Watch Adjustment

By Dewey Clark, President and Watchmaker, 2019

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“Repairing a watch is one thing. Rating it to position is something else.”

W.H. Samelius, 1944

Introduction

This article provides a description of the steps involved in returning a high grade watch to precision performance. It is based entirely on modern knowledge and practice as explained by a number of sources as long ago as 1963. Even in the US, W.H. Samelius was aware of these procedures in 1944.

The description is not based on new knowledge created by or the opinions of the author. It is taken from known sources that include WOSTEP, Greiner Vibrograf AG and H. Jendritzki, a Swiss watchmaking instructor.

The author became aware of some of this 15 years ago and started to question much of the information to which he had been subjected since 1985. After attending the WOSTEP program in Neuchatel he applied this knowledge in his business with satisfying results.

Watchmakers and collectors have been subjected to much misinformation about the proper service and performance capabilities of vintage precision watches. This is especially true when it comes to American Railroad (RR) watches, although it applies throughout the range of high grade watches.

This article is intended for the serious watch collector who wants to understand what a competent watchmaker will do in the course of service.

It was initially written after working with several recent graduates of global watchmaking schools. It became clear that after graduation, they have a period where they are uncertain how to apply what they were taught. Having attended one of these programs, I can attest that there is a lot of information to be absorbed and there is not much opportunity to digest it as a complete package.

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So one purpose is to summarize in one place what is taught about watch adjusting.

Another purpose is to assist those workers without the benefit of formal training in improving their work. While this article focuses on the technique of dynamic poising for positional adjustment, it must be cautioned that this technique is only useful in a correctly serviced watch. Dynamic poising will not overcome faults in an improperly serviced watch.

To that end, the subject is presented within the context of the watch adjustment sequence. These topics are treated briefly, as the knowledgeable watchmaker will understand and value that everything he/she does to a watch is to prepare it for positional adjustment as a precision instrument.

Less knowledgeable watchmakers may come to appreciate why they get less than desired results. This article may serve as a basis for determining a plan for skill improvement.

Finally, the watch owner will have a basis for evaluating the level of expertise of a watchmaker they propose to use for the maintenance of their watches.

Expectations for Precision Watches

Watches such as the American Railroad Watch were designed to be used as precision instruments. The American RR watch (typified by the iconic Hamilton 992) was sold, used and serviced with the expectation that it would have a maximum daily error of 5 seconds per day that was consistent and predictable. Given RR watches recorded 432,000 seconds in a day, this means the watch had a calibration error of 1 part in 86,400!

That is truly an accomplishment that should be, and can be, preserved. The original standard for the Hamilton 992 is tighter than the factory standard for a modern Rolex.

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Yet, many owners and watchmakers believe it is impossible or unrealistic to have these 120 year old watches perform to that standard today.

There are many reasons for this. Probably the biggest is that for 20 years or so these precision instruments were not appreciated for what they were. They were given to curious children and used by others as practice pieces. Secondly, and egregiously, authors popular with individuals without the benefit of formal training encouraged methods that actually amount to vandalism. Finally, even trained watchmakers came to conclude that most owners were unwilling to pay for the time required to properly service these watches and simply performed a "cleaning and lube" while telling customers they should not expect precision performance due to age.

Of course, any mechanical device can be returned to original performance if it is returned to factory condition and properly serviced. Because of the necessity to correct damage done by the naive, the initial cost can be high and may involve the use of a "donor" movement for unmolested parts.

But, after such work, the cost of service drops dramatically if the watch is serviced by a knowledgeable watchmaker. And while it generally costs $750 to $1000 to have a modern watch serviced, the cost to maintain a Hamilton 992 in proper condition is generally under $400. And it is a piece of American history.

Sadly, many precision watches have been altered/vandalized. There was a period during which these watches were not valued and they were given to children or used for practice by untrained workers.

The most common damage was to the balance assembly. For whatever reason, many came to believe that the balance must be statically poised after they replaced a staff. They then went on to remove material from screws, often then needing to add timing washers to correct for removing too much material.

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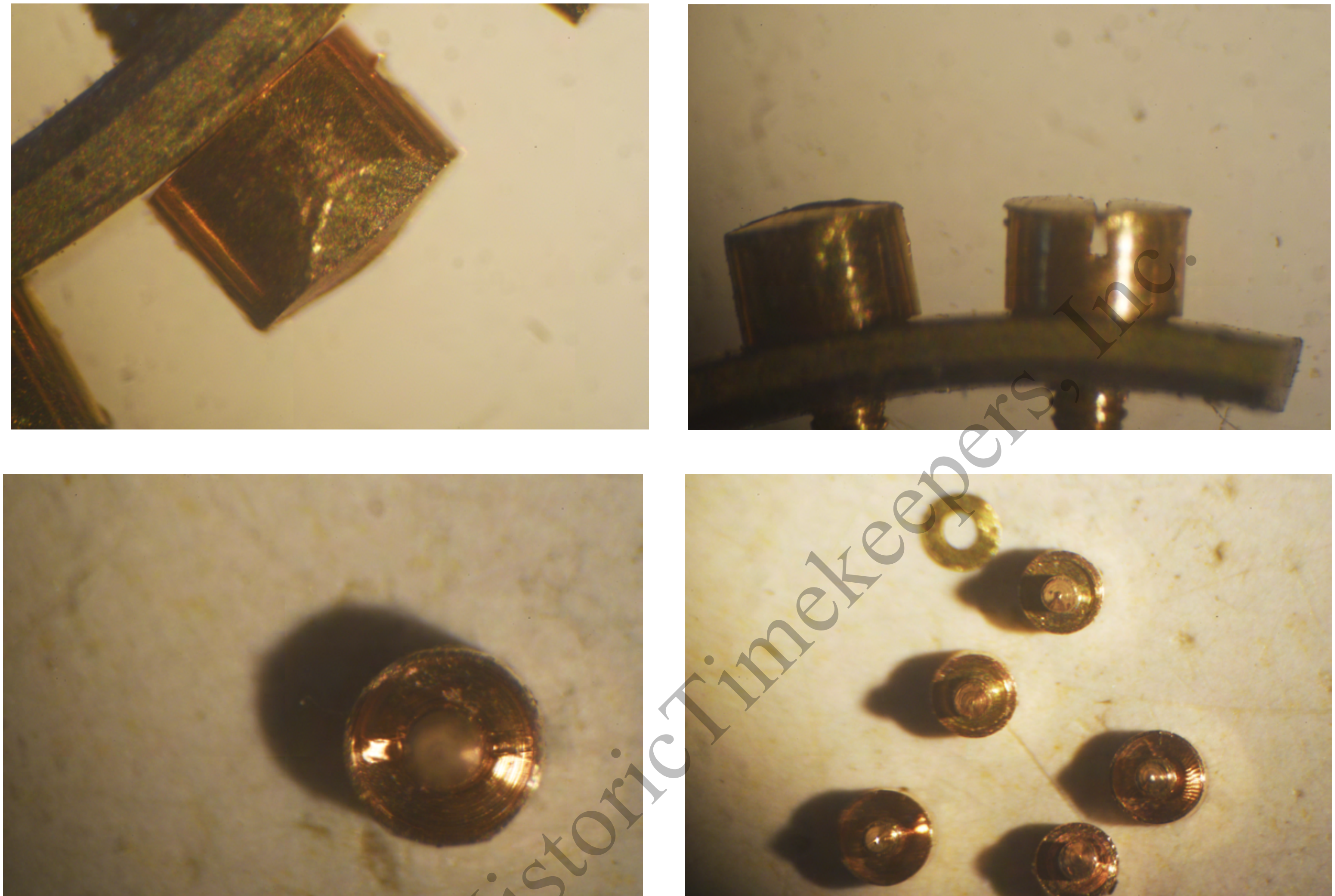

Vandalized balanced screws as recommended by certain authors

(The bottom left is now only a hollow thin shell; all these are solid gold)

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Not only was this incorrect, as you will learn from this article, it was futile from the start. Given that the methods used to remove material were based on files, drills, counter bores or the lathe, there was no way to accurately measure how much material was removed; let alone no way to determine the amount of material intended to be removed.

This damage often requires the watchmaker to find a donor movement with a good balance and balance spring. Since Railroad and other high grade watches have the serial number of the watch scribed on the underside of the balance, it is important the balance wheel itself be "rescued." The screws and balance spring from the donor watch must be transferred to the watch under restoration. Of course this means the donor watch has now been lost.

While returning a watch to original factory condition is time consuming and expensive, once done and adjusted, the cost of routine service drops dramatically as long as a competent watchmaker is used.

This article is primarily for young (in experience) watchmakers and owners who want to understand how a watch is maintained as a precision instrument. To use this information, the watchmaker must first master many skills including proper cleaning technique, lubrication, critical self appraisal, escapement adjustment, basic repairs such as staff replacement and pivot/jewel fitting, etc.

Watch adjustment cannot overcome a poorly serviced watch.

What is watch adjustment?

It is extremely important to understand watch adjustment cannot overcome faults present in a watch. All faults must be corrected prior to any attempt at watch adjustment. This particularly applies to magnetization.

A watch must be in "perfect" condition, otherwise a watchmaker is making random changes and chasing his/her tail.

There are several components to watch adjustment. All of these components lead to the final condition in which the watch performs as a precision timekeeper. For a Hamilton Railroad grade watch, this means that it will keep time to within 4 seconds per day in a consistent manner.

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This standard actually exceeds the factory specifications for a Rolex, which uses an alloy balance assembly and has automatic winding to maintain even power to the balance assembly.

From here on in it is assumed the watch has been properly cleaned and lubricated. The details throughout this discussion highlight the need to eliminate sources of variation due to physical differences. Banking pins must be straight and rigid so that the safety action of the dart and roller is consistent even as the lever changes its position due to the required end shakes. The balance spring must be centered between the regulator pins regardless of spacing to alter isochronism. The regulator pins must be straight and rigid. Pivots must be a close fit to their hole jewels and the pivots truly cylindrical.

<u>Temperature adjustment vs. Positional adjustment.</u> For better or worse, the distribution of the mass around the bimetallic balance wheel is used to adjust both *temperature* and *positional* rates. Both cannot be perfectly accomplished at the same time. The way the piece will be used must determine which adjustment is most important.

A pocket watch can assume any position but is kept at a fairly constant temperature in the pocket. A marine chronometer is generally used in one position but can be exposed to a wide range of temperature from below freezing to equatorial.

So position takes preeminence for pocket watches, temperature for marine chronometers.

