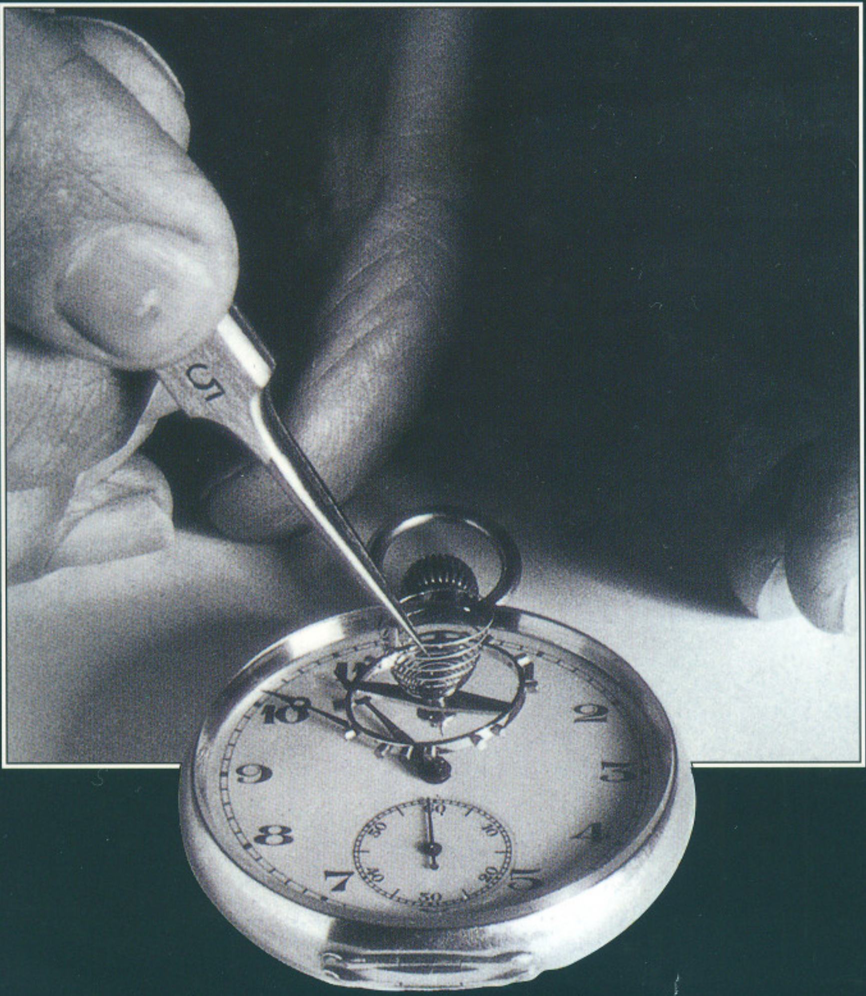
PRACTICAL WATCH ADJUSTING

Donald de Carle F.B.H.I.



PRACTICAL WATCH ADJUSTING AND SPRINGING

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PREFACE

Watch springing and timing is a full time occupation in itself, and in countries where watch manufacturing is an important industry a Springer and Timer commands higher remuneration.

In England, and other countries for that matter, the fitting of a new balance spring is just another job. This book is intended to help those who wish to enquire further into the art. Many men have devoted their whole lives to this subject, not just the balance spring alone, but the refinements necessary to the movement to obtain the best results from the mechanism.

We endeavour to attain perfection; that must be our standard, otherwise we should have no goal to work to. Until recent years the National Physical Laboratory organised tests known as "Kew", which originated from the days when watches were tested at the Kew Observatory, Old Deer Park, Richmond, Surrey, from 1842-1902. *Then the trials were transferred to the N.P.L. at Teddington, Middlesex, but they were still known as "Kew" tests.*

A watch issued with a Kew certificate was something with a meaning. A Kew Certificate indicated that it had passed the tests with "honours" and was appreciated by all. One could readily understand what such marks as 90 *and over meant. The record, held by the Omega Watch Company, was nearly* 98 *out of a possible* 100 *near perfection, but still not* perfection.

At the present time, watch trials are held at the N.P.L. but the specifications are so stiff and complicated that they have no meaning to the average person, and one cannot help feeling that the dropping of "Kew" was deplorable.

The Swiss have instituted an understandable system and a watch which passes the Official Bureau tests with honours, as it were, is entitled to be known as a "chronometer". These matters are discussed in this book.

I am greatly indebted to Professor D. S. Torrens, for kindly reading through the proofs and to Mr. Eric Bruton, the Editor of the Horological Journal, *who has made useful suggestions. Acknowledgements are made, in their place, where information has been obtained.*

Pinner, 1964. *Donald de Carle.*

PREFACE TO REPRINT

Unlike many subjects there is little, if any, to add to "Watch Adjusting and Springing". The subject matter of this book has not progressed, in fact – it has reached its peak.

Referring to page 139, the Tuning Fork watch is a fait accompli, *in fact it will be superseded by the quartz crystal watch, where timekeeping in the order of a few seconds per year can be expected.*

However, there are hundreds of millions of watches fitted with balance springs in existence, and likely to be, for many years to come, so the reassuring guidance of this book can still serve a useful purpose.

Highcliffe, Dorset, 1977. *Donald de Carle*

CONTENTS

LIST OF CHARTS AND TABLES

PRACTICAL WATCH ADJUSTING AND SPRINGING

INTRODUCTION

THE ART OF WATCH SPRINGING AND TIMING

ACCURATE TIME—so called—has become an essential part of our life. Time signals have educated the public to expect close timekeeping from their watches and the Swiss watch manufacturers have been among the first to see that their watches are well sprung and timed; it has become, with them, an everyday practice.

It is not uncommon to find, even among the most moderately priced watches, balance springs beautifully fitted and adjusted and with such matters as the " point of attachment " receiving attention.

It is comparatively simple, when dealing with mass production, to arrange or organise so that the correct adjustment is automatically achieved by paying particular attention to the prototype. But with the practical watch repairer at the bench it is an entirely different story: each watch he repairs is to him virtually a prototype—and the production of a prototype in the factory is a costly business. The wearer who brings a watch for repair which needs a new balance spring expects the same good timekeeping at a nominal charge.

Clear Instructions for Practical Men

Making a watch keep time to the best of its ability is not just a question of mystical adjustment of balance spring and timing screws. There are dozens of other ways and other small improvements to the functioning of the watch which will do much to improve its over-all performance.

This book deals with all these points and, as in the case of the author's previous writings on watches and clocks, in a thorough and exhaustive manner fully illustrated by practical drawings.

The general pattern of this book is:—

1. How to make a minute examination of a watch movement to judge its performance with special notes on the mainspring, the train, escapement, jewel holes, etc., with the object of close timing in mind.

2. The importance of efficient cleaning methods including notes on the cleaning machines and also on the new ultrasonic wave system.

3. The influence of oils and oiling on timekeeping; how to select the correct oil and grease and to use it with comprehensive charts.

4. The correct method of polishing balance staff pivots to give the best watch performance.

5. How the balance should be poised and what its effects are on positional timekeeping.

6. How to fit new balance springs, the Breguet overcoil and other terminal curves, the meaning of " point of attachment " and its effect.

7. Practical adjusting for positional timing. Many methods are described and illustrated in detail.

8. The systems employed by the most successful timers working in the Swiss watch factories.

9. How to make the best use of a timing machine when used for checking watch performance.

10. The effect of changes of temperature on watch rate and how adjustments are made for compensation.

11. Specifications of the various watch testing establishments and observatories in the world.

Making the Work Normal Practice

Numerous detailed drawings of tools and their uses will be a particularly valuable feature of this book and it should be stressed that the writing and method of treatment of the subject have been specially directed to the ordinary repairer.

A great deal has been written and much research made, about watch springing and timing, i.e. timing in different positions, and so on, but the subject has been approached more from the scientist's angle and not from the practical man's. The aim in this book is to simplify the art of springing and timing and make it an everyday practice. To that end the writing and the illustrations will be thoroughly practical and the methods thoroughly commercial.

In the main there are two ways of timing a watch. By " timing ", I do not refer just to adjusting the index, but rather to adjusting the balance spring so that the watch will keep time, to prescribed limits, in various positions and changes in temperature.

One method is to make adjustments so that the results are more or less permanent, so that after it has been taken to pieces for purposes of cleaning, the watch will (perhaps with slight adjustments, such as re-polishing balance staff pivots) repeat its original performance, or nearly so. Some watches are, we all know, inclined to be perverse. This may seem a strange thing to say about a machine. One could reason that if everything were perfect, and I say " perfect " with due reservations, the rating *must* be correct. This is not always the case, as we shall see.

The other method is where adjustments are made which are known not to be permanent; such adjustments are much more quickly made, but once the balance has been removed from the movement the adjustment is lost.

In a great measure the quality of the movement decides which course to adopt. A good quality movement may be in hand, where permanent methods would be justified, and the time spent—and it can be considerable—would be justified; it would pay.

On the other hand, it may be a waste of effort to try and adjust a watch of poor quality. There are so many requirements to obtain good results; good gearing to ensure an even transmission of power; good pivots and jewelling to minimise the effects of friction; good quality of component parts, i.e. escapement, mainspring, jewel holes, balance spring, etc.

Having said all that, it is strange to have to contradict it, or at least part of it, almost in the same breath. There are watches made in Switzerland fitted with the pin-pallet escapement, which have passed the Official Bureaux test of that country and have been granted certificates marked " with mention " which entitled them to be officially known as "chronometers". What would our forefathers say to a pin pallet recognised as a chronometer! It is stated that these watches are from a " series " and not made especially, but I deal with this at some length later on.

In this book, when discussing the various forms of adjustment, I shall first describe the ideal method, i.e. permanent adjustment, and then explain the alternative method which is quicker but not so permanent.

PRACTICAL WATCH ADJUSTING AND SPRINGING

CHAPTER ONE

GENERAL CONDITION OF THE MOVEMENT

To RATE a watch in positions it is essential that the movement shall be in as near perfect condition as is possible.

First the mainspring should be of the best quality and the correct length to suit the barrel. If the spring is the correct length, the maximum number of turns of the barrel arbor are obtained and thus the watch will run for the maximum number of hours. It is desirable for good timing that the watch should run for as long as possible. Firstly, with a long run, a more uniform force is exerted during the useful time of run; secondly, there is less friction, caused by the coils rubbing together, during the useful time of run.

The mainspring of the average 13-ligne watch has, say, six-and-a-half to seven turns. When the mainspring is fully wound, four turns provide running time of about 30 hours and the last two-and-a-half to three turns are the reserve. It is the first four therefore which are concerned with the useful time of run. If there are, say, only five turns of the barrel arbor, then there is only one turn as reserve, and during the useful time of run some part of the mainspring which is not as smooth as regards force is being used.

A good general rule to determine the correct length or thickness of a mainspring is that the mainspring should occupy 1/3 of the area

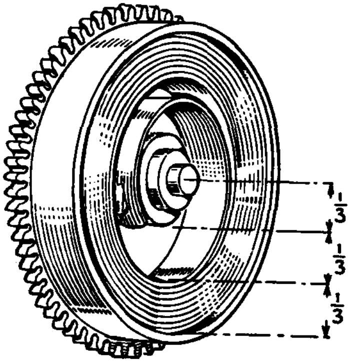


FIG. 1. *Correct proportions of mainspring to barrel.*

inside the barrel, 1/3 empty space to be occupied by the spring when fully wound, and 1/3 barrel arbor. (Fig. 1.)

The table given here, compiled by Lavlast, is a useful guide. The figures given have been calculated for a barrel with an inner radius of 1 mm. and it is stipulated that one rotation of the barrel be added up to six and one-and-a-half above six. The table provides for theoretical conditions where there is no space between the coils of the spring at the outer and inner hookings. It is estimated that an extra turn, or turn and a half, accommodates these practical considerations.

No. of Turns	Thickness of Spring	Length of Spring	Dia. of Barrel Arbor
5	0·0249	53·085	0·7968
5¼	0·0241	55·607	0·7698
5½	0·0239	56·088	0·7648
5¾	0·0235	57·361	0·7520
6	0·0231	58·791	0·7382
6¼	0·0227	60·133	0·7256
6½	0·0225	61·619	0·7120
6¾	0·0219	62·648	0·7018
7	0·0215	64·260	0·6888
7½	0·0209	66·800	0·6690
8	0·0203	69·400	0·6490
9	0·0192	74·200	0·6130
10	0·0182	79·100	0·5820
11	0·0173	83·800	0·5540
12	0·0165	88·400	0·5290

As an example, using the Lavlast table:—

Say the barrel has 80 teeth, centre pinion 10 leaves = eight hours running for one turn of the barrel.

We require five turns of the barrel to make the watch run for 40 hours, so $5 + 1 = 6$ turns.

Say the radius of the inside of the barrel is 2·75. For the thickness of the spring we find the table gives us, for six turns, 0·0231 ∴ $0{\cdot}0231 \times 2{\cdot}75 = 0{\cdot}063$ mm. thickness of mainspring.

Length $58{\cdot}791 \times 2{\cdot}75 = 161{\cdot}6$ mm.

Diameter of barrel arbor $0{\cdot}7382 \times 2{\cdot}75 = 2$ mm.

Height: The inside height of barrel less 0·05 mm. for freedom for small movement.

The inside height of barrel less 0·10 mm. for freedom for large movement.

If these conditions are observed we shall find that the maximum number of turns are obtained.

The bottom and inside of the barrel cover should be very smooth with no ridges at all. If there is any doubt about this, fit the barrel up in the lathe, on a wax chuck or in a step chuck, and with a piece of Montgomery stone, or a slate pencil, and water, stone the surfaces until all ridges are removed. The inside of the cover should be treated in the same manner. If there are any ridges at all, they are likely to make the mainspring jump, thus causing an irregularity of pull.

For smooth power output, the surface of the mainspring should be well polished; the presence of slight lengthwise ridges is not detrimental. If two *perfectly flat* surfaces are rubbed together they can be made to adhere one to the other. Johansson blocks rubbed together are witness of this. If the surfaces of a mainspring are dead flat they could be made to lock or adhere together when the spring is fully and tightly wound up. Even if they do not actually lock, the surface adhesion could be so serious as to affect the pull of the spring adversely. It is, however, important that the surfaces should be highly polished; they are not likely to be *dead flat.*

FIG. 2. *Mainsprings should have rounded edges.*

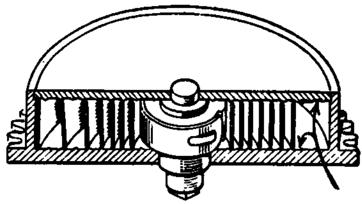


FIG. 3. *Ridges on the inside of a barrel.*

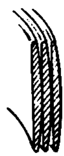


FIG. 4. *Section of an Isoflex mainspring.*

The top and bottom edges are very important; they should be rounded and well polished, so that they slip easily over the bottom surface of the barrel and the inside of the cover. (Fig. 2.) Fig. 3 shows, although greatly exaggerated, the effects of a square edge to a mainspring and ridges upon the surfaces it works upon.

The ideal section for a mainspring is as shown in Fig. 4. Such springs are now in production in Switzerland. They are known as Isoflex and made by the Resist Mainspring Manufacturing Co., Neuchâtel, Switzerland. They are made from round steel wire (piano wire), cold hardened by drawing. The strength and height of the mainspring is pre-determined by the diameter of the wire used. The wire is then flat rolled and unintentionally the strip takes the D-shape section as illustrated (the illustration is much exaggerated to illustrate the advantage of such a shape), which is most fortunate. Although the spring is steel, it is as unbreakable as the alloy of unbreakable springs, further, owing to its hard skin (practically case hardened) it is as resistant to corrosion as the alloy springs. It has the added advantage of a greater moment of force; therefore a thinner spring can be used with all its attendant advantages.

Oiling of the mainspring is important. If the oil is too thin, the pressure of the spring will squeeze it out from behind the coils, and if too thick it will retard the action of the spring. Further, we require an oil which flows so that when it has been displaced it will flow back into position. Some authorities recommend a graphite lubricant, others the stabilised lubricant made by the makers of Chronax oils. Generally speaking, a good quality clock oil, such as Ragosine seems to fill all needs.

A well designed and highly finished movement will run for 40 hours at least and in these circumstances good timing can be obtained with comparative ease.

The Train

Next we come to the train. This includes the barrel, which will be dealt with first. With the mainspring out and the arbor and cover in position, the barrel should spin perfectly freely on its arbor. Ensure that there is no loss of power due to binding in any part, including the barrel.

The arbor pivots should fit their holes closely, a slack-fitting barrel can rock with a twisting effect when the watch is wound, causing bad gearing with the centre pinion. Not only that, the barrel could foul either keyless wheels or plates. Sometimes a barrel is seen with a circular cutting on the top surface; this is caused by the transmission wheel cutting into the surface during the process of winding. This fault may be due to wide barrel holes. Not only these but the arbor holes in the plates should be close. The remedy is obvious: rebush the holes.

The barrel arbor needs very little end shake in the barrel. Usually the barrel has very little space between the plates, therefore excessive end shake is to be avoided and the barrel itself should rotate upright on its arbor and also the arbor should be upright between the plates.

It is true the barrel is the power end of the train. This power can overcome many faults. Even so, we want to transmit all power possible, but to transmit it evenly.

Hold the barrel arbor firmly in a chuck in the lathe, bring the T-rest up close, almost to touch the barrel, then turn the barrel on its arbor with a finger and observe that the barrel rotates at the same distance from the point of observation of the T-rest. In other words see that the barrel rides at right-angles to the arbor ; or, that it is upright.

If the barrel wanders from side to side this indicates that it is out of upright. The arbor must be made upright and this is quite simple to do; but I must refer you to my book, "Practical Watch Repairing", for instruction. Similarly, if the barrel arbor is out of upright between the plates, it should be made upright. There should be no perceptible end shake of the barrel arbor between the plates. The arbor must be free, otherwise winding will be stiff.

Next we come to the centre wheel. Again the holes must be a close fit with little, but perceptible, end shake. It is most important that the centre wheel should be perfectly upright. To test and correct, see "Practical Watch Repairing". Not only is it necessary for the hands to rotate at the same distance from the dial during a complete revolution (when out of upright, the hands are up on one side and down on the other) but, what may be more important, the depth between the barrel teeth and the centre-wheel pinion must not be faulty.

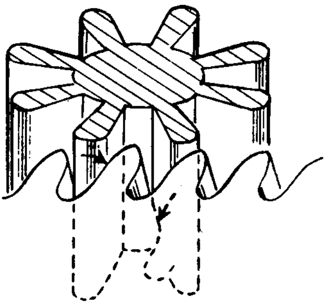


FIG. 5. *The effect of want of upright on gear engagement.*

To take a possible instance, the barrel could be out of upright, owing to the arbor in the barrel or the arbor between the plates, or both being out of upright; also the barrel could be thrown out of upright when the mainspring is wound, owing to wide holes. This condition combined with the centre wheel being out of upright could bind the train when the mainspring is wound up, to the point of cutting the power down to half or even less. Such a fault would be difficult to elucidate unless a methodical system were adopted at the outset. In such circumstances good timing would be impossible because the power exerted by the mainspring would vary at every stage of the unwinding of the spring. The friction caused by bad gearing would be greater when the mainspring is fully wound, and disproportionate towards the end of its run.

The foregoing remarks apply, perhaps to a lesser degree, to the other wheels of the train because the wheels are thin, but the greatest care and attention should be paid to the size of the holes and uprightness of the wheels. The illustration (Fig. 5), which is much exaggerated, shows the effect of want of upright on gearing. Sometimes a watch stops when the mainspring is wound up tightly, and it may well be that the barrel and centre depth is slightly deep, although not deep enough to warrant alteration. But the extra twist due to the pull of the mainspring throws the barrel slightly out of upright and binding of the gear ensues. This fault can sometimes be corrected by paying particular attention to the barrel holes, the holes in the barrel and also in the plate and bridge.

FIG. 6. *Left: straight-sided jewel. Right: olived jewel with convex face.*

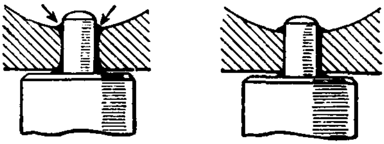


FIG. 7. *Left: effect of oil with olive hole. Right: oil squeezed away when straight-sided hole is used.*

Jewel Holes

Jewelling is a most important subject. To obtain good timing the watch must have good jewels, not only of good quality but of the correct form. All jewel holes should have " olive " shaped holes as opposed to holes with straight sides (Fig. 6). With the olive hole only a small portion of the side of the hole touches the pivot and therefore the " drag " due to oil viscosity is minimised (Fig. 7).

It is generally appreciated that to obtain *absolute* uprightness of parts is practically impossible in mass production. I do not refer to the obvious lack of uprightness, but to very slight deviation. Here the olive holes can help. Fig. 8 illustrates this point and it will be seen that even if an arbor is obviously out of upright its freedom will not be materially affected. Furthermore, lubrication is assisted and the oil, by virtue of capillary attraction, feeds the contacting surfaces. When straight-sided holes are used, the tendency is for oil to be squeezed out and away from contacting surfaces. Olive holes are no more delicate than straight-sided holes and there is no reason, other than expense, why they should not be used for all bearings where jewel holes are used, including the centre-wheel holes.

The underside of the jewel hole should be convex or *bombé* (Fig. 6, right). This also reduces friction and assists lubrication, for the same reasons that make the olive holes superior. There is less of the jewel surface in contact with the shoulder of the pivot (Fig. 9), and where contact is made it is at the smaller radius, where friction is less effective.

It is possible to impart a higher polish to the surface of a jewel hole than to metal; therefore the surface is denser and the friction is lower.

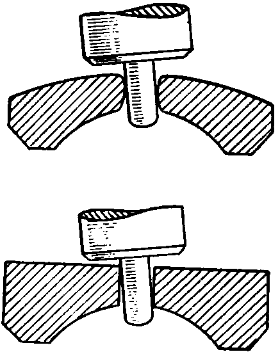


FIG. 8. *Top: out of upright pivot still free in olived hole. Bottom: out of upright pivot tight in straight-sided hole.*

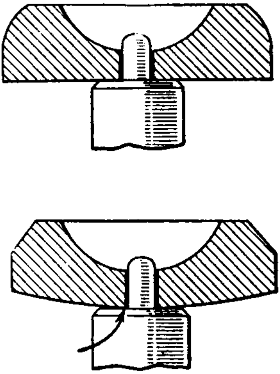


FIG. 9. *Top: friction along full surface of shoulder on pivot. Bottom: much less friction with convex hole.*

Modern watch jewels are made from synthetic corundum, which is the mineral name of ruby and sapphire. They are coloured red and are therefore, in fact, synthetic rubies. The cost of making synthetic ruby is very small, but the cost of machining it into jewel holes is relatively high. Apart from its cheapness, the synthetic ruby is purer than the natural variety and its physical characteristics are almost the same. The hardness, for example, rates at the high figure of nine on the hardness scale against six for the steel of which pivots are made. Synthetic ruby is inert to chemicals and the minute electrical charges that cause corrosion or rusting, which is also a big advantage. It may be asked why glass is not suitable for bearings. The main answer is that it is too soft, its hardness being less than that of hard steel.

The Lever Escapement

For the purpose of this book we shall consider the lever escapement only. The escapement should be as near perfect as possible, with light locking, little run to the banking, and so on. The ideal characteristics are tabulated in detail in "Practical Watch Repairing".

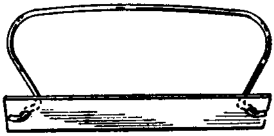


FIG. 10. *A burnisher for inside of the lever horns.*

It was considered necessary, some years ago, that the pallets should be poised, that was in the days when wide-angle escapements were used. Today with the low-angled escapement and consequently smaller and lighter pallets, poise is not so important. The metal from which pallets are made is lighter, the length of the lever less, and what is more important, the strength of the " draw " on the pallet stones is less. This is due to the fineness of the train, and the use of olive and *bombé* jewel holes, which reduces friction and oil drag, so that less power is needed. With less

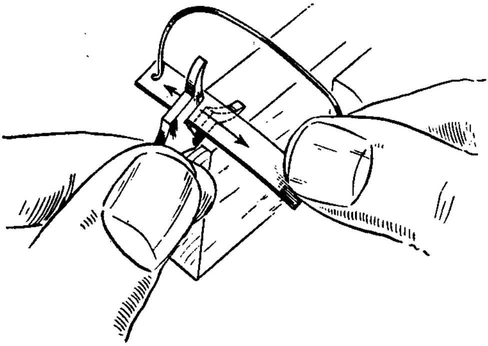


FIG. 11. *The burnisher in use.*

power requirement, a thinner mainspring is employed, and a thin mainspring means a greater number of turns in the barrel. Consequently the watch will run for a greater number of hours with one winding.

It is not uncommon to find watches that will run for from 42 to 48 hours with one winding, owing to the refinements just mentioned, and not least among them is a well-adjusted escapement. Too much attention cannot be given to the escapement. It will be appreciated that with a long thin mainspring there is not so much variation of force from one turn to another as is the case with a strong spring. Therefore the force is more constant, especially during the useful hours, i.e. the first 15-16

FIG. 12. *Another burnishing tool.*

hours. In these circumstances timing is greatly assisted by a more or less equal force, but this cannot be achieved unless the escapement also is near perfect. Although the balance and balance staff are part of the escapement I shall refer to them at some length later.

The lever escapement and its adjustment has been dealt with at some length in "Practical Watch Repairing", and we must refer the student to that book.

When preparing a watch for fine timing, all possible steps must be taken to see that all is as near perfect as possible. It should become a habit when repairing a watch to burnish the sides of the lever notch. There are

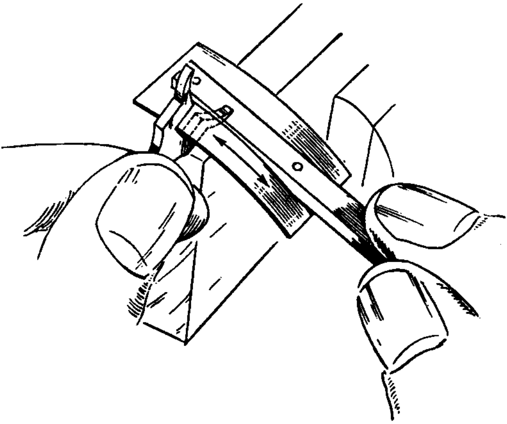


FIG. 13. *How to use the tool shown in Fig. 12.*

two methods of doing this and the tools are quite simple. Procure a piece of clock suspension spring about 3 in. long and 3/16 in. wide. Bend a piece of brass wire as shown in Fig. 10. The diameter of the wire is about 2 mm. Punch a hole in each end of the spring so that it will fit over the ends of the wire and hold it taut. The length of wire should be such that it is necessary to spring the bow inwards to hook the spring into position. On an emery stone, straight grain the spring crossways so that it will act as a burnisher, and hook it on to the wire bow with the acting surface outwards. When in use, the slight springing of the bow will give the required curve to the surface being burnished. Apply a smear of oil to the burnisher. Fig. 11 shows the burnisher in use. The burnisher is taken off the bow occasionally to sharpen the surface on the stone.

The other tool is as shown in Fig. 12. The length of the handle is about 4 inches. It is made from a brass rod about 6 mm. diameter. One end is filed with a slight curve, as shown. The burnisher is a piece of hardened and tempered steel about ½ in. long, ¼ in. wide and about 0·5 mm. thick. It is screwed to the handle after it has been sharpened cross grain, and the required curve is imparted by the screwing. The tool is used as shown in Fig. 13.

CHAPTER TWO

CLEANING AND OILING

MORE ATTENTION has been given to cleanliness in recent years than ever before. We have experience of benzine and brush cleaning and of cleaning machines. The Swiss have realised the necessity of cleanliness perhaps more than we have here in England. When benzine cleaning was in vogue the makers of better watches passed the parts through an alcohol bath after they had been cleaned in benzine.

It is not advisable to place the balance or the balance spring in a cleaning solution other than benzine. Some balances and springs are

FIG. 14. *Cleaning a balance spring in benzine by agitating the liquid with a bellows.*

made from alloys which are liable to be attacked by certain cleaning fluids, so be on the safe side and do not use them for this purpose. An effective hint when cleaning a balance or balance spring is to hold the part with tweezers in the benzine and then blow with the bellows just below the surface. This agitates the benzine and makes the cleaning more effective—a very mild form of " ultrasonic " cleaning ! (Fig. 14).

Cleaning in a machine with tetrachloride solution is perhaps a step forward, but the Swiss have now developed a system employing ultrasonic waves. During the process of cleaning, the parts are subjected to extreme vibrations, and it has been proved that by this means *absolutely perfect cleanliness* is obtained. The parts so treated have been examined under the microscope and they have been found to be devoid of foreign matter. Similar microscopic examinations have been made of parts cleaned by the more conventional methods, including a final cleaning with peg-wood and pith, but the parts, especially the surfaces of jewel holes and end-stones, have an uneven surface film of foreign matter.

It has been stated that a watch movement cleaned by the ultrasonic system affords better results when timing. The watches so treated time more easily and the oil lasts much longer; it is estimated that it is not necessary to clean and re-oil until after four years have elapsed, provided the movement is cased in a dustproof container, such as a water resistant case.

This system may not yet be a practical proposition for the watch repairer because of expense, but it does illustrate very forcibly the importance of cleanliness.

One can say, without wishing to be dogmatic, that the average watch repairer does not know what absolute cleanliness means or how important and essential it is to good timing.

It is no exaggeration to say that *cleanliness is the most important single item in the curriculum of watch timing*. One has only to consider for a moment a hypothetical instance. Suppose a watch is, from a practical point of view, perfect—mainspring, gearing, jewelling, escapement, balance poise, balance spring, and so on—and just one microscopical speck of dust finds its way into one of the balance jewel holes. Good timing is not possible.

Here are some details of the ultrasonic cleaning system. It has been developed in Switzerland by the Federal Institute of Technology, Zürich, in Britain by Mullard Ltd., London, and in America by the International General Electric Co., New York. A repairer's unit has also been developed in the U.S.A. by Branson Instruments Inc. Several watch factories in Switzerland, America and England have such installations and it is quickly becoming an established practice. The ultrasonic cleaner comprises an electric power supply, a high-frequency oscillator and a quartz crystal, or, in place of the quartz, a barium titanate transducer. The transducer, which, when quartz is used, is a single crystal, and in the case of barium titanate a polycrystalline ceramic, is placed in the bottom of a tank which contains the cleaning fluid. When a high-frequency voltage is applied, the crystal, or the ceramic, vibrates extremely rapidly and a continuous series of shock waves is transmitted through the tank fluid.

Oscillating frequencies vary from comparatively low values of, say, 250 kilocycles per second to 2 megacycles. It is considered that the higher frequencies are better for cleaning watch parts. At low frequencies the cleaning fluid is agitated so that it forms pockets of vapour in the fluid close to the part which is being cleaned. These pockets are almost immediately filled in by the cleaning fluid impinging on the surfaces of the parts. This comparatively violent action will clean away heavy deposits of lapping compounds, molecular surface films—such as would be left after the rigorous cleaning in the conventional manner. A frequency of, say, 1 megacycle is found to be the most suitable. At this frequency the pocket effect experienced with the lower frequencies is reduced and the very high vibrations imparted to the liquid, particularly by the sound waves, do, in effect, scrub the parts in the tank. The action can be likened to an extremely high-pressure hosing; in fact, Mullards have actually experimented with a hose delivering cleaning fluid at 1,000 lb. pressure per sq. in. to compare the results with this ultrasonic method. During cleaning, much of the foreign matter removed remains in suspension in the cleaning fluid, which, if left, would contaminate the parts as they are removed from the tank. In the factory system, therefore, there is a continuous filtering arrangement by a high-speed pump circulating the fluid through low-pressure filters and back again to the tank. All foreign matter is, therefore, removed from the fluid before the parts are removed, and they are constantly being scrubbed with clean fluid.

Many types of cleaning fluid can be used, such as benzine, tetrachloride, trichlorethylene and perchlorethylene. In the watch industry, benzine is preferred when there is no danger of fire, or perchlorethylene when there is.

The action of cleaning is very rapid. Watch parts are thoroughly scrubbed in 10 to 15 seconds. As a result of this excessive cleanliness a problem is set as regards oiling. If a drop of oil is placed upon a dirty surface it will spread because specks of dirt will break the drop up. On the other hand a surface covered by a film of cleaning fluid residue—such as is the case with conventional cleaning—the drop of oil will not spread, *but* the film of cleaning fluid will contaminate the oil. With the ultrasonic system there is no film and as a result the drop of oil will spread immediately; there is no obstruction, and the oil will be drawn away from the part where it is wanted. To overcome this, all parts cleaned by ultrasonics must be treated. A very thin film of stearic acid is applied.

Epilame Treatment

This system, known as epilame (French for surface layer) treatment, was devised by a Frenchman, Professor Paul Woog, in 1925 and developed by the Compagnie Francaise de Raffinage, Paris. Epilame is an extremely thin coating of fatty molecules. The coating can be applied by dipping, brushing, or by exposing parts to vapour. The vapour method has been developed by the Federal Institute of Technology, Zürich, and has proved most satisfactory. Vapour coating is extremely thin, about 0·00001 mm., and is invisible even under a high-powered microscope. It is claimed that it remains effective over exceptionally long periods of time, much longer than coatings obtained by dipping or brushing.

