Confabulations — A Humorous Look at Complications

By Richard Watkins (AUS)

Editor's Note: Richard Watkins combines his writing skill with a well thought-out understanding of watch mechanisms to explain the complications found in modern high-end watches. Richard critically evaluates the utility of these watches. But as one reviewer stated, "watches are generally collected as 'toys' or as art. The basic idea of collecting flies in the face of utility." The intense interest in modern complicated watches—as high-end works of mechanical art—reinforces our reviewer's comments. The mystique of these timepieces is partly derived from their role as perpetuators of centuries-old technology, executed with such finesse that they are, in fact, marvelous—however "useless"—and, of course, worthy of admiration.

Complicated Wristwatches

In recent years new Swiss watch companies—together with some prestigious old makers—have concentrated on building extraordinarily complicated wristwatches. These watches feature special mechanisms, including tourbillons, minute repeaters, sonneries, alarms, equation of time, perpetual calendars, chronographs, and multiple time zones. With perhaps one exception, these complications have their origin in the nineteenth century or earlier, and for more than 200 years watchmakers have created complicated timepieces that are arguably the pinnacle of mechanical engineering.

To appreciate both the complexity of such watches and the amazing skill of the watchmakers, we only need to look at the number of parts that have been fitted within the tiny space of a wristwatch. Many of these complicated watches have more than 600 individual parts and one has 834! And all these parts work together seamlessly to display and sound different aspects of time. It is hardly surprising that such watches are made in very small numbers and are very expensive. But even so, there are waiting lists of people wanting to buy them.

In this article I present some complications and their application in wristwatches in the modern world. With two exceptions they have been described in detail elsewhere, so I focus on a different aspect—their usefulness. In doing so I hope to show that, despite having great admiration and respect for the inventors, designers, and creators of these masterpieces, their products have a humorous aspect.

Equation of Time

Both what the equation of time does and how it is implemented are complex and often poorly understood, so I will spend some time explaining it.

A true solar day is the length of time between two consecutive passages of the sun through the meridian at any given place. Because the Earth moves in an elliptical orbit and its axis is tilted, true solar days vary in length by about 30 minutes.

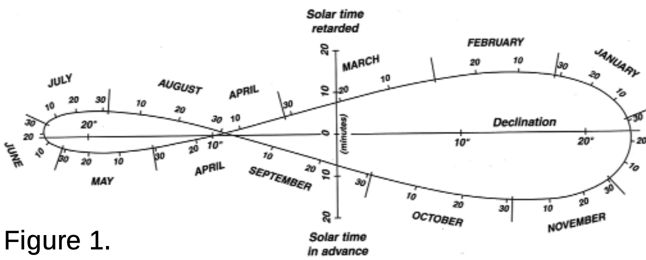


Figure 1.

REYMONDIN, ET AL., *THE THEORY OF HOROLOGY* (NEUCHATEL SWITZERLAND: SWISS FEDERATION OF TECHNICAL COLLEGES, 1999).

A mean solar day is the average length of all solar days in a year. A true solar day can be up to 16 minutes longer or shorter than a mean solar day.

The equation of time gives the difference between the two on any particular day, and tables are found in many books. I have used Lecoultre's *A Guide to Complicated Watches,* which explains the mechanism and provides a table of the equation of time. Figure 1, from Reymondin et al., *The Theory of Horology,* shows the equation of time graphically.

In the past, the equation of time was used to set a watch by a sundial; the mean time is the sundial time plus or minus the equation of time. For example, at noon on November 14 (when I wrote this) the equation of time is -15m32s and I must set my watch to 11h44m28s so that it shows mean time correctly; the sun is running fast. If it had been January 13, then the equation of time would be +8m46s and I would set my watch to 12h8m46s.