<u>Permanent adjustments designed into the watch.</u> These include the major factors that define the watch's performance in dial up, dial down and nearly wound and nearly run down conditions. They include the pivot sizes, hole jewels and the collet location for the balance spring.

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The pivot sizes must be identical for the watch to keep the same rate regardless of which pivot is supporting the balance assembly. Pivot size also impacts how similar the watch rate will be when the watch is suspended by both pivots (movement in a vertical position) as compared to when it is resting on a pivot end (horizontal positions).

The pivots, balance spring, balance and collet location and mainspring all determine how equal the watch rates will be when nearly fully wound and after 24 hours.

<u>This is called isochronism.</u> Isochronism means that the balance will complete its rotation in the same amount of time at high amplitudes (full power) and at low amplitudes (low power). Amplitude is how watchmakers measure the extent to which the balance rotates. If it rotates 270 degrees, it is said to be at high amplitude (which is standard for a freshly serviced watch) and 180 degrees is considered low amplitude.

We define amplitude as the angular displacement of the balance in one swing of the balance. The oscillation of the balance covers two swings, one forward and one return. So a balance with an amplitude of 270 degrees has a total oscillation of 540 degrees. This is often a point of confusion.

The importance here is that there is very little a watchmaker can do to improve isochronism. As will be seen later, a knowledgeable watchmaker can adjust the regulator pin spacing to improve isochronism. But, there has been much misinformation about how to use regulator pins for any number of things. Their only functions are to adjust the effective length of the balance spring and isochronism.

<u>The escapement.</u> The escapement includes the *escape wheel (EW), pallet jewels (entry and exit), impulse jewel* and *banking pins*; plus the *impulse roller* and *safety roller* mounted on the balance.

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The lever escapement is the most widely used for watches because the balance (oscillator) is free from the force of the mainspring for all but a small percentage of its rotation. This makes for a stable oscillator.

The escapement actually performs three independent functions. These are to power the oscillator (balance assembly), to release the train so the hands can advance on regular intervals, and to ensure the escapement is not deranged by normal shocks (safety).

<u>Powering the Oscillator (Impulse).</u> The most obvious function is to supply power to the *oscillator* (the balance assembly) through the escape wheel tooth, transmitting lift to the *pallet jewel* which then forces the lever over. At the end of the lever is a notch (impulse slot) which transmits power to the impulse jewel mounted on the balance wheel.

The lever is moved from side to side by the impulse jewel on the balance. As the impulse jewel enters the impulse slot it contacts the far side of the impulse notch unlocking the pallet jewel, which is locking an EW tooth. The pallet jewel then receives power from the EW tooth face which accelerates the lever and the impulse notch. The lever moves so fast that the other side of the notch catches up with the back side of the impulse jewel, delivering power to the keep the balance in motion. It is true impulse as defined by physicists.

This is how external power is supplied to maintain the oscillator.

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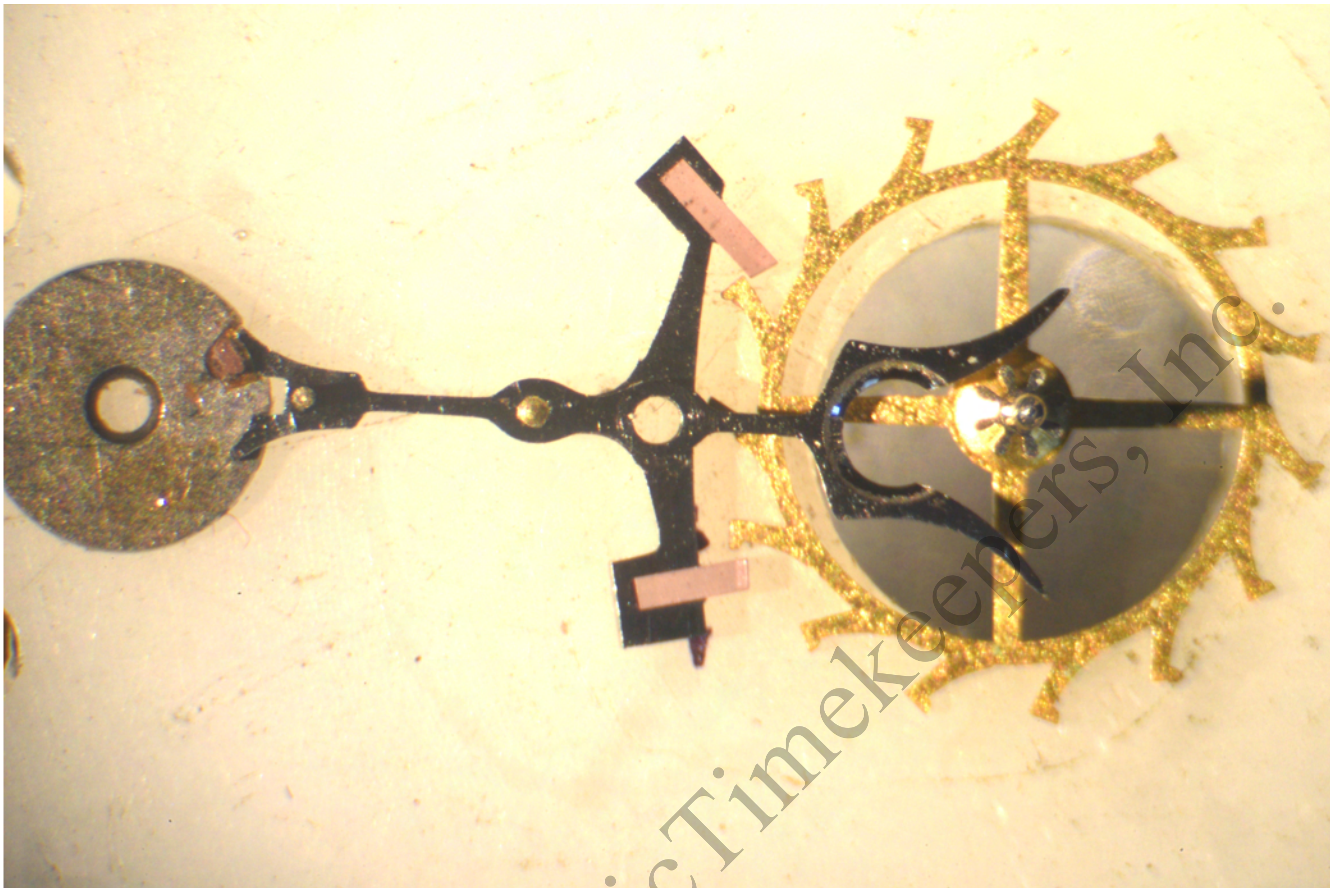

Lock A

The Escape Wheel tooth is locked on the EXIT pallet

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Unlock

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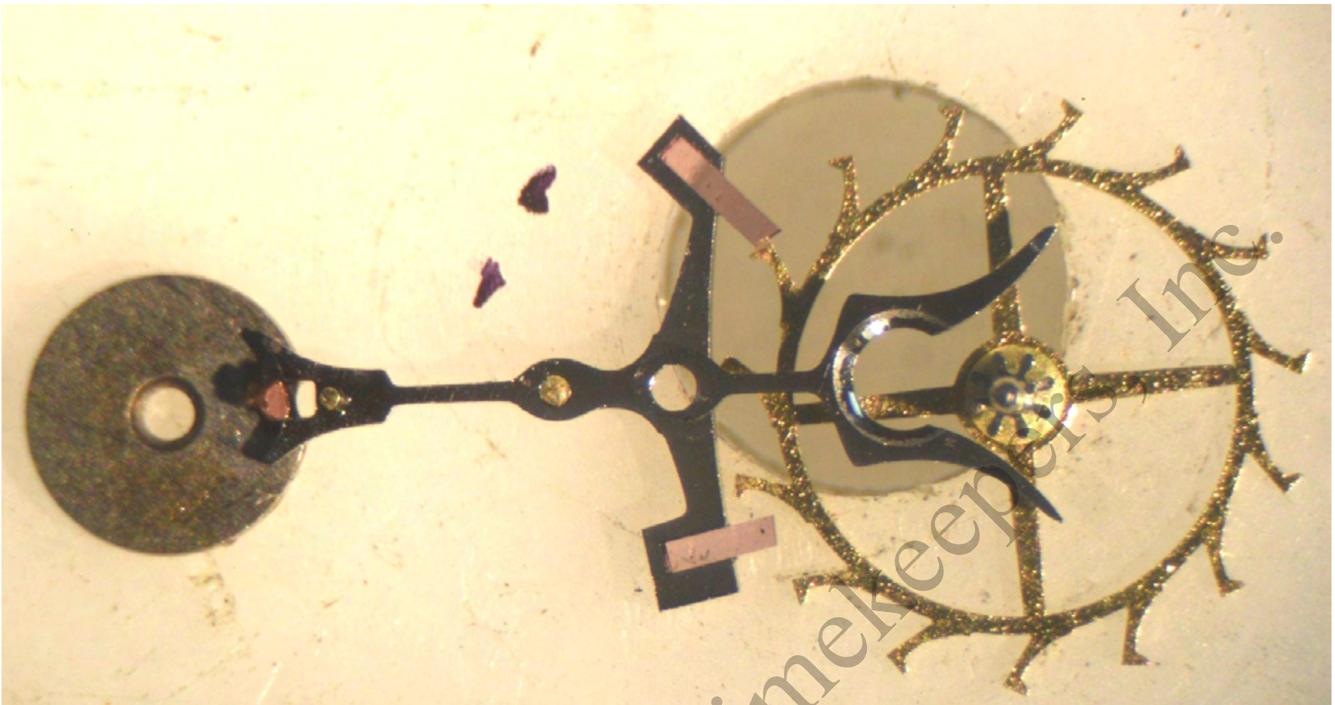