Although all this is most interesting, it can only indirectly help the watch repairer when preparing a watch for close timing inasmuch as—to repeat—it does stress the necessity for careful cleaning and subsequent handling.

Now we come to oiling—another very important problem. It seems that each item in the process of preparing a watch for close timing is IMPORTANT, and so it is, but some are perhaps more important than others. For watches an oil is required that will not spread rapidly, evaporate, or become thick. There are three types of oil—animal, vegetable, and mineral.

Animal oil, such as neat's foot, does not spread readily but in time it becomes acid and thickens and in its thickened state it retards movement owing to the increased "drag". In its acid state it attacks brass and eventually verdigris develops. Further, animal oil becomes more viscous at low temperatures.

Vegetable oil, such as olive oil, tends to spread very rapidly and it also evaporates, but it has many advantages. It remains more fluid at low temperatures, does not become acid and when highly refined does not leave a thick residue. The danger of spreading, in addition to oil leaving the parts required to be lubricated, is that the oil evaporates more quickly and in its spread condition suffers chemical deterioration more easily.

The most suitable oil is a mixture of mineral and animal oils. When the oil should be thin and light, as for balance pivots, etc., a greater proportion of mineral oil is used. When thick or heavy oil is required, such as for the mainspring, centre-wheel holes, etc., a greater proportion of animal oil is used. It is not necessary or desirable for watch repairers to prepare their own oil. Oils of the requisite viscosity can be purchased, and it is advisable to use these.

Parts to be Lubricated	$3\frac{3}{4}'''$ to $8\frac{1}{2}'''$	Pocket & Gents' Wrist Watches
Balance pivots	C	D
Pallet stones	O	O
Train wheels	F	H
Mainspring and arbor pivots	Stab. Lub.	Stab. Lub.
Keyless mechanisms	Act. Grease	Act. Grease

Patek Philippe recommend the following for all watches, men's and ladies':—

Third, fourth and balance pivots	D
Pallet stones	O
Barrel arbor and centre pivots	H
Mainspring	Stab. Lub.

A comparative chart is given here showing the English-made Smiths Ragosine oil with the equivalent Chronax oil.

Chronax Oil	Ragosine Oil
HHH	Grade 300 (a heavy oil)
H..	Grade 180 (chronometers and clocks)
C	Grade 120 (large watches and small clocks)
D	Grade 120 (large watches and small clocks)
CBA	Grade 60 (balance holes and escapements of small watches)

The Compagnie Francaise de Raffinage, of Paris, has developed a series of oils known as " Chronax Stablished " oils. They are divided into eight classes according to their viscosity, A, B, C, D, F, H, HHH and O. For watch work grades C, O and F are used and also " Stabilised Lubricant " and " Activated Grease " where a much heavier lubricant is required. The table (page 14) shows where the different grades should be used, as recommended by Compagnie Francaise de Raffinage.

The Federal Institute of Technology has published a booklet in which is illustrated the behaviour of oil under certain conditions. It is shown that after cleaning in an ultrasonic tank and subsequent treatment with epilame, a drop of oil will stay as a droplet and remain unchanged for two years. This is a great step forward and it supports the claim that a watch movement cleaned and epilame treated and oiled will function satisfactorily for four years, provided it is cased in a dustproof case, i.e., it is water resistant.

We turn next to the actual practical application of the oil. First and foremost the oil should be stored away from the light. Once a bottle of oil has been unsealed and opened it should not be used after one year. As the oil is used, air is allowed to enter the bottle and the lower the oil the more air enters and the oil becomes more or less oxidised. Therefore, after the expiration of 12 months, no matter how much oil is left in the bottle, discard it. It is economical to do so. At least once a day the oil pot should be cleaned out, wiped dry with tissue paper and then washed with benzine. The pot must be as clean as a cleaned jewel hole. Transfer the oil from the bottle to the oil pot with a perfectly clean dipper—a clock drill (Fig. 15) answers well. Before using the dipper plunge the blade into pith. Immediately cork the bottle and place the lid on the pot.

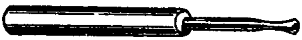


FIG. 15. *Clock drill for use as oiler.*

The oil in the pot should be exposed to the air as little as possible; this is vital. It is useless to take all precautions to ensure cleanliness of the watch movement if dirty oil is subsequently applied. For the general run of work, two oilers are necessary, one fairly large for use with heavy oil when oiling the mainspring, and so on, and the other, a fine one, for oiling the escapement and the rest of the train holes.

It is convenient to make the oilers from blue steel wire. For the larger oiler use wire of about 2 mm. diameter and about 2½ in. long. File one end to a slow taper—about 1 in. long to half its diameter. Use an old worn file for this job, being hardened and tempered the steel is not kind to files and furthermore an old file cuts it better. Finish with an arkansas slip so to leave the surface smooth. Flatten the extreme end of the tapered part by holding it on the anvil of the vice and tap it several times

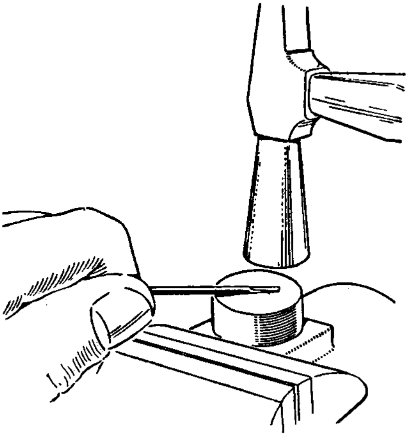


FIG. 16. *Making an oiler from steel wire.*

with the watch hammer, as in Fig. 16. Heavy blows will cause the steel to split. Shape the flattened end with an arkansas slip as in Fig. 17. It is worth while spending a little time making a good oiler as it is such an important item in the equipment.

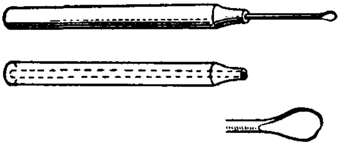


FIG. 17. *The larger oiler.*

For the handle, select a piece of brass clock bouchon wire about 2 in. long and 4 mm. in diameter, with a hole the diameter of which allows the oiler to be driven in tightly. Before fitting the oiler, turn the end down. When this is completed fix the oiler in the vice, between copper chops, and drive the handle on to the oiler so that it fits into the handle for about a half an inch. For the fine oiler use blue steel of about 1 mm. diameter and about 2 in. long. File one end to a slow taper of about 1 in. long and to about a quarter its diameter, spread and shape up the end as for the larger oiler. For the handle use a mapping pen holder made either of wood or bone cut down to about 3 in. long. For a refined job, you can fit a small brass ferrule and turn the end as for the larger oiler (Fig. 18).

Oiling

There are several schools of thought as regards the application of oil. One is to use oil pencils where the oil is retained in the handle and the

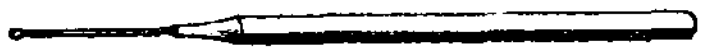


FIG. 18. *The smaller oiler.*

oiler has a stylus type of nozzle which emits oil when the part to be oiled is touched with it. This type may be suitable for mass production purposes, when the oil would be flowing almost continuously, but for the repairer there is a lot to be said for the oil pot. Very convenient stands are made which hold three to five pots with a rack in front for the oilers. We need a stand for four pots, one fairly large for the heavy oil and the other three smaller, for oil for the train, the escapement pivots and the pallet stones.

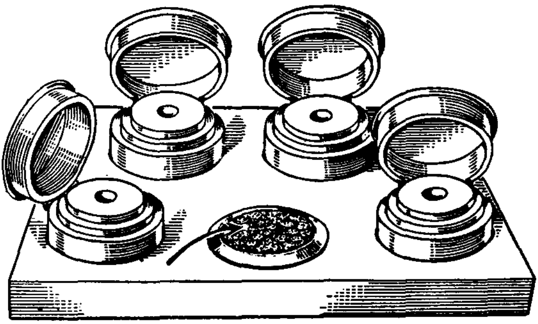


FIG. 19. *Oiling stand.*

It is essential to have a container for pith. Some oil stands are made with such a receptacle, which is admirable (Fig. 19.)

Every watch repairer should cultivate the habit of plunging oilers, the points of tweezers, and screwdrivers into pith before using them. Before placing the oiler into the pot to pick up oil, it should also be plunged into pith on every occasion; this should be automatic—into pith and then into oil. If you do not have a stand with a pith container, an old French clock barrel answers very well. Pack it tightly with pith, standing on end (Fig. 20).

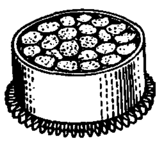


FIG. 20. *Clock barrel as a pith holder.*

When oiling, bring the stand, or the oil pot if you have no stand, close to the work. The depth the oiler is placed in the oil should be observed with an eyeglass. Do not stretch over to the oil pot not knowing how much oil is being picked up and then wave the oil-bearing oiler in the air,

FIG. 21. *Oiling the escape teeth.*

as it were, collecting dust en route to the movement. If it were possible to see the amount of dust floating about in the air most watchmakers would be amazed and wonder how it was possible to keep a watch movement really *clean*.

In the factory, air conditioning is employed; the floors are polished; the staff wear white linen coats; no outdoor clothes are allowed to hang in the workshop; and every precaution is taken to keep our greatest enemy, dust, at bay. The average watch repairer cannot enjoy these precautions, therefore he should do everything possible to prevent dust entering the watch. He knows, or should know, this:—take proper care of the oil, always keep it covered; place watch movement and its parts under a glass shade when not actually working upon them; never blow with the mouth to remove dust, always use the bellows. There are dozens of small contributory methods of keeping dust away effectively; one should always be conscious of the presence of dust.

As regards the actual amount of oil to be applied to the respective parts, this is a little difficult to convey in words or even by word of mouth, it must be seen. Some craftsmen advocate that the two surfaces of the barrel should be oiled; with clocks this may be necessary owing to the

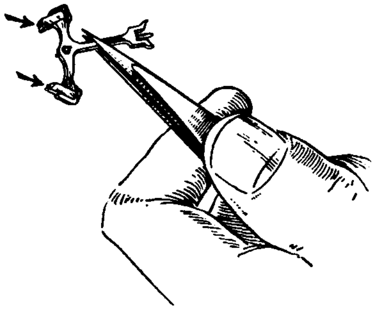


FIG. 22. *Oiling before assembly.*

width of the spring, but with watches it is sufficient to oil the top edges of the mainspring after it is wound into the barrel. Two or, maybe, three dips of the large oiler will be necessary according to the size of the barrel. First apply one dip and spread the oil over the top edges with the oiler so that they are moist and then apply another, if necessary, to complete the oiling; the barrel must not be flooded with oil. To arbor pivots give a light dip to each pivot.

The amount of oil taken up by the oiler can be controlled and for this purpose the eyeglass is essential. For instance, the blade of the oiler immersed to half its length in the oil can be considered light and sufficient for the arbor pivots. The centre-wheel pivots, oiled before assembling in the movement require about three-quarters of the blade immersed in the oil. The third and fourth pivots, one full blade of the fine oiler. It is a grave mistake to over oil. One sometimes sees pivot holes flooded with oil and to no good purpose. When the watch receives a jolt while in wear, the train wheels are made to move endwise suddenly and this can cause the oil to spread. The escape-wheel pivots require not quite a full charge of the fine oiler.

No oil at all should be given to the pallet-staff pivots if the movement is 12 ligne or under. There is practically no friction here and they are much more free without oil. Furthermore, the top pivot shoulder of the pallet staff is very close to the body of the pallets. If the top pivot therefore is only very slightly over-oiled there is a real danger of the oil spreading which would cause considerable drag on the pallets.

The pallet stones are oiled when the pallets are in position. Wind up the mainspring a little and move the pallets so that a tooth of the escape wheel is resting on the entry stone. Do not be tempted to move the pallets with an oiler; the oiler may be slightly oily and the lever of the pallets should be perfectly dry. For preference use a pointed piece of peg-wood. Pick up say half an oiler full of the special pallet oil, Chronax, grade 0, and touch the stone where the tooth is resting upon it (Fig. 21). Move the pallets backward and forward so to allow, say six to seven teeth to escape and then oil the entry pallet stone again. It is better to apply oil to the entry stone because it is more exposed.

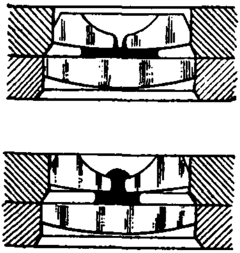


FIG. 23. *Distance of endstone from hole affects the amount of oil needed.*

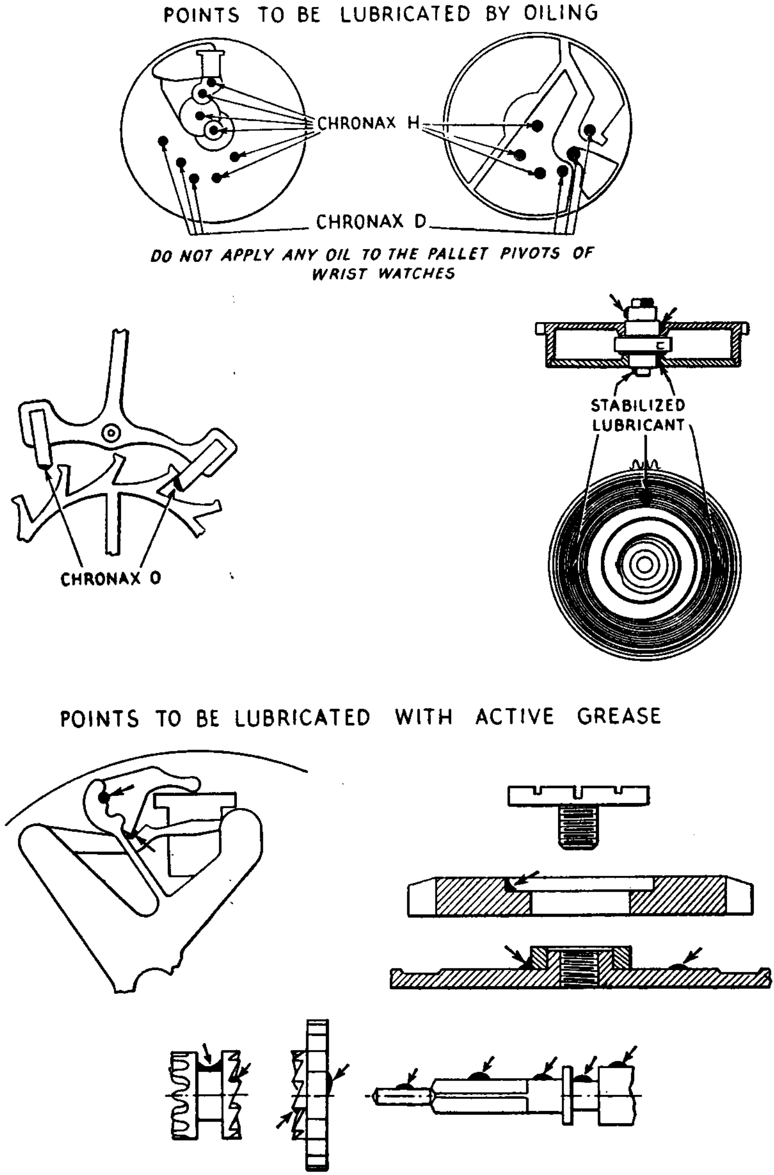


FIG. 24. *An oiling and greasing chart based on information supplied by Compagnie Francaise de Raffinage.*

Some craftsmen advocate applying oil to the impulse face of each pallet stone before assembling into the movement (Fig. 22). This sounds satisfactory but there is a risk of touching something with the pallet stones during assembly and then the oil will disperse. The escape-wheel teeth may not be in just the correct position and the oil will be smeared over the top surface of the wheel. There does not appear to be anything to commend oiling the pallet stones before assembling.

The impulse pin is not oiled at all. One good fine oiler full of oil is applied to each balance jewel hole after the endstones have been placed into position. Then with the ¼ in. glass observe the effect. More often than not the oil will find its way through the hole and on to the endstone. If upon examination the hole looks dry, apply a little more.

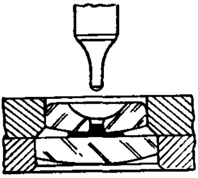
No two watches oil alike, even if of the same make. The endstone may be just a fraction further away from the jewel hole and in these circumstances more oil is required (Fig. 23). It is always advisable to be able to see the oil in the jewel hole after oiling. Some advocate that after the application of oil to a balance jewel hole, a fine feeler, such as a fine round pivot broach, should be passed into the hole to lead the oil through to the endstone. I do not think this is necessary or desirable; first it can form an additional means of introducing dust into the oil, secondly, the balance pivot will lead the oil through when the balance is assembled into the movement. It is sometimes pointed out and even illustrated to show that the balance pivot can lead the oil through to one side only, but I have yet to witness this. An oiling chart, by kind permission of Compagnie Francaise de Raffinage, appears on page 20 (Fig. 24).

Cleanliness is Vital

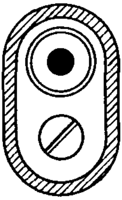
Attention is drawn to the necessity of absolute cleanliness of the surfaces to be lubricated; cleaning is of vital importance and a badly cleaned surface is liable to cause decomposition of the lubricant. Insufficiently refined solvents must not be used, i.e., commercial gasoline or benzine. Pure benzine should be used, and especially trichlorethylene, which is not inflammable. The neutrality of the trichlorethylene should be ascertained and it should be kept away from light.

Chronax stabilised oils, red oils which keep excellently at all normal temperatures, are those which, on account of their unctuousness, are best suited to the usual lubricating conditions of watches and clocks. These oils undergo special treatment preventing their decomposition through oxidation and deterioration through the action of light; they are remarkably stable and ensure first-class lubrication for long periods, and their superiority is universally admitted by the most highly qualified clock and watchmakers. In particular, the Swiss clock and watch factories, after numerous comparative tests, have been led to adopt the use of these products exclusively.

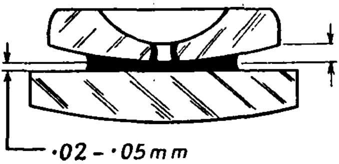
HOW OILING SHOULD BE DONE



OIL IN CORRECT POSITION

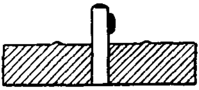


MAKE SURE THAT THE DROP OF OIL IS CORRECTLY CENTRED



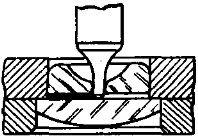
USE JEWELS OF LARGE DIAMETER WITH SUFFICIENTLY DOMED SURFACES, PRESSED-IN ACCURATELY FLAT. CHECK CLEARANCE BETWEEN JEWEL HOLE AND ENDSTONE

DO NOT APPLY MORE OIL THAN WILL FILL THE OIL SINK OF THE JEWEL



APPLY A SMEAR TO TO THE MINUTE WHEEL STUD ONLY

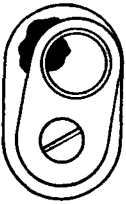
HOW OILING SHOULD NOT BE DONE



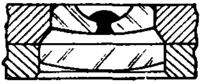
DO NOT USE FLAT JEWELS

DO NOT LEAVE TOO SMALL A CLEARANCE BETWEEN JEWEL HOLE AND ENDSTONE (LESS THAN ·02 mm)

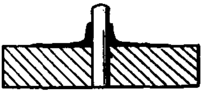
DO NOT APPLY TOO MUCH OIL, SO AS TO AVOID IT RUNNING BELOW THE UPPER ENDPIECE



DO NOT MOVE THE ENDSTONE OFF-CENTRE AS THIS MAY CAUSE OIL TO RUN BELOW THE ENDPIECE



DO NOT LEAVE TOO WIDE A CLEARANCE BETWEEN JEWEL HOLE AND ENDSTONE (MORE THAN ·05 mm)



DO NOT APPLY ANY OIL TO THE BOTTOM PART OF THE MINUTE WHEEL BEARING

Types	Resistance to cold (Extrusion point)	Viscosity at 35° C.
A	−12·4° C.	31 centistokes
B	−13·2° C.	36 ,,
C	−12·2° C.	45 ,,
D	−11·5° C.	55 ,,
F	−12·1° C.	61 ,,
H	−12·0° C.	66 ,,
HHH	−21·1° C.	207 ,,
O	− 5·4° C.	41 ,,

Minera oils, of mineral origin, are very unctuous and characterised by their resistance to deterioration and their great resistance to cold. They have been especially adjusted for all mechanisms working under very low temperatures. On the other hand they are those which best retain their properties in the presence of certain emanations which are destructive to lubricants; perfumes, wood of the cases containing the movements, fatty varnishes insulating the coils and lead wires of electric equipment, and so on. A type " hhh," of high viscosity, particularly suitable for the rotor axle of synchronous clocks, has been added to Minera oils.

By reason of the tendency of pure mineral oils to spread, it has hitherto been impossible to take advantage of their high resistance to deterioration for lubricating clocks and watches and small mechanical components. The discovery of the Epilame process has now made them available for this purpose. Minera oils should therefore be used with or without Epilame, according to whether they are intended to be kept at the contact points or, on the contrary, to spread and thus lubricate large surfaces.

Minera oils are classified in nine types according to their viscosity:—

Types	Resistance to cold (Extrusion point)	Viscosity at 35° C.
aaa	−80° C.	4 centistokes
aa	−51° C.	19 ,,
a	−35° C.	30 ,,
b	−32° C.	36 ,,
c	−28° C.	47 ,,
d	−27° C.	53 ,,
f	−21° C.	75 ,,
h	−20° C.	103 ,,
hhh	−23° C.	269 ,,

Synthax Oils

Synthax oils, of synthetic origin, are particularly stable and withstand spreading perfectly, due to their high molecular cohesion. They have been created especially for the lubrication of steel working on steel (V-screws for alarm clocks) and are particularly suitable when components are made of certain "free-cutting" steels, which contain additions of sulphur and phosphorus destructive for other lubricants.

Synthax oils are classified in three types by order of viscosity:—

Types	Viscosity at 35° C.
T	22 centistokes
V	26 ,,
X	33 ,,

Activated Lubricating Grease

The chief characteristic of activated lubricating grease is its practically non-existent spread between +10° and +50° Centigrade, (50° – 122°F) which permits normal lubrication of the components in contact between these temperatures. It ensures particularly smooth and regular running in all cases where two metals of the same nature are constantly under friction against each other.

Synthax Grease

Synthax grease, extremely resistant to both cold and heat, ensures excellent lubrication even at –20° Centigrade (–4°F) and remains perfectly in place at temperatures up to +100° Centigrade (212°F). Its use is recommended whenever it is desired to avoid all dispersion of lubricant and to ensure normal running of apparatus between wide temperature limits.

Epilame Bath

Chronax Laboratories have evolved the product Epilame which entirely does away with the spread of oils over surfaces. Moreover, treatment with Epilame has the added advantage of decreasing friction and thus improving the running of the mechanism in question. For watches and clocks it is absolutely essential to treat with Epilame, when using Minera oils which, like all mineral oils, have a definite tendency to spread. This treatment is not essential when Chronax oils are used, but it will always give additional reliability.

Epilame Varnish

Epilame varnish is a new product combining the advantages of the Epilame process to the protective qualities of the classic varnishes. In only one operation, it guarantees the protection of the metallic surfaces (frames of instruments, plates, live axles) against oxidation. Epilame varnish is transparent. It clings strongly to the surface, in spite of its thin thickness. The protecting and neutralising film withstands normal cleaning of holes and oil sinks with pegwood as well as the friction caused by the pressure of the pivots.

Epilame varnish is applied very easily before the assembly of the mechanism during manufacture with the air brush. It is necessary to have a vapour bath at 100° Centigrade (212°F), which allows the molecules of varnish to be evenly spread and to neutralise the surface.

Application of Chronax Products

Experience in the field of clock and watchmaking enables it to be asserted that it is impossible to ensure proper lubrication of a clock or watch movement, whatever may be its calibre, by means of a single oil of average viscosity. That is why several types have been created of different viscosities, each of which corresponds to the special lubrication of a given component, for Chronax, Minera and Synthax oils.

1. For clock and watch movements of all calibres, the following oils should be used in all cases for the components indicated:—

Lever pallets, *Chronax type O;*

Mainsprings, *Stabilised lubricant;*

Keyless winding and handsetting mechanisms, *Activated oils.*

2. *For other components*, the following recommendations should be observed:—

A/- *WATCHES AND CHRONOMETERS.*—For movements of medium calibre:—

High-speed moving parts (balances), *Chronax type D;*

Slow-speed moving parts (train wheels), *Chronax type H.*

For movements of very small calibres, use Chronax oils of the next lower grades of viscosity—i.e. Chronax F and Chronax HHH.

In the case of watches mounted with V-screws, *Synthax type T* oil will be used for lubricating the latter.

Users who may wish to make personal tests, are advised to employ the *highest viscosity* type compatible with proper running of the part to be lubricated.

3. *APPLICATION OF EPILAME.*

(a) With Chronax oils, treatment with Epilame is not essential, but its application always ensures additional reliability.

(b) With Minera oils, treatment with Epilame is essential if it is desired to eliminate spreading of the lubricant over the surfaces entirely.

(c) With Synthax oils treatment with Epilame is not necessary.

For use and convenience, Chronax have created for the technician and the clock and watch repairer, small boxes which contain the different types of the oils for use:—

1°. *The Service set for watches which contains:—*

1 bottle of 5 grs., Chronax type D;
1 bottle of 5 grs., Chronax type O;
1 bottle of 15 grs., Chronax type H;
1 bottle of 15 grs., Stabilised lubricant;
1 tube of 5 grs., Activated grease.

2°. *The Service set for clocks and alarm clocks which contains:—*

1 bottle of 5 grs., Synthax type X;
1 bottle of 5 grs., Chronax type O;
1 bottle of 15 grs., Chronax type HHH;
1 bottle of 15 grs., Stabilised lubricant;
1 tube of 5 grs., Activated grease.

These service sets can be used on a Bakelite cruet-stand, which allows a practical use of the oils and preserves them from light and dust.

TABLE 1

Application of Chronax Products to Horology

Parts to be oiled	Very small watches	Watches of other sizes for normal use	Small clocks, Alarm clocks, Stop watches	Aviation watches: all calibres	All public clocks, Time switches
Balances	Chronax C	Chronax D	Chronax H, excepting cone-shaped screws	Minera	Minera
Pallet jewels	Chronax O	Chronax O	Chronax O	Choose the Minera oil, the viscosity of which corresponds to that indicated in Chronax for oiling similar parts.	
Train wheels (centre, 3rd, 4th escape wheel)	Chronax F	Chronax H	Chronax HHH		
Mainspring and barrel arbor pivots	Stabilised lubricant and graphited stab. lub.	Stabilised lubricant and graphited stab. lub.	Stabilised lubricant and graphited stab. lub.	Remark: The Minera oils should be used on surfaces previously treated with Epilame.	
	The graphite lubricant allows of the use of weaker springs.*				
Cone-shaped screw			Synthax X		
Alarm mechanism Quick moving parts			Chronax D		
Mechanisms	Activated grease	Activated grease	Synthax grease		
Mechanisms requiring particularly thick grease, i.e., where there is friction between parts made of the same metal.		Activated grease in three types: thick, semi-fluid, and fluid.			
Clock cables	Grease: 141,736				
Lacquered pieces	Epilame varnish has the advantage of protective qualities.†				

* The graphited stabilised lubricant used for mainsprings ensures a very steady and constant rate of timekeeping. The running down of the springs is very smooth.

† *Method of use.* By immersion, with a brush or air brush, then heat the pieces for 10 to 15 minutes in 100° C.

Cleaning. It is absolutely essential to clean very thoroughly the pieces to be lubricated or lacquered. A badly cleaned surface will cause rapid deterioration. Use pure Benzine or Trichlorethylene.

CHAPTER THREE

BALANCE PIVOTS

Lever Escapement—Refinements of Finish

The polishing of balance pivots is of utmost importance and much depends on this. It is not sufficient to just burnish the pivots; it is necessary to ensure that no facets are created. Burnishing a pivot in the ordinary way can create facets and it has been calculated that the length of movement given to the burnisher should bear some relation to the diameter of the pivot being polished. The length of movement given to the burnisher should equal the linear length of the diameter of the pivot. For instance, and to make the calculation simple, we will assume the diameter of the pivot to be 1 mm., therefore the linear surface will be $1 \times 3{\cdot}14$, the circumference of a circle is equal to π (diameter) $= 3{\cdot}14$; for, say, six complete revolutions of the balance the linear surface will be equal to $3{\cdot}14 \times 6 = 18{\cdot}84$ mm. Therefore, while the balance is made to rotate six times, 18·84 mm. of the burnisher only should be used.

During the practical application of this theory it will be noted that both the bow and the burnisher appear to be moving very little and at the same time they should be moving very quickly so that the linear movement of pivot and burnisher are the same. If, for instance, the bow—and, consequently, the balance—were moved slowly and the burnisher quickly then facets, or flats would be created on the pivot; it would almost be equal to holding the balance still and burnishing the pivot, making the surface flat.

It is not suggested that each pivot should be measured and then the number of revolutions counted to find the amount of the burnisher to be used, but it should be calculated once so as to ascertain the amount of movement of both burnisher and bow necessary to achieve this object. Once this information has been acquired, it can be applied to other sized pivots automatically without calculation.

Facets Hinder Perfect Poise

Sometimes, when poising a balance, it may be noticed that it is difficult to get the balance into *perfect* poise, and this is no doubt due to facets or a facet on the surface of the pivot. If the balance is observed very closely it will be noticed that at some point it hesitates; it may be *very* slight, but that hesitancy indicates a facet and the facet may be so slight as not to be discernible even with a strong eyeglass. It is well worth while to examine a balance-staff pivot under a miscroscope. Polish a pivot, so that you think it to be perfect, and then examine it under a microscope. *Any imperfection* in the staff pivots will have disastrous consequences when timing in positions. An important manufacturer in Switzerland employs a system whereby all balance-staff pivots are made to rotate in a jewel hole to ensure that the pivot is perfectly cylindrical so that no facets exist.

The tool used for this purpose is a Jacot tool. The balance is made to rotate by a bow. The tool is screwed in the vice with the head—pulley end—on the right. The normal runner is fitted into the other end of the tool. In place of the bed for polishing pivots, a specially made runner with a large jewel hole set into the end is used. The jewel hole is shaped as in

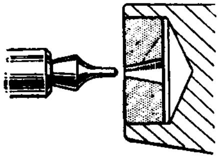


FIG. 25. *A large jewel hole for checking the pivot.*

Fig. 25. The diameter of the hole is a very close fit, almost a tight fit on to the staff pivot. Oil is applied to the hole and with the balance held in the tool with the right hand the runner is brought up to the pivot. The balance is then made to rotate fairly quickly and the jewel hole, set in the runner, is pressed on to the staff pivot the amount of the length of the parallel part of the pivot (Fig. 26). In this manner the pivot is made *perfectly cylindrical* and at the same time all facets—if any—are removed. Such a procedure may not be possible in the average repair workshop

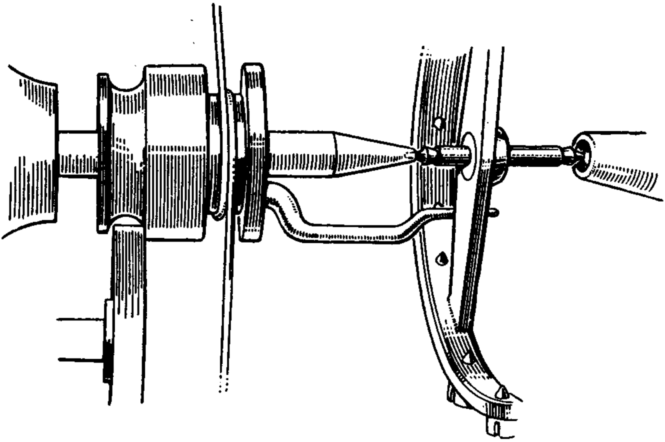


FIG. 26. *Ensuring no facets exist on the pivot by rotating in the Jacot tool.*

because of the multiplicity of the sizes of pivots handled, but it does emphasise the importance of having no facets. The finish of the ends of the pivots is important, too.

Some watch adjusters say that the flatness, or want of flatness, can materially affect the timing. It is true that if the ends of the pivots are flat a retarding action is introduced which does, to a certain extent, compensate for the retarding effect when the watch is placed vertical—when both pivots are creating extra friction. In practice, however, a flat end to a pivot may not contact the endstone to the full extent of its flat surface. Numerous errors creep in, such as the want of *absolute* uprightness of the balance staff. A staff may be termed upright for all intents and purposes, but *dead* accuracy is difficult and certainly, with the majority of commercial watches, no matter how good, impossible to achieve. The odd one or two may be found perfectly accurate, but they will be exceptions. So it is not wise to count upon this, since the surface we are concerned with is minute compared with the other factors.