Unfortunately, there is a problem. The definition of true solar time includes the word meridian. That is, it is the local time at a specific longitude. Now, I live in Hobart, Tasmania, which has a longitude of about 147°26´ (Figure 2). But my watch is set to the time zone GMT +10 hours, which is the local time for longitude 150°. In fact, Hobart is ahead of GMT by only 9h49m45s and the time zone time displayed by my watch is 10m15s fast! Consequently, for my watch to display time zone time correctly I have to set it by a sundial at noon on November 14 to 12h0m0s + 10m15s - 15m32s or 11h55m43s.

Of course, with time zones and radio time signals you are unlikely to ever want to set your watch by a sundial. But you might want to do the reverse calculation and check the accuracy of a sundial. You work out your local time from your longitude and from that and the equation of time you know that your sundial should

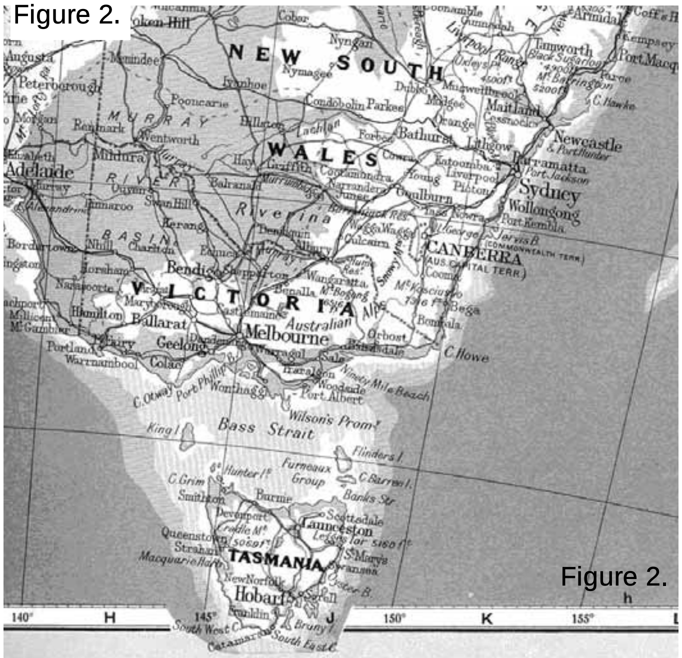


Figure 2.

be exactly on 12 noon when your watch reads 11h55m43s.

Provided you are in Hobart and it is November 14. Because tomorrow (November 15) the equation of time will be -15m22s and there is a 10-second difference. Because the Earth does not suddenly jump from one day to the next, but moves continuously, the equation of time is continuously varying and tables show the difference at midday. Consequently, from noon on November 14 to noon on November 15 the equation changes smoothly and continuously from -15m32s to -15m22s and my watch slowly gets out of synchronization by about 0.4 seconds per hour.

As long as you don't go anywhere, you can probably cope with this situation. But what happens if you drive down the road or fly to another place? If on November 14 I flew to Melbourne, which is in the same time zone but at longitude 145°0´, local time would be 9h40m0s ahead of GMT and to set my watch to time zone 12 noon I must set it to 12h + 20m - 15m32s or 12h 4m 28s at solar noon on a sundial, about 8 minutes later than in Hobart. If instead I was in Sydney, which is also in the same time zone but at longitude 151°7´, local time would be 10h4m26s ahead of GMT, and I would have to set my watch to 12h - 4m26s - 15m32s or 11h40m22s at solar noon on a sundial, about 14 minutes earlier than in Hobart.

My brother lives in a suburb of Melbourne and his longitude is about 145°13´, so his local time is 5 seconds later and ... sorry, I am going mad and you will have to work out the rest yourself!

So an equation of time display tells us the difference between true solar time and a time we do not know. Pointless unless I am bedridden and set my watch to true local time, or I carry a calculator and a GPS device everywhere.