Impulse

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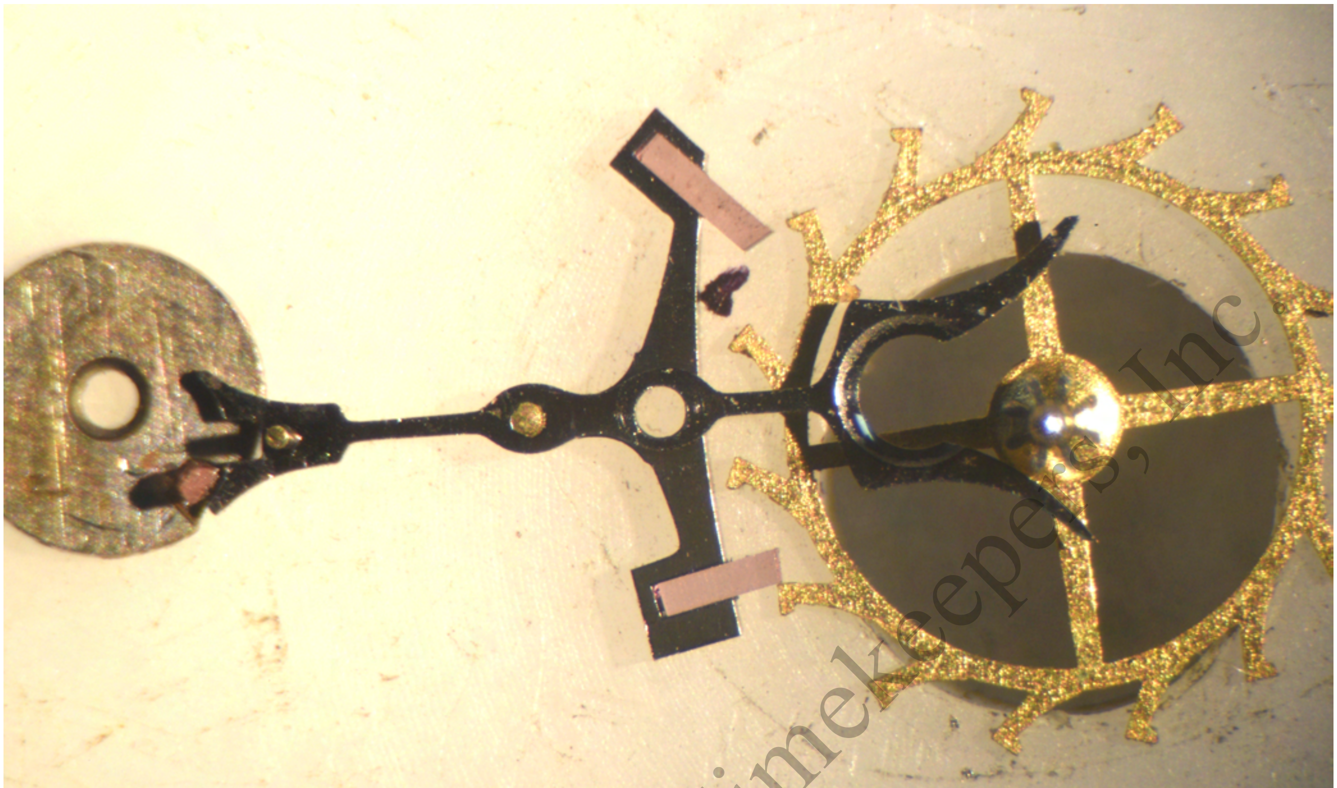

Lock B

The Escape Wheel is locked on the ENTRY Pallet

The above photos show the escape wheel, pallet fork assembly and roller in their approximate locations. In these 4 photos, the single roller table is upside down in relation to its orientation in the watch so you can see the impulse jewel.

The ENTRY pallet is the where the EW tooth locks on the outside face of the jewel. The EW tooth locks on the inside face of the EXIT pallet jewel.

In Lock A, the escape wheel tooth has just dropped on the locking corner of the EXIT pallet jewel (drop lock). The impulse jewel has cleared the notch on the pallet fork.

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In Unlock, the balance is on its return swing. The impulse jewel is serving its second purpose by hitting the far side of the notch and moving the lever so the EW tooth can unlock from the pallet jewel.

In Impulse, the impulse plane of the EW tooth is delivering power to the impulse face of the pallet jewel. If you look carefully, you can see the far side of the pallet notch is now delivering that power to the impulse jewel on the side opposite to the one that just enabled unlock.

In Lock B, you can see the ENTRY pallet jewel is now locking an EW tooth and the sequence will start again but in the other direction.

These are the sounds heard by your timing machine.

Counting the seconds. The second function of the escapement is the release of the gear train which advances the second, hour and minute hand. Each time the escape wheel provides power to the balance assembly, a second pallet jewel blocks (*locks*) another tooth of the escape wheel. Each time this occurs, the second hand advances ⅕ second on an American RR watch.

This time interval is determined by the balance assembly (oscillator). It is a function of the balance mass, balance diameter and the strength of the balance spring. The ⅕ second period of the American RR watch is termed 18,000 beats per hour (5 beats per second X 60 seconds X 60 minutes). Marine chronometers have a beat of 14,400 beats per hour (2 beats per second) and many modern watches have beats up to 36,000 beats per hour. As an aside, a positional error of 5 seconds in 24 hours results in a calibration error of 1 part in 86,400.

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<u>Safety Function.</u> **There is a third, less obvious function of the escapement. This is to ensure the lever does not cross to the wrong side of the impulse jewel (over-banking) which would stop the watch. This is called the safety function and there are two types.**

The *single roller* uses the impulse roller into which the impulse jewel is mounted and a vertical pin in the center of the pallet. If the watch is knocked while the lever is at rest (locked), the pin will hit the roller and prevent the watch from over-banking.

The disadvantage is that the impulse jewel roller is large and there is significant interference in timing when the safety action of the single roller is activated by a shock.

The *double roller* minimizes this. A second smaller roller (safety) is mounted below the impulse roller. A small dart is added to the lever which extends past the lever fork. The dart still hits the safety roller, but since the roller is smaller the impact on timing is greatly reduced.

Both designs are equally effective at preventing over-banking. If a single roller escapement over-banks there is a fault which must be corrected.

The black dots in the next two photos represent the banking pins and the lever has been lifted off by a shock. They represent the safety action of the two escapements.

In the Single Roller Safety Action photo, you can see the lever lifted off the banking pin and how the vertical dart now hits against the impulse jewel roller. This is why these rollers have to be clean, polished and round (not stretched or cracked).

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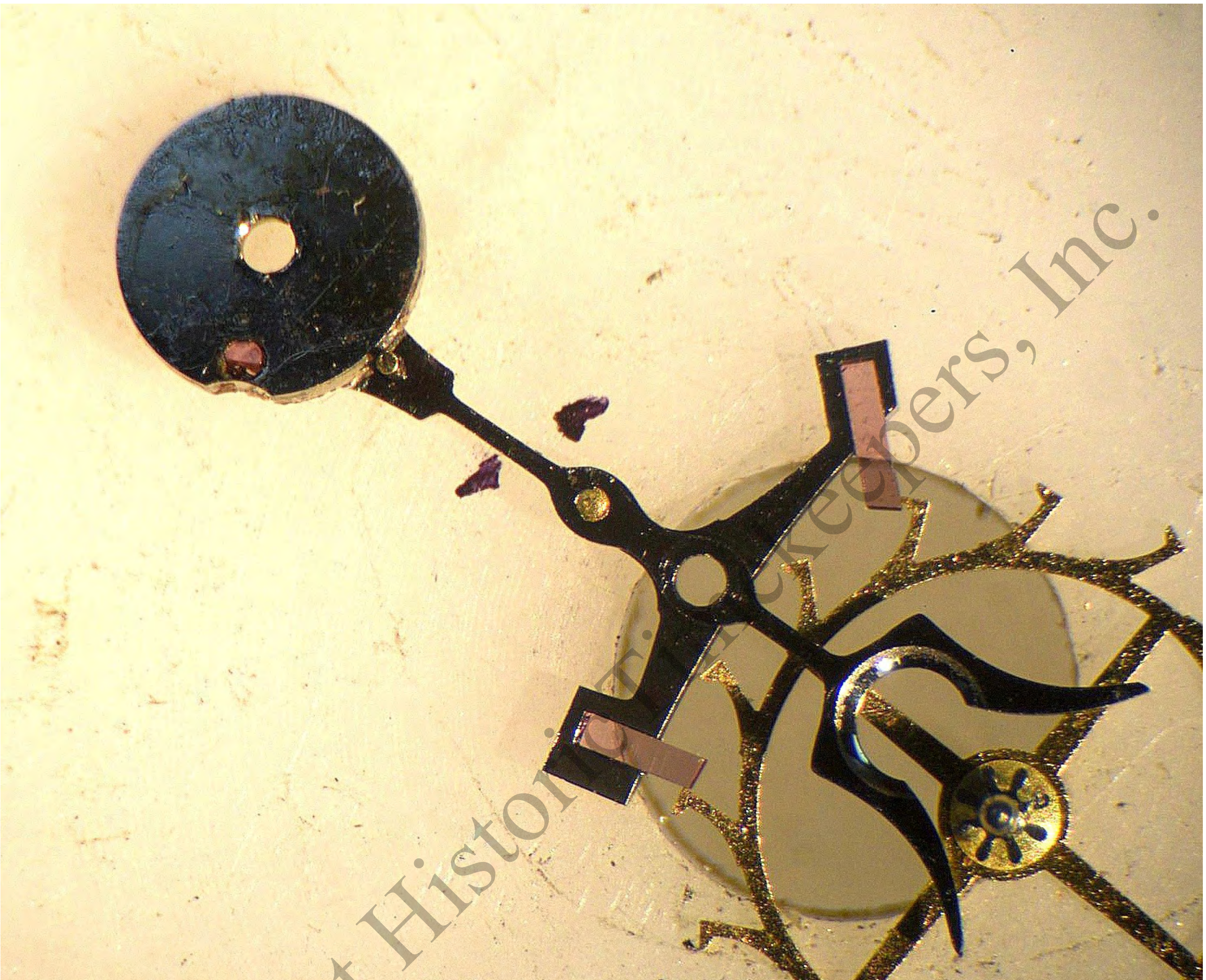