Again, the endstone may not be at dead right angles to the end of the pivot. There are many factory production errors—each very slight in themselves maybe—which make this possibility remote, therefore it is not possible to be sure that the *full* flat end of a pivot is in *full* contact with the stone. In these circumstances it is advisable to give a slight radius to the ends of balance pivots, as in Fig. 27; and we know then that the

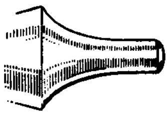


FIG. 27. *A balance pivot showing the radius at the end.*

part in contact is constant. It is important that the ends of the pivots should be perfectly polished and, while the rounding up of the ends of staff pivots may be considered a simple everyday job, great care is necessary if close timing is to be obtained. As much attention should be given to the ends of balance-staff pivots as to the cylindrical part; they affect the dial up and dial down positions and thus relatively influence the vertical positions.

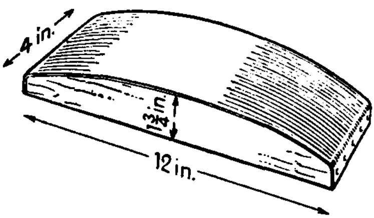


FIG. 28. *Block for dressing a burnisher.*

Correct polishing of balance-staff pivots is controlled by the burnisher and its condition. On no account should an emery buff be used to dress a pivot burnisher. To dress a burnisher proceed as follows: Use either a stone or a lead-surfaced block dressed with carborundum powder, medium grade. First, the stone; these stones are not easily come by. Those used by the Swiss timers appear to be made especially for them; that is, they cannot be purchased at a material dealers even in Switzerland. In appearance they are about 4 in. wide and 6 in. long and about 1½ in. thick. The texture is similar to that of an Indian stone and they are used dry, with no oil. Failing such a stone, make a lead block. Procure a piece of wood about 12 in. long and 4 in. wide and 1¾ in. thick. Shape the 4 in. surface lengthways to a gentle curve so that the ends are about ¾ in. thick. These blocks can be purchased in Switzerland.

Dressing a Burnisher

On to the block lay a piece of sheet lead about ⅛ in. thick. Secure the lead at one end with nails and with a small wood mallet tap the lead

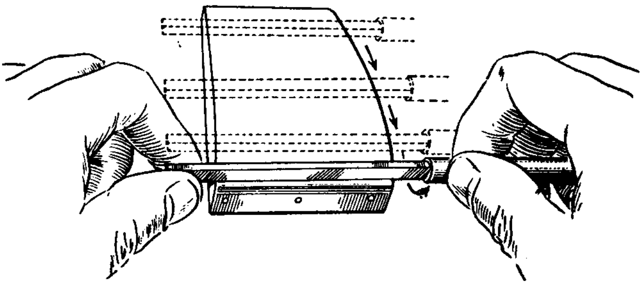


FIG. 29. *Action of dressing a burnisher.*

so that it fits snugly on to the wood and then nail the other end (Fig. 28). Now scrape the lead surface with the edge of a fairly large, flat burnisher. Tilt the burnisher slightly and draw it towards you so as to scrape a little of the lead off, and continue thus until all bruises are removed from the surface.

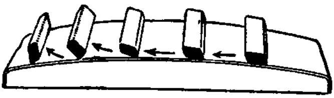


FIG. 30. *How the burnisher is rocked.*

Dust on to the lead surface a little emery powder or carborundum powder grade 170. Place the block flat on the bench with the narrow side towards you: hold the balance-pivot burnisher, with the rounded edge away from you, firmly on to the block with both hands (Fig. 29).

Firmly and slowly push the burnisher over the surface and then draw it towards you equally firmly without removing it from the block. When the burnisher is near to the end of the block, slightly twist it so that the rounded edge of the burnisher—the part which burnishes the cone part of the pivot—receives treatment (Fig. 30). Four or five firm, steady strokes are generally sufficient to give a good, sharp surface to the burnisher. Wipe the burnisher well with a clean linen rag before using. The block is so curved to ensure that the flat part of the burnisher is really flat.

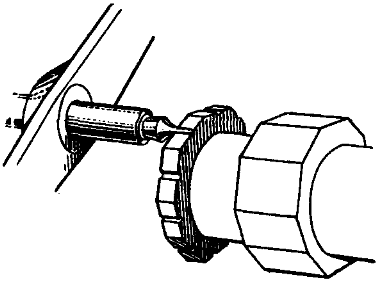


FIG. 31. *Pivot in correct bed.*

Polishing a Pivot

It must again be stressed that polishing balance-staff pivots is of the utmost importance. It will often be found that during timing the desired results can be obtained by retouching the pivots. To polish a pivot, first select a bed to suit the pivot. It should rest in the bed a little less than

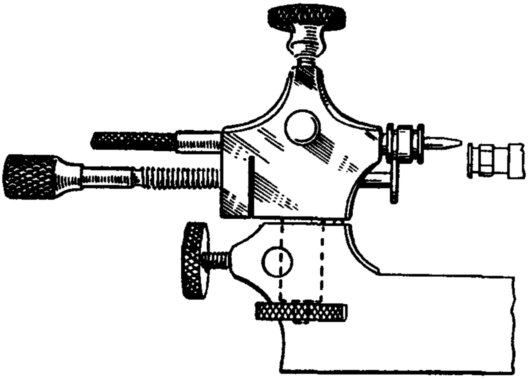


FIG. 32. *Adjustable Jacot tool.*

half its diameter; in other words the pivot should be exposed above the bed a little more than half its diameter (Fig. 31). Smear the burnisher, including the rounded edge, with good clock oil. Place the balance in position in the Jacot tool with the pivot to be polished on the bed and then place the burnisher on the pivot and proceed to polish. Apply good clock oil to the other pivot, and always keep this countersunk hole clean, with a pointed piece of peg-wood and pith.

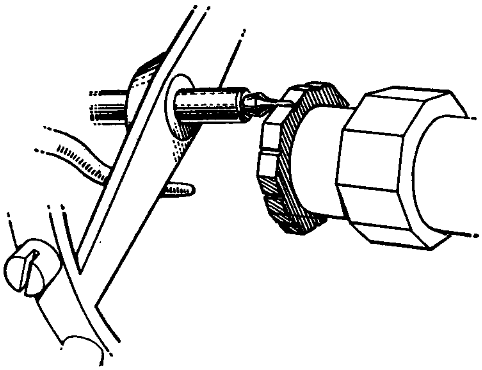


FIG. 33. *Pivot slightly tilted.*

Some Jacot tools are so made that one end can be adjusted to height. The ordinary tool has a fixed end for the runner so that the bed is parallel with the other pivot runner. With the adjustable tool (Fig. 32) the pulley end can be raised and by doing so the balance pivot on the bed

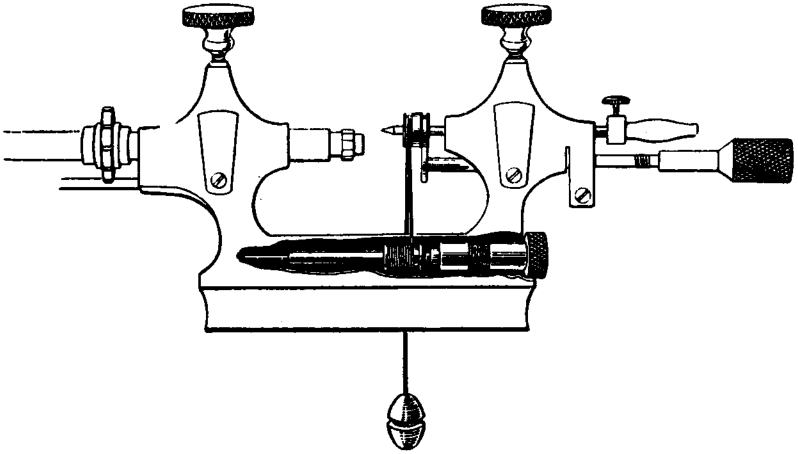


FIG. 34. *Jacot tool with built-in spool*

can be made to tilt up so that the active part of the pivot receives most attention from the burnisher. The pulley end should only be lowered very slightly indeed so that the pivot being polished is hardly tapered at all (Fig. 33). Such tools are used, as a rule, in the watch factory where it is a man's sole job to polish staff pivots. This tool is mentioned here to emphasise the importance of imparting to the cylindrical part of the pivot a flawless surface. It is good practice, therefore, to tend to apply more pressure to the right-hand side of the burnisher while polishing; the rest of the pivot, other than the end, is of little importance. It is necessary for the cone to be polished so as to retain the oil, but it is not as important, for purely timing purposes, as the cylindrical part.

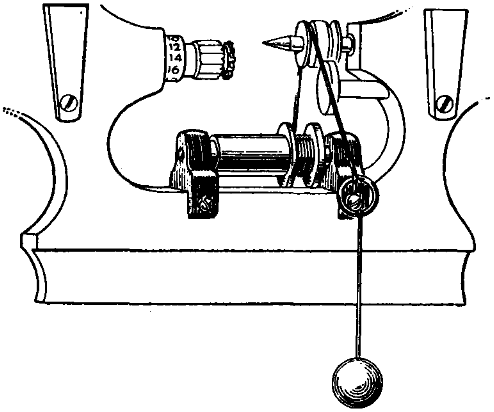


FIG. 35. *Another Jacot tool with a spool attachment.*

Jacot tools are made which dispense with a bow, as shown in Fig. 34. The attachment for rotating the pulley is built into the tool in this model, but the spool, which keeps the cord taut as it is pulled and released alternately, can be purchased separately and attached to the tool as shown in Fig. 35.

The end of the pivot is polished in the lantern runner of the Jacot tool, as in Fig. 36. Select a hole in which the pivot fits freely; it must be quite free yet the hole must not be much too large otherwise the surface

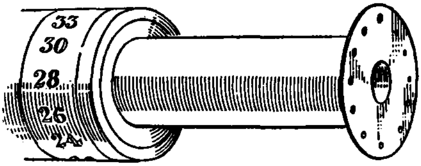


FIG. 36. *The lantern runner of a Jacot tool for polishing the ends of pivots.*

of the pivot might be damaged. When fitting the balance in to the tool, bring the lantern up to the pivot carefully and free of the cone part of the pivot (Fig. 37). Apply plenty of good clock oil to both pivots.

The burnisher to use on the pivot ends is a small, thin, flat tool about

2 in. long and 3/16 in. wide and perhaps 1/16 in. thick, tapering to about half that thickness. This burnisher is dressed on a No. 2 emery stick. Well wipe the burnisher with a clean linen rag and smear it with a good clock oil before using. The balance is made to rotate backward and forward fairly quickly, and the burnisher is also operated backward and forward quickly. At the same time it should be constantly twisted so to

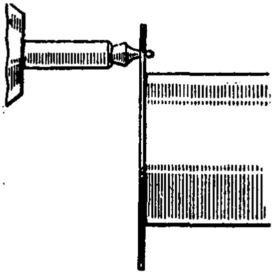


FIG. 37. *The lantern should be brought up carefully to the pivot but should be free of the cone part.*

give a rounded end to the pivot and ensure that no facets are formed. If the burnisher is held rigid with the back and forth movement only flats would immediately be formed. The curve or radius of the pivot should be as in Fig. 38. After burnishing the end of the pivot, just bring the burnisher round to the edge to remove any slight burr that may be

FIG. 38. *Care should be taken to avoid flats being put on the pivot. The curve should be as that shown in the figure.*

formed. As a test to ensure the end of the pivot is smooth, hold the balance in the left hand and draw the end of the pivot across the nail of the third finger. This nail is very sensitive and a slight facet will scratch it. The importance of a perfectly clean hole at the pulley end of the Jacot tool will at once be apparent; otherwise the polished end could be damaged while polishing the other pivot end. Make it a habit always to dab the hole with pith and apply clean oil before using.

Poising the Balance

There is little doubt that, for accurate poising, a poising tool is best (Fig. 39). Some craftsmen advocate calipers, rubbing the edge of the calipers to cause the balance to rotate, but by using the knife edges of the poising tool there can be no doubt. Some poising tools are fitted with agate jaws, which may have some advantages but have a decided drawback; should the agate become damaged it is a major job to restore the jaws. There is a great deal to commend steel jaws; they can be polished periodically with diamantine to keep them in good order, but as it is necessary to work close to the tool, the steel is liable to rust slightly owing to condensation of the breath on the cold steel. It is necessary therefore

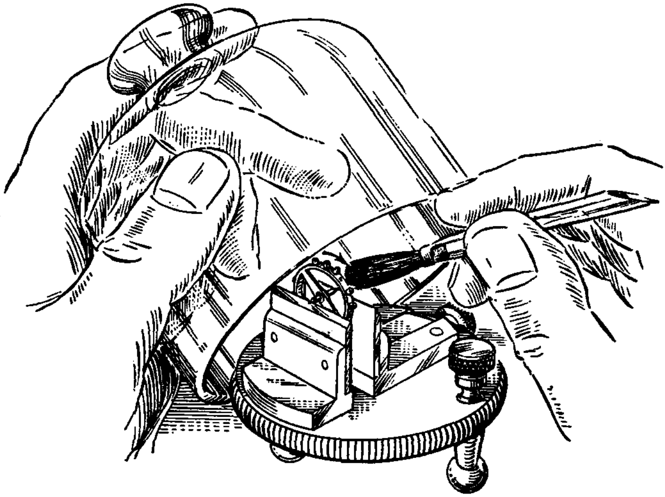


FIG. 39. *Using a poising tool. To avoid damaging the balance or pivots a camel hair brush should be used to rotate the balance.*

to keep the jaws scrupulously clean and dry and, to achieve this they should be constantly wiped with pith (Fig. 40).

The balance should be poised with the roller in position and, strictly speaking, with the balance spring collet, a length of balance spring

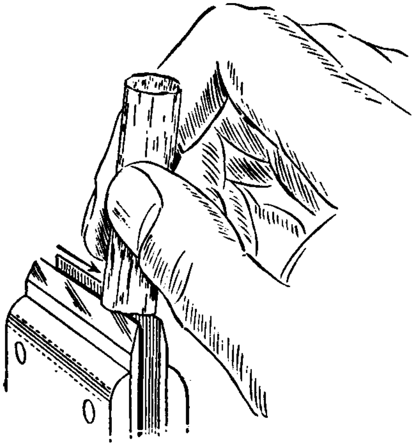


FIG. 40. *The jaws of the poising tool should be kept scrupulously cleaned with pith.*

in the collet equal to the length of the hole, and the pin. Some manufacturers use poised balance spring collets. It will be noticed that such collets have a flat filed on them opposite the slot as in Fig. 41. The practical necessity for this refinement is however debatable. The distance apart of the jaws of the poising tool should be adjusted so that the cone part of the pivots is free of the sides of the jaws; the cylindrical part of the pivot only should rest on the knife edges (Fig. 42).

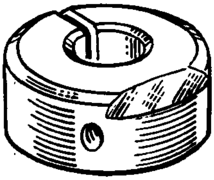


FIG. 41. *A poised balance spring collet. Such collets have a flat filed on them opposite the slot.*

It is important that the knife edges of the poising tool be slightly rounded; they should not be left with a razor-like edge. If the edges are slightly burnished with an oval burnisher a sufficiently rounded edge will be imparted. If a knife edge is examined with a microscope it will be found to be jagged and a light balance resting on such edges will be influenced by this rough surface so that a true poise of the balance will be impossible. Note the rounded edges in Fig. 42, somewhat exaggerated, for purposes of illustration.

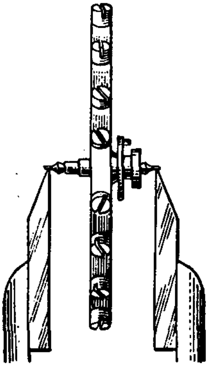


FIG. 42. *The poising tool should be adjusted so that the cone parts of the pivots are free of the jaws.*

During the final stages of poising it is essential that the bench should be free from vibration and the balance free from draughts. The balance is very lightly touched with a camel hair brush to set it rotating and a glass shade (Fig. 39) held over it to ensure that it is not influenced by the movement of the air. A disturbance of the air caused by breathing or somebody passing or the opening and closing of a door, is sufficient to

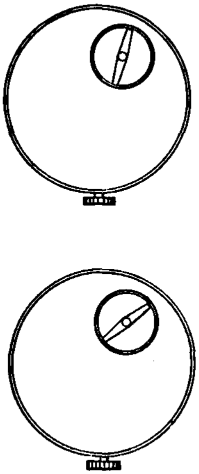


FIG. 43. *If a balance needs poising the effects are considerable on the positional timing of the watch.*

give an incorrect poise. The object of poising is that there shall be no heavy point; the balance should slowly come to a standstill and then perhaps start to roll back. It is advisable then to touch the balance again lightly and make it roll in the opposite direction to the original direction to ensure that there is no error in the position of the tool.

The effects of want of poise of the balance are considerable on the positional timing of the watch.

Taking regard of the position of the balance when in the watch is, say,

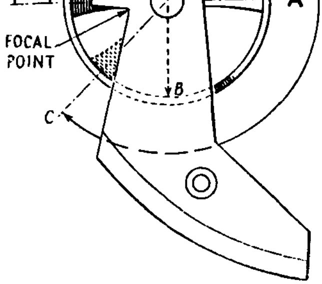


FIG. 44. *Estimating the arc of vibration of a balance.*

for example, pendant down; if the balance has a heavy point at the bottom, the watch will gain, provided the extent of the vibration of the balance does not exceed one to one-and-a-quarter turns. If the vibration is in excess of this it will lose. At the top in Fig. 43 the heavy point is noted by a dot; at the bottom is shown the maximum arc of vibration of the balance before a losing rate will set in.

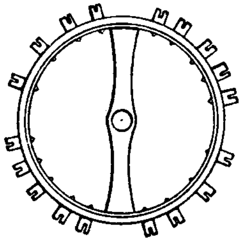


FIG. 45. *A Glucydur balance with timing screws. These screws facilitate poising.*

The arc of vibration is estimated as follows: with the balance at rest note the position of the arm with relation to a fixed point of the watch, say the balance cock where the stud is fixed (Fig. 44). Release the balance and observe the point as indicated and, as the arc increases, the point will eventually reach the place marked A, which is half a turn. It is calculated that a half-turn to return to zero (the stud fixing) is equal to one turn. When the point B is reached the arc is said to be one and a half turns, i.e., another quarter-turn in one direction only, and when reaching C the balance vibration equals one-and-three-quarter turns, the maximum we are interested in. Above one-and-three-quarter turns the impulse

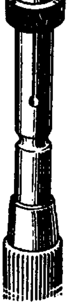


FIG. 46. *Washers are placed under the heads of balance screws with balance screw tongs.*

pin is liable to touch the back of the lever, when " knocking the banking " is experienced or " knocking", as it is commonly known. It takes some little practice to estimate the arc of vibration reasonably accurately and this subject will be referred to again when dealing with positional timing.

Practically all modern watches are fitted with solid balances and self-compensating balance springs. Better quality watches have balances made of a beryllium alloy known as Glucydur. This alloy has valuable properties; it is non-magnetic, rustless and is little affected by changes in temperature. Also, and very important, Glucydur is fairly hard and in addition is capable of being highly polished. Lower grade balances are made of nickel bronze, and while they are good as regards temperature, they

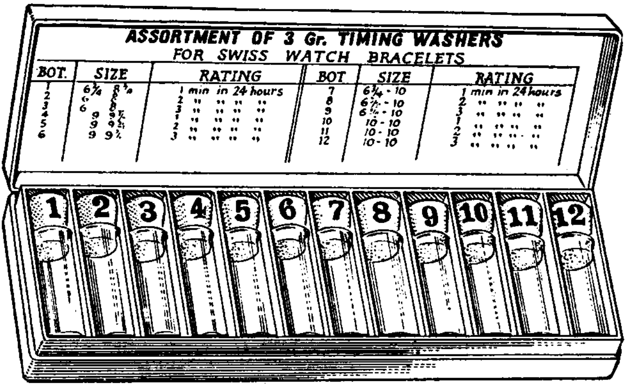


FIG. 47. *Washers are sold in phials in boxes and a table inside the lid of the box gives the contents of each bottle.*

have the drawback of being soft. Soft balances do not stand up to the re-fitting of balance staffs; after a staff has been knocked out once or twice, the hole in the balance enlarges with the result that either a hand-made oversize staff must be used or extra riveting to make an interchangeable staff secure, with the resultant risk of making the balance out of true. Other than hardness and finish the Glucydur balance has practically no advantages over nickel. Balances of this metal are made with timing screws (Fig. 45) which facilitate poising and are also essential for mean time purposes. If it were not for the screws it would be difficult to alter the weight of the balance both when poising and timing.

The modern trend is to fit balances with no screws: it is claimed that they are not disturbed by air currents. We feel this is a very fine point and prefer balances with screws.

For the average craftsman there is only one way to increase the weight of the balance—to correct for gaining, other than altering the balance spring—and that is to add collets (or washers) to the balance. Collets are placed under the heads of the screws and the most convenient method of doing this is to use the balance screw tongs as in Fig. 46. The washers are sold in phials in boxes (Fig. 47). The corks (Fig. 48) are numbered and a table inside the lid of the box tabulates the contents of each bottle. Some are numbered giving the diameters of the hole and the exterior of the washers, while other sets are made up giving the size of watch movement the washers are intended for, and the effect the addition of a pair of

FIG. 48. *The corks of the phials are numbered.*

washers will have on the timing of the watch. This information acts as a guide only. Each bottle contains washers of identical weight and size. Experience will teach the correct size washer to use. Having removed a screw from the balance and isolated a washer from the bottle selected, pick it up by pressing the pad of a finger on to it and introduce the thread of the screw into the hole of the washer, at the same time twisting the tongs clockwise, in order to screw the washer on to the screw, as shown in Fig. 49. In this manner the washer can be picked up quickly; it is much better than placing the washer on to the screw with tweezers.

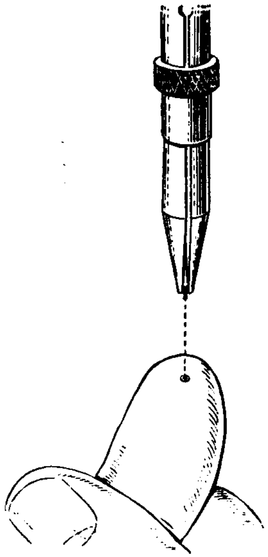


FIG. 49. *Picking up the washer from the finger with the balance screw tongs.*

Mr. Zibach, the successful timer and adjuster, late of Patek Philippe, Geneva, has invented a balance—Glucydur—which has decided advantages (Fig. 50), and known as the Gyromax balance. The advantages are two-fold; firstly, all the weight, in addition to the weight of the balance itself, is concentrated on the rim of the balance and not partly on the rim and partly on the screws normally screwed into the side of the balance. Secondly, and the most important, the effective weight of the balance can be altered without adding timing washers or altering the weight of the screws.

Split collets are pressed on to studs or pins, which are fixed to the balance and project upward from the top of the rim. The collets are not screwed on to the studs but are held friction tight. When the watch leaves the timer, the collets are left so that the slots of a pair of collets point

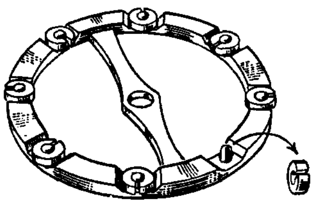


FIG. 50. *Gyromax balance. Split collets are held friction tight on the studs.*

in the same direction, as will be noted in Fig. 50. If, for instance, it is required to make the watch lose, an opposite pair of collets are turned so that the slots point towards the centre of the balance, therefore more weight is moved to the outer diameter of the balance and the watch will lose. Conversely, to make the watch gain an opposite pair of collets are turned so that the slots point outward from the centre of the balance.

A complete half-turn of a pair of collets from the position where the slots point radially to the centre of the balance to the position where they point radially away from the centre will have the effect of making the watch gain 20 seconds in 24 hours. It will be seen, therefore, that there is considerable scope for purposes of regulation. Furthermore, the amount of movement made to a collet can be estimated with a greater degree of accuracy than would be the case with a side screw, because the diameter of the collets is relatively greater. This being so, the poise of the balance need not be materially affected when a mean time adjustment is made, therefore the balance need not be removed from the movement with the attendant necessity of re-poising.

CHAPTER FOUR

FITTING A FLAT BALANCE SPRING

WHEN FITTING a balance spring first check that the spring provided is the correct one. Take a piece of beeswax about the size of a pin's head and roll it into a ball. Press this ball lightly on to the centre of the balance spring and then press the top pivot of the balance staff into the centre of

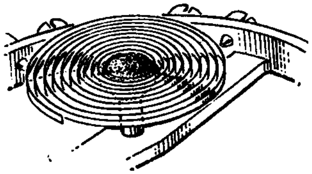


FIG. 51. *The top pivot of a balance staff pressed into a ball of beeswax.*

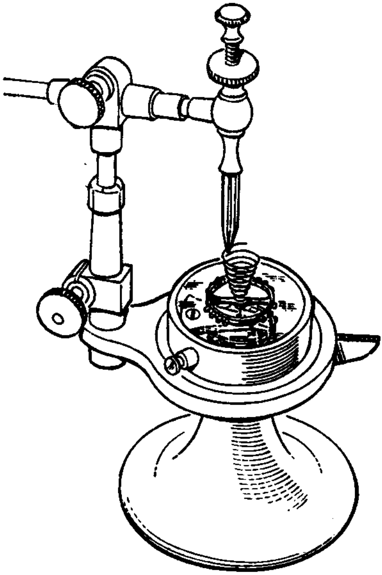


FIG. 52. *Vibrating tool with a spring and balance wheel in position.*

the ball (Fig. 51). Lift up and the spring will adhere to the pivot. If you possess a balance vibrating tool, fit up as Fig. 52 and start vibrating Assuming the train is an 18,000, a balance vibrating 18,000 vibrations per hour is used as the test balance. Other counts are available. Grip the balance spring at about the position where the index pins will operate and if you are satisfied that the spring is correct you can proceed to pin it up to the collet.

If you do not possess a vibrating tool proceed as follows: Lay a watch with a seconds hand flat on the bench. Hold the balance spring with a

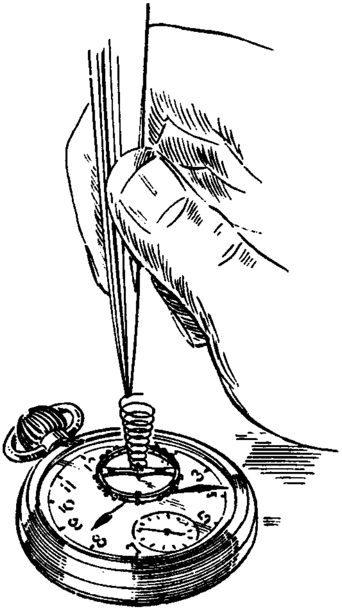


FIG. 53. *Vibrating spring and balance when a tool is not available.*

pair of tweezers as in Fig. 53 and give a slight twist to start the balance vibrating; you do not require a big one, about half a turn is sufficient. An 18,000 train equals 300 vibrations per minute, that is 150 alternative vibrations. Count the arm as it vibrates towards you, these will be alternate vibrations. When you have got the rhythm of the swing of the balance, observe the seconds hand of the watch and when it reaches 60 start to count the vibrations of the balance. Count up to 75 and by that time the seconds hand should point to 30 seconds. Take up more of the spring in the tweezers if the balance is slow and conversely, let out the spring if fast. Continue thus until the balance is vibrating to time and eventually, when the time is correct for 30 seconds, count 150 vibrations for 60 seconds.

If the spring is not the correct strength and size it can be returned to the material dealer for another, as it will not be damaged.

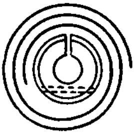


FIG. 54. *The first coil of the spring should be at a distance from the collet equal to the distance between coils as shown here.*

To pin up, first lay the spring over the collet and gauge the amount of spring to be broken away from the centre. The centre should be cut away sufficiently large so that when the collet is in the centre, the first

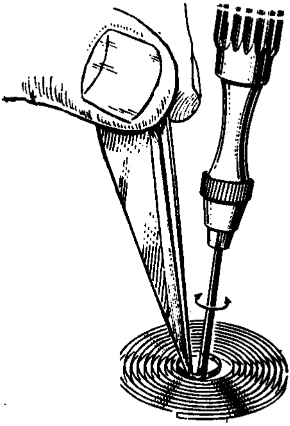


FIG. 55. *The method of breaking the balance spring to the required length.*

coil of the spring should be at a distance from the collet equal to the distance between the coils; this is most important (Fig. 54). Modern balance springs are softer than their predecessors, the steel springs, so breaking away the spring is simple. Hold the spring firmly with a pair

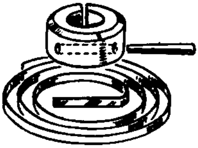


FIG. 56. *Portion of spring shown straightened for pinning to the collet*

of tweezers at a point a little less than the amount the spring is to be broken and with another pair of tweezers, or, a needle with half its eye stoned away, held in the pin tongs, work the end of the spring backward and forward until it breaks as in Fig. 55.

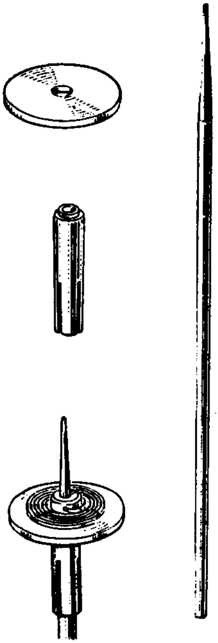


FIG. 57. *A tool for holding the collet and balance spring when pinning up and making true.*

Next straighten a portion of the inner coil of the spring (Fig. 56). This is that part of the spring which is to be pinned to the collet. Invariably the new spring supplied is longer than required, so break a piece off the outer coil—about ½ in. and straighten it. This is to be used while making the pin. A convenient tool to hold the collet while pinning up and making true is as follows:—

Procure a piece of mild steel rod about 2·5 mm. diameter and 4 in. long. Fit up in the lathe and turn or file ¾ in. to a taper, reducing the end to 0·5 mm. It is on this part that the balance spring collet will be pressed. Now select a piece of brass clock bouchon wire, 1 in. long, which allows the steel rod to slide in with ease. Turn the bushon down to 4·5 mm. and to a slight taper to 3·5 mm. At one end turn a shoulder and at the other end make two saw cuts about ¼ in. long. The four prongs are bent in slightly so that they grip the rod and act as springs. The bouchon can now be made to slide up and down the rod and it should stay where wanted with some rigidity. On to the shoulder is riveted a round brass plate about ¾ in. diameter and 1·5 mm. thick, see Fig. 57.

With this tool in the left hand and held against the edge of the bench to steady it, press the collet on to the tapered end, the right way up. File up a piece of brass wire to a long gentle taper until it will enter the hole in

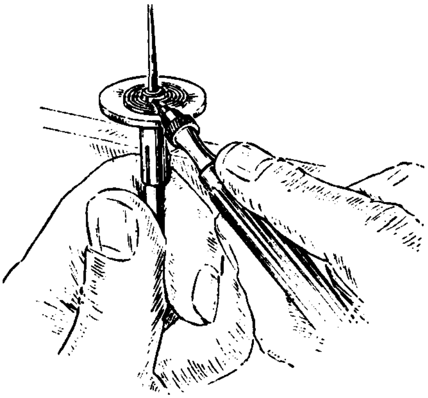


FIG. 58. *Pinning the spring to the collet while the two are in position on the tool.*

the collet and finally stroke it with an arkansas slip lengthways with a draw filing motion. Now introduce the piece of balance spring into the hole and then the tapered wire. Force it in as far as it will go to be sure that the piece of spring in the hole takes on the same curve as the inside of the hole. Make sure the pin enters the hole from the correct end; this is dictated by the direction the coils develop and depend upon the position of the balance spring stud.

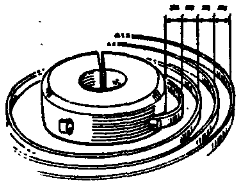


FIG. 59. *The spring should be central and the distance between each coil should be equidistant.*

When the pin is quite tight mark with the blade of a knife, saw fashion, on the wire at the point where the pin projects from one end, and the point where it enters at the other end.

Withdraw the wire and, with the knife, cut away the end piece. Place the wire on to the filing block and a little pressure on the knife will sever it. With the arkansas slip make the end flat and just wipe the edges to remove all burrs. We now have the length of the new pin on the end of the wire. Hold the wire on the filing block and at the remaining mark saw a little more than half-way through with the knife, but do not break the pin off yet.

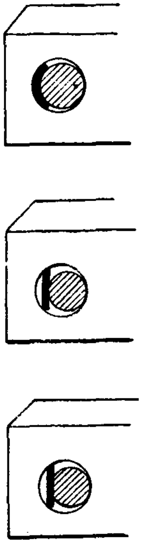


FIG. 60. *Top: Soft balance spring takes curvature of hole when round pin is used. Centre: Effect of round pin when used with hard balance spring. Bottom: Flattened pin holds hard balance spring securely.*

Place the collet on the tool—making sure it is the right way up (Fig. 58)—and press down firmly but make sure not to open the collet, so that it fits loosely on to the balance staff. Slide the tray up to the collet and place the balance spring into position ready for pinning. Lead the straight part of the spring into the hole the correct amount. We want the spring to be central (Fig. 59). It will have flopped down on one side; insert the pin—still on the end of the wire—so that it enters in the same direction as the spring, press home lightly and at the same time twist the pin slightly to ease it in and make the spring in the hole take the same curvature as the inside of the hole. When the pin is about half-way in or perhaps a little more, twist it, if necessary, to bring the spring up and parallel with the tray, i.e., flat. While doing this it is convenient to hold the tool against the edge of the bench; with a round file, file a slight notch in the edge of the bench to rest the rod part of the tool in; then it will not slip. When you are satisfied that all is in order, break off the pin. To do this hold the tool firmly and work the wire with the pin on the end backward and forward very slightly; after one or two movements it will break off.