Even if you can work out a way to use the equation of time, there is another problem: accuracy. Unless you have a transit telescope or something similar, you cannot determine true solar time accurately enough. The equation indicator on most watches is so small that it would be very difficult to determine the equation of time to better than about +/- 30 seconds. A few watches, like the Audemars Piguet "Jules Audemars Equation of Time" in Figure 3, provide as big a scale as possible by marking the equation of time on the bezel. But even then errors of at least 10 seconds are likely, and such a large error should not be acceptable for a fine watch.

NAAS, ED., *GRAND COMPLICATIONS* (TOURBILLON INTERNATIONAL, 2005).(2)

Figure 3.
Audemars Piguet.

An interesting feature of this Audemars Piguet watch is that it is "adjusted to correspond to the longitude and latitude of the location determined by its owner." Adjusting latitude makes sense because this watch also shows the time of sunrise and sunset, which are dependent on latitude. But longitude? No, it is meaningless. In fact, watches are always set to a longitude. You do this when you set the hands to your local time zone, so watches are set to longitude in 15° increments. The moment you shift the hands you change the longitude setting of the watch. For example, if you advance your watch hands by one hour for daylight saving, you are in fact changing the longitude setting of your watch by 15°. So an internal mechanism to set longitude is meaningless.

Figure 4.
Blancpain.

Finally, another equation display is that of the Blancpain "Equation Marchante" watch in Figure 4. Here the equation of time is shown by coaxial minute hands, one indicating mean solar time and the other indicating real solar time. However, unless you live exactly on the meridian of your time zone and do not adjust your watch for daylight saving, the displayed time difference is always wrong.

The Equation Mechanism

The equation of time is a lot more complex than the above discussion suggests. We will look at the mechanism first and then examine the equation a bit more closely.

The mechanism used for the type of display in the Blancpain watch is fascinating. The following description is based on Lecoultre's *A Guide to Complicated Watches*, from which I have copied the illustration.

The equation of time hand must rotate with the minute hand, but at the same time it must move relatively forward or backward by the amount of the equation of time. In addition, if the hands are reset, both hands must move together. To achieve this, a platform is mounted on the cannon pinion and the equation train is built up on it; see Figure 5. The equation hand is mounted on a pipe and this train controls its position relative to the minute hand. Because hand setting rotates the canon pinion, both hands are set together.

The platform rotates once per hour with the cannon pinion, and once each hour the finger **v** meshes with the star wheel **A** and turns it. The star wheel is the first wheel of the equation train, which consists of wheels **A**, **B**, **C,** and **D** and their pinions. In Figure 5 it has 12 points and rotates twice a day, and the equation train is geared so that **D** rotates once in 365 days, 5 hours, 37 minutes, and 30 seconds.

Attached to **D** is the kidney-shaped equation cam **M**. The spring **F** holds the rack **E** against **M** and while **D** rotates, the rack **E** oscillates as it follows the shape of the cam. This rack meshes with the pinion **P** on the equation hand pipe and so causes the equation hand to move backward and forward relative to the minute hand. Of course, the cam must be positioned to the current date. So watches with calendar mechanisms (and most do have this feature) should be designed so that changing the date also changes the position of the cam.

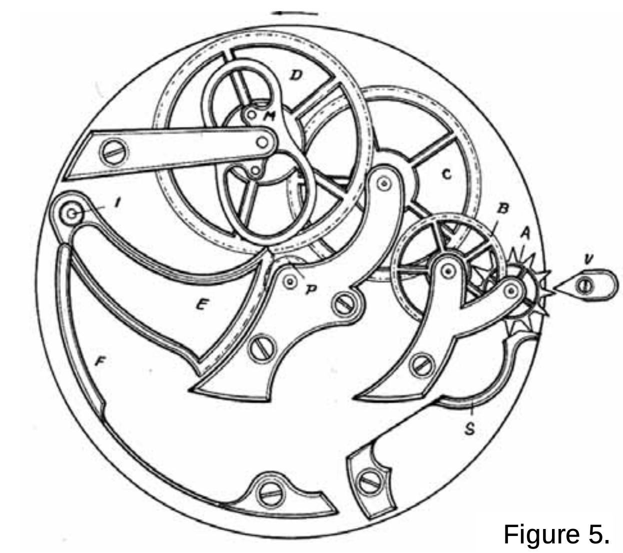
The mechanism to display the equation of time on a sector (as in Figure 3) is simpler. Instead of mounting everything on a rotating disk, the equation train is put on a fixed plate. The rack **E** can then be positioned to move a hand placed at any convenient spot on the dial or concentric with the minute hand.