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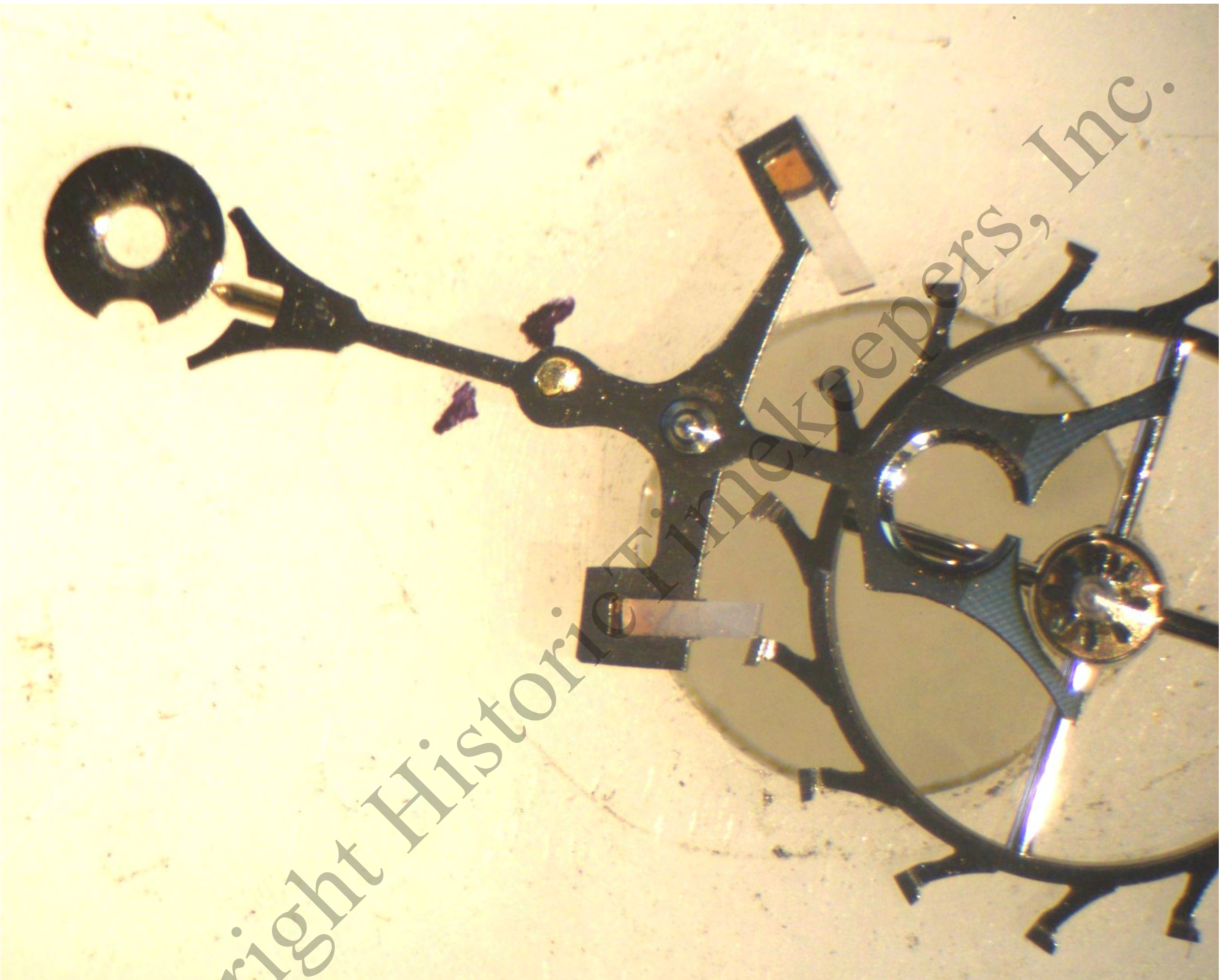
Single Roller Safety Action

In the Double Roller Safety Action photo, you see the advantage of the double roller. It is smaller in diameter and offers less of a lever arm for the resistance caused when the dart contacts the roller. These small safety rollers can be cracked very easily by forcing them onto over-sized staffs (not unusual). This deforms the roller creating unpredictable positional adjustment challenges. Measure the original and the replacement staffs and correct if the replacement staff is over-sized!



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Double Roller Safety Action

The two photos below clearly show how the impulse roller in the single roller escapement is used to provide safety while the double roller escapement employs a second, smaller roller beneath the impulse roller.

Single Roller Escapement

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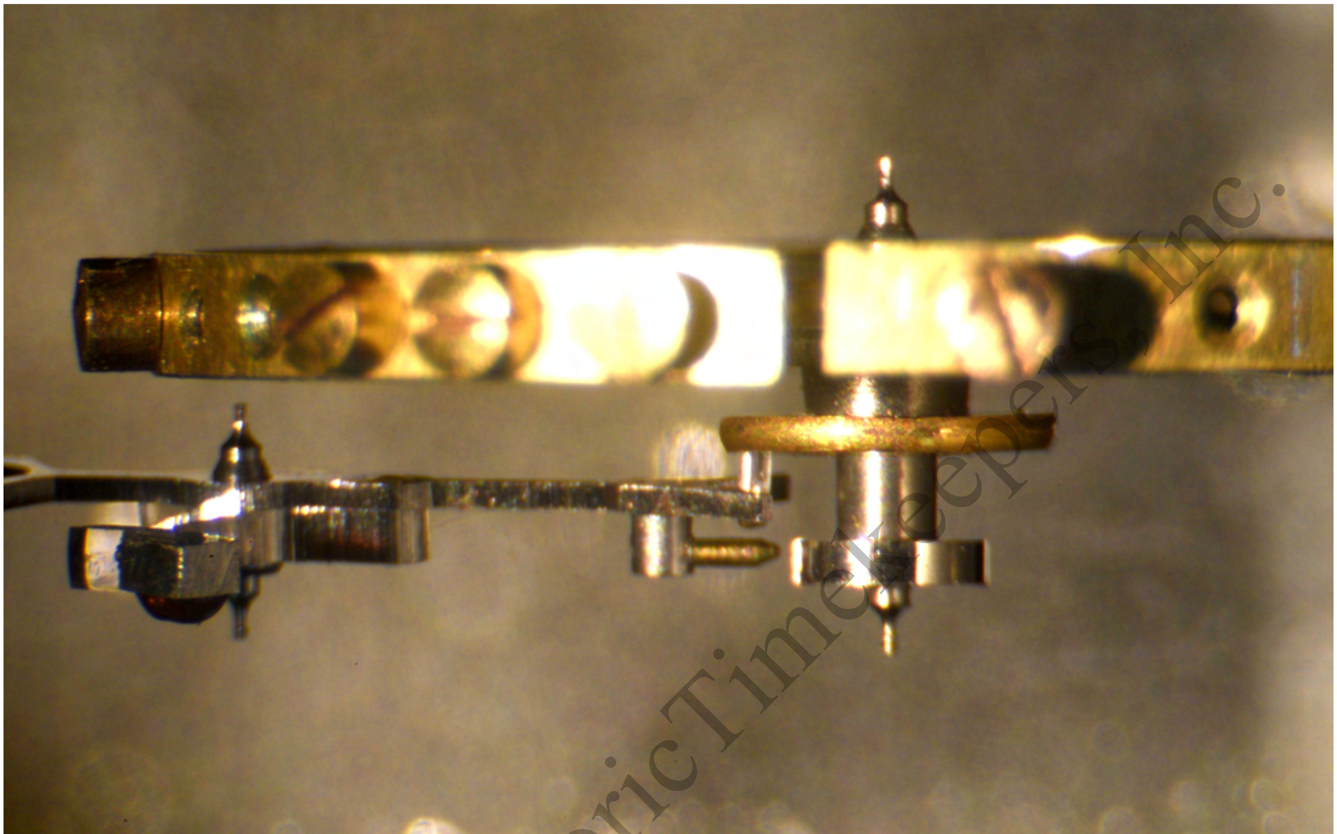

Double Roller Escapement

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<u>Adjusting locks requires a means of measurement.</u> Many of the methods described by American authors suggest locks can be adjusted by eye. This is patently untrue. How is the pallet stone returned to the original position if it was the wrong move? How do you reduce or increase a move by a precise amount?

<u>Measurement.</u> The Swiss for years have used a tool called an escapement meter with a scale marked in hundredths. No one knows what the scale really measures since the geometry and size of pallet assemblies varies widely. But it does not matter. For THAT pallet assembly, the scale will

indicate a unit increase or decrease and after trial the pallet can be returned to the tool, adjusted to the last scale indication and altered from there. The math minded will know this as an interval scale (has direction but "4" is not twice as big as "2," like a thermometer vs. a ruler).

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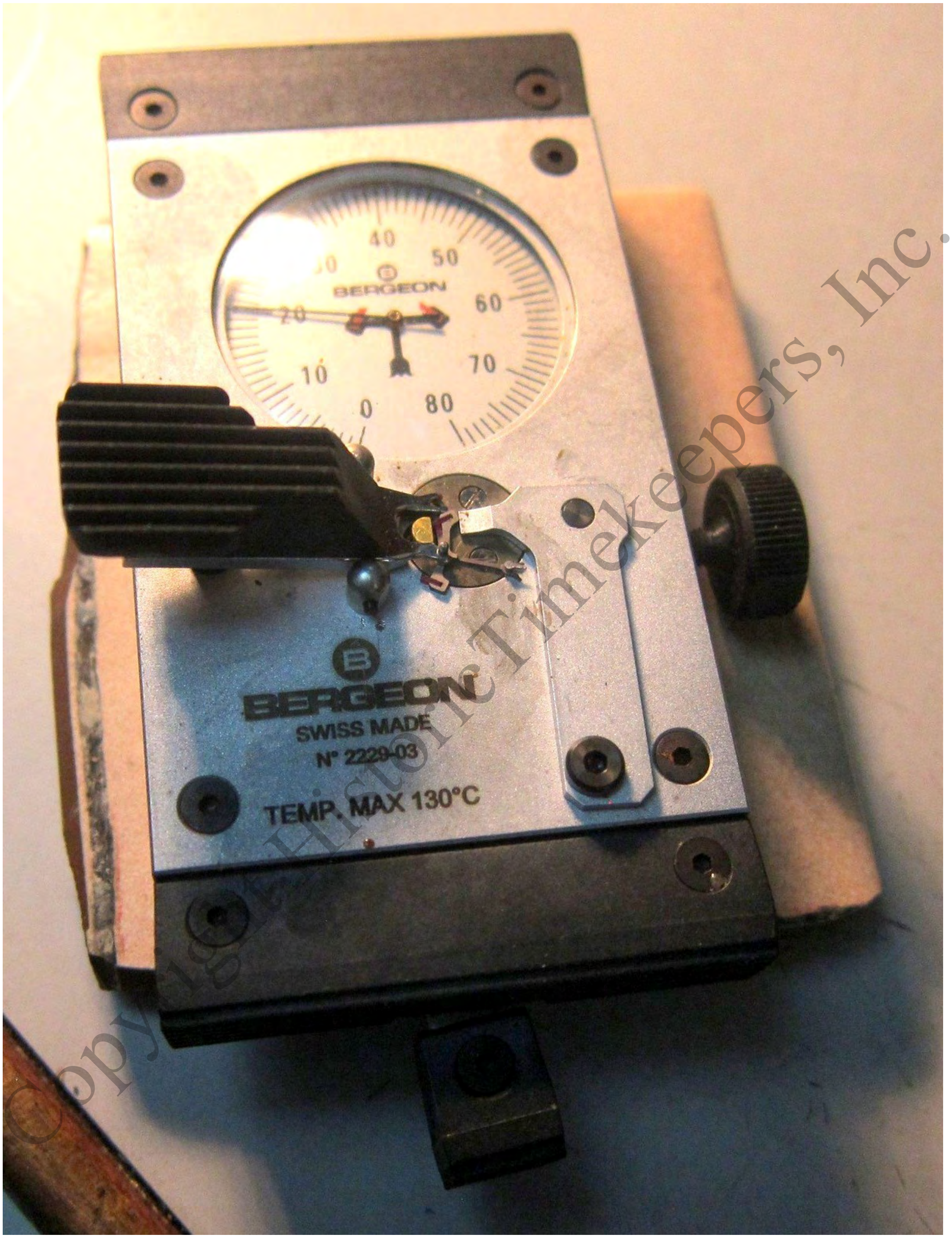