Finally press the pin home firmly with the points of a fairly stout pair of tweezers or some form of pusher such as a needle with a flatted end, held in pin tongs. It is essential for the spring to be very firmly fixed.

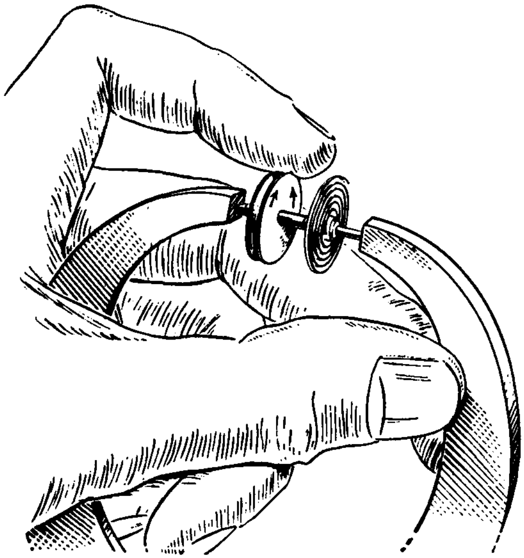


FIG. 61. *Rolling forefinger on ferrule while truing balance spring.*

If a steel spring is being fitted, then the pin must have a flat filed on it. The steel is too stiff to give to a round pin and if such a spring is pinned up with a round pin there is a risk of it not holding securely.

Fig. 60 illustrates this point. The procedure to pin up a steel spring, is first of all to file the pin to fit the hole in the collet without the piece of

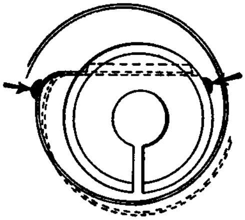


FIG. 62. *Straddle tweezers across collet, one limb bearing on the collet (right) and the other on the elbow of the balance spring (left).*

spring. Then place the spring in position and file a flat on the pin, approximately a quarter of its diameter. Stroke the flat and the round part with an arkansas slip, as was done for the plain round one. Then proceed precisely as before, marking the pin for length but presenting the flatted side of the pin to the spring.

It is now possible to slide the tray off the rod to remove the collet. Cut a piece of white note paper about the size of a sixpence; pierce a hole in the centre of the paper and slide this on to the rod and follow it up with the tray. The white background will facilitate the preliminary centring up of the spring. By twisting the rod between the thumb and first finger the spring will be seen to run flat; the final truing will be done later.

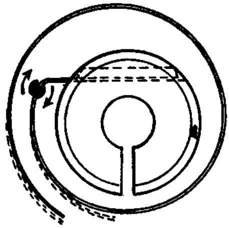


FIG. 63. *Twisting spring out from collet.*

A good deal can be done to make the spring true on the tool. Twist the rod and while so doing observe the development of the coils of the spring. They should leave the collet in a smooth spiral and if it is necessary to make any adjustment—as well it may be—operate on that part of the spring between the collet and the convolutions, i.e., the straight part.

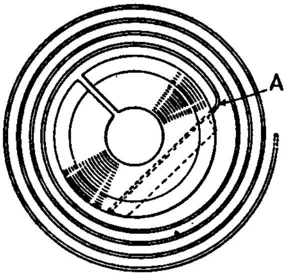


FIG. 64. *" A " indicates the elbow of the balance spring at the collet.*

It may be necessary to bend the spring at the elbow, i.e., where the convolutions start from the straight part, but do not attempt to bend or alter the spiral of a coil. Once a coil has been bent it is almost impossible to make it true again. As for flatness, the final truing will be done later.

Remove the spring with collet from the tool and put it in place on the balance staff. Fit up in the vibrating tool and cut the spring down to size, noting that where the spring is gripped by the tool is the position of the index pins so that an allowance from the index pins to the stud and plus a little extra must be made before finally cutting the spring to size. Truing can be finished now the spring is cut to size; it is much easier to true when short as there is not so much spring to flop about. To true the spring, place it on an arbor with a ferrule, rotate the arbor in the callipers as illustrated in Fig. 61, and first concentrate on the centre. If the spring has been pinned by the correct amount, little truing will be necessary.

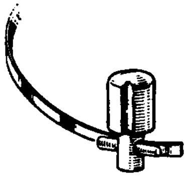


FIG. 65. *Correct length of stud pin.*

Make the arbor rotate by rolling the forefinger along the ferrule in the direction of coiling up the spring. In this manner the convolutions of the spring can be better observed. The spring should develop out from the collet in an even flow, with no jerks or kicks. Practice alone can teach the art of truing and it does take some little practice to be proficient.

For truing the spring use fine pointed tweezers and keep them for this

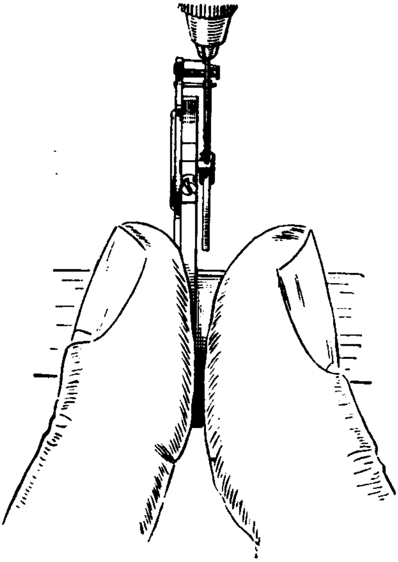


FIG. 66. *Twisting stud pin to make balance spring parallel with underside of balance cock.*

purpose only. Before making any bends, study where the bend should be made first. If, for instance, the spring appears to bulge as in Fig. 62, straddle the tweezers so that one limb touches the collet and the other the elbow and then press the limbs slightly together. If the bulge is as in Fig. 63, bend the spring slightly as shown, and so on. When the spring is true in the centre, observe for flatness. A very gentle up or down movement at or near the elbow, i.e., where the spring curves from the straight part, is all that is usually necessary. If it has been necessary to make any adjustment for flatness, it is advisable to check the centring as sometimes bending the spring near the centre will throw it out. Truing is one of those operations where it is necessary to make an adjustment in one part and then check again after another adjustment to make sure that

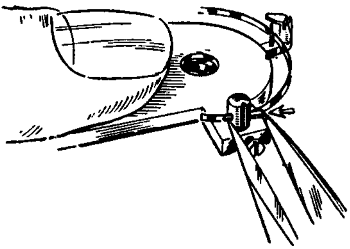


FIG. 67. *Pressing stud pin firmly home with stout tweezers.*

the last touch has not deranged a previous one. Eventually the spring will run perfectly flat and true in the centre and appear, as it is made to rotate, to just flow smoothly out of the collet. All adjustments to true a balance spring in the centre should be made by manipulating the short straight part of the elbow A in Fig. 64; the original coiling or convolution of the spring should not, as mentioned earlier, be touched.

The next step is to fit the spring to the stud. It is convenient to secure the stud to the balance cock. File up a pin as was done for the collet and mark the pin so that when fitted tightly an equal portion of it projects from both sides of the stud. (Fig. 65.)

Before breaking the pin off hold the balance cock up for convenience of viewing and twist the pin until the spring is parallel with the underside of the cock. (Fig. 66.) When satisfied that the spring is flat break off the pin, as when pinning to the centre. Finally, press the pin home firmly with a pair of stout tweezers. (Fig. 67.)

After pinning the spring to the stud lay the balance cock flat on the bench and then place the balance spring on the cock with the centre of the collet *exactly* over the centre of the jewel hole. It is almost sure to be necessary to manipulate the outer coil of the spring so that the end will lead naturally between the index pins and into the hole of the stud, i.e., that the spring is not strained to one side. Figs. 68, 69, 70 should make this clear. That part of the spring which operates between the index pins must be concentric with the jewel hole, otherwise, as the index is moved the spring will be strained to one side or the other. This adjustment is most important with *all* springing.

If the spring is small in diameter—and there is nothing against this, within reason—to such an extent that the collet is well towards the stud, make a bracket in the spring, near to the stud, as in Fig. 71. By this

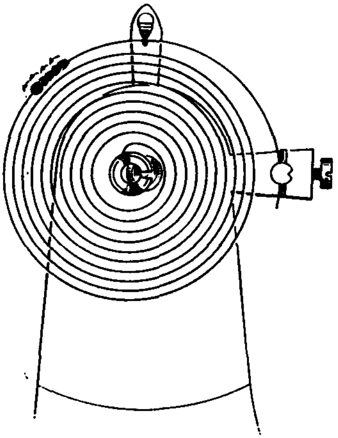


FIG. 68. *Method of manipulating spring to bend it towards the stud to make it central.*

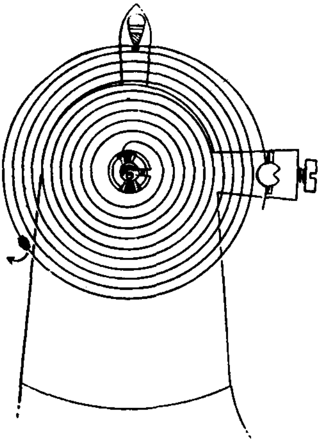


FIG. 69. *Manipulating spring to free it from index pin.*

means the outer coil is concentric with the balance jewel hole and the index pins will operate correctly and, at the same time, the convolutions of the spring will be correctly spaced, causing no undue side pressure on the balance staff pivots. Side pressure caused by the developing of the spring is a problem which has been the subject of much study and research by springers and timers through the ages and it is not yet completely solved. More will be said about this later.

Pick the balance cock up and observe that the spring is flat, that is, parallel with the underside of the cock. It will be necessary to hold the

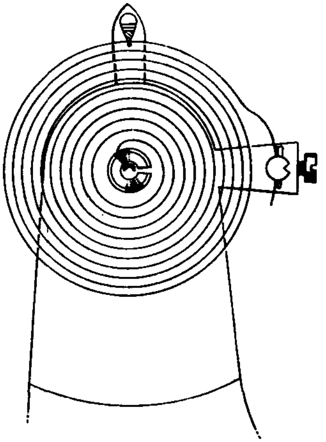


FIG. 70. *Method of forming outer coil of balance spring when the spring is small.*

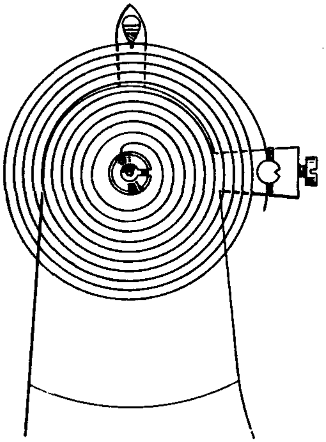


FIG. 71. *Balance spring central: free of stud and index pin and collet central over balance jewel hole.*

cock at right angles to the bench because the collet will bear the spring down and it will not be possible to judge if the spring is flat. Hold as in Fig. 66. Next, fit the spring on to the balance and assemble it into the movement without the pallets. Give the movement a twist to start the balance vibrating fairly vigorously. Watch closely the flatness of the spring. It may be advisable to unscrew the stud and adjust it to the correct height. The hole in the stud should be the same distance from the balance cock as the hole in the collet. This is not always easy to gauge but it can be observed by the balance spring itself. For instance, if the spring tends to cup or become concave it is an indication that the stud is too high (Fig. 72), and needs lowering; conversely, if the spring

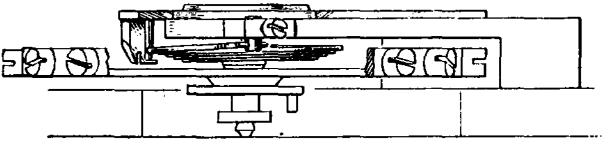


FIG. 72. *Balance spring stud too high.*

tends to be convex it indicates that the stud wants lifting (Fig. 73). It may be correct to push the stud into the balance cock as far as possible. When satisfied that the stud is the correct height make the final adjustments by bending the spring, if necessary, to make flat. If the spring rises up from the stud as in Fig. 74, it may be because the stud does not fit

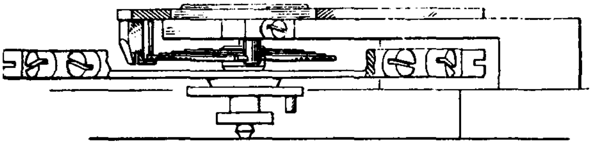


FIG. 73. *Balance spring stud too low.*

well and firmly in the balance cock; try loosening the stud slightly and push the stud to one side, away from the index pins, so to bring the spring down. Should this be of no avail then with the inside of one of the limbs

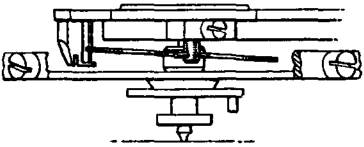


FIG. 74. *Balance spring needs to be bent down at the stud.*

of the tweezers bend the spring down slowly and carefully by pressing on the spring so that the bend is at the stud hole (Fig. 75).

Springs Should be Flat

If the index is fitted with a boot (guard) it will be necessary to open this first. If the spring is parallel, say from the stud to the index pins, but cocks up under the balance cock, it is necessary to twist the spring slightly as indicated by the arrow and the dots. (Fig. 76). The spring should not be twisted where the index pins operate, because when moving the index, especially if the pins are close as they should be, the spring

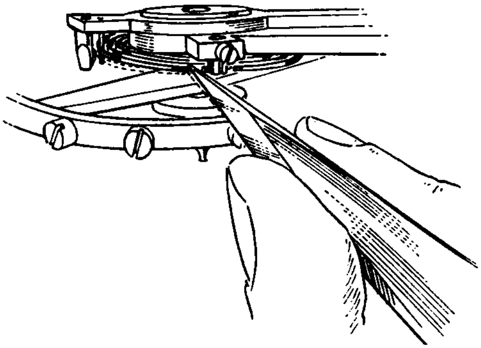


FIG. 75. *Bending balance spring down at the stud.*

will be distorted. It takes some little practice to get a spring nicely flat. All adjustments should be slight; it is better to make several alterations rather than one bold one and that too much, so that the spring has to be bent or twisted back again. It may be some little consolation to know that want of flatness, provided the spring is perfectly free, and does not touch anything, does not materially affect the timing—but a spring which is not flat shows want of craftsmanship.

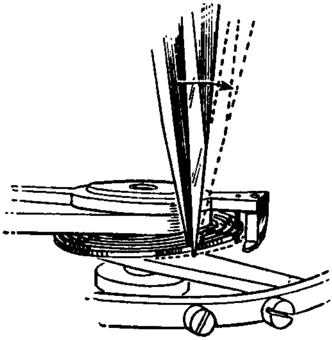


FIG. 76. *Twisting balance spring up to make parallel.*

Centring, however, is another story; a spring out of centre does affect timing adversely and it is not difficult to understand why. Want of an even flow from the centre affects the development of the spring and the errors so created can be multitudinous and unpredictable, as the arc of vibration of the balance varies. If the arc were constant—which is practically impossible—the errors also would be constant and adjustments could be made to correct them. Therefore, apart from craftsmanship, a true centre is essential for fine timekeeping.

Centre of Gravity

The centre of gravity of a balance spring is constantly changing and for it to be out of truth in the round aggravates this error. The fact that

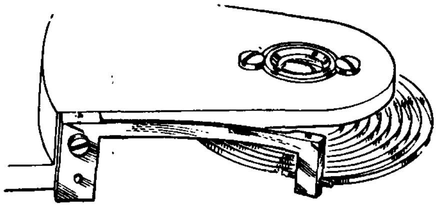


FIG. 77. *Resilient balance spring stud.*

the spring is fixed at the outer terminal causes the change of position of the centre of gravity, and the overcoil (Breguet) alleviates this to a great extent. Many years ago this "fault", or error, was recognised and Fig. 77 shows a method to overcome it to some extent. The spring is pinned to a stud which is in itself a spring and thus relieves some of the side pressure

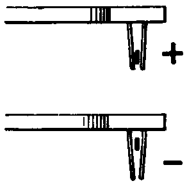


FIG. 78. *Index pins not parallel: Top: + dial up. Bottom: – dial down.*

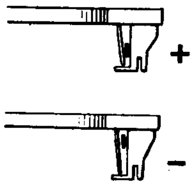


FIG. 79. *Same conditions as Fig. 78, but index fitted with foot.*

on the balance staff as it develops, when the balance is vibrating. This drawing is made from an English free sprung movement made about 1875. Although a flat spring, it follows the principle of the Breguet spring.

Having got the spring flat, make the balance vibrate fairly well and watch the centre closely. The spring should develop smoothly with no kicks or jerks. For a spring to be well centred, the third or fourth coil from the centre should remain stationary with the remaining coils " breathing " in and out evenly.

The correct adjustment of the index pins or curb pins, as they are sometimes called, is vital. First they should be parallel so as to ensure the same conditions, dial up and down. If the pins are as in Fig. 78 the watch should be correct to time dial down and losing when dial up. The remedy is to bend the pins as shown in Fig. 80. If the index is fitted with a boot and one pin as in Fig. 79 the pin is usually at fault; in any

FIG. 80. *Index pins bent to make parallel.*

FIG. 81. *Index pin, with boot, bent to make parallel.*

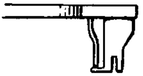


FIG. 82. *Index pins with foot.*

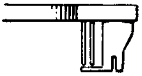
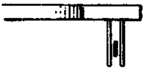


FIG. 83. *Shows effect of twisted balance spring between the index pins.*

FIG. 84. *Balance spring should be parallel between parallel index pins.*



case, it is the more readily corrected. The pin is bent as shown in Fig. 81. Sometimes an index with two pins is also provided with a boot as in Fig. 82. In such an instance either pin is bent as circumstances dictate; it may be advisable to bend one or other of the pins so as to ensure that the spring is not thrown out of round, or it may be obvious that one of the pins is bent.

Another point to observe with index pins is that the portion of the spring operating between the pins, no matter where the index is moved, should be upright and not twisted when manipulating the spring to get it flat. The objection to this is that if the pins are close the spring will be made out of flat as the index is moved. Furthermore, if the pins are open, one edge, maybe the top or lower edge only, will touch the pins, which will result in making the spring tremble (Fig. 83). The full width of the spring must contact the pins as in Fig. 84. The ideal position apart from the index pins is that they should be close with no perceptible play of the spring. At the same time the spring *must* be quite free, otherwise if the pins grip the spring, moving the index will cause the spring to buckle. If the pins are opened very slightly, say with an oiler, not sufficiently to bend them so that the pins are opened permanently, the spring should " beat " between them evenly, and upon releasing the pins the movement of the spring should stop.

More will be said about index pin adjustment further on, when discussing the less permanent systems of positional timing adjustments.

CHAPTER FIVE

FITTING A BREGUET BALANCE SPRING

THE INITIAL stage of fitting a Breguet spring is precisely the same as fitting a flat spring with the exception that the outer coil is pulled up.

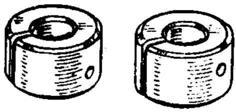


FIG. 85. *Left: Balance spring collet for Breguet spring. Right: balance spring collet for flat spring.*

The collet for a Breguet spring has the hole for the spring drilled lower than is the case of a collet for a flat spring (Fig. 85). The reason is that more room or height is required for the Breguet spring and therefore the hole in the collet is drilled lower down, also, pinning to the stud is not dependent upon the position of the collet hole, as it is for a flat spring.

Having reached the stage where the spring is pinned to the collet and the balance is vibrating to time, proceed to form the overcoil. There are two or three methods which can be employed. One, the spring is bent up and then down to make the overcoil parallel to the body of the spring at comparatively sharp angles.

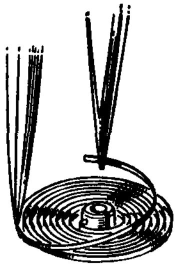


FIG. 86. *First pull up when forming the overcoil.*

Making the overcoil parallel to the body of the spring at comparatively sharp angles was a system once favoured by the Americans, although not so popular today. In another system, the overcoil is formed by pulling the outer coil of the spring up and then manipulating it down to make it parallel. This system is employed in most Swiss watch factories at the present time, and is the one recommended. Other systems, however, will also be explained here.

The forming of an overcoil is quite simple, but considerable practice

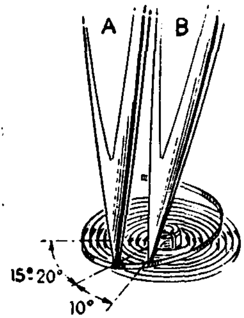


FIG. 87. *Position of tweezers when making first bend down to make overcoil parallel with body of spring.*

is needed to obtain the correct form with a minimum of manipulation of the spring. It is desirable to bend or twist the spring as little as possible: to bend weakens the spring, it disturbs the molecular structure of the material and could cause it to fracture and break. The actual shape of the curve will be referred to later, after first considering pulling up the overcoil.

To do this, place the spring flat on the bench and hold the outer

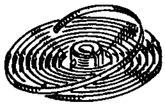


FIG. 88. *Appearance of overcoil after first bend down.*

coil at 280° to 300° from the end with a fairly stout pair of tweezers, i.e. not the very fine tweezers. Do not dig the tweezers into the bench, but hold so that the points just touch the bench. With another pair of tweezers, grip the end of the spring and pull straight up, fairly high, so that the appearance is as Fig. 86. Modern self-compensating springs

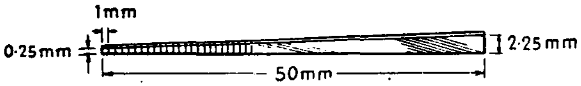


FIG. 89. *Gauge to measure the height of the overcoil.*

being softer than hardened steel ones, the pull up must be gentle. Experience alone can teach the force necessary. The overcoil, where it leaves the body of the spring, must be free before it is bent inwards, otherwise the start of the overcoil will rub the body of the spring during vibrating. To ensure that this cannot happen, allow about 15° to 20° before starting to bend down to make the overcoil parallel. In other words, grip the spring with the fairly stout tweezers about 15° to 20°

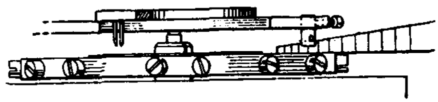


FIG. 90. *Method of using the height of overcoil gauge.*

from where it first starts to bend up. The height of the overcoil is now determined. Before pulling up the spring for the overcoil, fit the stud into position in the balance cock, place the balance with spring in the movement and screw on the balance cock.

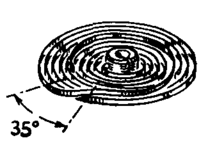


FIG. 91. *Indicating the angle occupied by the knee or bracket to form the overcoil.*

A Simple Gauge

Make the simple gauge (Fig. 89) from a piece of thin brass sheet about two inches long. The thickness of the metal can be 0·25 mm. and the width at the narrow end 0·25 mm. widening out to 2·25 mm. at the wide end. File lines on the gauge as illustrated are at about 1 mm. intervals. Slide the gauge between the balance and the balance cock,

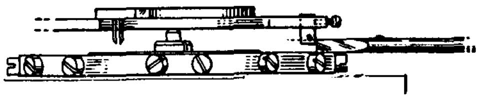


FIG. 92. *The blade of a watch screwdriver used in place of the gauge, Fig.* 89.

near the stud, and observe the number of divisions from the narrow end of the gauge to the lower part of the hole in the stud (Fig. 90). Say the number is five, this gives the height the overcoil is to be. The height of the hole in the collet is, as a rule, equal to the height of the balance rim from the arm of the balance. The gauge is an arbitrary measure, but it does give the approximate height of the overcoil so that the watchmaker now knows where to bend to make the overcoil parallel.

Then, with another pair of tweezers, grip the spring about 10° from the first pair of tweezers, as in Fig. 87. Hold the tweezers *A* firmly and press tweezers *B* downwards until the overcoil is parallel to the body of the spring and the spring looks as shown in Fig. 88.

It has been mentioned that the actual bend, or knee, to bring the overcoil up should occupy 15° to 20° and it will be observed that if the

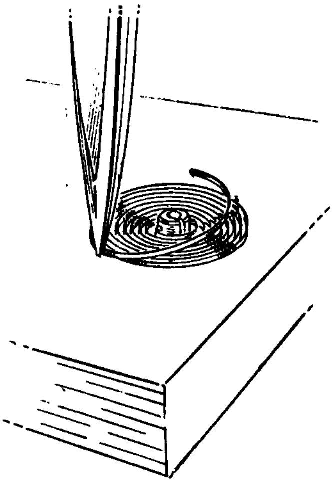


FIG. 93. *Method of forming overcoil by gripping spring with tweezers and digging into soft wood.*

instructions given are carried out, the angle of the knee will be approximately 35° (Fig. 91).

Another method employed by some watchmakers is to select one of the three or four watch screwdrivers used and to employ the width of the blade as shown in Fig. 92. An almost infallible guide, much used in

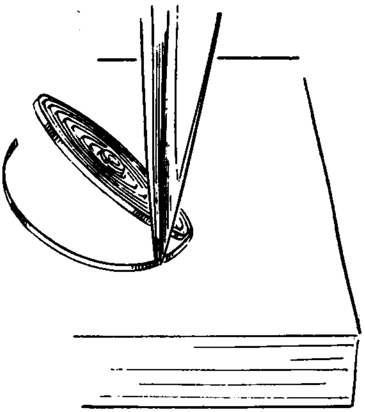


FIG. 94. *Second bend to make overcoil parallel with body of spring*

Switzerland when springing a modern watch, is to make the overcoil the same height as the collet, that is, with the spring pinned to the collet to make the top edge of the overcoil level with the top of the collet (Fig. 92). Then bend the overcoil up, if necessary, so that the end of the spring

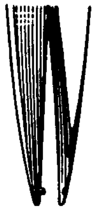


Fig. 95. *Special tweezers for forming overcoil.*

will enter the hole in the stud. It is preferable, if anything, for the overcoil to be a little too low rather than too high. If the overcoil is too high it is difficult to bend it down (so that it is free of the underside of the balance cock) and still keep the body of the spring flat. Once the overcoil has been formed, it is a major job to reduce its height.

Fitting a Soft Spring

A method of forming the overcoil, recommended only for soft springs is to place the spring flat on a piece of softwood, such as the handle end of an

Figs. 96 *and* 97. *Overcoil before forming the curve.*

emery buff, grip the spring at the point where the first bend is to be made with a fairly stout pair of tweezers held perfectly upright and dig down into the wood (Fig. 93). This will cause the free end of the spring to

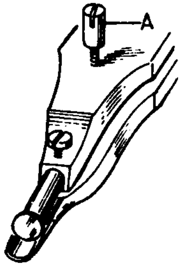


Fig. 98. *Tweezers for forming a sharp knee or bracket.*

bend upward. The extent of the bend is controlled by the amount of pressure applied to the tweezers. As before, the angle of the bend should be 35° (see Fig. 91). This method of bending is much more severe than the method previously explained, so the spring should be bent the exact angle required.

FIG. 99. *Appearance of knee of overcoil when the tweezers as Fig.* 95 *are employed.*

Now turn the spring over so that the bent-up part is underneath. Grip the spring again with the stout tweezers held at about 15° to 20°. from the first bend and dig into the wood so as to bring the remaining part of the spring parallel with the body of the spring as in Fig. 94.

Fitting a Stiff Spring

When a stiff spring is to be fitted, such as some of the stronger steel springs and the large springs made of self-compensating alloys as would be used for pocket watches, tweezers with a pin running through the ends are employed (Fig. 95), because it may not be possible to grip the spring tightly enough to prevent slipping when digging into the wood. The finished overcoil, before forming the curve, should look similar to that in Fig. 96.

The other method of forming the overcoil is to use the tweezers shown in Fig. 98. These can be purchased in various sizes to suit—as near as possible—the curve of the spring. At the point where the first bend up is to be made, grip the spring under the plunger and screw to make tight. Screw in the large screw *A* so that the concave part of the tweezers cannot contact the round tube part. Apply pressure to both limbs of the tweezers to close them together and then slowly unscrew the screw *A* until the concave part makes contact with the spring and starts to bend it by making it curve round the tube end. The amount of the bend depends, to a great extent, upon the withdrawal of the screw *A*. A spring can, in this manner, be bent at right angles to the body of the spring, but this is not either necessary or desirable. A very sharp bend can disturb the molecular structure of the metal from which the spring is made. It is advisable to adhere to the angle of 35° as in Fig. 91.

The second bend is made in a similar manner, moving the tweezers along about 15° from the first bend. An overcoil formed in this manner has the appearance shown in Fig. 99. Before using these tweezers on a spring for the first time it is advisable to try them on a spare piece first. The concave under the spring will cause the end to bend upwards.

When satisfied that the bend up is satisfactory, that the knee is correct and the overcoil parallel, a start can be made to form the curve.

There are one or two mathematically correct curves, and the one most used is that devised by the mathematician, L. Lossier.

L. A. Breguet, the great horologist, who was born near Neuchâtel, Switzerland, but spent practically the whole of his life in France, was the inventor of the overcoil, and springs with an overcoil are known as Breguet springs. Breguet realised that, with a flat spring, side pressure was exerted on the staff pivots as the spring wound up while the balance was vibrating and it occurred to him that if the last coil was lifted up and secured above the plane of the body of the spring, the overcoil would give and thus relieve the side pressure. Since then, Professor M. Phillips, a French mining engineer, was persuaded by a French watchmaker to make a mathematical research into the problem. It was apparent that there was a change of curvature in the overcoil during vibration, which could produce want of isochronism. Phillips devised many curves complying with a formula he had laid down to overcome lack of isochronism and it is upon Phillips' formula that subsequent curves were designed.

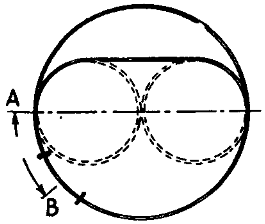


FIG. 100. *Phillips' curve, suitable for a watch with index pins as for a flat spring.*

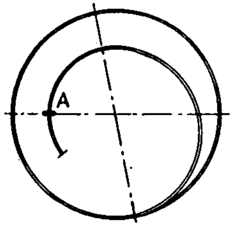


FIG. 101. *Lossier curve.*

The most popular of Phillips' curves is shown in Fig. 100. It will be seen that this is a convenient curve when the index pins are at a distance from the centre equal to the radius of the body of the spring. In other words, it is suitable for a Breguet spring used in a watch designed for a flat spring. Lossier designed a curve (Fig. 101) to the formula of Phillips and it is this curve which is used more than any other today.

When designing a new watch calibre, it is possible to arrange that the distance of the index pins from the centre is such that it will conform to the design of the curve as made by Lossier. In these circumstances the factories in Switzerland have prepared plates upon which are engraved the exact size of the body of the spring and the curve for a particular calibre of movement.

It should be mentioned here that Lossier followed the work of Grossmann. The curve we in England know as the Lossier is known as the Grossmann curve in Switzerland.

Should the student wish to draw his own curve he should proceed as follows:—

The Lossier curve: draw a circle the diameter of the balance spring,

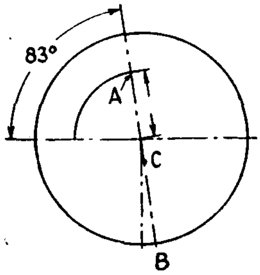


FIG. 102. *Method of drawing the Lossier curve.*

then draw an arc of 83°, with a radius equal to the distance of the index pins from the centre of the index (Fig. 102). Draw a line from one end of the arc through the centre of the outer circle to meet the outer circle, and then bisect the line, shown *AB*, which gives the centre *C*. Using this centre *C*, draw a semi-circle to connect *A* to the outer circle at *B*. This gives the Lossier curve.

The design as evolved by Lossier decrees that the 83° segment shall be 0·67 of the radius of the outer circle as in Fig. 101. But we are dealing with a watch where the index pins determine this radius and, for practical purposes, this dimension must be used when designing the index, one would drill for the index pins at 0·67 of the radius of the balance spring. For a free sprung watch, this point would not arise.

It is better to form a curve as near theoretically correct than just to make a curve without regard to any rules. The result when timing in positions must be better.

To produce a Phillips' curve, draw a circle the same diameter as the balance spring. In that circle, draw two more with diameters equal to the radius of the main circle (Fig. 100), and connect the two circles with a straight line.

The watch repairer, as he handles many calibres, cannot resort to the convenient system of engraved plates. The alternative is to make use of other systems. One is to make the curve as near as possible, using one of the series of springs illustrated here (Figs. 103-126). If the index pins are at a distance equal to the diameter of the body of the spring (i.e., the pins are so planted that they would embrace the outer coil of the spring, as for a flat spring) then the Phillips' curve, as illustrated can be employed. In either case, the Lossier or the Phillips, select the drawing to suit the diameter of the body of the spring in hand and work to that.