The first point to note is that in a wristwatch the cam **M** is very small and moves a very small amount, about 1° each day. Consequently, the equation of time can only be displayed with low accuracy.

The second point is that the cam does not rotate once per calendar year, but once per solar year. The consequence of this is that, relative to the calendar year, the equation of time drifts in a four-year cycle until the extra day in a leap year brings it back into alignment. Milham, in *Time and Timekeepers*, illustrates this in a table showing the equation of time for March 1 from 1904 to 1923; a few entries from this table are:

1904 -12m33.65s
1905 -12m35.35s
1906 -12m38.65s
1907 -12m41.42s
1908 -12m32.46s

This drift, up to 10 seconds, further compromises the use of an equation of time mechanism in a wristwatch. So, together with errors in the cam and in reading the dial, we can only expect an accuracy of about 30 seconds; this is pretty woeful considering the watch is probably accurate to a couple of seconds. (Not only does the equation of time drift it also changes slightly from year to year. These changes are only a few seconds and are irrelevant in the context of a watch.)



LECOULTRE, *A GUIDE TO COMPLICATED WATCHES* (NEUCHATEL, SIMONIN: 1993)

Figure 5.

Finally, it is usually impossible to construct a simple train of gears that can accurately represent an irregular number. The common example is that of moon phase displays. The Moon's rotation around the Earth takes approximately 29-1/2 days and normally a gear train is used which includes a wheel with 59 teeth. For most purposes this is close enough, although the drift is large enough to require reasonably frequent resetting. The time it takes the Earth to rotate around the sun, a solar year, is approximately 365 days, 5 hours, 48 minutes, and 46 seconds. So the cam in the mechanism described above rotates 11m16s per year too fast, and it slowly gets out of synchronization. However, it will take about 128 years for it to be a day fast, which is unlikely to bother the owner. (The best discussion that I have read of how to calculate such gear trains is "On the Teeth of Wheels" by Brian Hayes, which was reprinted in the NAWCC MART, October 2003.)

Complication or Confabulation ?

As we have seen, building a modern wristwatch with an equation of time mechanism is rather pointless, because it never indicates the difference between solar time and local time zone time correctly. So why do it?

The word complication has always meant to me an extra mechanism in a watch that does something useful. So, with tongue-in-cheek, I coin a word to describe an extra mechanism in a watch that is useless! Although the verb to confabulate commonly means to talk informally, the *Reader's Digest Great Illustrated Dictionary* provides another, obscure meaning: to replace fact with fantasy. So a confabulation is a special mechanism in a watch that is meant to perform some useful task but doesn't.

The need for this new word comes from the changing relationship between watches and their environment, which has altered significantly over the last 200 years. Originally, complications served useful purposes and watchmakers created complicated timepieces that were undoubtedly masterpieces of design and construction. These superb examples of the watchmaker's craft are still made today, but the mechanisms in wristwatches no longer have a practical purpose, and so they are better described as confabulated wristwatches. Indeed, if the watch buyer believes that he or she has a watch containing multiple, useful features, when in reality these additions are of little or no practical value, the buyer is also confabulated!

Although the equation of time doesn't work, other complications do function correctly. But are they useful?

What Time Is It ?

For hundreds of years, watchmakers have toyed with different ways to display the time: (e.g., *bras en l'air*, differential, jump hour, and wandering hour). A modern example is the Franck Muller "Crazy Hours" watch in Figure 6. This is a simple watch, only having 244 parts, a tourbillon, and a clever mechanism that displays the time in an almost unusable way.