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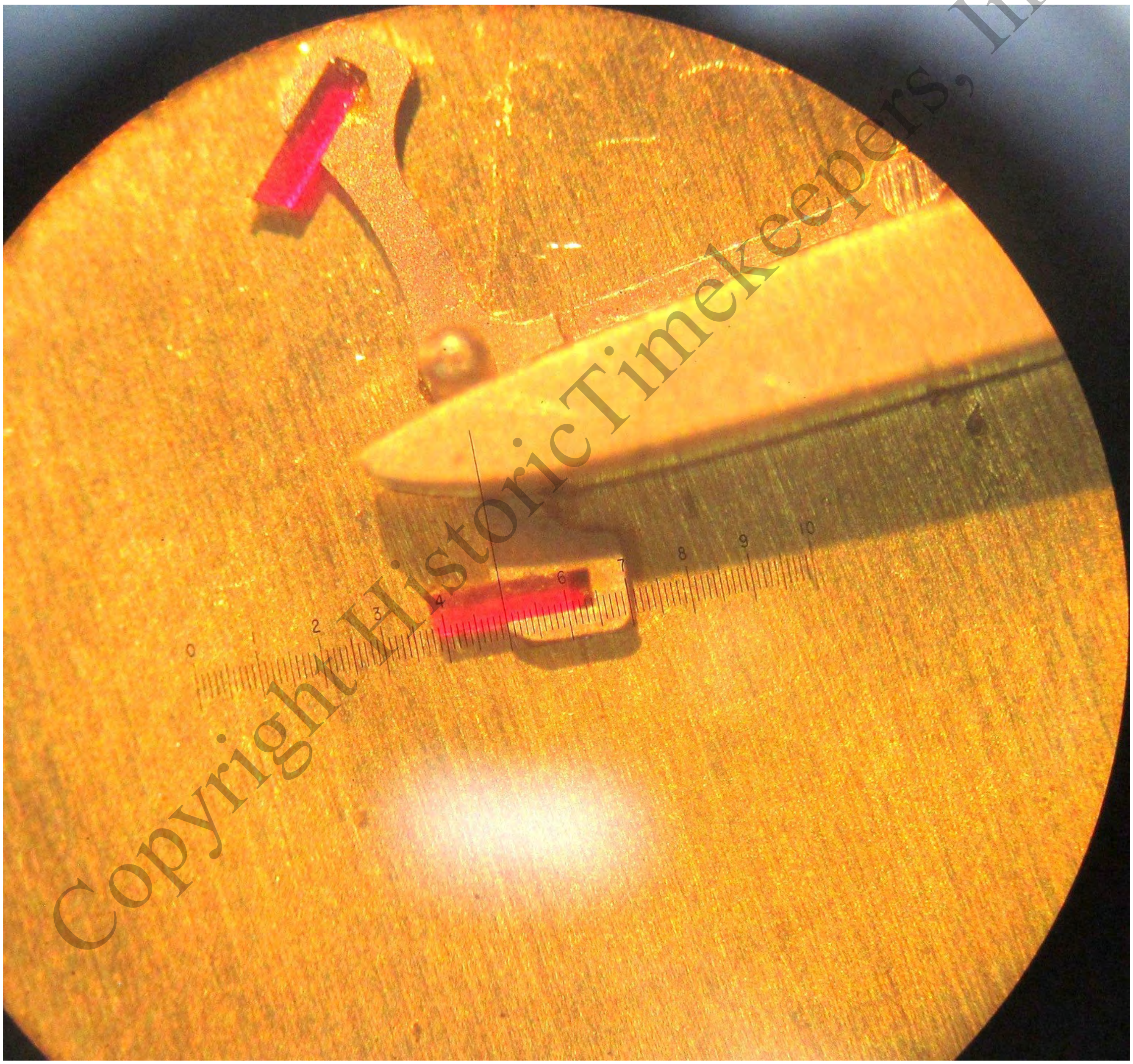
Bergeon Tool

These tools are quite expensive and may be why American authors never mentioned them.

But, there is a way to measure with a microscope equipped with a reticle. You can measure the jewel exposure from one of the pallet frame corners. You do need to make a clamping plate but it works.   I developed it in response to a readers who asked about an alternative.



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View through eyepiece showing reticle scale against the pallet jewel

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Plan for Precision Pallet Adjustment showing plate and heat resistant pad under scope

While this is not the place for details on normal tasks, there is no need to buy a special Swiss heater for adjusting locks. Simply placing the tool or clamp plate on an adjustable hotplate does the same thing.

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Adjustable hot plate

In my opinion, every watchmaker should have a good stereozoom microscope and hot plate. Alcohol lamps are simply unneccesary. Bluing can be done on a lab grade hot plate much more consistently.

<u>Natural errors of the lever escapement.</u> There are several aspects of physics which must be understood at this point concerning forces applied to a rotating body such as the rotating balance assembly. These forces can be resistive or additive.

Again, the neutral point refers to when the impulse jewel is centered in the impulse notch of the pallet.

A negative force applied before the neutral point will cause a loss. Such a force is the resistance to unlocking.

A positive force applied before the neutral point will be additive, but becomes negative after the neutral point is passed. Both happen during impulse.

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Merksatz: Alle Einflüsse in Richtung auf die Mittellinie zu bewirken einen Vorgang. Alle Einflüsse von der Mittellinie fort bewirken einen Nachgang (Abb. 1a, 1b).

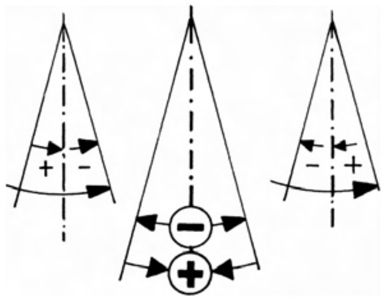

Abb. 1a Beeinflussung des Gangreglers
links: Einwirkung in Schwingungsrichtung:
vor der Mittellinie = Vorgang
hinter der Mittellinie = Nachgang
rechts: Einwirkung entgegen der Schwingungsrichtung:
vor der Mittellinie = Vorgang
hinter der Mittellinie = Nachgang
Mitte (vereinfacht):
Einwirkungen zur Mittellinie = Vorgang
Einwirkungen fort von der Mittellinie = Nachgang

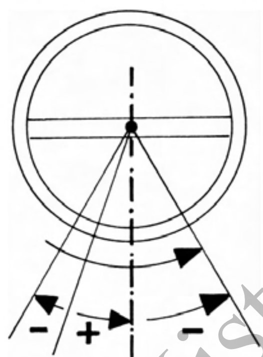

Abb. 1b Einwirkung der Hemmung auf das Schwingsystem Unruh–Spiralfeder
Auslösungs-Widerstand weit vor der Mittellinie = Nachgang
Kleiner Teil des Antriebes vor der Mittellinie = Vorgang
Größter Teil des Antriebes hinter der Mittellinie = Nachgang

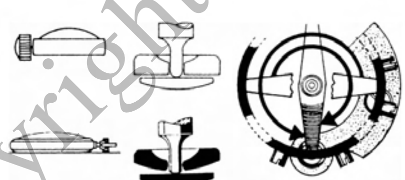

Abb. 2 Amplitude horizontal 270°

Durch die Hemmungseinflüsse ist es natürlich unmöglich, dass ein Schwingungssystem die großen und die kleinen Schwingungen in der gleichen Zeit ausführt, also „isochron" schwingt.

Ein frei arbeitendes Schwingsystem – Unruh – Spiralfeder – könnte durch Berücksichtigung aller Reglageregeln dem „Isochronismus" nahegebracht werden, aber die Hemmungseinflüsse würden einen immer stärkeren Nachgang hervorbringen, je kleiner die Schwingungsweite der Unruh wird. Diese Verringerung der Schwingungsweite erfolgt nicht nur durch ungleichmäßige Zugfederkraft, durch Eingriffsstörungen, sondern auch durch eine Zunahme der Reibung beim allmählichen Verdicken des Öls oder Verschmutzen der Uhr.

Um all diesen verzögernden Einflüssen und nicht zuletzt auch dem – noch immer unvermeidlichen – Reibungszuwachs in der Unruhlagerung in den senkrechten Positionen von Anbeginn entgegenzuarbeiten, ist uns ein Isochronismus nicht nur unerwünscht, sondern wir brauchen einen Vorgang in kleiner Schwingungsweite, damit der Nachgang gemildert wird oder ganz verschwindet. Und falls ein kleiner Vorgang entsteht, ist dieser immer angenehmer als ein Nachgang.

Um diesen Vorgang in kleinen Schwingungen zu erreichen und damit die Reglage für längere Zeit zu stabilisieren, nutzen wir alle Möglichkeiten aus, die insbesondere der Ansteckpunkt der Spiralfeder an der Rolle (point d' attache) zur Stellung des äußeren Ansteckpunktes und zur Stellung des Werkes (Kronenlage) bietet.

Die Reglage einer Uhr wäre wesentlich leichter, wenn die Schwingungsweite der Unruh gleich groß bliebe. Da dies nicht der Fall ist, müssen wir in der Praxis versuchen zu erreichen, dass die Zeitdauer der einzelnen Schwingungen einigermaßen gleich bleibt.

Aber selbst wenn dies gelingt, bleibt oft noch ein Unterschied zwischen den beiden waagerechten Positionen: Zifferblatt oben und Blatt unten, und den vier senkrechten Positionen: Krone oben, Krone links, Krone rechts und Krone unten. Dieser grundsätzliche Unterschied entsteht durch die veränderten Reibungsverhältnisse in der Lagerung der Unruhwelle.