As shown in Fig. 102, the diameter of the termination of the outer curve for the Lossier is 0·67 of the radius. If the index pins are at about half the diameter of the body of the spring, curve the spring shown in the appropriate drawing, making a slight alteration to the termination so that it will pass between the index pins and eventually to the stud.

The second method to employ, where the radius of the index pins does not suit the Lossier curve and it is necessary for the curve of the overcoil to be correct, is the set of drawings in Figs. 104 to 126. The curves comply with Phillips' conditions and the length of the actual curve from the knee to the index pins is 240°. The spring was pulled up at about 280° to 300°. By the time the knee has been made, and allowing for the length of the spring from the index pins to the stud and the formation of the curve, the length of the curve will be about 240°. (Fig. 102.)

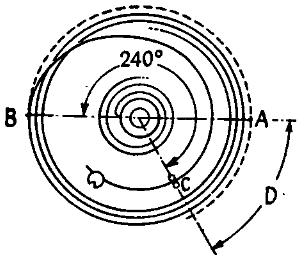


FIG. 103. *Diagram for use in conjunction with the drawings on pages* 69-85.

Now measure the distance of the index pins from the centre (a) and multiply by 100; next measure the radius of the body of the spring at the point where the curve will be formed (R) and divide this into the index pin figure thus $\frac{100 \times a}{R}$. The result will give the number of the drawing to be used for the curve. Say the distance from the centre to the index pins is 15 mm. and the radius of the spring is 25 mm. $\frac{100 \times 15}{25} = 60.$

Select a group of drawings to suit the diameter of the spring in hand (after it has been counted and broken down to size) and from the group select number 60 and bend the curve as shown. To be theoretically correct, the spring should be embraced by the index pins at *exactly* the point shown in Fig. 101 *A*, i.e., the termination of the theoretical curve.

This does not allow for any alteration of the index; in practice, an almost impossible condition. To be absolutely accurate the watch should be "free sprung" (no index). Then the spring, after the formation of the curve, should be placed in a projection microscope to throw an enlarged image of the actual spring on to an enlarged drawing of it with its correct terminal curve. The two curves may then be compared, and we *might* get somewhere near perfection. These drawings will be referred to at some length later.

For commercial purposes, especially with wrist watches, the Breguet spring is not necessary. The object of the Breguet spring is to make the vibrations of the balance isochronous, i.e., beat equal time for different amplitudes. This means that the long or full arc of vibration of the balance and the short or small arc vibration should be in the same time, so that if the rate of the watch is observed at several periods during 24 hours, say at 2 or 3-hour intervals, the rate or error will be constant.

For instance, say a watch is gaining 6 seconds in 24 hours, i.e., 0·25 seconds per hour. If the readings are made at two-hourly intervals, then the first 2 hours' running will show 0·5 seconds; the second 2 hours, 1 second; and the third 2 hours, 1·5 seconds; and so on, regularly building up until the last reading at 24 hours will show 6 seconds fast. But for general purposes, such close timekeeping is not required. The flat spring will not respond satisfactorily to such tests. With the advent of the automatic winding watch, however, the lack of isochronism is not so acute, because the mainspring is at approximately the same tension for the greater part of the day, while the watch is worn—and the arc of vibration of the balance is therefore practically constant.

If a watch is to be submitted to a severe test such as the Craftsmanship Test at the National Physical Laboratory, Teddington, or an Observatory Test at Geneva or Neuchâtel, then a Breguet spring is essential.

It should be noted that the majority of wrist watches made in Switzerland at the present time are fitted with flat springs and, a very high percentage of the watches presented to the Official Testing Bureaux of Switzerland are fitted with flat springs. Many such watches pass with the "With Mention" Certificate. The specification is shown at the end of this chapter.

A recent report shows that of 50,931 watches submitted, 50,596 were wrist watches.

To obtain good timing there are other conditions to be observed such as the correct point of attachment at the collet, which will be described in the section on "Positional Adjustment". Now to return to the question of overcoils.

Should it not be considered necessary to make a correct curve to suit the existing position of the index pins, use one of the drawings illustrated. The method is to place the spring (after it has been counted and broken down to size) on the drawing where the outer circle is the same size as the spring and bend the overcoil of the spring to follow the curve. For bend-

Continued on page 85

THEORETICALLY CORRECT RIGHT-HAND TERMINAL CURVES FOR PRACTICAL USE

These Phillips' Terminal curves for Breguet hairsprings are taken from a table of the same name compiled by M. Bossart, Directeur de l'Ecole d'horlogerie, Soleure, in 1955, and are reproduced by kind permission of the publishers, Editions Horlogeres, Chs Rohr et Cie, Bienne, Switzerland.

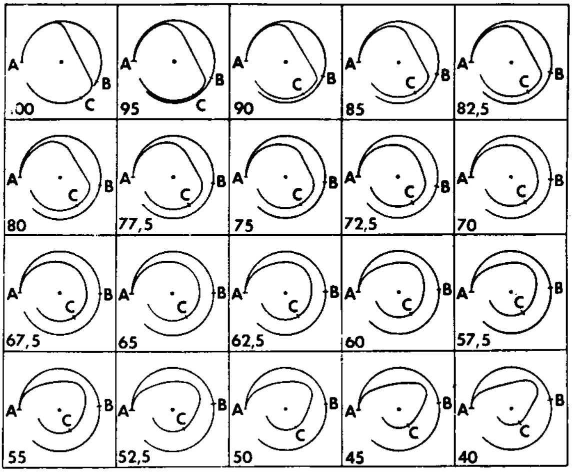


FIG. 104.

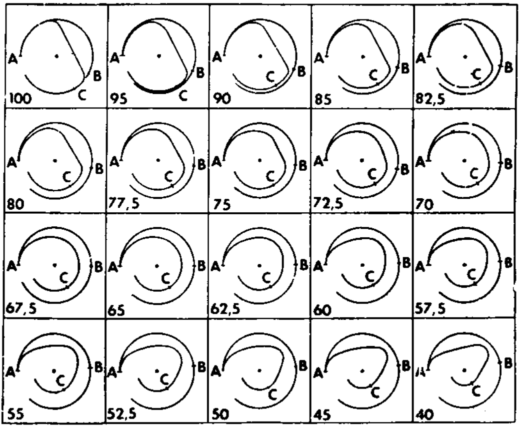


FIG. 105.

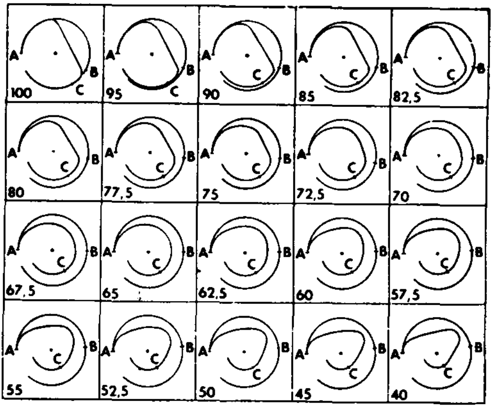


FIG. 106.

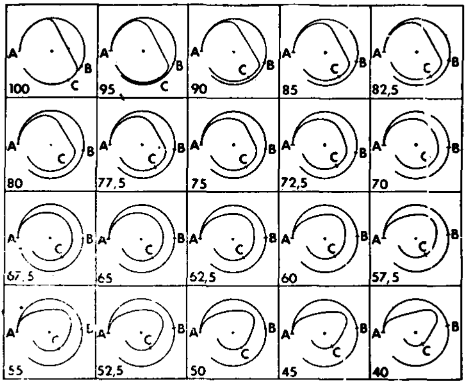


FIG. 107.

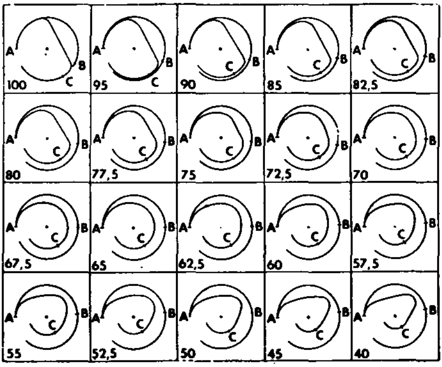


FIG. 108.

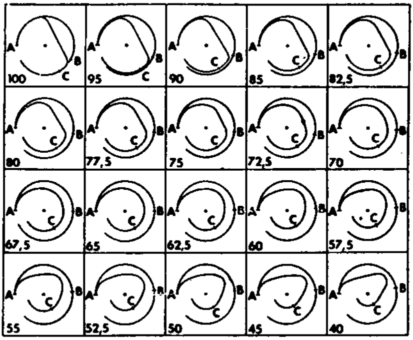


Fig. 109.

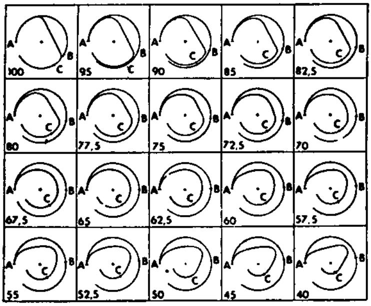


Fig. 110.

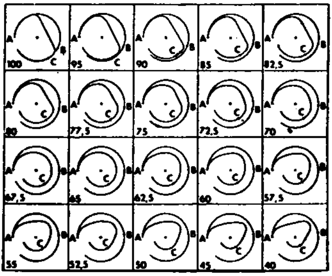


Fig. 111.

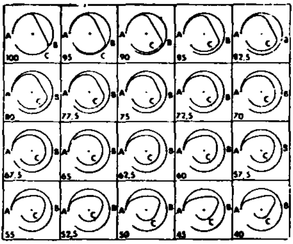


FIG. 112.

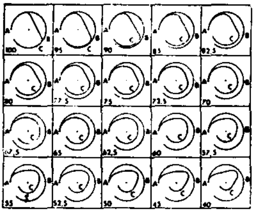


FIG. 113.

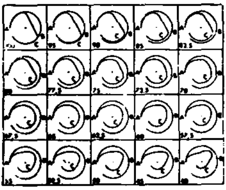


FIG. 114.

THEORETICALLY CORRECT LEFT-HAND TERMINAL CURVES FOR PRACTICAL USE

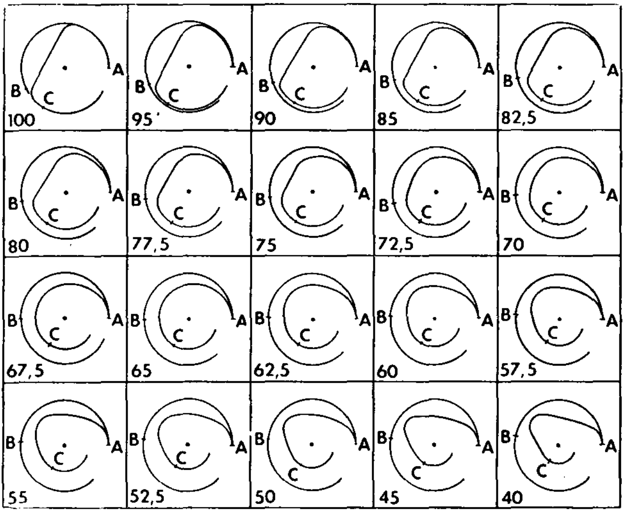


FIG. 115.

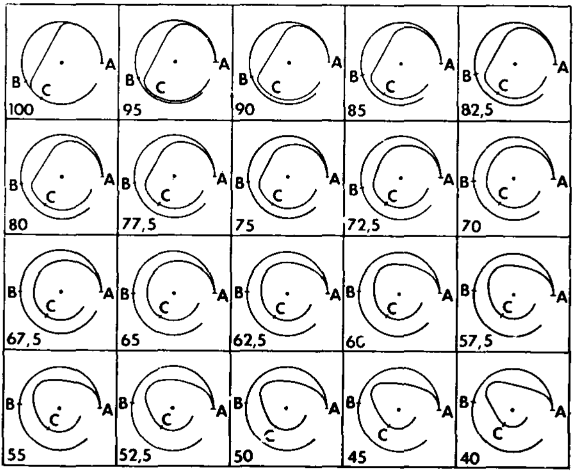


FIG. 116.

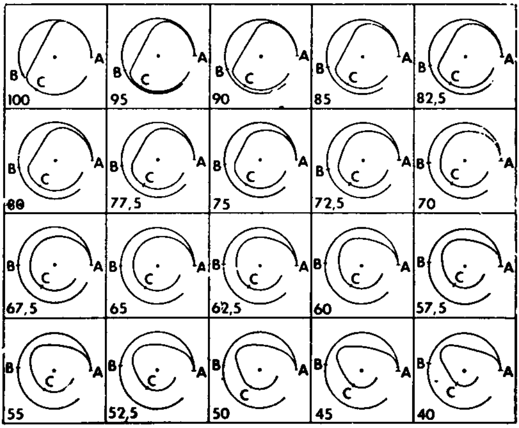


FIG. 117.

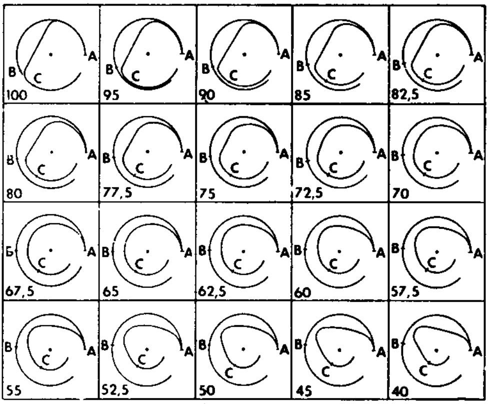


FIG. 118.

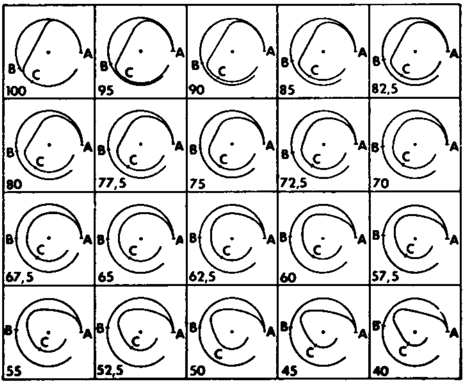


FIG. 119.

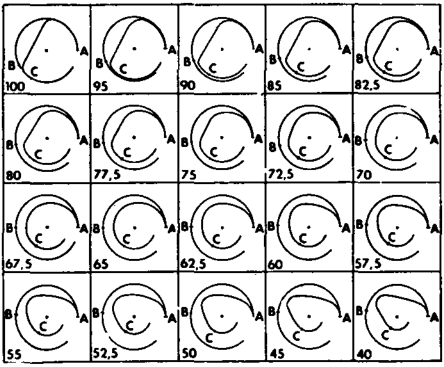


FIG. 120.

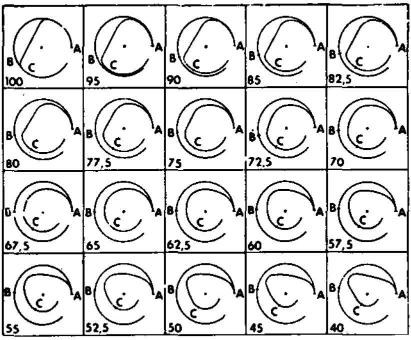


FIG. 121.

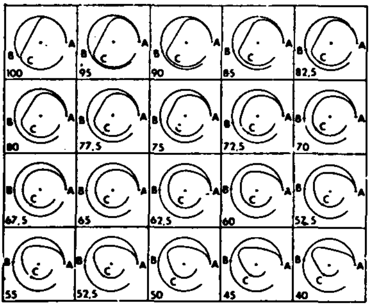


FIG. 122.

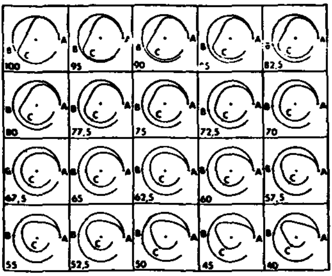


FIG. 123.

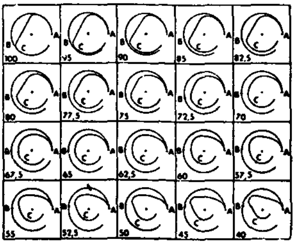


FIG. 124.

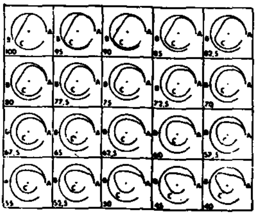


FIG. 125.

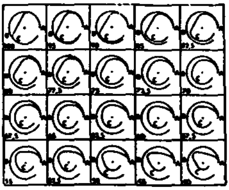


FIG. 126.

ing, use the tweezers shown in Fig. 127. These can be purchased with various sized ends.

When bending a spring to follow a curve the tweezers being used should be held perfectly upright, otherwise the spring will not only bend towards the centre but the overcoil will be bent up or down according to how the tweezers are held out of the perpendicular. Before using, make

FIG. 127. *Special tweezers for putting the curve into the springs.*

sure the jaws of the tweezers are the correct way round, with the solid end on the inside of the curve and the hollow end outside. The curve of the end of the tweezers should be a little smaller than the natural convolution of the spring. The extent of the bend depends upon the amount of pressure applied to the tweezers. Starting from the point *A* Fig. 128, run the tweezers along the spring towards the free end giving many very light nips on the way. This method will persuade the spring to form a gentle smooth curve with no nicks or sharp bends. At no time should the tweezers be pressed hard together, as this would make a sharp bend which is difficult to remove.

Practise first on an unwanted piece of spring; it takes some little practice to become proficient.

During the forming of the curve constantly place the spring over the drawing to ensure all is well. While manipulating the spring to form the curve, the overcoil may have been thrown out of flat because the curved tweezers were not held perfectly upright. This can quite easily happen and, if the overcoil is out of flat, it must be corrected, as already explained. Again, after making flat, place over the drawing to ensure that the curve has not been altered. It may well be necessary to adjust both the curve and flatness several times before a satisfactory result is obtained, for instance, twisting the spring to make the overcoil parallel has an adverse effect when using the curved tweezers.

When the curve is completed, we can pin it up in the stud. Prepare a pin as was done when fitting the flat balance spring. Fit the balance spring on to the balance. Screw the stud on to the balance cock, place the balance in the frame and screw the cock into position. It is convenient when fitting a new balance spring to have the bottom plate quite free of other parts, and just retaining the balance with spring and balance cock.

Carefully lead the balance round so that the end of the balance spring approaches the index pins. To be correct it should pass between the pins and eventually to the stud. As the weight of the spring is inclined to bear down the end, it may be necessary to lift the end slightly so that it will enter the hole in the stud. The spring should project a little way through the stud as Fig. 65.

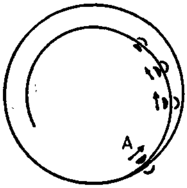


FIG. 128. *Forming the curve of the overcoil with special tweezers.*

Fit the pin into the hole, in the same direction as the spring entered. Press the pin in a fair distance so that it grips the spring but not tightly yet. Examine the spring for flatness and if necessary the spring can be made flat by twisting the pin. When you are satisfied that all is in order, break the pin off. The pin is finally pressed home with a stout blunt-ended pair of tweezers, as in Fig. 67.

Finally check over, make the balance vibrate fairly vigorously and observe that the coils of the spring open and close smoothly, that the spring at the centre develops from the collet without jerking, and that the overcoil is perfectly free of the underside of the balance cock. Also observe that the overcoil, where it bends up and over the body of the spring, is free of the body of the spring; this is most important. Move the index from one side to the other, to its full extent, and observe, the overcoil carefully, *there must be no movement of the spring at all*: the segment of the spring where the index pins operate must be concentric with the centre of movement of the index, i.e., the balance jewel hole. Having fitted the balance spring we now proceed to time the watch. For the vast majority of watches it may suffice to first regulate to a reasonable rate but many of the better quality watches are timed in positions and the procedure is discussed in the following pages.

TABLE 2

OFFICIAL CONTROL BUREAU FOR THE RATING OF WATCHES INSTITUTED IN THE TOWNS OF BIENNE, LA CHAUX-DE-FONDS, LE LOCLE, LE SENTIER ST.-IMIER.
EXTRACTS FROM THE RULES

Art. 1. The official Control Bureau instituted in the Towns of Bienne, La Chaux-De-Fonds, Le Locle, Le Sentier and St.-Imier, receives watches from the factories, to be submitted to various tests, to establish their rate.

Art. 5. The rate of each watch is compared every 24 hours, with the rate shown by a precision Clock checked every day from the Astronomical and Chronometrical Observatory at Neuchâtel.

Art. 9 & 14. DURATION AND TYPE OF TESTS.

POCKET WATCHES			8-DAY WATCHES			WRIST WATCHES		
Duration	Position	Temperature	Duration	Position	Temperature	Duration	Position	Temperature
2 days	PU	room	7 days	PU	room	2 days	PL	room
2 ,,	PL	,,	1 day	PL	,,	2 ,,	PU	,,
2 ,,	PR	,,	1 ,,	PR	,,	2 ,,	PD	,,
2 ,,	DD	,,	1 ,,	DD	,,	2 ,,	DD	,,
2 ,,	DU	,,	7 days	DU	,,	2 ,,	DU	,,
1 day	DU	ice	1 day	DU	ice	1 day	DU	ice
1 ,,	DU	room	1 ,,	DU	room	1 ,,	DU	room
1 ,,	DU	oven	1 ,,	DU	oven	1 ,,	DU	oven
2 days	PU	room	2 days	PU	room	2 days	PL	room
—			—			—		
15 days			22 days			15 days		

TABLE 3

LIMITS TO OBTAIN A BULLETIN

	POCKET WATCHES				8-DAY WATCHES		WRIST WATCHES	
	Without mention	With mention	Special without mention	Special with mention	Without mention	With mention	Without mention	With mention
Mean daily rate in five positions	−4+10	−2+5	−4+12	−2+6	−5+10 VH & HH	−2, 5+5 VH & HH	0+15	0+15
Mean variation in the daily rate in five positions	3	1, 5	4	2	7 VH & HH	3, 5 VH & HH	7	4
Greatest variation between two consecutive daily performances in the same position	5	2, 5	6	3	10	5	12	8
Difference between flat and pendant	±10	±5	±12	±6	±10	±5	—	—
Greatest difference between the average daily performance and one of the performances in five positions	±12	±7	±15	±9	±20	±12	±26	±16
Variation in degrees centigrade	±0, 5	±0, 25	±0, 7	±0, 35	±0, 5	±0, 25	±1, 4	±0, 8
Secondary error	±9	±4, 5	±11	±5, 5	±9	±4, 5	—	—
Repeat of rate	±5	±2, 5	±8	±4	±10	±5	±14	±8

TABLE 4

BUREAUX OFFICIELS
DE CONTRÔLE DE LA MARCHE DES MONTRES
Institués dans les Villes de
BIENNE, LA CHAUX-DE-FONDS, LE LOCLE, LE SENTIER, ST.-IMIER

Trials for wristlet watches (Suisse). **The office of** Le Locle
hereby delivers the watch rate Certificate No. 193945 **for the movement No.** F43076/32116
Chronometre: **Diam. of movement:** 26·4 mm. **Height:** 3·9 mm.
Escapement: Ancre. **Hairspring:** Auto Compensateur. **Balance:** Rolex.

MONTRES ROLEX S.A.,
Bienne—Geneve.

1951	Days	Daily Rate	Variation of the Daily Rates	Position	Temperature
November	14	+ 8		Vertical, Crown left	Of the testing room
,,	15	+ 7	1	,,	,,
,,	16	+ 3		Vertical, Crown up	,,
,,	17	+ 5	2	,,	,,
,,	18	0		Vertical, Crown down	,,
,,	19	+ 2	2	,,	,,
,,	20	+ 6		Horizontal, dial down	,,
,,	21	+ 8	2	,,	,,
,,	22	+15		Horizontal, dial up	,,
,,	23	+18	3	,,	,,
,,	24	+16		,,	In the refrigerator + 2° C.
,,	25	+17		,,	,,
,,	26	+17		,,	In oven of testing room + 32° C.
,,	27	+ 5		Vertical, Crown left	,,
,,	28	+ 6		,,	,,

Mean daily rate in the different positions .. +7·2

Mean variation .. .. 2·0

Maximum variation .. .. 3·0

Summary

Greatest difference between the mean daily rate and any individual rate .. .. +10·8

Variation of rate per 1° centigrade .. .. +0·03

Rate resuming .. .. − 1·5

Le Locle, 28th November, 1951.

(Sgd.)..............................DIRECTOR.

A rating certificate showing especially good results.

CHAPTER SIX

POSITIONAL TIMING

BEFORE ATTEMPTING to time in positions the rate of timekeeping of the watch must be brought to within fairly close limits.

The signs used when timing in positions are as follows:—

Dial up D.U. or ——

Dial down D.D. or ═══

Crown or Pendant up P.U. or T

Crown or Pendant right P.R. or ⊣

Crown or Pendant left P.L. or ⊢

Crown or Pendant down P.D. or ⊥

All vertical position signs refer to the position of the watch when viewed *from the movement side*, i.e., not from the dial.

Wrist watches are tested D.U., D.D., P.D., P.L., P.U. and not as a rule P.R. If, however, it is required to test P.R., then P.L. is deleted. Watches are not tested in four vertical positions. If the watch is to be worn on the right wrist it is adjusted in the P.R. position. The reason for the pocket watch vertical positions is that the watch is normally P.U. when in wear in the waistcoat pocket and it may fall to the right or left but never P.D. Wrist watches P.D. when in wear with the arm hanging down, P.R. when resting the arm on the arm of a chair or table, or arm outstretched, and P.U. as when head resting on hand. See Figs. 129 to 131.

It is practically impossible to wear a wrist watch P.L. on the left wrist unless the watch is worn on the inside of the wrist. If the watch is worn on the right wrist then testing P.R. is necessary and P.L. is deleted, and the watch is then P.U. when arm hanging down and P.D. when hand is up. For ordinary commercial purposes wrist watches are tested D.U. and P.D. and it is generally understood in Switzerland that when a watch is specified " Point of attachment (Point d'attache) 30 seconds " it means that the position of the point of attachment of the balance spring at the collet is correct and that the watch shall be regulated to within

30 seconds in each of the D.U. and P.D. positions. The point of attachment will be referred to later.

Another test is D.U., D.D., P.U., P.R. and P.D., and if the watch responds to the specification as laid down by the Official Bureaux, Switzerland, and obtains a certificate " With Mention " the watch is entitled to be known as a " chronometer". This is rather ironical because the grade

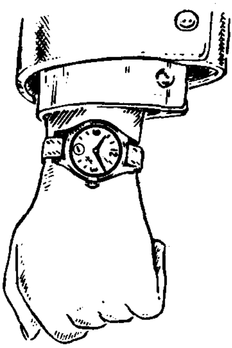


FIG. 129. *Pendant down, arm hanging down.*

" chronometer " was intended to include only watches of high quality, that is watches which were capable of complying with the specification, but without regard to their construction. I have nothing against the pin-pallet escapement when it is associated with low-priced watches, but

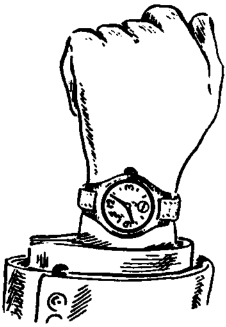


FIG. 130. *Pendant up, elbow resting on table or chair arm.*

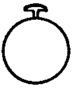
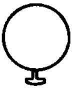
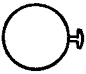
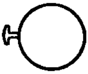
such watches have passed the tests satisfactorily and are therefore, by the standards set by the Swiss, entitled to be marked chronometers !

The word " chronometer", in these circumstances has lost its significance and can be a misleading designation. In England, previously, the term chronometer (time measure) applied to the detent escapement,

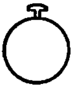
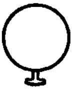
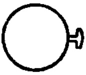
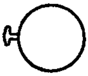
TABLE 5

For left-hand coiled hairsprings, view from movement side

Influence on time with watch in following positions:

Position of point of attachment with balance at rest				
	Slight error	Slight error	Fast	Slow
	Slight error	Slight error	Slow	Fast
	Fast	Slow	Slight error	Slight error
	Slow	Fast	Slight error	Slight error

For right-hand coiled hairsprings, view from movement side

				
	Slight error	Slight error	Slow	Fast
	Slight error	Slight error	Fast	Slow
	Slow	Fast	Slight error	Slight error
	Fast	Slow	Slight error	Slight error

an escapement of very high precision, as used in a scientific instrument on board ship to register the time of day and enable the longitude of the ship to be calculated, generally known as a box or marine chronometer.

Point of Attachment

In the latter part of the 19th century, Jules Grossman of Le Locle, Switzerland, discovered that the position of the development of the balance spring from the collet with relation to the vertical position of the watch

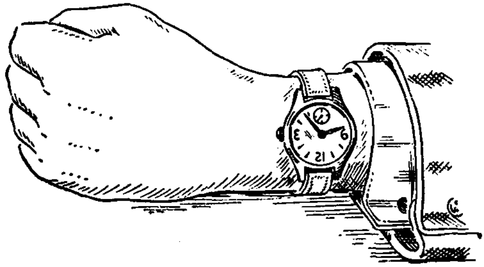


FIG. 131. *Pendant left, arm on table.*

influenced its rate. At first the theory was recognised as applying to watches fitted with the Breguet balance spring. In comparatively recent years it has been applied to flat balance springs with excellent results.

With a pocket watch the rule is that the spring shall develop up from a line drawn at right angles to a line parallel to a vertical line drawn through the centre of the pendant (Fig. 132). If these conditions are compiled with, a lesser difference of rate between the vertical positions and between the horizontal and vertical positions will be experienced. The greater difference will be found in the P.D. position, a position in which a pocket watch is not worn.

Influence on Timekeeping

With a wrist watch the requirements are different. The watch is worn mostly when in the vertical position, P.D., therefore the spring develops up when the pendant is down (Fig. 133). While this is correct theoretically, it is not correct in practice because the influence of the escapement and the side pressure on the balance pivots requires the point of attachment to develop from a different position. With a flat hair-spring, the side pressure on the balance staff pivots is considerable as the spring develops. If, for instance, a Breguet balance spring has a theoretically correct inner and outer terminal, it would be nearly correct, but there would still be the influence of the escapement to consider. With a flat balance spring the poise of the spring itself must be considered in addition to the influence of the escapement.

The chart on page 92 shows the point of attachment of a flat balance spring where the influence of the escapement has been taken into consideration and the drawings are as viewed from the back of the watch, i.e., the movement facing the viewer. Springs developing from the collet to the right and left are shown and the chart is a useful guide when examining the point of attachment of a spring which has already been fitted to a watch.

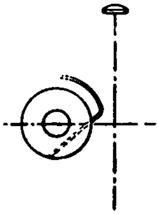


FIG. 132. *Position of point of attachment at centre for a pocket watch.*

The positions of a wrist watch are not as stable as those for a pocket watch; most people wearing a pocket watch wear it in the left-hand waistcoat pocket and often with a chain which keeps it practically always P.U. or slightly to the right, which is to the left when viewed from the movement side. On the other hand hardly two people wear a wrist watch alike. Some hold their hands down (P.D.) a great deal while others, following a sedentary life, hold theirs at right angles to the body (P.R.) but it is agreed that P.D. predominates, so that for the majority of wrist watches the normal vertical position is P.D.

Find the Pinning Point

To obtain the correct pinning point of the collet of a wrist watch, proceed as follows: Draw a line on the board paper at right angles to the edge of the bench, and then another line at right angles to that (Fig.

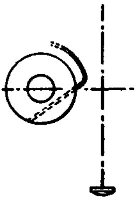


FIG. 133. *Position of point of attachment at centre for a wrist watch.*

134). Make a small indentation at the intersection of the two lines and place the movement, with the balance cock in position, flat on the drawing with the centre arbor on the indentation. Turn the movement so that the winding shaft is at the bottom (for a wrist watch) and in line with the vertical line. Mark on the paper the position of the index pins—with the index central—and draw a line, passing through the centre line, parallel to the first line drawn and the index pins mark (Fig. 135).

On this drawing place the colleted balance spring, now fitted to the balance, and hold the balance with the lower pivot in the indented mark

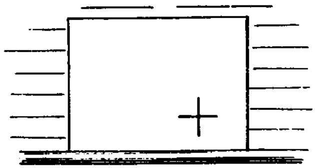


FIG. 134. *First drawing on board paper to find point of attachment.*

and turn it so that the centre of the spring develops up from the horizontal line (Fig. 133). While doing this, make sure the balance is held parallel to the bench. It is convenient to hold the balance with the thumb and first finger of the left hand, and to grip a coil of the spring with a pair of tweezers along the index pin line at *A* (Fig. 136).