Actually, the hours are not "crazy" and the mechanism is fairly simple. I presume that on the hour the hour hand jumps forward 5/12ths of the dial; as the hands move from 4:59 to 5:00, the hour hand must move around from the digit "4" to where the digit 3 is usually placed. I expect the minute hand behaves normally and is at "2" when this happens.

When I was young I was taught how to read an analogue dial; over the last 55 years this ability has become an ingrained habit. Just a glance at the dial of a watch or clock is sufficient for me to know the time. So for me this watch reads "10 past 10" and it would take a conscious effort to check the numbers and so work out that it was really "ten past four." Even worse, I learned to say the time as "past" before the half hour and "to" afterward. If the minute hand pointed to the digit 9 (where the 11 should be), my response would either be "5 to 10" or "5 to 9," depending on whether I read the hand positions or the numbers. Actually, if the hour hand jumps from one digit to the "next" (on the other side of the dial), I am likely to say "5 to 4" before I got used to that behavior. I doubt if I would realize that it was actually "55 past 4" or "5 to 5."

From the positions of the hands in Figure 6, it appears that the hour hand moves smoothly and normally from the digit 4 to the digit 9 as the minute hand goes around the dial. So at 4:55 both hands are near the digit 9, in which case the time could be "55 past 4," "5 to 9," "5 to 11," or "5 to 5," depending on how you read the dial. (If this is correct, the hour hand jumps forward 4/12ths of the dial.)

Figure 6.
Franck Muller.

The minute hand could do the same thing and jump forward 4/12ths of the dial every 5 minutes, but if that were the case, then I think most people would last about a week before they took a hammer to this watch or returned it for a refund.

Tourbillons

A device that might seem to be useful is the tourbillon. But before looking at it we need to understand what rate means.

The rate of a watch is how many seconds a day it gains or loses. Any mechanical watch will gain or lose time, and the Swiss *Contrôle Officiel Suisse des Chronomètres* allows a tolerance of +/- 4 seconds per day, about 2 minutes per month, for chronometer certification. This is determined by running a watch for several days and noting how much it has gained or lost at the end of each 24-hour period. Add up these amounts and the rate is simply the average. For example, if the daily rates are +2, -1, +1, the average is +2/3, and the rate of the watch is +0.66 seconds.

In addition to rate we need to know the rate variation. In the above case, on the first day the watch is running 1.33 seconds faster than its rate, -1.66 seconds on the second day, and +0.33 seconds on the third day; the sum of these will always be zero. So the rate varies from day to day, and the average variation is the sum of the variations (ignoring the signs) divided by the number of days: 3.33/3 or 1.1 seconds.

If you set a watch exactly and it gains exactly 4 seconds a day (the rate variation is zero), then you always know the exact time; after 4 days just subtract 16 seconds. In contrast, if the watch we have been considering is set exactly, then after 4 days it should have gained 2.64 seconds. But because the rate varies by 1.1 seconds, the watch could be fast by any amount between 1.54 and 3.75 seconds, and we do not know the exact time. So this watch is not as good.

To complicate matters, watches run at different rates in different positions; much of the problem is caused by the force of gravity pulling the escapement one way or another. By using carefully formed terminal curves on the balance spring, shaping the balance pivots and jewels, and manipulating the dynamic poise of the balance, the positional errors can be minimized. But they remain a significant influence on the rate of a watch.

Mainspring torque, and hence isochronism, also affects rate and rate variation, but we shall look at this later.

The best solution is that used by the marine chronometer and the clock; make sure the timepiece stays in one position all the time. Because that is not possible with watches, they are adjusted so that the effect of positional errors is minimized. A pocket watch, for example, is adjusted so that its best performance, the least rate variation, is for the five positions dial up, dial down, pendant up, pendant left, and pendant right. Often improving the going in one position will make the going in another position worse. So as far as possible any significant error is moved to pendant down, because a pocket watch is very rarely in this position.