2 In der Uhr-Position „Waagerecht liegend" dreht sich die Unruhwelle bei fast nur punktförmiger, also sehr geringer Reibung mit der Zapfen-Arrondierung auf dem Deckstein.

3 In der Uhrposition „Senkrecht stehend" liegen beide Unruhzapfen auf den Lochwandungen und drehen sich mit ihrem Zapfenradius, wodurch die Reibungsarbeit unverhältnismäßig größer geworden ist. Die Schwingungsweite der Unruh nimmt daher in fast allen Uhren mehr oder weniger ab, je nach Ausführung der Steinlager, deren Lochwandung darum „oliviert" (ausgerundet) wird.

Diese Abnahme der Schwingungsweite ist (noch) unvermeidlich. Sie kann durch das entsprechende Anstecken der

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Natural Escapement Errors from *Watch Adjustment*, Jendritzki, 1963
Coutesy of http://www.booksimonin.ch

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The net effect of these is to produce a loss due to escapement error.

The corollaries are:

> **The further from the neutral point, the smaller the impact.**
>
> **The smaller the amplitude, the greater the effects.**
>
> **Even the resistance of the balance spring must be taken into account.**

<u>These result in several implications.</u> First, to reduce the impact of natural errors, the watch should run with high amplitude as long as possible. Most of the escapement error occurs while the escapement is in direct contact with the balance. In Hamiltons this is 48 degrees of the balance rotation. In Swiss watches it is 52 degrees. This is the lift angle in our charts.

Forty eight of 180 degrees is a much greater percentage than 48 degrees of 270 degrees.

Secondly, it is why isochronism in the "ideal state," where external influences are ignored, is insufficient. It must be adjusted in real conditions which include the external forces required to maintain motion and those that result from the natural escapement errors. It requires trial and error to find the best location for the pinning point of the collet and even the type of terminal curve at that location for a new design.

This is one of the many reasons I am skeptical about all those claims to "fit a new balance spring." Without the factory patterns, how can one person fit springs to a wide variety of watches, especially since it takes weeks to master one spring design when supplied with the pattern!

The resistance forces must be kept to a minimum. Increased depth of lock results in increased resistance; draw too strong does the same. These are both effects of "opening banking pins." Banking pins (if adjustable) should

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be opened only to allow minimum total lock (drop lock plus slide) required for the safety action. Modern watches eliminate adjustable banking pins.

A less obvious impact comes from the balance spring. If the balance spring is still winding when it should be unwinding (*beat error*) after the balance has passed the neutral point, it will impact timing. The balance spring must be fully relaxed when the balance is at its neutral point.

<u>This is adjusted using *beat error*.</u> Beat error is the difference in the time interval it takes to deliver impulse in from one balance swing and the impulse in the return swing from the other. It is why a beat error under 1 millisecond is emphasized.

The strength of force by which the pallet jewel is held against the escape wheel tooth (*draw*), the depth of the pallet jewel on the escape wheel tooth (*lock*) and the extent to which the pallet must be moved to disengage the escape wheel tooth (*slide),* all have significant impact on the natural errors.

<u>Adjusting the escapement includes beat error, lock, slide and draw.</u> The interfering forces applied by these conditions must be minimal.

Beat error is initially adjusted with the mainspring completely let down. The balance spring collet is rotated on the staff until the impulse jewel is centered in the pallet notch when the balance is at rest.

However, visually setting the beat error is not precise. This is due to the fact that the balance rotates more in one direction than the other depending on whether the balance spring is winding or unwinding. Final adjustment must be made with an electronic instrument. A beat error of under 1 millisecond has no measurable impact on timing.

The locks must be as light (shallow) as possible consistent with safe locking on all escape wheel teeth. The draw must be just strong enough.

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A watchmaker can only alter this to a small degree. The slide must be minimal as is consistent with proper functioning of the safety roller.

Like altering balance screws, these adjustments cannot be properly executed with guess work. Watchmakers who apply heated needles to the pallet stone cement so they can "move it a little" are wasting time. An accurate way to measure the alterations (and reverse them) is needed.

The banking pins must be as closed as is safe. Wide banking pins are a sign of a mechanical fault that precludes watch adjustment.

All of these things are permanent until someone consciously alters them. In a watch with a history of good and proper service, these will not need to be touched. But vintage watches often have not been properly serviced.

<u>Adjusting to Position.</u>

After the watch has been serviced it should be "perfect." Pivots fit their jewels correctly, escape wheel acts on the center of the pallet jewel faces, pallet jewels are level and well secured, proper end shakes, ensure all parts are centered and cannot move enough to foul on another part, balance spring is level and true, same with balance wheel and the watch is properly lubricated. The watch is fully demagnetized.

<u>Adjusting to position ensures the watch will keep a consistent rate when worn.</u> If a watch has a rate difference of 6 seconds among the horizontal and vertical positions, it cannot develop a rate error that exceeds 6 seconds per day when worn.

Watches regulated to be 15 seconds fast per day in use, but which can be made to show an error of 2 seconds after spending the night dial down, are not adjusted! The owner is trying to compensate for a fault in the watch.

Adjusting the regulator so the watch splits its timing problems is also not adjusting. This is exemplified by setting the regulator and /or regulator

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pins so the watch is 15 seconds fast in the horizontal and 20 seconds slow in pendant up.

An adjusted watch will show a proportional error throughout the 24 hours. That is, if it has an error rate of plus 4 seconds per day, it will show a dial reading error of plus 2 seconds 12 hours after being wound and plus 4 seconds 24 hours after being wound. Its dial error will be proportional to the time since it was last compared to a standard (like GPS time).

<u>Isochronism</u> is checked by timing the watch at low power (180 degrees amplitude) and at high power (250 to 290 degrees amplitude) in one horizontal position (dial down).

A precondition is that the balance spring be centered between the regulator pins when it is at rest and in beat (beat error under 1 millisecond.)

There is little the watchmaker can do to alter this. However, if the watch uses regulator pins, the pin spacing can be altered to bring the rates between high and low amplitude as close together as possible while keeping the balance spring centered between them.

<u>Horizontal Positions.</u> Check the dial up and dial down rates. They should be identical. If not, find the fault now. They are a function of movement prep, including pivot condition and lubrication. Check for fouling of parts. If the watch was in "perfect" condition, there should not be a problem. If there is a difference, there is a problem.

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Vertical position adjustment. This is where the trouble starts. It takes time and discipline to perform this. It requires a good electronic timing instrument.

The traditional description of the 4 vertical positions are pendant up, pendant right, pendant down and pendant left.

The procedure discussed here discards the pendant as a reference point in favor of the escape wheel. This makes it easier to determine where the adjustment should be made.

This description will use a post 1920 Hamilton railroad grade pocket watch. This is because these watches have 4 adjustment screws (timing screws) referred to as ¼ screws. The method here is extremely useful on high grade balance assemblies without timing screws; but those require the use of timing washers.

NOTES OF CAUTION:

Never remove material from the balance assembly. Regardless of what has been written, this is nothing short of vandalism. If the screws were of the proper mass when the watch left the factory, by what mechanism did they acquire MORE mass? If adjustments are needed to a balance without timing screws, add timing washers.

Check the vertical rates before doing anything else. You are doing this now anyway; but this is because you will never static poise (poising tool) a balance again. For an after-sales watchmaker, the poising tool amounts to a parlor trick. Cool to do but pointless.

Static poise only has value when making a completely new balance assembly (balance and spring). It provides a starting point. But after the watch is adjusted to positions, the balance will by definition be OUT of static poise. It left the factory out of static poise! The old books make it

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appear static poise is an end to itself. The end to be reached is equalization of rates in the vertical positions: dynamic poise.

Dynamic poise **is to watches what dynamic wheel balancing is to automotive mechanics. It is not enough to assume a statically poised balance will result in a poised balance assembly while in motion.**

In the watch, there are various factors that influence dynamic poise. The easiest to understand is that the balance spring is always in motion. Static poise is undertaken without the spring mounted. Dynamic poising takes the spring, natural escapement errors and the whole system into account.

<u>Dynamic poising is in fact what was done by factory watch adjusters.</u> It just took longer. At the factory, railroad watches were tested for 24 hours in each vertical position. The adjustment was determined and executed and then another week of testing. It is known this process could take 3 months.

It is not unusual for me to need 6 trials with an electronic instrument (I very much favor the Vibrograf MU-700) and there are times it takes 15 trials to zero in the adjustment. Where each trial takes me 12 to 15 minutes, in the early 20th century this translated into 6 to 15 weeks.

And yes, this means final adjustment can take up to 4 hours. But, it is like zeroing in a rifle sight. Each successive grouping gets tighter.

We are aiming for the original factory performance. For the Hamilton, this means no more than 5 seconds difference across the 2 horizontal and 4 vertical positions. Other companies had their own standards.

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<u>Procedure for Equalizing Rates via Dynamic Poising.</u> **Research has shown the interaction between vertical position and amplitude. For example, all vertical rates are magnified at low amplitude (under 180 degrees) and conversely high amplitudes minimize those positional rate differences. Also, 220 degrees of amplitude is a "magic" value where vertical rates have little to no differences. For these reasons, see the diagram below.**

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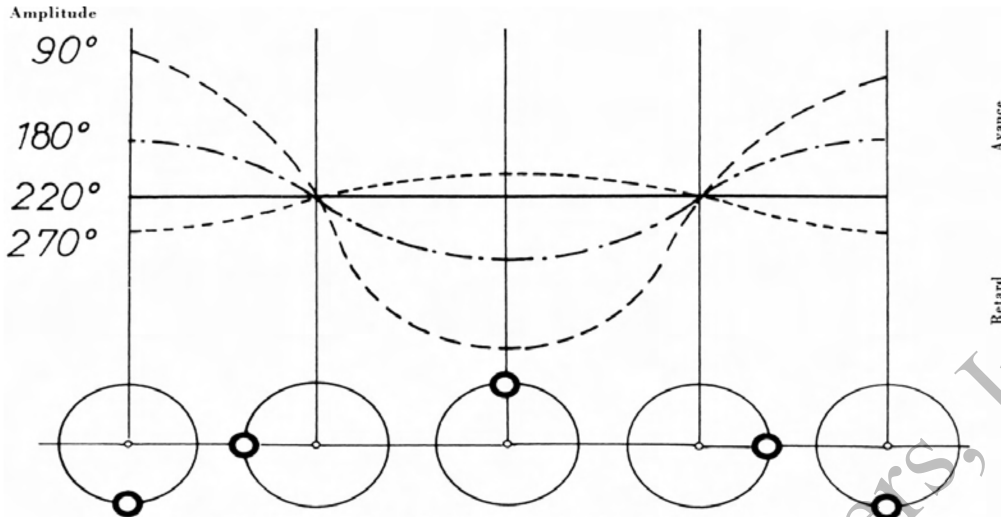

Fig. 5. Influence d'un défaut d'équilibre dans les différentes positions.