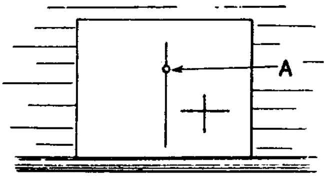


FIG. 135. *The position of index pins A, count point marked.*

If it is necessary to move the count point (the point where the spring is held during counting—i.e. the position *A* where the index pins are—to keep the position shown in Fig. 132), it means that the balance is not fast enough and a complete coil of the spring must be taken off, or if too fast, a complete coil taken in to slow it. If the counting is to be done on a vibrat-

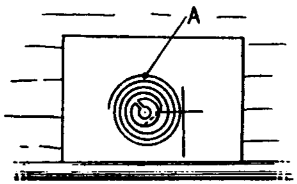


FIG. 136. *Balance spring in position to determine count point A and correct point of attachment.*

ing tool, then the spring must be fitted up between the clamp at the point selected with the tweezers. It will be seen that during the counting or vibrating, a time may come when a complete coil, one way or the other, may have to be considered. Sometimes, perhaps, a half-coil from the count point will be the correct spot. Having arrived at the correct count point, or the nearest to it, break away the unwanted spring. It is important to remember that the count point is where the index pins will operate, so an additional length of spring from the index pins to the stud

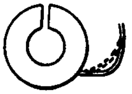


FIG. 137. *How the spring is bent when "shortening".*

plus a short piece to go through the stud and a little over will be required. To bring the balance to close time it is either weighted—to make the time slower—or lightened—to make the time faster.

During the counting it is advisable to check the balance on the

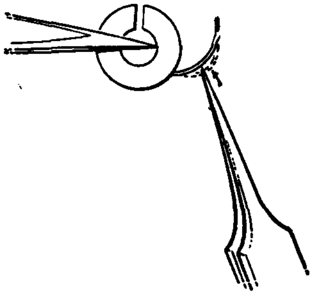


FIG. 138. *Method of "shortening".*

drawing occasionally to make sure that the count point is on the index pins line. If this is observed, the pinning point will be correct.

The position of the index pins with relation to the stud is, with the majority of modern watches, 90° (quarter of a circle). Little of this portion of the spring is used except when the index is moved towards

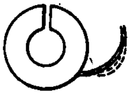


FIG. 139. *How the spring is bent when "lengthening".*

slow. To be correct, the index should not be moved by the adjuster. Any alteration necessary to bring the watch to time should be done by altering the weight of the balance only. On no account should the index pins themselves be used to bring the watch to mean time.

Pin the Balance Spring

Now proceed to pin the balance spring to the stud as explained earlier in this book. When this is completed, hold the movement in a vertical position, with the winding shaft down, and examine to see that the pinning point of the collet is correct, i.e. that it develops up from an imaginary line drawn horizontally and at right angles to a vertical line drawn parallel to a line passing through the winding button as Fig. 133.

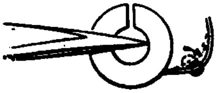


FIG. 140. *Method of "lengthening".*

The watch is now ready for testing. It must be appreciated that the conditions that have just been described are more or less theoretical, because very many errors creep in, in practice, and it is during the test—the running of the watch—that these errors are brought to light. To start with, testing D.U., D.D. and P.D. will be considered. If there is a considerable difference between the D.U. and D.D. positions, the error should be obvious, i.e., want of freedom of the balance spring. It may be free D.D., but touches the underside of the balance cock when D.U.; or

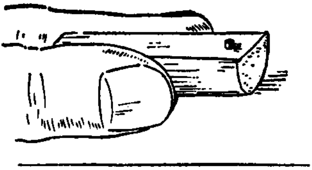


FIG. 141. *Pin in pith.*

conversely, it may be free D.U. and rubs the balance arm when D.D.

The ends of the balance staff pivots may be faulty; there may be loose end stones, faulty jewel holes, or similar troubles; the error then may be due to some mechanical fault. There are some instances where the diameter of the staff pivots and /or the radius of the ends of the pivots are not the same and, say, the watch loses D.U. more than it should (so much depends upon the quality of the watch to estimate the amount of the

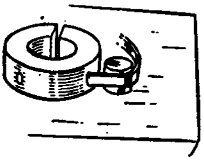


FIG. 142. *Bending the spring.*

difference), when compared with the D.D. position. Slightly lowering the spring towards the balance—not sufficient to be perceptible—will lift the balance a little and relieve the top pivot when in the D.U. position and at the same time will increase the pressure of the bottom pivot when in the D.D. position. By creating a slight error in one and easing in another the two horizontal positions can be made more or less equal.

When the two flat positions, i.e. D.U. and D.D., are correct or nearly so, we can start testing in the vertical positions P.D.

Variations in Different Movements

Say the watch is −10 seconds in the D.U. position (and practically the same D.D.) and −5 seconds in the P.D. position. This means that the P.D. error is −15 seconds, when compared with the D.U. position, indicating that the point of attachment is too high. Upon examination, the pinning point may appear correct as in Fig. 133 and it will be dis-

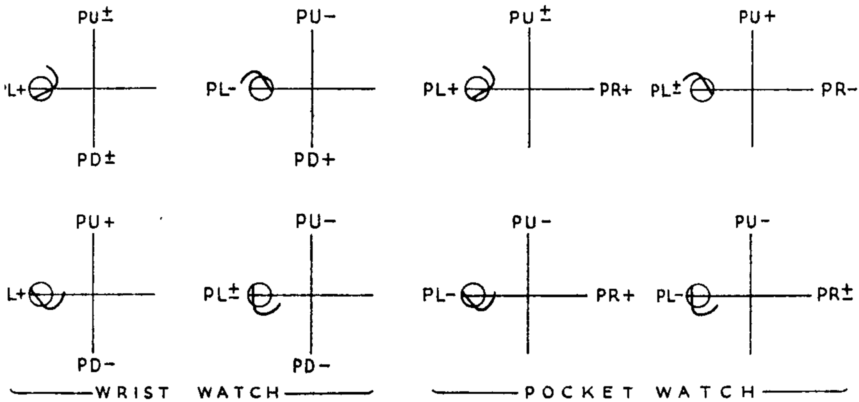


FIG. 143. *How the point of attachment of the balance spring affects the rate of the watch.*

covered with experience that the visual correct pinning points may not be correct in practice for a particular movement. Once the correct pinning point is established for a certain calibre of movement, all movements of that calibre will require the same position of the point of attachment and they will respond in a similar manner.

There are two methods of correction. One is to alter the position of the pinning point, subsequently making the balance heavier or lighter to bring it to time again; the other is to make an adjustment in the centre of the spring. Here again, there are two methods of doing this; one is to bend the spring as shown in Fig. 137 and the other is to unpin the centre, cut a little away, and re-pin. Referring to Fig. 137 it will be observed that the bending takes place at the straight part of the spring: the original convolution of the spring is not touched. A convenient method of bending is as follows:—

Place the spring flat on to a piece of white paper on the bench. Hold the collet down fairly firmly with a pair of tweezers and with one limb of another pair of fine tweezers straddled across the collet and one limb bearing on the side of the spring, press together. This will bend the straight part of the spring a little, as in Fig. 138. Hold the fine tweezers perfectly upright so as not to put the spring out of flat more than can be helped. After this adjustment it will be necessary to make the spring true in the centre again and also to test for flatness. The alteration made will be as shown by the dotted line in Fig. 137, and it is known as "shortening the spring".

Another method of bending is as follows: Cut a piece of pith about 1½ inches long in half. Take care in cutting so as to keep the surface flat. File up a brass pin to a diameter that fits between the collet and the spring. Cut off a short length of the pin and press it into the pith (Fig. 141). Over this place the spring as in Fig. 142. Straddle a pair of fine tweezers with one limb on the collet and the other on the spring and close together gently to bend the spring; this method gives great control and assures that there will be no sharp bends or kinks. These adjustments are known in Switzerland as "retouching", one of the most highly skilled of jobs.

If, on the other hand, the difference between D.U. and P.D. is +15 sec., the spring must be bent down as in Fig. 139 to make it longer. It is bent in a similar manner (Fig. 140). The chart (Fig. 143) will help in deciding in which direction the point of attachment is to be altered. Sometimes it is necessary to bend the convolution of the spring to make it run true; but very close to the upright part.

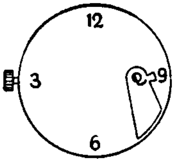


FIG. 144. *Finding the correct pinning point.*

Final timing in positions is a matter of trial and error and a lot of time can be expended upon it obtaining good, close results.

If the watch is to be tested P.U. and P.L., the procedure is the same and the adjuster must decide how he is to balance the errors, i.e. the difference of rates between the various vertical positions.

Another method of finding the correct pinning point is as follows: First observe the correct position as indicated in Fig. 133 and place the watch in that vertical position. Say, for instance, it is necessary to turn the watch so that the figure 2 on the dial is in the pendant down position. Note the difference of the error in time when compared with the D.U. position. Then turn the watch through an angle of 90° to the left, i.e. one o'clock on the dial is in the bottom or P.D. position, and note the time error again. With the figure 8 on the dial in P.D. position, and note the time error once more. All tests are of 24-hour duration. This way the position of the point of attachment can be altered to discover, by the error in timekeeping, the correct pinning point. The necessary adjustment to the centre, as explained earlier, should then be made.

Rotating the diagram (Fig. 144) will make this clear. As illustrated, the pinning point is theoretically correct, but this condition may not suit the particular watch in hand. (For purposes of illustration the balance cock and the balance spring collet are drawn out of proportion.)

It is almost impossible to get the vertical rates all the same, and

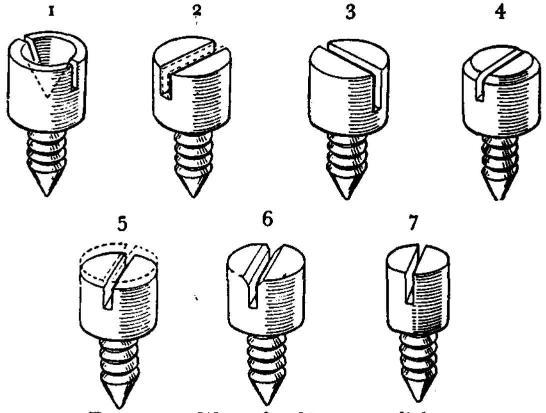


FIG. 145. *Ways of making screws lighter.*

tolerances are allowed in all official tests. There are other methods, or one might almost say dodges, for correcting positional errors, and a section has been devoted to this.

A useful table to compute a 24-hour error (taken from " Watchmaker at the Bench ": Pitman) is given on page 101.

If, for example, a watch has been running for 8 hours and the error is $+ 3\frac{1}{2}$ seconds, $3 \cdot 5 \times 3 = 10 \cdot 5$ seconds gaining. If after $7\frac{1}{2}$ hours the error is + 5 seconds, this would give $5 \times 3 \cdot 2 = 16$ seconds gaining.

There are several ways of reducing the weight of balance screws. Most of the factories in Switzerland making what may be termed moderately priced watches, stand on no ceremony over this job; they just file a piece off the screw. With the repairer rating just one watch, a little more care may be taken and the following methods are suggested, depending upon the amount of metal to be removed. In Fig. 145, numbers 1, 2, 3 and 6 screws could be lightened while the screw is in the balance, but it will be necessary to remove the balance from the movement and the spring from the balance, because it is advisable to repoise the balance after reducing the weight of the screws.

The tool best suited for this purpose is the one illustrated in Fig. 146, which chamfers the head of the screw as in No. 1 of Fig. 145. In the same tool a flat-ended cutter can be used to reduce as No. 5. For Nos. 4

TABLE 6

H. Min.	Multiple	H. Min.	Multiple	H. Min.	Multiple	H. Min.	Multiple	H. Min.	Multiple
0 15	96·00								
0 30	48·00	10 —	2·4	20 —	1·2	30 —	0·8	40 —	0·6
0 45	32·00	10 30	2·286	20 30	1·171	30 30	0·787	40 30	0·593
1 —	24·00	11 —	2·18	21 —	1·142	31 —	0·774	41 —	0·586
1 30	16·00	11 30	2·087	21 30	1·112	31 30	0·762	41 30	0·579
2 —	12·00	12 —	2·00	22 —	1·09	32 —	0·75	42 —	0·572
2 30	9·6	12 30	1·92	22 30	1·066	32 30	0·738	42 30	0·565
3 —	8·00	13 —	1·846	23 —	1·043	33 —	0·727	43 —	0·558
3 30	6·857	13 30	1·778	23 30	1·021	33 30	0·716	43 30	0·552
4 —	6·00	14 —	1·72	24 —	1·00	34 —	0·706	44 —	0·545
4 30	5·33	14 30	1·655	24 30	0·98	34 30	0·696	44 30	0·539
5 —	4·8	15 —	1·6	25 —	0·96	35 —	0·686	45 —	0·533
5 30	4·364	15 30	1·548	25 30	0·941	35 30	0·676	45 30	0·527
6 —	4·00	16 —	1·5	26 —	0·923	36 —	0·666	46 —	0·522
6 30	3·692	16 30	1·454	26 30	0·906	36 30	0·657	46 30	0·516
7 —	3·43	17 —	1·412	27 —	0·889	37 —	0·649	47 —	0·510
7 30	3·2	17 30	1·371	27 30	0·873	37 30	0·64	47 30	0·505
8 —	3·00	18 —	1·33	28 —	0·857	38 —	0·632	48 —	0·5
8 30	2·823	18 30	1·297	28 30	0·842	38 30	0·623	48 30	0·495
9 —	2·67	19 —	1·263	29 —	0·828	39 —	0·615	49 —	0·489
9 30	2·526	19 30	1·231	29 30	0·814	39 30	0·607	49 30	0·485

Table of multiples to calculate daily errors from errors over shorter periods of time.

TABLE 7

Total Error	1 m.	2 m.	3 m.	4 m.	5 m.	6 m.	7 m.	8 m.	9 m.	10 m.
Days Run	s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.
2	30	1 0	1 30	2 0	2 30	3 0	3 30	4 0	4 30	5 0
3	20	40	1 0	1 20	1 40	2 0	2 20	2 40	3 0	3 20
4	15	30	45	1 0	1 15	1 30	1 45	2 0	2 15	2 30
5	12	24	36	48	1 0	1 12	1 24	1 36	1 48	2 0
6	10	20	30	40	50	1 0	1 10	1 20	1 30	1 40
7	9	17	26	34	43	51	1 0	1 9	1 17	1 26
8	7	15	22	30	37	45	52	1 0	1 7	1 15
9	7	13	20	27	33	40	47	53	1 0	1 7
10	6	12	18	24	30	36	42	48	54	1 0
11	5	11	16	22	27	33	38	44	49	54
12	5	10	15	20	25	30	35	40	45	50
13	5	9	14	18	23	28	32	37	42	46
14	4	8	13	17	21	26	30	34	39	43
15	4	8	12	16	20	24	28	32	36	40
16	4	7	11	15	19	22	26	30	34	37
17	4	7	11	14	18	21	25	28	32	35
18	3	7	10	13	17	20	23	27	30	33
19	3	6	9	13	16	19	22	25	28	32
20	3	6	9	12	15	18	21	24	27	30
21	3	6	9	11	14	17	20	23	26	28
22	3	5	8	11	14	16	19	22	25	27
23	3	5	8	10	13	16	18	21	23	26
24	2	5	7	10	13	15	17	20	22	25
25	2	5	7	10	12	14	17	19	22	24
26	2	5	7	9	12	14	16	18	21	23
27	2	4	7	9	11	13	16	18	20	22
28	2	4	6	9	11	13	15	17	19	21
29	2	4	6	8	10	12	14	17	19	21
30	2	4	6	8	10	12	14	16	18	20

Table to calculate the daily error of a watch from an accumulated error

and 7, the screw must be removed and fitted up in the lathe to turn and reduce the diameter of the screw or to turn a bevel. The slot of the screw is deepened with a slitting file as shown in No. 3, while the screw is in the balance and held between the first finger and thumb. The edges of slot No. 6 are filed while held in a similar manner.

The tool shown in Fig. 147 can be used when it is necessary to reduce weight and it is not required to repoise the balance, since the balance does not have to be removed from the balance cock.

In some factories in Switzerland an electrically-operated screw-reducing tool is used, where the amount of metal removed is controlled. The same amount can be removed from two opposite screws, and the poise of the balance is not affected; further, the swarf (metal removed) is extracted automatically. In these circumstances the balance is not removed from the movement, but such an appliance is not at the disposal of the watch repairer.

The table (page 102), taken from an American journal, was compiled by C. T. Higginbotham. It forms a ready calculation of the daily error of a watch. Fractions of a second have not been considered and the calculations are to the nearest second. Accumulated error can be very deceptive. A wearer may use the watch for, say, 30 days and then find that the watch is 9 minutes slow, an appreciable amount. But when the error is reduced to seconds per day, i.e. 18 seconds per day, it is not quite so

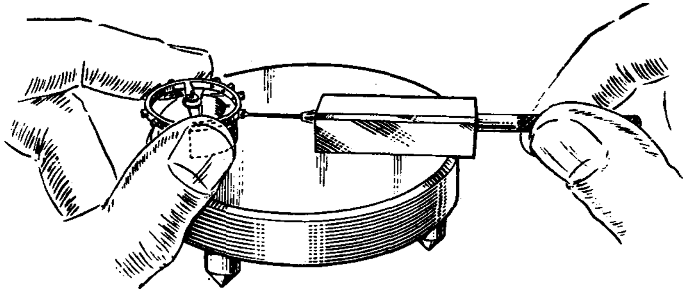


FIG. 146. *Tool for chamfering screw heads.*

alarming; further, the watchmaker can better estimate the amount of adjustment necessary when considering 18 seconds per day than 9 minutes in 30 days.

To find the daily error, check across the top of the table (page 102) to find the minutes gained or lost. Then go down the column underneath this figure to the row giving the Days Run. This figure will be the seconds (or minutes and seconds) lost or gained in 24 hours.

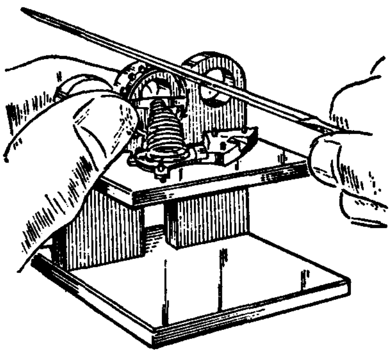


FIG. 147. *Tool for use without removing the balance from the balance cock.*

For a greater total error than is shown in the table, add the results of two or more columns together, i.e. for 23 minutes total error add the results of column 10 (twice) and column 3, or columns 10, 8 and 5. For an odd 30 seconds, average the results from the columns, both sides of the required figure, i.e. for 6 minutes 30 seconds take the average of 6 m. and 7 m.

CHAPTER SEVEN

FURTHER CONSIDERATIONS WHEN FITTING A SPRING AND OBSERVING THE POINT OF ATTACHMENT

THE VAST majority of watches in wear at the present time are worn on the wrist and are therefore subject to more or less violent jerks. The balance spring best able to stand up to shocks is the flat spring (with no overcoil terminal). With the flat spring it is possible to arrange so that the spring cannot become " caught up " by paying particular attention to the curb pins with some system of protection, such as a boot, where the top ends of the cub pins are covered over so that the spring cannot jump out.

Whatever the system, it should be carefully designed and finished so that if, as the result of an excessive jerk, the second coil of the balance spring is jerked under the first coil it will slide back into its normal position again, unassisted manually. If the boot is correctly shaped and finished with a perfectly smooth surface, the spring cannot catch up. But if the boot is designed so that the lower part is bigger than the top part, i.e. it is not tapered towards the bottom, the second coil of spring could be held once it had been jerked into that position. Also, if the surfaces of the boot are left rough and with burrs, the spring could still be held whatever the shape of the boot.

With this possibility as regards the boot in mind and, observing the same precautions with the stud to which the spring is fitted, it is well nigh impossible for the spring to catch up, no matter how violent the treatment

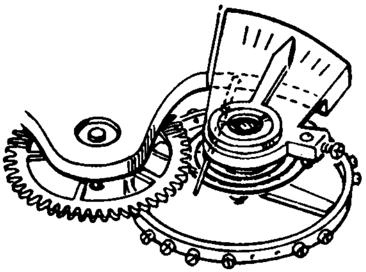


FIG. 148. *Pin fitted as a guard.*

of the watch. There is perhaps an exception to this and that is where the spring is jerked over the centre wheel: this rarely happens but if it does the remedy is to fit a long pin to act as a guard.

The method is quite simple. Drill a hole in the balance cock foot opposite to the index pins and at a height so that the pin fitted into it is free of the top of the spring as Fig. 148. File up a long pin almost parallel and well burnish it with the flat burnisher, fit firmly into the hole and cut to length, round and burnish the end. Bend the pin towards the centre wheel.

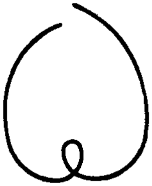


FIG. 149. *Path of centre of gravity of balance spring.*

The same cannot be said for the Breguet or overcoil spring. It is difficult, and in any case not practicable, to fit a foot to the curb pins, and even if all precautions possible are taken as regards the curb pins and the stud there is still the real danger of the flat convolutions of the spring catching up in the overcoil itself. The observation is not imaginary, it does sometimes happen.

Where the flat part of the spring is large in diameter the risk is even greater and, in persistent instances, where the catching up prevails, a long

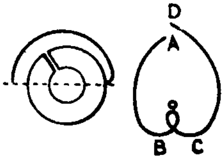


FIG. 150. *The pendant left position.*

outer curb pin can be fitted. The end of the pin is bent under the inner pin which is of normal length so that it closes the spring in between the pins and then passes over the flat convolutions for a length equal to about a third of the radius of the spring and parallel to it. If the watch is jerked the spring will be held in position, not a very satisfactory arrangement, but better than the spring catching up.

It will be seen therefore that there is much to be said in favour of the flat spring, especially for wrist watches. Comparing the virtues of the Breguet spring with the flat spring, quite apart from its practical application, the Breguet spring is more stable as regards rating. There is, if the overcoil is correctly formed to comply with Phillips' formula, practically no side pressure on the balance staff pivots as the spring coils up and uncoils when the balance is vibrating. For pocket watches the Breguet spring is good, but the advantages are far outweighed by the disadvantages when the watch is worn on the wrist.

The flat spring is standard practice today and the majority of the manufacturers of all qualities adopt the flat spring for wrist watches. With the adoption of the " point of attachment " to flat-sprung watches of, say, 12‴ and under it is possible to time in three vertical and two flat positions and to such a degree of perfection that the watch will pass the requirements of the Official Bureaux of Switzerland and obtain sufficient marks to enable the certificate to be marked " Especially Good ", or as the Swiss term it, " With Mention ".

The variation of rate from the horizontal to the vertical position and the variation of rate in different vertical positions is due to two causes. One is the change in position of the centre of gravity of the spring and the other is the side pressure of the balance staff pivots on their bearings. The side pressure is, as has been said, more pronounced with the flat

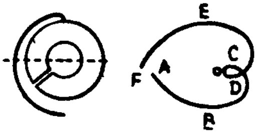


FIG. 151. *The pendant down position.*

spring but even with the Breguet spring, where this trouble is removed, provided the curve is accurate, there is side pressure due to the weight of the balance when in a vertical position.

The position of the centre of gravity of a balance spring describes a curve or path as Fig. 149 in the course of a complete vibration.

It is established by experiment that if the point of attachment of the spring develops up from a horizontal line which is drawn through the centre of the balance in any particular vertical position, the watch will show a gaining rate in that position.

The Official Bureaux of Switzerland require the watch to be tested in three vertical positions—pendant left—when viewed from the dial side of the watch—pendant up and pendant down. Fig. 150 shows the point of attachment when the watch is P.L., and as the centre of gravity passes from A to B the watch will gain, from B to O−, O to C−, and C to D+ with the over-all error +.

If the watch is now turned through 90° to P.D. as Fig. 151 the reading will be A to B, B to C−, C to D+, D to E+, and E to F−, with the over-all error of + or practically no error. Turn the watch through 180° as Fig. 152 to P.U. The readings are then A to B−, B to C+, C to D−, D to E−, E to F+ with the over-all error of + or practically no error. But if the watch is turned 95° to P.R. (Fig. 153), the readings are then A to B−, B to O+, O to C+, and C to D−, with the over-all error −. The watch is not worn in the position pendant right, provided it is worn on the left wrist.

The effects of the point of attachment just referred to were first observed by Grossmann, in his study of the development of the balance spring.

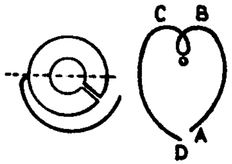


FIG. 152. *Pendant up position.*

When a flat balance spring is considered, the error due to side pressure, already mentioned, is more considerable than the error due to the purely positional error referred to.

Pierre LeRoy, the eminent French watchmaker, stated as the results of his studies that with each balance spring there is a certain length where all the vibrations are isochronous. David Glasgow, the English watchmaker, considered that if the spring makes complete turns, the condition of LeRoy is practically fulfilled.

If the spring has full turns from the point of attachment to the curb pins, the short arcs will be quickened, i.e. when in the vertical position the arcs are small when compared with the horizontal position. If the gain is in excess of that required, the point of attachment is brought nearer to the stud, that is, less than complete turns see Fig. 154.

It must be pointed out that each calibre of movement requires individual treatment to obtain the correct pinning point and that movements much larger than 12‴ the short arcs will be fastest when the coils of the balance spring make full turns.

To obtain the minimum error between one vertical position and another, i.e. P.L.—P.U.—P.D., the position of the point of attachment as Figs. 132 and 133 should be observed. (See page 94.)

Breguet Spring

If an overcoil balance spring has a theoretically correct inner terminal curve (Grossmann curve) and a theoretically correct outer terminal curve (Phillips' curve), the centre of gravity of the spring remains at the axis of rotation at all times, there is no side pressure of the balance staff pivots and if the conditions are complied with good results in the vertical positions will be obtained, provided that matters in connection with the pivots and jewel holes, as mentioned previously, are observed.

Where the spring is provided with a correct outer terminal curve only and an ordinary pinning at the centre, some account must be taken of side pressure, and there is also the lack of complete accuracy of the curve of the terminal; in other words, theory alone is not sufficient, adjustments to suit individual requirements must be made.

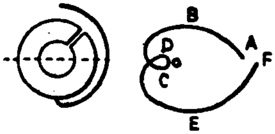


FIG. 153. *The pendant right position.*

Watches are to be seen with good records, yet the point of attachment not in the position one would expect, but in a position dictated by the requirements of the watch itself, maybe due to side pressure on the balance staff pivots, malformation of the curve of the overcoil, slight escapement faults, interference with the motion of the balance by the lever, etc., etc.

When making use of the point of attachment with the Breguet spring, the procedure is a little different from that for the flat spring. The counting point is first ascertained, and then with the help of the table given on page 109 we are able to select the curve, etc.

Say that, after the preliminary counting of the balance to determine the approximate size of the spring, it is found that the diameter of the spring is as Fig. 103, (see p. 67) and the distance of the index pins as calculated by the method explained on page 67 of this book is 67·5, then upon referring to the drawing 67·5 in Fig. 104, the outer curve (overcoil) of Breguet balance spring is given.

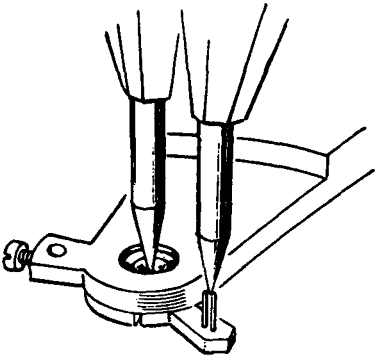


FIG. 154. *Finding the radius of the curb pins.*

There are two sets of curves, for right hand and left hand springs respectively.

In the table, the length of the overcoil, from the point B Fig. 103 (*see p.* 67) *where the curve commences to the count point A where the spring is embraced by the curb, or index pins, is* 240° *in all cases.*

The curves are lettered as follows: B is the point where the curve begins (note that the *pull-up point* is 15° farther back, therefore B is the position of the second bend (down) of the " knee "). A is the position of the count point *before* the overcoil is formed. C is the position of the count point *after* the overcoil has been formed. B is the *angle* through which the count point moves when forming the overcoil. It is, of course, the angle between the radius passing through A and that passing through C.

The table shown below gives the values of the angle D for each of the curves in the series of curves represented on pages 69 to 83.

TABLE 8

Terminal curve	a	Terminal curve	a	Terminal curve	a	Terminal curve	a
No. 100	32°	No. 80	49°	No. 67.5	59°	No. 55	66° 30′
„ 95	36° 30′	„ 77.5	52°	„ 65	60°	„ 52.5	67°
„ 90	39° 30′	„ 75	53°	„ 62.5	61° 30′	„ 50	67° 30′
„ 85	44° 30′	„ 72.5	55°	„ 60	65° 30′	„ 45	69°
„ 82.5	46°	„ 70	57°	„ 57.5	66°	„ 40	72°

The *number* of the curve has to be determined in each case; which is calculated as follows:

1. Find the radius of the curb pins by measuring from the centre of the balance cock jewel hole to the space between the pins. This can be done by using a watch depth tool with one centre in the jewel hole and adjusting the other centre until it is just over the space between the curb pins (Fig. 154), then transfer the depth tool to the millimetre gauge and note to the nearest tenth of a millimetre, the distance between the centres can be measured direct with the aid of a vernier gauge. Next find the radius of the spring at the count point. The number of the curve is then ascertained by multiplying the radius of the index pins by 100, and dividing the result by the radius of the count point. The quotient is the number of the curve of the overcoil required. If the balance spring is small in diameter a more accurate result can be obtained by taking the diameter of the spring at the count point and doubling the radius of the index pins.

Example. If the diameter at index pins is 5·4 mm. and diameter at count point 8 mm., then $\frac{5\cdot4 \times 100}{8} = 67\cdot5$; or if the radius at index pins is 2·7 mm. and radius at count point 4 mm., then $\frac{2\cdot7 \times 100}{4} = 67\cdot5$.

The number of the overcoil required is therefore 67·5. On consulting the table we find that angle D corresponding to the number 67·5 is 59°. The procedure in the case of a Breguet spring with *point d'attache* is then as follows:

The angle D is 59°. Place the spring on the degree chart Fig. 155 (which is, in effect, a protractor), and measure as follows. The completed curve = 240°, to this is added the 15° to form the knee, or uplift, to form the overcoil, and the distance from the index pins to the stud, which is usually 90°, plus say 5° for the pinning into the stud, making the total 240 + 15 + 90 + 5 = 350°. As the 90° estimated for the angle

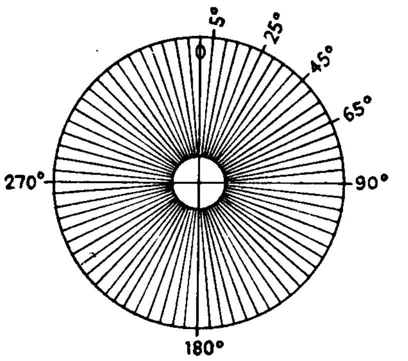


FIG. 155. *A degree chart for balance springs.*

from the pins to the stud is measured before the formation of the curve, the linear length of the spring will be less when the curve is formed, and to find this use the Chart Fig. 155. Say that the next result is 320°, allowing 60° for the distance beyond the curb pins to and through the stud. From the 320° we must take away the 60° (from the stud to the index pins) which leaves 260°. This is the count point. Turn the chart round so that the 260° point is on zero and then measure the 260° and mentally draw the radius line. It is on this line that the first pull up is made to form the overcoil. If the position is correct it will give the correct point of attachment and all is well and, if not quite correct, the balance is made heavier or lighter to bring it to time, but it is essential that the pull up is on that line. Then measure about 15° for the knee and start forming the curve as Fig. 104 number 67·5 and when the curve is formed the angle from B to C Fig. 102 will be 240° and the requirements of Phillips' formula are fulfilled. What has been done in effect is to hold the point of attachment in its correct position.

Another method is to lay the spring on the selected drawing, say, number 67·5, with the count point at B, and from the point A measure 15° for the knee and from this point make the first pull up. If this method is employed the question of the point of attachment must be adjusted afterwards. With practical work it may not be possible to measure degrees but by observing the chart, Fig. 155, 15° can be estimated.

We can then start timing, firstly to as near mean time D.U. as possible, and then D.D., P.D., P.R., P.U., for a wrist watch or D.U., D.D., P.U., P.R., P.L. for a pocket watch, making the necessary adjustments to the point of attachment as explained when dealing with the correct point of attachment of the flat spring.

It is a good rule, before starting to test in the vertical positions, with a flat or Breguet sprung watch—to make this test. Wind the mainspring up fully and observe the arc of vibration of the balance, say it is 1¾ turns, i.e., 270°: now test on the timing machine, D.U. and note its rate. Assume it is 10 sec. + in 24 hours. Let the mainspring down until the arc of vibration of the balance is 1 turn, i.e., 180° and test again on the machine D.U. To ensure that the vertical positions shall be good the difference between the fully wound and partly wound should be 10 sec fast, i.e., the rate when the arc is 180° should read +20 sec.