Positional errors cease to matter if a watch continuously moves through all positions. Then the rate of the watch is set to the average rate in all positions, and it will keep time more accurately; the rate variation will be smaller. One way to do this was used on the first Waterbury watches where the whole movement rotated slowly in its case.

A much more sophisticated solution is the tourbillon. In a tourbillon the escapement is mounted on a revolving platform, which is often set up to rotate once a minute so that it carries the seconds hand. When the watch is held vertical, the tourbillon ensures that the escapement rotates through all positions. Although positional errors are not eliminated, they are averaged out, and the watch will keep this average rate.

An ordinary tourbillon only acts in the plane of the watch and cannot affect the variations that occur in the horizontal positions, dial up and dial down. However, one company has produced watches with a gyrotourbillon that rotates in all directions at once. Both ordinary tourbillons and gyrotourbillons are mechanically extremely delicate, complex, and expensive to implement.

Unlike the equation of time, the tourbillon seems to have some value. But does it?

First, what is important to ordinary people is rate, not rate variation; if you are asked the time and you say it is 3h17m15s, you will look a bit foolish if it is actually 3h16m15s. For example, you have a fine, chronometer-certified tourbillon watch, which is rated +2 seconds. Unless you can set the hands to the exact time (within less than half a second) or note the exact deviation from true time when you set it, and you regularly calculate the difference caused by the rate, you will not know the true time. Without regularly calculating these differences you will not know the time much more accurately than a person with a cheap mechanical watch and a lot less accurately than someone with a $10 quartz watch.

More importantly, after a month your watch will be 1 minute fast, so you reset the hands. The fact that the rate variation is extremely small is irrelevant, because what matters to you is the rate and the displayed time; you are unhappy if your watch does not agree with local time signals. The rate variation could be quite large and you would still reset your watch. After all, for everyday use a watch that is 2 seconds fast +/- 3 seconds is much better than a watch that is 60 seconds fast +/- 0.05 seconds. Consequently, a tourbillon might mean the rate variation is very small, but because you don't know the correct time does it matter?

Second, there is another, very sophisticated device that achieves the same results as a tourbillon; it is called an arm. A watch worn on an arm is continually, if erratically, changing position and so evening out the effects of positional variations. I don't know of any research into the effects of wearing a watch on an arm, but it is reasonable to assume that most of the work done by a tourbillon will already have been achieved by drinking a beer while reading the paper.

Third, tourbillons are simply unnecessary. It is possible to have chronometer-certified watches without tourbillons (Rolex makes lots of them) whose rates and rate variations are well within the accuracy needed for normal use.

Before leaving the problem of accuracy, two other points are worth mentioning.

First, 200 years ago it was realized that much better performance could be obtained if a free-sprung balance spring with inner and outer terminal curves was used. A regulator with curb pins seriously affects isochronism, and springs without terminal curves exert lateral forces that cause positional errors. However, many complicated wristwatches use flat spiral balance springs and regulators, even with tourbillons. Admittedly, the motions of the wearer's arm and much improved construction have overcome many problems, but it is strange that some of the finest watches ever made use features discredited 200 years ago.

Second, it should be noted that a tourbillon is completely useless in a clock, and as far as I know, it is the only confabulation that has never been put into one. This finding suggests watchmakers are more creative and ingenious than clockmakers.

Power Reserves and Torque Indicators

Slightly more useful than a tourbillon, but still rather pointless, is the up-down indicator, also known by the more sophisticated name of power reserve indicator.

A power reserve indicator is a fairly simple mechanism. It shows the number of turns of the barrel and hence of the mainspring, but usually the indicator is marked in hours rather than turns. With a going barrel, the barrel arbor turns during winding and the barrel during unwinding, and some clever gearing is required so that the barrel arbor moves the indicator one way and the barrel teeth move it the other way (Humbert's *Swiss Self-winding Watches* describes several ways this can be done). It is much easier with a fusee where the fusee arbor rotates during both winding and unwinding.