Défaut d'équilibre (balourd) du balancier et amplitude la plus favorable

C'est seulement dans la position horizontale de la montre que la marche de celle-ci n'est pas influencée par la gravité agissant sur un balancier non équilibré.

Il n'en est pas de même dans les positions verticales.

Si, au repos, le centre de gravité de l'organe oscillant se trouve au-dessous de l'axe de rotation, la montre avance d'autant plus que l'amplitude est faible ; cette avance diminue au fur et à mesure que l'amplitude du balancier augmente, devient nulle pour l'amplitude de 220° puis, devient un retard moins prononcé. Si le centre de gravité au repos est au-dessus de l'axe, l'effet sera un retard aux petites amplitudes et une légère avance dès que l'amplitude dépasse 220°. Lorsque le centre de gravité est à droite ou à gauche mais à la hauteur de l'axe, la gravité n'a aucune influence sur la marche de la montre.

5 L'amplitude de 220° est donc une amplitude privilégiée ; elle correspond à un cheminement de 1 1/4 tour.

Il n'y a donc, en général, aucun intérêt à examiner au chronocomparateur une montre avec une forte amplitude du balancier dans les positions verticales parce que, dans ce cas, l'influence d'un défaut d'équilibre se manifeste à peine.

Pour l'usage courant de la montre, l'amplitude favorable de 220° (cheminement 1 1/4 tour) est importante. Si le balancier pouvait conserver cette amplitude lorsque la montre est placée verticalement, nous n'aurions pas à nous inquiéter de la position du centre de gravité de l'oscillateur. Cette *amplitude de référence* pour les oscillations du balancier dans les positions verticales garantit, dans les montres neuves, la plus grande précision de marche.

L'amplitude du balancier diminue lorsque la montre passe d'une position horizontale à une verticale ; on admet comme amplitude favorable *270° dans la position horizontale ;* cette amplitude est réalisée lorsque les bras du balancier « croisent » sur la tête du pont d'ancre (voir fig. 2).

Nous retiendrons que les défauts d'équilibre de l'organe oscillant se manifestent surtout aux petites amplitudes, donc plutôt dans les positions verticales de la montre, et que leur influence diffère suivant que l'amplitude du balancier est plus petite ou plus grande que 220°. *Aux amplitudes supérieures à 220°, la montre retarde lorsque le centre de gravité de l'organe réglant au repos est au-dessous de l'axe*

5

Interaction between Position and Amplitude on Rate

From *Watch Adjustment*, Jendritzki, 1963

Courtesy http://www.booksimonin.ch

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Two things to understand. Isochronism is not to be confused with testing the vertical positions at low amplitudes. The watch must be wound to produce 180 degrees amplitude in the vertical positions. A correctly prepared watch will lose up to 40 degrees of amplitude between horizontal and vertical. Also the amplitudes in the various vertical positions should be within 10 degrees of each other (ideally the same).

Mount the watch vertically in the microphone with the balance facing you. Set the lift angle for your watch on the instrument. Hamiltons are 48 degrees; most Swiss are 52. Lift angle is the portion of the balance rotation during which the escapement is in direct contact with the balance.

Wind the watch slowly until the instrument reports the amplitude is 180 degrees. Now, verify the amplitude in the 4 vertical positions and the 4 positions intermediate to those. We will be using these 8 vertical positions from now on.

If the amplitudes vary by more than 10 or 15 degrees, find the fault and correct. You can go no further because you will be unable to separate rate differences due to dynamic poise from those due to amplitude.

This next part becomes confusing for most. The neutral position (of the balance) is the impulse jewel centered in the lever fork. The escape wheel will be the positional reference, not the crown. The heavy point of the balance is located at the escape wheel position that produces the fastest rate. When the microphone is returned to the position that produces the fastest rate, hold the balance in the neutral position. The heavy screw will be located plumb (vertical line straight down) from the balance staff.

This will become clear as you proceed.

You will also need plenty of paper. Make an X-Y graph. Now divide each of those quadrants in half so you have 8 lines intersecting in the center. The

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rates in each of the escape wheel (EW) positions will be recorded on this chart.


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Typical Vertical Position Rate Observation Diagram

Mount the watch on the microphone vertically so that the EW is directly below the balance. I rotate the microphone counter clockwise so the second position will have the EW 45 to the right of and below the balance. The third position places the EW directly to the right of the balance. In the fourth position the EW will be to the right and above the balance, and the fifth position will place the EW directly above the balance.

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Escape wheel directly below balance

Escape wheel rotated 45 degrees counter clockwise

Escape wheel rotated 90 degrees counter clockwise

It likely will look “wrong” until you can get used to it. Just remember the focus is on the EW.

Note the position of the stopped balance in each of the above photos. It is stopped with the impulse jewel centered in the pallet fork. THIS is the neutral position.

At 180 degrees amplitude, the heavy point on the balance will correspond to the microphone position at which the fastest rate was observed. Put the microphone back into that position with the balance stopped at the neutral point. The heavy spot will be at the bottom most screw.

Record the rates of the watch in each position on the chart. They should form a logical progression and pattern. Slowest rates opposite fastest rates; a progression from fast to slow and back to fast.

Wait at least 60 seconds for the watch to settle down in each position before recording the rate.

If the pattern does not make sense (20 fast followed by 10 slow followed by 15 fast) check the amplitudes in each position. If it varies, there is a fault. If the watch passed to this point, verify banking pins, magnetism, draw, safety action.

If the amplitude does not vary, then verify the balance spring and the regulator pins.

Assuming the watch is perfect, the heavy spot will be identified using the fastest rate. Put the microphone mounted watch in the position that

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produced the fastest rate. Hold the balance in the neutral position. The heavy spot (screw) will be at the point on the balance directly below the balance staff.

I mark that point with red ink so that I know where I made the alteration.

If this points directly to a timing screw, terrific. You can either move that screw in (¼ turn per trial) or the opposite screw out. If it falls between two screws, move the two screws on either side ½ of the adjustment.

If the watch does not use timing screws, add known timing washers to the screw opposite the heavy point.

Now do the testing again. The overall rate will have changed. But the differences should be smaller. Repeat until you zero in on your accepted performance.

When done, test the watch again in all horizontal and vertical positions to ensure success.

Below are the charts used to zero in the rate of a Hamilton 950B.

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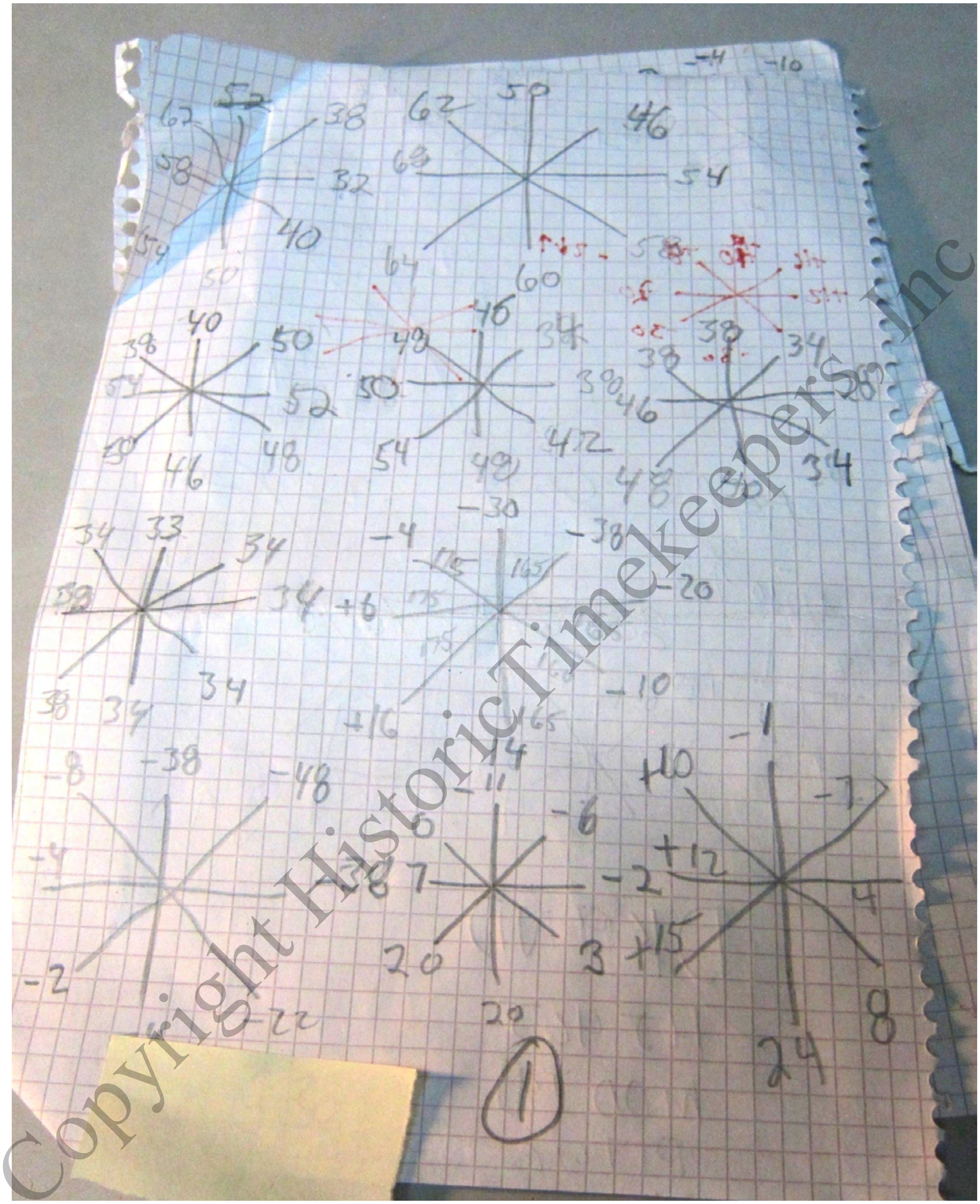

