be shaped in such a way that they provide the greatest possible strength. They are kept short, which can be done because each tooth only works over a very small angle and then is replaced by another. The sides should not be parallel, but the gap should narrow towards the base; however the base should be rounded, in order to strengthen the tooth as much as possible.

167. With rocking bar winding the tooth pitch is, in most cases, prescribed by teeth of the minute wheel, and consequently finer teeth than desirable are used in many keyless mechanisms of this kind. If we fasten another wheel concentrically on the rocking bar wheel, which has the same pitch as the minute wheel and meshes with it, then we can get rid of this restriction and make the teeth of the winding wheels of any desired pitch. With all other winding systems we can select the tooth pitch as desired.

168. Steel is generally used for the winding parts and has no substitute for the arbors and pinions. However, where the wheels are concerned, in particular the larger of them, we might fear that their durability would be affected by hardening without any faults being perceptible to the eye. For this reason, for long a time I made them from aluminium bronze; however I stopped using this, not because it was unsatisfactory but because most of my customers preferred steel wheels.

169. Casing a keyless watch requires somewhat more work than one with key winding. The case pin must be put near the pendant, deviating from the usual rule (Art. 90), since otherwise we cannot put the movement into the case.

With the mechanisms where the hand setting parts are on the stem, it is best to make the stem and crown removable. These will be supported by a steel bridge fastened at the edge of the pillar plate while the inner pivot runs in a stud riveted to the pillar plate.

The winding pinion and ratchet must have only just sufficient clearance from the plate necessary for free movement, because otherwise they could shift when the stem is pulled out and re-insertion of it would be difficult.

In addition, this method makes case fitting much simpler and has the advantage that we can see the bevel gear in operation even when the watch is not in its case.

The crown is fastened in the usual way to the outer end of the stem and the stem is held by means of a screw, which goes through the side of the pendant and whose inner end fits in a grove in the stem. The screw head is sunk into the pendant so that it is flush with the surface.

With this arrangement we can remove the movement after the stem is pulled out just as easily as a key wound one. With hunter watches the stem must have a little movement along its length and the shoulder on the stem must not rest against the steel bridge, but be situated further out. The smaller part of the stem goes freely through a hole in the end of the case spring and the shoulder rests on the outside surface of the spring, so that we can cause the front cover to jump open with a pressure on the crown.

170. In most keyless watches the pusher for hand setting projects from the case band. With this method we must arrange the pusher so that the hole in the case through which it projects can be completely sealed. Usually this is done by a round pin with a button (Fig. 41) or a semicircular plate, half as wide as the band of the case and with its smaller half protruding from the edge of the case.

However, there are complaints about these protruding pushers. First it is possible that accidental pressure will engage the motion work and change the position of the hands, and under some circumstances the watch can temporarily stop. In particular, with the heavy and large link chains now used to carry watches, it is very likely that part of the chain will slip into the pocket and eventually press against the pusher. Furthermore it was objected that any lateral opening in the case should be rejected as it is an entrance for dust and impurities. Little weight should be put on this because a well implemented pusher will let extremely little dust through; probably none of us has found, in watches that have been carried for a long time, that the penetrated dust has come directly from there.

In addition, the protruding pusher was objected to on aesthetic grounds, because it gives an unacceptable asymmetry to the outside of the case. This objection is also insignificant.

171. But the united influence of these doubts produced a noticeable effort to create devices for hand setting without an external pusher; or, if a pusher had to be retained, to design it so that it is totally impossible for the watch to accidentally move into the hand setting position while being carried.

The first class of mechanisms has been discussed already (Art. 140 to 147). In the latter direction some recent inventions have achieved this purpose very well.

With hunter watches, some use the normal protruding pusher, but put a pin in it at right-angles; this pin extends upward through the case body and fits into a hole at the edge of the front cover. Hence, so long as the front cover is closed it is impossible to set the hands. Only after opening the cover can the pusher be pressed in and the hands set, and when the case is closed it is automatically secured again.

Other watches have the usual lateral pusher with a button (Fig. 41) and pressing it in is prevented by a protruding part of the front cover. After opening the cover this obstacle is removed, as already described.

One of the best solutions, in particular for open-face watches, is the following (already briefly mentioned in the Art. 143): A pipe is soldered into the case band at the appropriate place, so that it extends both outward and inward. The pusher is simply a smooth piece wire which fits into the pipe and whose exterior end is flush with the end of pipe. The pipe is provided with a slit which allows a fingernail to enter and press the pusher, while it remains unaffected by any other contact (Fig. 42).

172. The form of the crown is mainly a matter of taste. But those watches which require the crown to be pulled out to set the hands must have one that cannot be easily pulled out when winding the watch. With all other winding systems it is desirable to select the largest diameter of crown that will suit the work; not only because the best leverage is obtained, but also because the indentations of the crown are deeper and provide the fingers with an efficient grip, as well as offering a greater resistance to wear.