CHAPTER EIGHT

GENERAL NOTES ON SPRINGING AND TIMING

IT HAS been calculated by R. A. Fell that the errors of time due to the interference of the escapement amount to as much as 30 sec. per day and even more according to the quality of the watch. If the arc of vibration of the balance were constant at say 270° = 1¾ turns, the error is a loss of 9 sec. per day and if the arc falls off to 225° = 1¼ turns—when in a vertical position—the loss will be about 16 sec. per day. If to 190°—just over 1 turn—when in a vertical position after 24 hours running, which can quite easily happen, the loss will be about 30 sec. per day. The greater part of the error is compensated by regulation and adjustment but the condition is not constant, the arc of vibration of the balance is not constant.

Index or Curb Pins

An error is introduced by the index pins. It is necessary that the balance spring be free between the pins—there should be no perceptible play—and with freedom there must be some movement and here an error creeps in. Furthermore, where a stiff balance spring is employed, the pins themselves must give and this is accentuated when thin and long pins are used. Even with a weak spring and long thin pins, there must be some movement when the balance is vibrating. With a free-sprung watch there is no index error, but even so, this does not warrant the introduction of the free-sprung, with its attendant inconvenience when it is required to regulate a watch for mean time quickly.

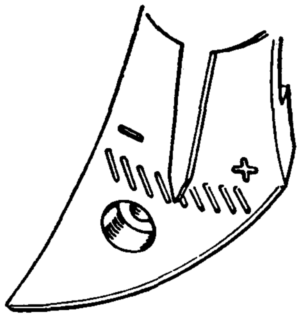


FIG. 156. *Index scale marked at an angle to aid setting the tail.*

Air Resistance

A. Gideon Thisell, formerly instructor with the Elgin Watch Co., U.S.A., has made an interesting experiment in connection with the air resistance to the balance, as is noted in this book *Science of Watch Repairing Simplified*. A watch was rated for five days and its error is noted as an average of −2 sec. per day. The pallet cock was removed and coated with lacquer to a thickness of 0·001 inch (1/1000th of an inch) and the rate was then found to average −6·6 sec. per day over five days, a difference of 4·6 sec. This seems to point to the necessity of having the balance as far away from the pallet cock as possible.

There is little doubt that air resistance does play an important part. Paul Ditisheim investigated the effects of changes in the density of the air on the rating of watches and chronometers and was aware of the influence of air resistance.

Inner Terminal Curves

Inner terminal curves should have the theoretically correct curve at the collet. Introduced by Grossmann, the object of these correct curves is to improve the isochronism. We have seen that the Breguet spring with theoretically correct outer terminal curve is necessary to obtain isochronism. Side pressure on the balance pivots is relieved during the winding up and unwinding of the balance spring and the centre of gravity of the spring is more stable and near to the centre. The inner terminal curve assists the stability of the centre of gravity. The necessity of using the inner terminal curve only arises with pocket watches, where a very high precision rate is required.

Index Scale

The general trend is for greater accuracy in timekeeping. It has become a habit with many wearers of watches, both pocket and wrist, to check the rate with a time signal and most time signals are very accurate. The watch repairer is often required to make an alteration to the index in an endeavour to correct quite a small error. When the index is actuated by some form of micrometer screw, a slight alteration can be made with some degree of certainty. The screw is given ⅛ or less of a turn with regard to the index scale engraved on the balance cock. When there is no form of index control—known erroneously as micrometer, obviously for the want of a better term, because it bears no resemblance to the measuring instrument bearing the name micrometer—slight adjustments are difficult and chancy. Often the index moves in jumps and the scale is not efficient and this is aggravated by the tail of the index being too thick or, so narrow that it bends, spring-like. The ideal is for the index to move smoothly, the tail to be fairly narrow and thin and the scale marked as in Fig. 156. The movement of the index can then be observed along one of the diagonal lines.

Poise of the Pallets

The poise of the pallets is not so important in modern watches. The low angle escapement requires a shorter lever and while such pallets are out of poise, movements are so designed that P.D. and P.U., the relative position of the lever, is almost the same. See Fig. 157. When P.U., the lever is then in the least trying position with the ruby pin falling away from the notch. When P.R., the error due to the want of poise of the pallets is about +1 sec. P.D. about −3 sec. and P.R. about − 5 sec. per

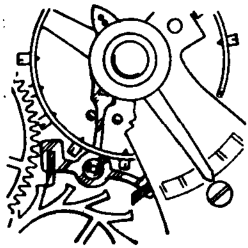


FIG. 157. *The position of the pallets to minimise pallet poise error.*

day when comparing with the D.U. position as +. When considering the poise of the pallets only, and not the influence of the escapement, the error is practically constant.

With some of the very small movements, 6½ lignes and under, the want of poise of the pallets does have an effect on the rate when in the vertical positions. The weight of the balance is proportionally less and therefore its momentum is less and the weight of the pallets has more influence on the balance than is the case in a larger movement. Furthermore, the draw of the pallets by the escape wheel is proportionally greater than is the case in a larger movement. The unlocking therefore has a greater influence on the arc of vibration of the balance. The errors thus created are not constant and a greater difficulty is experienced in adjusting such small watches in positions. Fortunately, a close rate is not as a rule expected from small movements. In recent years, however, movements have been so designed that larger and heavier balances can be employed and a marked improvement in positional timing has resulted; but even so, the difficulties have not been removed.

In some of the older movements with wide angle escapements and long levers, a counterpoise was necessary, and some very fine pieces of craftsmanship are to be seen where the counterpoise takes the form of finely worked antlers or whiskers.

CHAPTER NINE

OTHER METHODS OF POSITIONAL ADJUSTMENT

We have considered the correct method of positional adjustment, correct inasmuch as the adjustment is permanent. There are three other methods which are quicker to effect, but with two of them the adjustment is not as permanent. They are adjustment of the balance-poise; the index pins, and the balance pivots. Adjustments affect the horizontal position and one vertical position only. With a wrist watch the vertical position is usually P.D. and a pocket watch P.U.

The poise of the balance will be considered first. If the balance is thrown out of poise intentionally, this is a permanent adjustment, since taking the balance out does not affect its poise. Starting with the balance in perfect poise, if we make the lowest point of the balance heavy, when the balance is at rest and in a vertical position, the watch will gain in the vertical position when its rate is compared with the rate in the horizontal position provided that its arc of vibration does not exceed 1¼ turns: if the arc of vibration is in excess of 1¼ turns the opposite effect is obtained and the watch will lose. Therefore to make the watch gain in the vertical position, the lowest point of the balance is made lighter. With some of the lower grade watches, the arc of vibration of the balance in a vertical position does not exceed 1¼ turns (Fig. 158), and where the quality of the

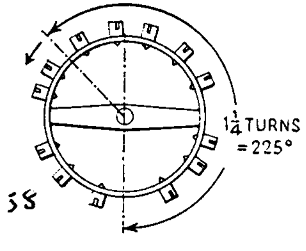


Fig. 158. *Arc of vibration in vertical position not exceeding 1¼ turns.*

watch does not warrant the expenditure of time—and positional timing can be expensive—throwing the balance out of poise is permissible.

A watch can be made to gain quite a considerable amount in the vertical position, anything from a few seconds to as many minutes in the

24 hours, and the procedure is as follows: Taking the under 1¼ turns case first. Say that a wrist watch loses 2 minutes when tested P.D. The watch is held up at sight level pendant down, the lowest point of the balance—when the lever is midway between the banking pins—is noted, and the balance is made heavier at that point by placing a timing collet under a screw. If a screw on the balance does not happen to come at that point, then place a collet under a screw on each side of the place required to make heavier (Fig. 159). Experience will teach; if two collets are added, each collet can be lighter. Also it must be borne in mind that the balance must eventually be made lighter to bring in to time again. Therefore, the screw or two screws opposite the heavy point can be made lighter, which will accentuate the heavy point.

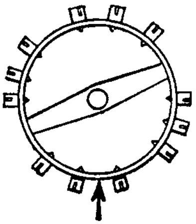


FIG. 159. *Heavy point made by two timing collets.*

We have seen previously that there are many contributing causes of error—the escapement; centre of gravity of the balance spring, i.e., dynamic poise of the spring; poise of the balance spring collet—and it may well be that to throw the balance very slightly out of poise as dictated by the going of the watch is the correct thing to do. It does not necessarily mean that a balance in poise on the poising tool is in poise when vibrating in the movement, as there are so many disturbing influences.

When the arc of vibration of the balance exceeds 1¼ turns and the heavy point is at the bottom, the watch will lose when P.D. and the reason is not far to seek. When the heavy point passes the topmost point (Fig. 158) and continues on its downward path, as indicated by the smaller arrow, it tends to slow up the movement of the balance and it has been calculated that beyond 1¼ turns—which is in fact ½ a turn plus ⅛ of a turn or 225°—the losing is pronounced. This method of timing is termed "timing in reverse". When employing this method care must be taken to ensure that the arc is never less than 1¼ turns in the vertical position, otherwise the reverse of the effect required will result and the watch will lose P.D. Therefore, to use this system to correct a big error can be dangerous because, as the oil of the watch ages, the arc of vibration will become less and there is no means of controlling this. Positional timing by poising should be employed on the lower grades of watches and great care taken when the arc of vibration is beyond 1¼ turns.

Positional timing by operating on the balance staff pivots is not permanent because as the staff pivots wear, the effect is lost. If the watch loses P.D. (wrist watch)—this method applies to one vertical position only—it can be made to gain when compared with a horizontal position (D.U.), by making the D.U. position slow. To do this, the ends of the balance staff pivots are made flatter, i.e., less rounded as shown by the dotted line in Fig. 160. Sometimes it is expedient to resort to this method when adjusting to make the two horizontal positions equal (D.U. and

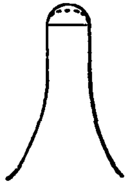


FIG. 160. *Flattening the end of a pivot.*

D.D.). If the D.D. position is slower than the D.U. position they can be made equal by making the lower staff pivot more rounded, i.e., less flat, or by making the upper pivot less round so that it will match or equal the lower pivot. Often the amount necessary to make more rounded or less rounded is so slight that it cannot be detected with an eye-glass. The author has examined a modern Swiss watch where the balance end stones have been made rounded eccentrically so that the effect is to bind the pivots when the watch is in a horizontal position, thus creating a losing rate D.U. or D.D., which gives the comparative gaining when vertical. This system—good or bad for want of experience—is not a general practice and has been mentioned to illustrate a method of obtaining a gaining rate in a vertical position (Fig. 161).

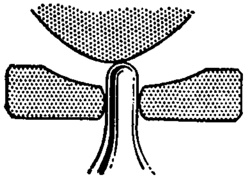


FIG. 161. *Specially rounded end stones.*

Although the rounding of the ends of staff pivots may not be a permanent adjustment, it has the advantage over the out of poise balance of not adversely affecting the other vertical positions. A final word about staff pivots: both pivots should be of the same diameter. One pivot larger than the other will cause a losing rate when the larger pivot is in operation, i.e., when the watch is horizontal.

With some of the smaller watches—3¾'''—it is found practically impossible to make P.D. equal the rate when D.U. This is due to the relatively light balance and large diameter pivots. While one does not associate positional timing with these minute watches, the large P.D. error does affect the general over-all timekeeping. The author has found it necessary to make the top pivot practically flat in order to reduce—but not eliminate—the persistent losing P.D. rate, i.e., to make the D.U. position slow has the consecutive effect of making the P.D. position fast or at least not so slow. The reason for this abnormal losing is no doubt due to the large diameter of the staff pivots, relatively larger than for say a 12''' movement but to make the pivots finer and fit smaller jewel holes, would introduce other troubles.

Index Pins Adjustment

The index pins play a vital part in positional adjustment. It has been noted elsewhere that the pins should be close so that the balance spring is just, and only just, free between them. If the pins—and by pins the boot and one index pin is included—are open and the spring working evenly between them, i.e., the spring is in the centre when the balance is quiescent, the watch will, relatively, lose when the arc of the balance is small and gain when the arc is large. When the arc is small the spring may not touch the pins and the effective length of the spring is therefore from the stud and the watch will lose. As the arc increases, the spring will contact the pins, and its effective length diminishes, therefore the watch will gain (Fig. 162). The pins can be so wide that they are not effective at all at any arc of the balance, the watch is then virtually free sprung. With the index pins open and the balance spring made to bear against one pin the watch will, relatively gain, but when the arc is large it will lose, because the spring will leave the pin it has been bearing upon and the spring up to the stud will be effective (Fig. 163).

There is great scope in this form of adjustment, but it is not permanent, since it is not possible to remove the balance from the cock and be sure it is replaced in *exactly* the same position, with relation to the spring between the index pins. Say a watch is losing in the vertical position, when the arc of vibration of the balance is less than when in the horizontal position; it can be made to gain by making the spring bear against one pin, as we have seen. Alternatively, if the watch is gaining in the vertical position

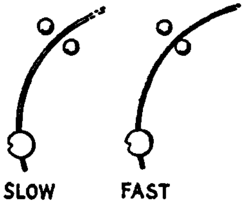


FIG. 162 *left, and* FIG. 163 *right.*

it can be made to lose by making the spring work evenly between open pins.

The extent of the gain or loss can, up to a certain limit, be made by the extent of the distance between the pins and the pressure of the spring upon one pin in the case of the gaining and of the extent of the opening with the spring working evenly in the case of the losing. The actual amount of the gain or loss can be in the order of a few seconds to as many minutes. Here again, as the arc of vibration varies due to the condition of the oil, etc., so will the effectiveness of the adjustment vary. Therefore, if this form of adjustment is used to correct large errors it can be dangerous. On the other hand, if the pins are close, we have seen that there must be some movement and, a slight persuasion of the spring to one pin can and will quicken the rate in the vertical position. The index pin adjustment does not affect adversely the other vertical positions. The author has

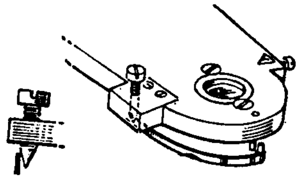


FIG. 164.

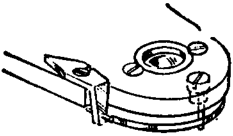


FIG. 165.

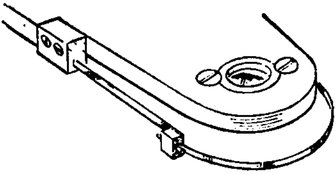


FIG. 166. *Spring Stud.*
Systems employing index pin adjustment.

examined a fine quality Swiss pocket watch, without index, where one pin has been fixed in the balance cock and the other pin fitted into a long spring so that as the balance vibrates this pin " gives " thus causing the watch to lose when the arc of vibration is large, with its relative gain when the arc is small. The strength, and therefore movement of the spring index pin, can be controlled by a cone-shaped screw. See Fig. 164.

Also another watch, a fine quality English free sprung, in which one pin only is fitted eccentrically into a screw and the screw fitted into the balance cock so that the pin can be adjusted on to or away from the spring for purposes of positional adjustment in a similar manner to that explained when two pins are used. (Fig. 165.)

Another watch of English manufacture, Fig. 166, employs a spring stud. When the arc of vibration of the balance is large, the spring to which the stud is fitted comes into operation and a losing rate is experienced, with the relative gaining when the arc is smaller, as would be the case when the watch is in the vertical position.

These three systems have been mentioned to show that index pin adjustment has been taken seriously, but that was before the advent of the correct point of attachment system.

It may well be that in addition to a correct curve overcoil balance spring and correct point of attachment, etc., slight errors can be corrected by employing one or more of the three systems of adjustment just discussed. Fine adjusting to close limits is a very difficult business; one cannot work to theory alone. When it comes to accuracy we have seen that a watch movement is full of inaccuracies, from the mainspring down to the pallets; the balance with its spring is the timekeeper and it suffers a great deal from its source of motive power. If it were possible to keep the balance vibrating at a constant arc in all positions, *without* external interference, then it would be a different story. The adjuster is constantly devising ways and means to counterbalance the errors of the movement and, what is more perplexing, the errors themselves are not constant.

CHAPTER TEN

TIMING MACHINES

The introduction of the timing machine has been of inestimable value to the watch adjuster. It tells him immediately the variation of rate in the different positions. Where, previous to its introduction, there was a delay of perhaps 24 hours before one could ascertain the rate in any one position, the rate of all five positions can be ascertained in a few minutes.

Timing machines have their limitations, however, they cannot give the errors due to want of isochronism; the watch must be run for the 24 hours to discover that.

A great help is to test the watch on the machine during different stages of winding up the mainspring. The first test, after winding two turns of the mainspring, the second after half wound, and the final test when fully wound. For normal commercial purposes it is estimated that a wrist watch correct by the timing machine loses up to 30 seconds in 24 hours in wear. It is therefore advisable to leave a watch gaining say 20 to 30 seconds per day in the workshop, and, when testing by the three-stage method, the first reading should be within that limit.

It is when the arc of vibration of the balance is small that the rate is liable to be slow. The half wound and the fully wound stages are more likely to be good and, if there is a marked tendency for the watch to lose in the early stages of winding it indicates that something is wrong with the movement—an excess of friction, which may be due to want of freedom, an escapement fault, poor mainspring, etc. If the error is slight, this may be natural, especially with a flat balance spring or even with an overcoil spring where the curve of the overcoil is not mathematically correct.

For ordinary purposes the final regulation is carried out while the watch is in wear and here the timing machine is most useful. Say the wearer finds the error to be 30 seconds per day slow; before touching the index, test the watch on the machine, and if it is found to read correct it indicates that the wearer has a personal error of −30 seconds. The index should be altered until the reading is +30 seconds. If the error is −10 seconds per day in wear and the machine reads +10 seconds, it indicates that the personal error is −20 seconds and the index should be altered accordingly. As mentioned before, so much depends upon the quality of the watch.

There are two types of timing machines, one where the readings are visual and the other where the reading is printed or burnt on to a paper tape. The visual type is the less expensive and it serves a useful purpose, but the readings cannot be taken off as accurately as the printing type. Furthermore, the printed tape forms a permanent record which can be studied.

We are indebted to Universal Escapements Ltd., La Chaux-de-Fonds, Switzerland, the makers of the Vibrograf machine for the information and drawings which follow:

The Vibrograf

It is explained by the manufacturer that the basic principle is the comparison between an exactly known period of time and the interval between two sounds made by the pallet stones of the watch. The exact time is obtained by a high-frequency quartz oscillator. The high frequency is reduced sufficiently to enable it to drive a synchronous motor which revolves at a constant speed of 1,800 r.p.m. and turns a drum fitted with three raised helicoidal bands.

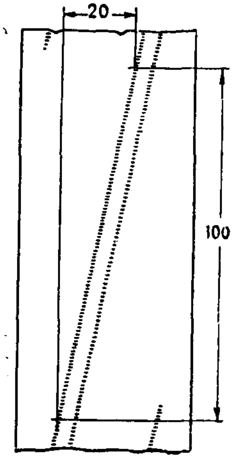
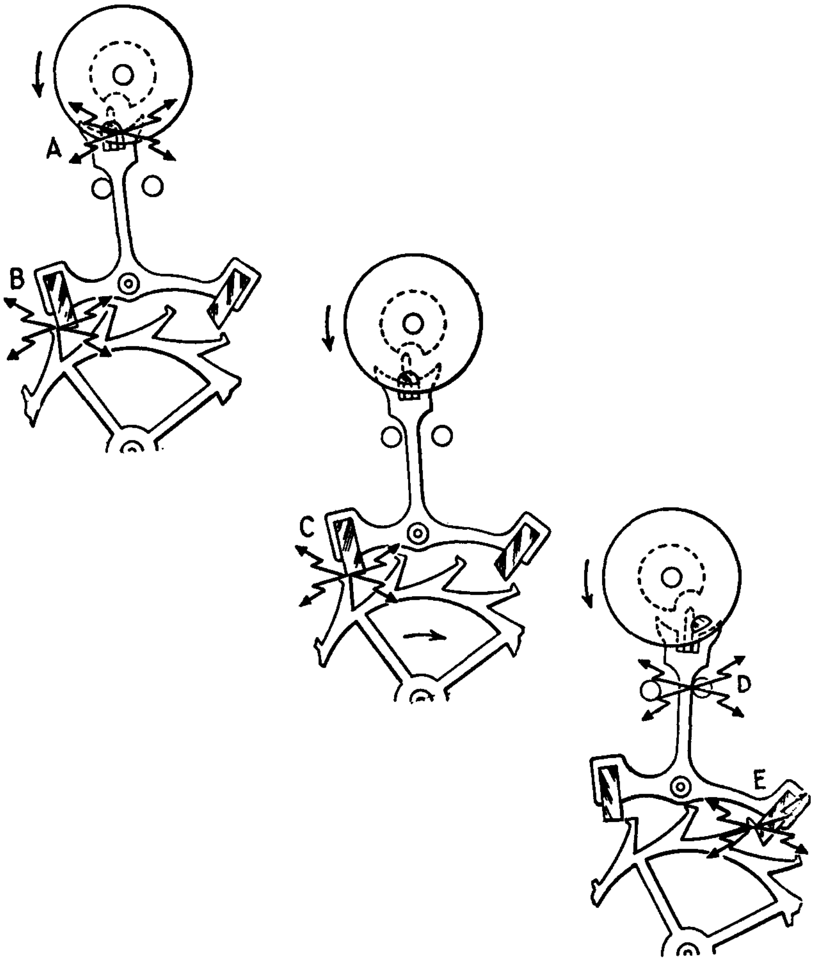


Fig. 167.

The printer consists of a microphone to convert the mechanical sounds of the escapement into electrical impulses and an amplifier to increase the amplitude of these impulses. There is an electromagnet which acts every time the watch ticks. This electromagnet attracts the printing arm, which strikes a carbon ribbon placed just above the drum with the helicoidal bands.

The recording paper runs between the inker—or carbon—ribbon and the drum. The printing arm can only make contact with the drum at a single point, except at the sides, where contact is made at two places to ensure the continuity of the record. Each tick of the watch will therefore print on the paper band only one point, or at most two. The position of the point with relation to the edge of the paper depends upon the position



FIGS. 168, 169, *and* 170. *Escapement sounds.*

of the helicoidal band at the instant of striking. If the striking takes place at fixed intervals corresponding to a given position of the helicoidal band then the points will make a straight line, parallel to the edges of the paper band as it is propelled forward.

This happens if the watch is *perfectly* timed. If the watch is gaining, the ticking will be more rapid and at each stroke of the printing arm the helicoidal band of the drum, which runs obliquely under the paper, will be slightly late when compared with the preceding stroke. Thus contact will be made with the helicoidal band at a point further to the right and the line printed by the successive points will incline towards the right. Conversely, if the watch is losing, the printed line will be to the left; to summarise, a straight line, no error, to the right, fast, to the left, slow.

To determine the amount of error, the paper band passes over a calibrated scale by means of which the error per 24 hours can be read. An occasion may arise when it is necessary to read the graph without the aid of the scale. In this case, measure the inclination of the graph over a given length of paper; the inclination expressed as a percentage of the length of paper will give a figure corresponding to the error in seconds per 24 hours.

For instance, Fig. 167 shows an inclination of 20 mm. over a length of 100 mm. i.e. 20 per cent or a gain of 20 seconds in 24 hours.

The machine indicates the error of the watch at the moment of observation and not its error *after* running for 24 hours. It is necessary for an " accurate " watch to be isochronous, i.e., it must maintain a constant rate during its period of running, i.e., 24 hours.

For instance, say a watch gains 1 minute during the first 12 hours after winding and loses 1 minute during the second 12 hours, the net result after 24 hours will be nil, but, if such a watch is wound fully night and morning, it will show a gain of nearly 2 minutes in 24 hours.

Therefore, it is advisable to test watches at three stages of winding of the mainspring, about one or two turns of the barrel arbor, half wound and fully wound, as explained previously. In any case the final test should be over 24 hours of running.

The Escapement

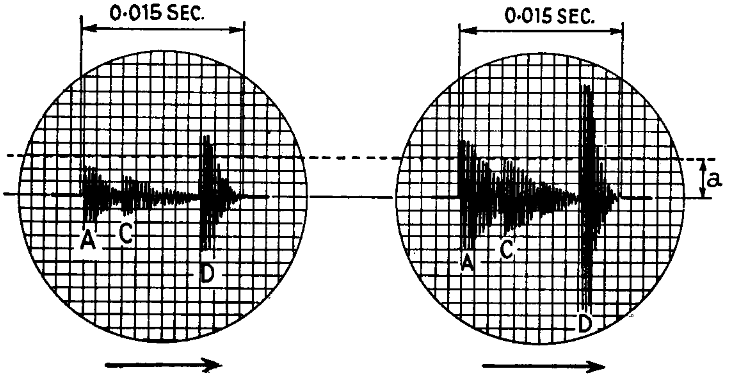
To understand these machines and to put them to the best use it is desirable to study the action of the escapement, which is that part of a watch that produces the *sound* vibrations used by these machines.

As has been said, the machine records the sounds of the escapement. Fig. 168, A, indicates the sound made by the impulse pin contacting the side of the notch of the lever and the pallet B unlocks the escape wheel. During unlocking the escape wheel recoils slightly and a light sound is made, but owing to the speed of this operation and the lightness of this sound, it is not recorded independently. Fig. 169 indicates the sound made during impulse at C, and this sound varies with the power exerted by the mainspring. Fig. 170 indicates the sound at E by the escape wheel tooth dropping on to the pallet and also the lever striking the banking pin at D, both these sounds are strong and practically simultaneous.

If the escapement is correct and with it the transmission of the power of the mainspring is constant, the points printed on the paper band will always correspond to the same cycle of sounds made by the escapement.

To understand what is happening it is necessary to know the working of the machine.

The sounds of the watch, having been transformed into electric vibrations, are amplified by electronic valves, after which the combination of sounds acts on a relay. This is a gas triode or thyratron valve connected in series with an electromagnet actuating the printing arm. Thyratrons are subject to ionisation, i.e., they become conductors when a certain fixed potential is applied to one of the electrodes. If the necessary potential, Figs. 171 and 172, is represented by a dotted line at the level *a* it will be observed in Fig. 171 that this line cuts across the record at D and this sound will then be recorded on the paper band.



FIGS. 171 *and* 172. *Watch sounds turned into electric vibrations.*

In Fig. 172 the dotted line crosses the record at A and D. These two sounds would cause the printing arm to operate if it were not for the fact that the relay system can only give a limited number of impulses per second, a number hardly exceeding the ticking of a watch. Therefore only the sound A will act on the electromagnet and one point be printed. In addition, the action of the escapement may show a number of factors, which, though of importance, modify the amplitude of various sounds, i.e., side shake of less pivots varying quantities and condition of oil, etc. The sounds may vary continually in amplitude and it may be that either the locking, unlocking, or impulse, or two of them together, will act alternatively on the relay, in which case the printed record will not be clear.

It will be appreciated therefore that it is necessary as a rule, to use sufficient amplification to ensure that only the unlocking of the escape wheel is recorded on the paper band. On the other hand, extraneous noises, such as that of a typewriter, may disturb the recording if amplification is excessive.

In certain instances it will be preferable to reduce amplification so as to record the sound of the locking of the escape wheel teeth, e.g., when testing the escape wheel. Eccentricity of the wheel will produce a wavy line and a damaged tooth will produce a point clearly separated from the line of the record.

The following Vibrograf records will explain the method of ascertaining timing errors and escapement defects.

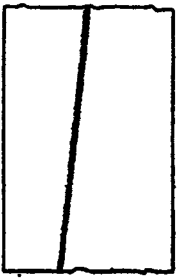


Fig. 173.

Record 1. Fig. 173. The record shows a gain of 5 seconds in 24 hours. The movement is working regularly, the left hand swing of the balance taking exactly as long as the right hand swing.

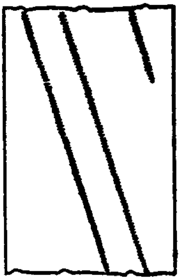


Fig. 174.

Record 2. Fig. 174. The record shows a losing rate of 15 seconds in 24 hours. When comparing this record with record 1 it is evident that the escapement is out of beat, the two lines are too far apart. It must be borne in mind that the space between the lines increases in inverse ratio to the arc of vibration of the balance. For instance, if this record were taken with the movement vertical, the lines will not be so far apart in the horizontal position. The arc is less vertical than horizontal. Otherwise the time is regular.

Record 3. Fig. 175. The record shows a gain of 25 seconds in 24 hours, but the escapement is defective. The impulse pin does not strike the notch at the same point on each vibration of the balance, due to a bent pivot, loose impulse pin or loose jewel hole, etc. Also, one of the pallet stones mislocks or one of the stones is worn.

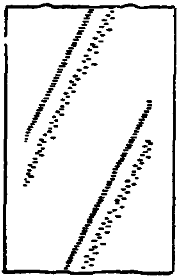


FIG. 175.

Record 4. Fig. 176. The record shows a gain of 9 seconds in 24 hours. The wavy line indicates that the escape wheel is not perfectly round. Power is not transmitted regularly to the balance.

As a rule a regular curvature to the lines indicates irregular transmission of power, which may be due to a faulty wheel and pinion depth

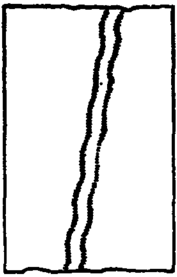


FIG. 176.

or a train wheel or pinion that is not quite round. The same effect is produced if an arbor is bent or a pivot not concentric.

Record 5. Fig. 177. The record shows a losing rate of 29 seconds in 24 hours. Also, one tooth of the escape wheel is slightly damaged. If the defect were more serious, both lines would be affected in the same way.

Record 6. Fig. 178. The record shows a gain of 10 seconds in 24 hours. Also the arc of vibration of the balance varies in amplitude. It will be observed that this variation does not cause any variation in the running of the watch, therefore the balance is isochronous. The escapement fault is slight and may be that one of the balance staff pivots binds in its hole, or oil is defective. Usually, repolishing the staff pivots and cleaning and re-oiling the escapement will rectify.

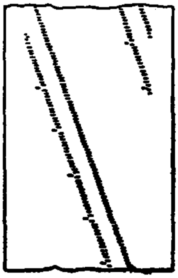


FIG. 177.

Record 7. Fig. 179. The escapement is knocking the banking, the arc of vibration of the balance is too great. This defect can also be heard by the galloping noise made by the printer, the lines always shift to the right. On the other hand, if the escapement catches, due to a lack of run

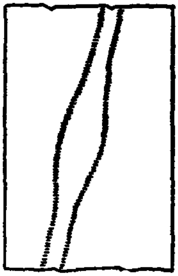


FIG. 178.

to the banking, etc., a similar pattern will be printed but the displacement will be greater and the line may shift to the right and the left and the knocking sound will not be heard.

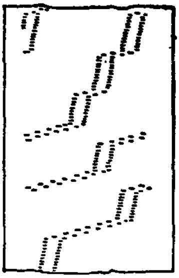


FIG. 179.

Record 8. Fig. 180. This illustrates a quick and simple method of ascertaining the isochronism of the balance. The movement is first tested dial up and the lines above dotted line indicate the error as nil. The

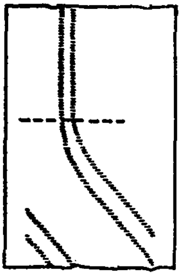


FIG. 180.

movement is then tested in a vertical position, pendant down is the more usual for a wrist watch. The lines curve gradually as the arc of vibration of the balance decreases owing to the change of position. The lines then

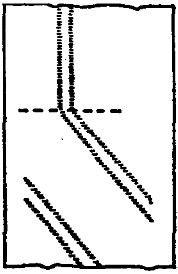


FIG. 181.

veer to the right, indicating a losing rate. The balance is not isochronous, but it may be that the defect will rectify itself, and that after curving the lines will resume the direction as shown when the movement was tested dial up. If, however, the losing rate persists, it indicates that there is a

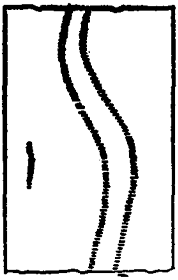


FIG. 182.

variation of friction of the balance pivots, conditions of the oil or faulty pivots. It is evident that the diminished arc of vibration of the balance affects the time to a greater extent than it should.

Record 9. Fig. 181. The same test as record 178 is carried out and it will be observed that the lines below the dotted line strike off at a well defined angle, they do not curve as in record 180. This indicates that the balance is out of poise and the remedy is to poise the balance and start again.

Record 10. Fig. 182. The record shows a variation in the time of the balance although the over-all timekeeping is good. Faulty transmission of power is indicated and somewhere well back in the train, e.g., between the centre wheel and third wheel pinion. This case is similar to that of record 167 though the variation is slower.

Record 11. Fig. 183. Brief test of a movement by reading Vibrograf records: The errors are first noted for the various positions.

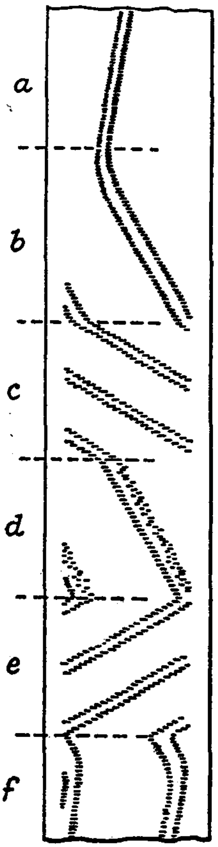


FIG. 183.