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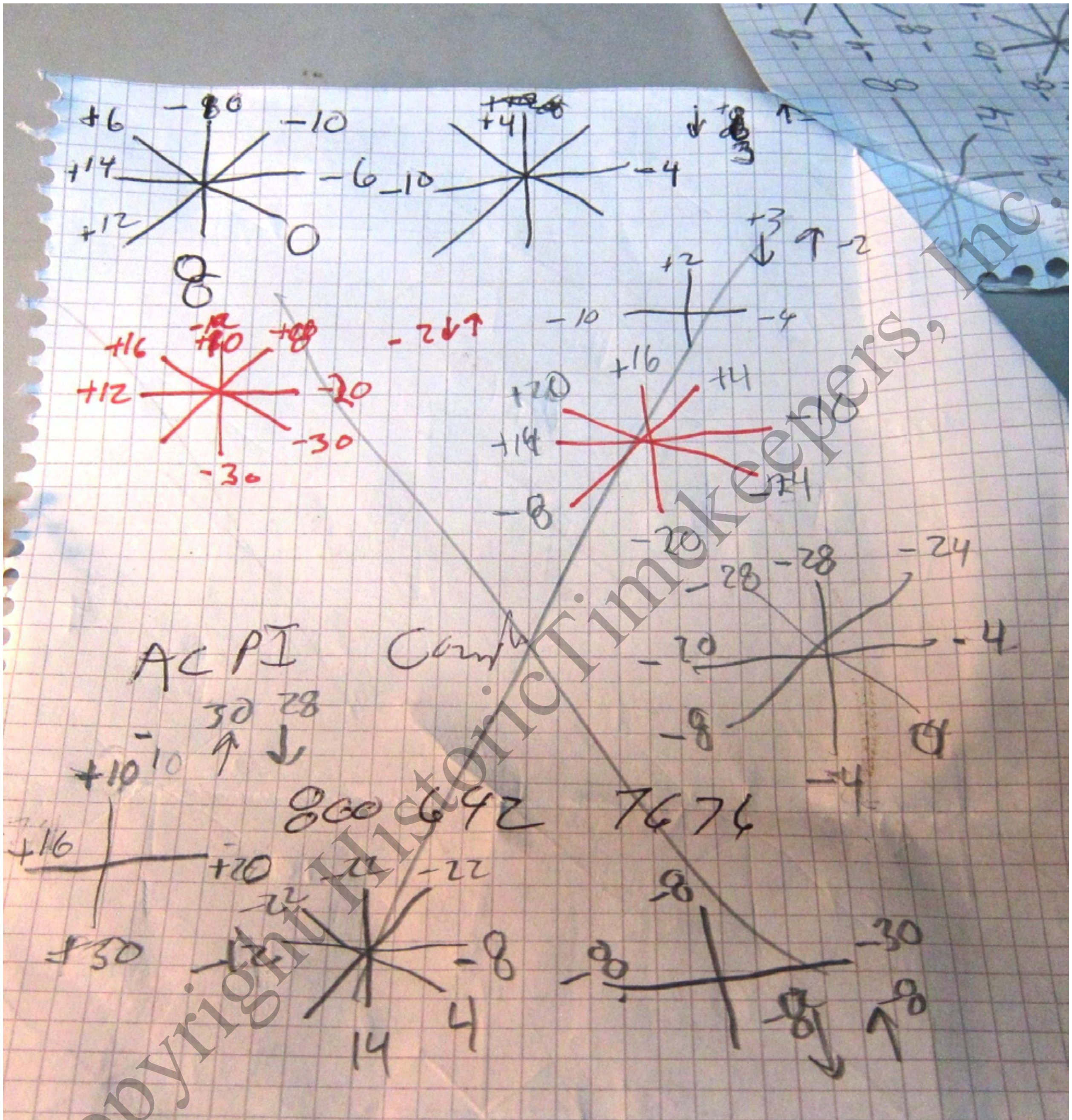
First of Several Trials



More Trials

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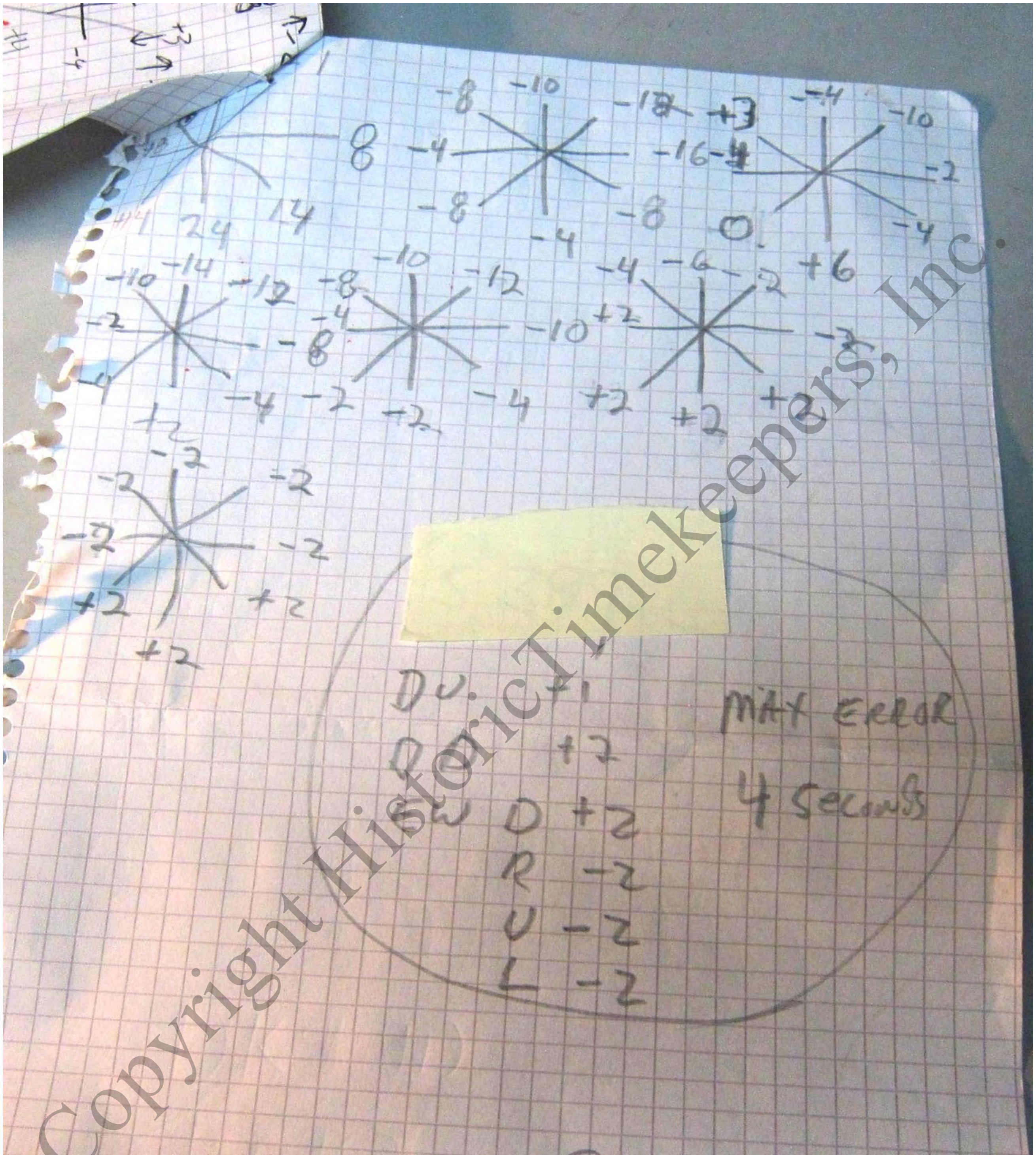

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Final Trials and Positional Rates Achieved

It is also very useful to perform amplitude and positional tests on a watch BEFORE service. This provides you with a way to assess the improvement you provided as well as offer hints at what you may need to correct.

It should now be clear that even the most seemingly insignificant thing can have major impacts. It should now be apparent why the impulse jewel must be straight and vertical in the roller table. Any slant in the jewel changes its effect as a new position is taken due to endshake. Likewise, it should be clear that the impulse jewel size is not simply an issue of "what will fit." Its size was chosen in the design to ensure unlocking and impulse were delivered at the optimum moments.

The timing machine is your task master. It does not close its eyes. It is an objective witness to your work.

At first it is extremely frustrating and annoying. But, if you accept what the timing instrument is telling you and troubleshoot each bad report, your technique will improve, making you a much better watchmaker.

As a historical note, dynamic poising was known to the top American watchmakers as early as 1944. Samelius and Purdom highlight the importance of understanding the difference between static and dynamic poise in their "It's Timing that Counts." It is clear however, their understanding on how to use it is tentative and they fail to describe a procedure.

Samelius (perhaps the top U.S. instructor of the period) and Purdom go into detail about what makes a "perfect watch" ready for precision adjustment. One of their quotes is "Repairing a watch is one thing; rating it is something else."

This book also provides an example of the promotion of a theory by experts that was subsequently discarded. Samelius and Purdom go into great

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detail describing something called “needling the balance spring” that involved stroking the balance spring with a steel needle. It sounds like they are manipulating the magnetism of the spring.

It is interesting in their preparation of the watch for adjustment that they ignore the importance of demagnetization.

This is not throwing rocks at two of the giants in the field. It is a cautionary tale for those trying to rely on older, traditional sources of information. Promoted theories that are discredited are very rarely directly retracted; they just kind of disappear from further discussion.

This material presented here was drawn from the direct instruction of the excellent teachers of WOSTEP and two books. One is the owner’s manual for the Greiner Micromat Timer published in the late 1970s. Section 2 of that manual goes into many of the factors discussed and provides a procedure for dynamic poising. Copies of this manual are very rare however.

Thanks to the generosity of Greiner Vibrograf AG, and particularly Mr. Michael Klaefiger, I have permission to provide a PDF of this manual via my website documents area. You can access it at:

http://www.historictimekeepers.com/documents/Micromat.pdf

Watch Adjustment by H. Jendritzki is seen more often. This book goes in and out of print and can be difficult to find. It may be available through the current publisher http://www.booksimonin.ch/. Mr. Simonin is the founder of WOSTEP.

We thank Mr. Simonin for providing the PDFs of the pages from Watch Adjustment for inclusion in this article.

This article was completed only with the encouragement and help of a number of people. First of whom is my wife Mary who had the unenviable task of editing.

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I want to thank the reviewers who volunteered to ensure accuracy and readability. These include Karl Mansson, Lukas Hedman, Graham Morse, Doug Smith, Robert Kunin, Dushan Grujich and Clint Geller. I especially want to thank Graham for using his expertise in image reproduction for ensuring the photos were adjusted correctly.

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