(a) Horizontal	.. ..	+ 8 seconds
(b) Pendant left (all viewed from the dial)	..	−30 „
(c) Pendant up	.. ..	−87 „
(d) Pendant right		
(e) Pendant down	.. ..	+87 „
(f) Repeat of horizontal	.. .. ..	+ 8 „

Deductions

(1) The average of the vertical position errors is

$$\frac{-30-87-30+87}{4}=-15$$

The difference between the vertical errors and the horizontal position is $-15+8=-23$ seconds.

(2) The balance is not in perfect poise. It has been determined that for an arc of less than 220 deg. the heavy point at the bottom (when the balance is at rest) causes a gain. It is simple to ascertain the point at which the balance must be lightened to put it into poise.

In the case under test the maximum loss was registered in the pendant up position. The heavy point in the balance is therefore at the top.

(3) Deflective isochronism. The lines curve from (a) to (b), the same observations are as for record 9.

(4) In the pendant right position (d) one of the pallet stones is not being held by the escape wheel when in the position of rest: there is a lack of " draw". Having regard to the position of the escapement while in that position, it is a simple matter to ascertain which pallet stone is at fault as the pallet lever is out of poise. It is obvious that the defect occurs in the position in which the weight of the lever reduces the impact.

While the timing machine is of inestimable value to the modern watchmaker, this is not the complete story. The principal advantage of the machine is that it gives the error of the watch in the different positions immediately; it also gives the mean time error approximately, that is, it gives the error for the short period of time the watch is under that test, it cannot give the variations during the actual 24 hour run.

The Swiss factories overcome this to a large extent by testing watches on the machine during three stages of mainspring tension—with the spring wound up one turn, half wound, and fully wound. An alteration is made to the index to adjust for the mean of the three readings. Having got the mean time error (i.e. dial up) as close as possible, it is necessary to test the watch for a series of 24-hour runs, also dial up. Generally speaking, if the result of the 24-hour tests is satisfactory the positional errors, i.e. the differences between D/L and P.D., etc., will be as the readings on the timing machine.

If the watch is being prepared for an official test, it will be necessary to test for 24 hours in each of the positions prescribed by the specification.

Another great advantage of the timing machine is when adjusting the index for the wearer of the watch, who is waiting. Say, for instance, it is observed by the wearer that the watch is gaining 30 seconds per day; test on the machine before making an alteration to the index and you may find that the reading is fast by 60 seconds per day. This indicates that the personal error of the wearer is fast so the index is altered until the watch gains 30 seconds per day on the machine, which should reduce the error in wear.

Usually, wrist watches lose while in wear and it is therefore advisable to leave a gaining error of approximately 30 seconds per day. There is no hard and fast rule concerning this and one does occasionally come across a gaining personal error.

However, this system of regulating while in wear is most useful.

The general high standard of timing by the manufacturers, employment of the correct point of attachment for the balance spring, the fine running of trains with the resultant weak mainspring and longer running with one winding, make for excellent timekeeping, even with some of the lower priced watches. Wearers of watches have been educated to expect close timekeeping, and time signals encourage this.

We all know the man who keeps a daily record of his watch—a bit of a nuisance—who will relate that he has discovered by manipulation of the positional errors, he can keep his watch to the second. He may, for instance, have discovered that his watch gains 20 seconds when placed pendant up overnight, thus if the watch loses 20 seconds during the day he will rectify it by the morning. I once had a peculiar experience in this connection, not then being aware of this manipulation. After the watch had been brought fairly close to time in wear, one day the owner produced a graph extending over about two months and the curve was practically straight. The results were so good, the graph was sent to the manufacturer in Switzerland with a note of congratulation. Many months later the man called and inquiries after his watch were made. He said he was very sorry, but he had not had access to a time signal and was therefore not able to make the daily correction by manipulation of the errors due to change in position.

This is of course by the way, but it does point out where modern timing is leading us to.

Compensation

Compensating for changes of temperature is almost forgotten in the curriculum of the present-day watchmaker, that has been taken care of by the metallurgist with the introduction of the self-compensating balance springs, but before discussing this form of compensation, we shall consider its predecessor.

Many watches still pass through the workshop fitted with the cut balance and steel balance spring. The early watches were fitted with balances made of gold, brass, or steel, known as plain balances, not dissimilar to the modern balance, but the spring used was of steel. For some years it was thought that watches so equipped lost time in the heat due to the elongation of the spring, but the real cause was discovered to be the loss of elasticity. Elongation accounted for some of the loss but to a certain extent it was compensated by the other dimensions (thickness and width) increasing proportionally.

In 1773 Berthoud tabulated the effect of temperature on a steel balance spring and in passing from 32 deg. to 92 deg. F. the loss per day as:

Expansion of balance	62 seconds
Loss of elastic force of balance spring	312 ,,
Elongation of spring	19 ,,
	393 seconds

In 1882, T. D. Wright pointed out in his *Technical Horology* that Berthoud's theory was not correct in as much that the expansion in thickness and width compensated the elongation. To overcome this temperature error, compensation curbs to the index were first employed. Brass has a greater coefficient of expansion than steel, and if strips of these two metals are fused, or fixed, together the strip will curl in heat, the brass on the outside and the steel inside. Advantage was taken of this and the strip so bent and fixed that the free end replaced one of the curb pins. See Fig. 184.

In heat the space between the curb pin and the end of the bimetallic strip will close, thus causing the watch to gain and compensate for the loss. Contrawise, the space will increase in cold, causing a loss to compensate for the gain due to the stiffening of the spring.

At a later stage, the bimetal principle was employed in the form of the balance itself. A piece of steel, in the form of a disc, had brass fused

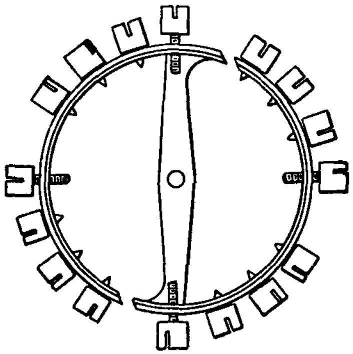


Fig. 184.

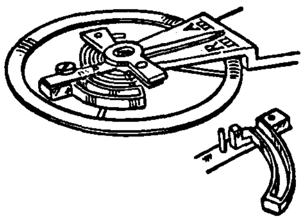


Fig. 185.

on to its outer edge. The centre of the steel was pierced out to form the arms of the balance and the outer edge of brass turned down so that the proportion of brass to steel was two parts brass to one of steel. Opposite sides of this rim, near the arm, are cut, so that in heat the bimetallic limbs curl inwards, making the diameter of the balance smaller, thus causing a

TABLE 9

Balance Springs for Bimetallic Cut Balances

Type of Balance Spring	Compensating Balance to be used	Quality	Colour	Temperature error over a range of approx. 32 deg. F. in 24 hours	Middle temperature error in 24 hours	Physical Properties
				Sec.	Sec.	
Tempered steel	Guillaume	Highest	Blue	0 to 0·36 approx.	0 to 1	Subject to magnetism and rust.
Tempered steel	Steel & brass cut	1st grade	,,	0 to 1·8 ,,	0·5 to 3	,, ,,
First tempering	,, ,, ,, ,,	,, ,,	,,	0 to 1·8 ,,	0·5 to 3	,, ,,
Hardened steel	,, ,, ,, ,,	Fair	,,	0 to 1·8 ,,	0·5 to 3	,, ,,
Soft steel	,, ,, ,, ,,	Inexpensive	,,	0 to 1·8 ,,	1 to 4	,, ,,
X-A-M	,, ,, ,, ,,	1st grade	Yellowish	0 to 1·8 ,,	0 to 3	Non-magnetisable and rustless.
Melius	,, ,, ,, ,,	Medium	,,	0 to 5·4 ,,	0·5 to 3	Only slightly magnetisable. rustless, good elasticity,

TABLE 10

Balance Springs for Monometallic Balances

Type of Balance Spring	Balance to be used	Quality	Colour	Temperature error over a range of approx. 32 deg. F. in 24 hours	Middle temperature error in 24 hours	Physical Properties
				Sec.	Sec.	
Elinvar 1	Glucydur "affixes"	1st grade	White or blue	0 to 9·0 approx.	0 to 3	Only slightly magnetisable and rustless.
Elvinar 1	With attachments	,, ,,	,,	0 to 9·0 ,,	0 to 3	,, ,,
Elvinar 2	Glucydur	Medium	,,	9·0 to 36 ,,	0 to 3	,, ,,
Elvinar 3	Nickel	Fair	,,	36 to 72 ,,	0 to 4	,, ,,
Parelinvar 1	,,	Inexpensive	,,	72 to 108 ,,	0 to 5	,, ,,
Parelinvar 2 }	,,	,,	,,	90 to 108 ,,	0 to 5	,, ,,
Melior }	,,	,,	,,	90 to 108 ,,	0 to 5	,, ,,
Metelinvar 1	Glucydur	1st grade	White or blue	0 to 9·0 ,,	0 to 3	Almost non-magnetisable and rustless.
Metelinvar 2	,,	,, ,,	,,	9·0 to 36 ,,	0 to 3	Very good elasticity.
Metelinvar 2	Nickel	Fair	,,	36 to 72 ,,	0 to 4	,, ,,
Nivarox 1 from 10½ ligne	Glucydur	Highest grade	Blue	0 to 9·0 ,,	0 to 4	Non-magnetisable and rustless.
Nivarox 1 small movements	,,	1st grade	,,	0 to 18 ,,	0 to 8	,, ,,
Nivarox 2	,,	,, ,,	Red brown	0 to 36 ,,	—	,, ,,
Nivarox 3	Nickel	Fair	,, ,,	36 to 72 ,,	—	,, ,,
Nivarox 4	,,	,,	White	72 to 108 ,,	—	,, ,,
Nivarox 5	,,	Inexpensive	,,	108 and over ,,	—	,, ,,

TABLE 11

TEMPERATURE ADJUSTMENT CHART

Use in conjunction with illustration on facing page

24-HOUR TEST	24-HOUR TEST
92° F.	32° F.
— 5 sec. Move screws 7 and 7a to holes 4 and 4a.	— 5 sec. Move screws 4 and 4a to holes 7 and 7a.
— 10 sec. Move screws 7 and 7a to holes 2 and 2a.	— 10 sec. Move screws 2 and 2a to holes 7 and 7a.
— 15 sec. Move screws 8 and 8a to holes 1 and 1a.	— 15 sec. Move screws 1 and 1a to holes 8 and 8a.
— 20 sec. Move screws 8 and 8a to holes 1 and 1a and also screws 7 and 7a to holes 2 and 2a.	— 20 sec. Move screws 1 and 1a and screws 2 and 2a to hole 8–8a and 7–7a.
— 25 sec. Remove screws 3 and 3a and replace with screws made of platinum.	— 25 sec. Move screws 1–1a and 2–2a and 3–3a to holes 9–9a—8–8a—7–7a.
— 30 sec. Remove screws 1 and 1a and replace with screws made of platinum.	+ 5 sec. Move screws 7 and 7a to holes 4 and 4a.
+ 5 sec. Move screws 4 and 4a to holes 7 and 7a.	+ 10 sec. Move screws 7 and 7a to holes 2 and 2a.
+ 10 sec. Move screws 2 and 2a to holes 7 and 7a.	+ 15 sec. Move screws 8 and 8a to holes 1 and 1a.
+ 15 sec. Move screws 1 and 1a to holes 8 and 8a.	+ 20 sec. Move screws 8 and 8a to holes 1 and 1a and also screws 7 and 7a to holes 2 and 2a.
+ 20 sec. Move screws 1 and 1a and screws 2 and 2a to holes 8–8a—7–7a.	+ 25 sec. Move screws 9–9a and 8–8a and 7–7a to holes 1–1a and 2–2a and 3–3a.
+ 25 sec. Move screws 1–1a and 2–2a and 3–3a to holes 9–9a, 8–8a, and 7–7a.	

gain. To control the amount of gain or loss in heat and cold, screws or sliding weights are fitted to the limbs. This adjustment is quite simple. To increase the gaining, the screws or weights are brought nearer to the free end of the limb and vice versa. The illustration, Fig. 185, is of a typical compensation balance, and the table on the facing page, in conjunction with Fig. 186, forms a useful temperature adjustment chart.

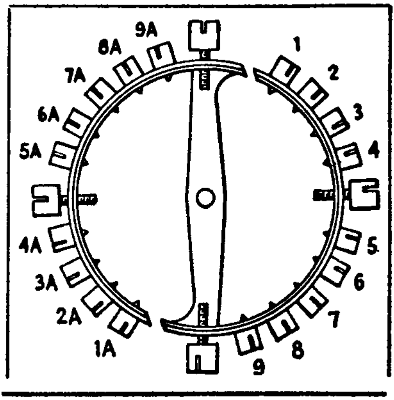


FIG. 186.
Cut balance with screws numbered for use in conjunction with Table 11, on facing page.

Many Disadvantages

The disadvantages of this system of compensation compared with the modern system are many. The cut balance is delicate to handle, it is liable to rust, as is the steel spring; it is magnetic; it is subject to the middle temperature error. If the balance is adjusted to a temperature of say 85 deg. F. and 32 deg. F. and then tested at 60 deg. F. another error will appear which amounts to approximately 2 sec. in 24 hours for a change of 40 deg. F., and there is no means of correcting this " middle temperature error " satisfactorily. Devices known as auxiliary compensation have been used but the results were doubtful.

An important point to bear in mind is that when fitting a new balance spring to a cut balance it must be made of steel. If a self compensating spring is used the watch will gain in heat because there is nothing to compensate

Self Compensating Balance Springs

The first metal to be used was Invar, an alloy of nickel and steel, in the early days of the present century. It derives its name from the word INVARiable and was quite satisfactory up to a point. It is non-magnetic and rustless but very soft and the rate of the watch suffered with the variable arc of vibration of the balance. The aim then was to find an alloy with the above qualities but harder. The first in this field was Elinvar, derived from ELasticity and INVARiable which is an alloy of steel, nickel and chromium. These springs were quite successful but they have further been improved, i.e. made much harder, with the introduction of beryllium and other metals into the alloy. Trade name, Nivarox. With the harder metal a better rating is effected, quite apart from the temperature consideration because the arc of vibration of the balance is not so adversely influenced as the power of the mainspring decreases, there is more " life " in the spring.

The tables here give the relative values of steel balance spring and bimetallic cut balance and self compensating springs and plain or monometallic balance.

The balances in common use at the present time are made of nickel bronze for the lower grade watches, and Glucydur for the higher grade watches. Glucydur is the trade name of an alloy of iron, beryllium, cobalt and copper, etc. It has no compensation value and its virtue is that it is hard and capable of taking a good finish. The nickel alloy is soft and balances made of it suffer when balance staffs are replaced.

The chief defect of the self compensating balance springs is that they tend to make watches lose in the short arcs, as already mentioned. M. Dubois has succeeded in developing an alloy which has been named ISOVAL—not noted in the table—which is harder than the other springs. It is claimed that by the use of this alloy isochronism can be effected over a much wider range of variations of the arc of vibrations of the balance than hitherto. The thermal compensation is at least equal to the best of the other self compensating springs.

Essential Points to Observe to Obtain Good Timing Results

(1) The maximum power of the mainspring to be transmitted to the balance. To obtain this the train must be as free as possible, good gearing and as weak a mainspring as possible. This ensures the minimum friction and thus a steady flow of power to keep the balance vibrating at nearly a constant arc of vibration at least for 24 hours. An absolutely constant arc is not possible but the aim should be to make it constant.

(2) A near perfect escapement, i.e. the actions of the escapement to be as near perfect as possible.

(3) Perfect poise of the balance.

(4) The balance spring to be very securely pinned to the collet and the stud.

(5) Index pins to be close and not too thin.

(6) Perfect cleanliness of the movement.

(7) Fresh oil.

It is strange to reflect that as something is brought to near perfection the birth of something else is waiting to replace it. Over the years we see it in many things, that is progress, and watches are not neglected.

The compensation balance was replaced by the self compensating balance spring. The automatic winding watch has practically solved the problem of constant arc of vibration of the balance and so brought accurate time nearer to perfection, which has of course been assisted by point of attachment and other considerations, as noted in this book. Is all this now to be superseded by the new "tuning fork" electronic watch? It certainly looks like it. The future seems very bright for the new infant. Practically no positional errors; no compensating worries; no shock proof system; no wear, or practically none, the count train is not subject to pressure; no oil troubles. The count train needs oil, but since there is no escapement the timing is not affected by the condition of oil. The snag as far as watch repairers are concerned is that it may mean no watchmakers wanted, just battery service men, but that must be many years ahead.

The next stage may be that watches as we now know them will be impulse dials controlled by a master clock. It is within the realm of possibility.

Events move fast and horology is not left behind.

Approximately 1400 to 1750—The verge escapement, about 350 years; 1750 to 1950—The lever escapement, about 200 years; 1950 to 1960—Electric watch with balance and staff, about 10 years; 1960 to ?— Tuning fork watch ?; Impulse dial watch next year?

General Notes on Timing as Given by the Manufacturers of the Vibrograf Machine

Timing. Before starting the test it is necessary to decide which shall be the main vertical position. For pocket watches it is invariably pendant up in the first place, this is because it is required by the observations and official control or testing officers, the other two vertical positions are pendant left and pendant right.

For wrist watches the vertical test is pendant down, pendant left (viewed from the dial side) and pendant up.

It is important to remember that accurate timing is only possible when components of the finest quality are used; hairspring, balance, jewel holes, mainspring, etc. Also the assembly must be carried out impeccably.

The timer must check the following with especial care:

(1) *Fitting of hairspring.* The hairspring must be fitted firmly to the collet and the stud.

(2) *Centring of hairspring.* A badly centred hairspring upsets the poise of the balance unit and makes isochronism impossible in the vertical positions.

(3) *Flatness of hairspring.* This is comparatively unimportant but the spring must be perfectly free of the balance, balance cock, etc.

(4) *Escapement.* The escapement must be in perfect beat.

(5) *Concentricity.* It is essential for the hairspring to be perfectly concentric.

(6) *Index pins.* The index pins must not grip the hairspring, the spring should be just free between them.

(7) *Amplitude, or the arc of vibration of the balance.* The arc should be about 1½ turns—270 deg. in each direction—in the vertical positions when the mainspring is fully wound. The increased arc in the horizontal position must not give rise to knocking the banking. After this check has been completed place the movement in the Vibrograf.

Rough Adjustment

1st Operation. Rough adjustment to reduce the error to less than one minute.

2nd Operation. Observation of errors in four vertical positions. The mainspring should be wound one turn of the barrel arbor only. Ascertain the position showing the maximum gain. If the arc is less than 220° in each direction the heavy point will be at the bottom of the balance.

3rd Operation. Adjustment for want of poise of the balance. This needs great care. The addition of 1 per cent may be sufficient to compensate a difference of 30 seconds between two opposite vertical positions. Weight is removed if the watch loses and added if it gains.

4th Operation. Checking isochronism in the horizontal position. This is checked at various amplitudes of the balance corresponding to the amount the mainspring is wound. If a gain is shown with the smaller amplitudes of the balance it may be possible to correct by very slightly opening the index pins. As a general rule, a difference of from 10 to 15 seconds may be permitted between the fully wound and run down condition of the mainspring.

Faulty isochronism is due to the quality of the hairspring (provided other parts of the watch movement are as near perfect as possible). Nivarox hairsprings generally show a gain in the small amplitudes, while Elinvar show a loss. Hardened and tempered steel is practically faultless. Consequently, if there is a serious isochronism fault it is advisable to change the hairspring.

5th Operation. Checking the difference between the vertical and horizontal positions. To be correct, there should be no difference. When the difference is great the discrepancy may be due to faulty balance pivots, adjustment of the hairspring and very many other faults.

Obtaining Good Reading

It should be noted that obtaining a good reading in the vertical and horizontal positions is more a question of the design and manufacture of the calibre than the technique of adjustments; thus it is very necessary to reduce the decrease in amplitude of the balance in the vertical positions, which is due to gearing, pivot friction, etc.

In conclusion, a few words concerning temperature: watchmaking circles have tended to overlook the influence of temperature on the hairspring especially since the invention of the self-compensating nickel steels. Yet this influence is not negligible. With very cheap hairsprings, movements may show an error of as much as one minute in 24 hours for a change in temperature of 18 deg. F. It is not reasonable to expect of such a movement more than it can give.

Much of what Vibrograf have to say has been said before and in fuller detail but it is all well worth repeating. Some we may not quite agree with, but it all helps to emphasise that timing is an individual operation. No two movements are alike and this is accentuated with different calibres.

APPENDIX I.

Fourteen Cardinal points when fitting a new balance spring and rating

1 The balance spring *must* be firmly fitted to the collet and the stud.

2 For good timing in positions, the balance spring *must* be well centred at the collet. It must run true. Also the spring as a whole must be centred, not leaning to one side. A spring slightly out of flat, while not good from a craftsmanship point of view, will not affect positional timing, provided it is free and does not touch anything.

3 The escapement *must* be set as near perfect as is humanly possible.

4 The balance should be in poise.

5 The watch *must* be in perfect beat.

6 The balance spring *must* be free between the index pins.

7 The watch *must* have a good action. The arc of the balance should be $1\frac{3}{4}$ turns when fully wound and not less than $1\frac{1}{4}$ turns after 24 hours of running.

8 After fitting a new balance spring reduce the error of timekeeping to the minimum before starting positional timing.

9 All watches (especially when worn on the wrist) should be left with a gaining rate. A losing rate is most undesirable. Most wearers of wrist watches have a natural losing rate. Nobody wants a watch that makes them late for appointments.

10 It is not wise to use the word " accurate ". There will be the odd person who will take you at your word and demand a watch which shows *no error*—that is the accurate meaning of the word " accurate " —and such people can be a loadstone. Modern methods of conveying accurate time (by time signals) to everybody can be very trying.

11 It is good to suggest the final timing while the owner is wearing the watch, make the occasional adjustment to the index while he is waiting.

12 Be wary of the person who says his watch never varies. And equally, of the person who says he cannot wear a watch because he has too much magnetism in him (mostly her!).

13 To obtain the best results, it is advisable to wind the watch in the morning. An automatic winding watch takes care of this problem.

14 Advise that the watch be worn in as regular a manner as possible; i.e. if worn during the night to continue doing this, not to wear it one night and another to take it off.

APPENDIX II

SPRINGING AND timing watches in the factory is, as one would expect, very much different from that explained in this book, which applies to the craftsman repairing an individual watch. Even so, the spring is still pinned to the collet by hand; it is the counting which is automatic. Years ago the Swiss counted individually and it is only in recent years that the automatic system has developed to such an extent.

In La Côte-aux-Fées, a delightful village high up in the mountains above Neuchâtel, Switzerland, is a model factory—factory is hardly the right word, it is almost like a laboratory—here Piaget make the flatest watches in the world and I was priveleged to observe the methods of springing and timing there.

After the springs have been pinned to the collets as explained in pages 42-58 of this book, they are submitted to a department where the counting takes place. A Super-Spiromatic machine, invented and made by Messrs Greiner, of Langenthal, Switzerland, is employed as in Plate 1 following page 146. Plate 2 is a diagramatic drawing of the machine. The lower balance staff pivots rests on the ruby plate 8 and the spring passes through the count pin 1 and the feed shaft 6, which draws up or lets out the spring until the correct count is attained, when the cutter 7 cuts the spring. The distance from the count pin to the cutter is predetermined to suit the calibre of movement in hand.

Each machine is individually manufactured according to the train count requested by the factory, i.e. 14,400; 18,000; 19,800; 21,600, and so on. Some machines cater for as many as three different train counts in the same machine.

When the balance is set up in the machine, the sliding window fitted on the top of the machine is closed, a trip lever actuates the air pump which directs puffs of air on to the balance through the air nozzle 9 and the count starts. While this is taking place, the other window is opened and another balance fitted up for counting in the same manner. So it goes on from one side to the other, at the rate of about 250 timed balances to the hour.

If it is necessary to bend the balance spring as in Fig. 70. page 53, the machine can be set to do that also; such is progress.

While visiting the Tissot factory in Le Locle, I saw in operation the Greiner/Multi-purpose timing machine, shown in Plate 3. After the balance has been timed and fitted into the movement, it is tested on this machine, which first shows the arc of vibration of the balance on a stroboscope. If the amplitude is not sufficient in different positions, the movement is rejected by the operator as not fit for further timing.

The next operation is to test for mean time. It is possible to make minor alterations to the index during the actual test. The movement is then transferred to the clip on the right hand side of the machine, where it is automatically tested in the different positions required, and the reading shown on the right hand printed record. While this is taking place, the operator proceeds with the arc of vibration and mean time tests of another movement.

Thanks are due to Turner Electronics, 58 Upper Tooting Rd,. S.W.17, for the illustrations of the Greener timing machines; they are the English agents for that company.

Experiments are proceeding with a system of soldering the balance spring to the collet in place of pinning. A system of cementing the spring is employed in America and a description of the system is given here.

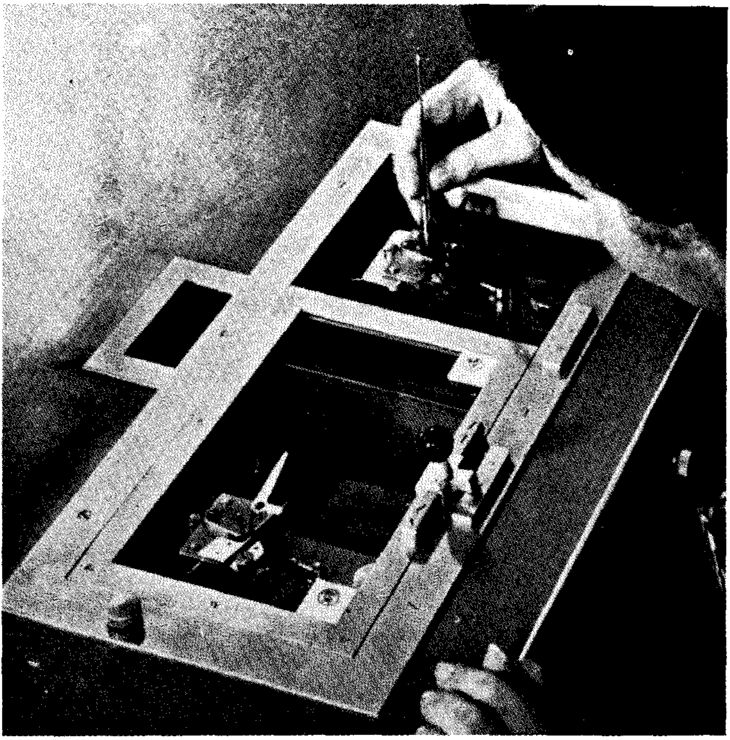


PLATE 1.—*The Greiner Super-Spiromatic machine in use in a factory. It automatically times balance and spring units.*

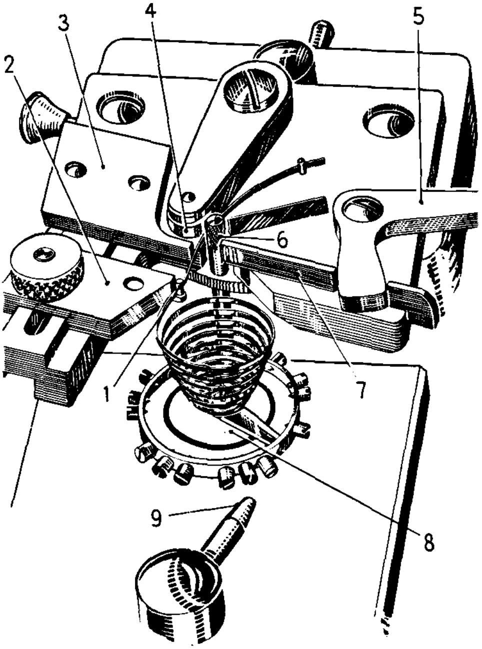


PLATE 2.—*Diagrammatic drawing of the Super-Spiromatic machine showing* (1) *counting pin;* (2) *counting pin slide;* (3) *cutter plate;* (4) *pressure roller;* (5) *cutter lever;* (6) *feed shaft;* (7) *sliding cutter;* (8) *ruby plate;* (9) *air nozzle.*

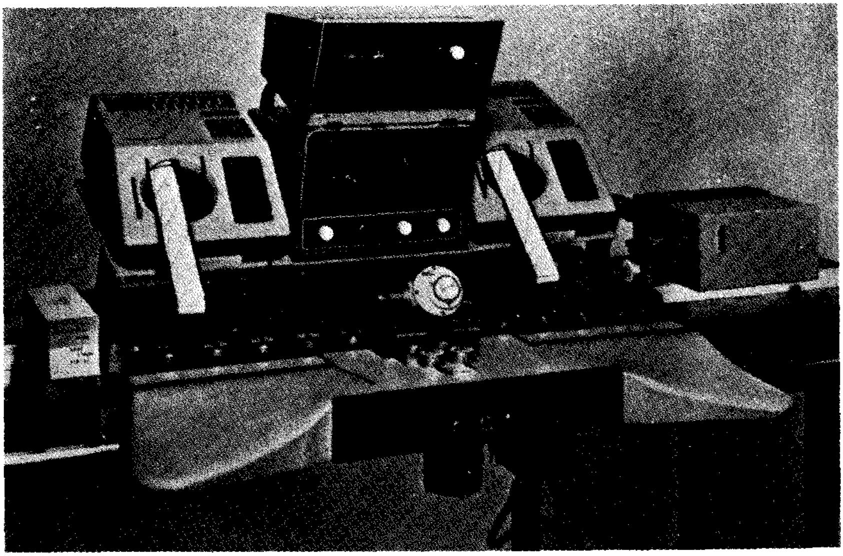


PLATE 3.—*Multi-purpose Greiner timing machine as used in the Tissot factory.*

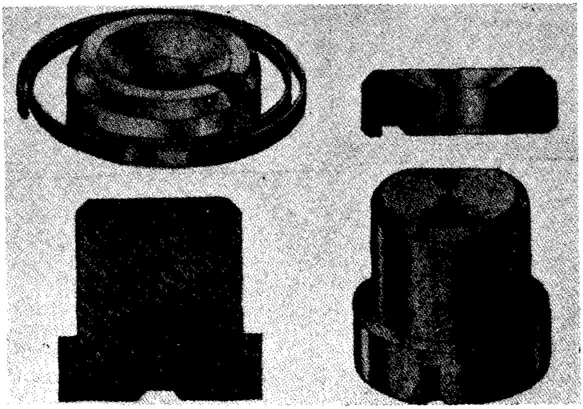


PLATE 4.—*How the Elgin balance spring is cemented into a slot cut across the collet, without stressing. The lower pictures show a new type of stud into which the outer end of the balance spring is cemented. The round stud seeks its own position in the balance cock and is then anchored with a stud screw.*

APPENDIX III

A NEW METHOD OF ATTACHING HAIRSPRING TO COLLET AND STUD

The problem of how to correct errors caused by pinning the hairspring to the collet and stud led Elgin National Watch Company to an exhaustive examination of means of attachment. After many years of experimenting with spot welding, soldering, etc., Elgin's Research Department developed a new cementing material which gave excellent strength in cementing metals securely together.

Development of this cementing material made it possible to design a completely new method of attaching the hairspring to the collet and stud, which—although more expensive—eliminates most of the disadvantages of the old way. The method uses a slot instead of a round hole in both collet and stud and eliminates the tapered pins. They are replaced by the special cement material which virtually makes the hairspring, collet, and stud a homogenous unit. The material adheres to metal as the finish of a car bonds itself to the body, and it has excellent resistance to all commercial watch cleaning and rinsing solutions used in the accepted manner of procedure.

By the use of special techniques, tools, and equipment, including a microscope, the hairspring is positioned so accurately in relation to the centre of the collet that it is automatically true in the flat and in the round. Elimination of excessive truing and levelling does away with the former conditions of stress and results in a watch that keeps a more constant rate over an extended period of time. Plate 4 illustrates the new method of attaching the hair spring to the collet and stud. A feature of the round stud is that it is made of a light-weight, non-magnetic alloy material which eliminates more than two-thirds of the weight of the old stud. This reduces the danger of hairspring entanglement when the spring is being assembled or cleaned.

Handling the Hairspring Units.

The cementing material used is superior to any adhesive on the market, but it has not been made available to watchmakers because of the techniques and equipment needed to work with it. Furthermore, it has now been used in millions of watches with only a very small percentage of cases in which the cement has loosened.

If absolutely necessary, you can cement the spring to the collet and stud by using shellac. Shellac, however, is not as satisfactory as the correct cementing material and may present problems when the watch is serviced in the future.

Extensive tests with various types of commercial watch cleaning and rinsing solutions on the market today have shown that practically all such solvents have a negligible effect on the cementing material. A few commercial solutions, however, contain high percentages of active chlorinated solvents which—if not used with caution—noticeably reduce the strength of the cementing material in a similar manner to that of alcohol with shellac. A hairspring should not be allowed to remain in a cleaning solution more than a few seconds which is all that is needed to remove film, dirt or oil. It should then be dried immediately in warm sawdust or warm air. Hairsprings always should be handled carefully during cleaning operations to eliminate damage to the spring. On the other hand, it would be perfectly safe to use benzine for cleaning purposes.

INDEX