A power reserve indicator is certainly of some use on marine chronometers; the persons responsible for winding them faced instant punishment if they forgot. But for an ordinary wristwatch? I suppose some people with erratic personalities may forget to wind their watches regularly, but I never had any trouble; I and virtually everyone soon get into the habit of winding regularly.

Erratic people don't worry about the time and don't need a power reserve indicator. And people who are always concerned about the time develop the habit of ensuring their watches are correctly wound and don't need it either. So a power reserve indicator displays something nobody needs.

Audemars Piguet has gone a step further, providing a dynamograph that provides a real-time indication of the mainspring's winding stress. To understand this we need to know some basic points about mainspring behavior.

The torque produced by the mainspring varies with its winding state. Figure 7 (derived from Berner *Practical Notes for the Watchmaker*) shows the torque of a wristwatch mainspring with about 6-1/2 turns as it unwinds. Initially, the torque is very high and drops rapidly. It then declines fairly evenly until the last turn when it drops quite quickly to zero. The top curve N shows the torque of a spring that has not been oiled, and the bottom curve H is the same spring after oiling. Because of friction between the coils causing them to grip together, the unoiled spring shows many minor perturbations, and the curve of the oiled spring is much smoother.

Changes in torque produce changes in the amplitude of the balance oscillations. Isochronism is the term used to describe the ideal state when the balance oscillations take exactly the same time irrespective of their amplitudes. Unfortunately, precise isochronism is virtually impossible to achieve and the rate of a watch varies as the mainspring unwinds. But the change for the middle turns of the spring can be kept very small.

Watchmakers have spent the last 500 years trying to overcome the effects of mainspring torque variations. Probably the most important factor has been the dramatic improvement in mainsprings and lubrication. With modern metals and fabrication methods, mainspring behavior has become very uniform and predictable. As Figure 7 shows, properly lubricated modern springs produce a nearly linear decline in torque for the middle turns and are far, far better than springs of 100 or more years ago.

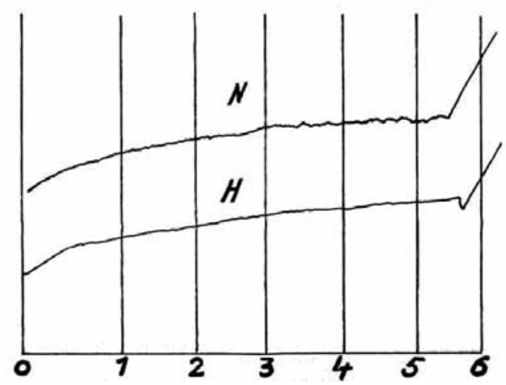


Figure 7.

One way to control mainspring torque is to use a long mainspring and have stop-work on the barrel so that only the middle turns are used; the old Geneva stop-work did just this. But stop-work is regarded as "obsolete," probably because it is useful and consequently not a confabulation. So most watches just use a loose recoil click, which prevents the spring from being completely wound up. This avoids most of the problem at the start of unwinding, and it is hoped the watch owner will wind the watch before it runs down too far. Figure 8 (also from Berner *Practical Notes for the Watchmaker*) shows one such click. As the watch is wound, the winding wheel **w**, attached to the barrel arbor, rotates clockwise, and tooth **a** of the click rides over the teeth on the wheel; it is kept in mesh by the spring **t**. When winding stops, the winding wheel rotates anticlockwise under the force of the mainspring, and the click rotates with it until tooth **b** of the click jams in the winding wheel and prevents further rotation.

Of course, an automatic watch that is worn regularly has no problem. The mainspring is never tightly wound, because a slipping device is used, and it never runs down. Indeed, most of the time an automatic watch runs at nearly constant torque, and there is no problem with isochronism.

A much better solution is the fusee. If a fusee is cut to match a particular mainspring, it is possible to get

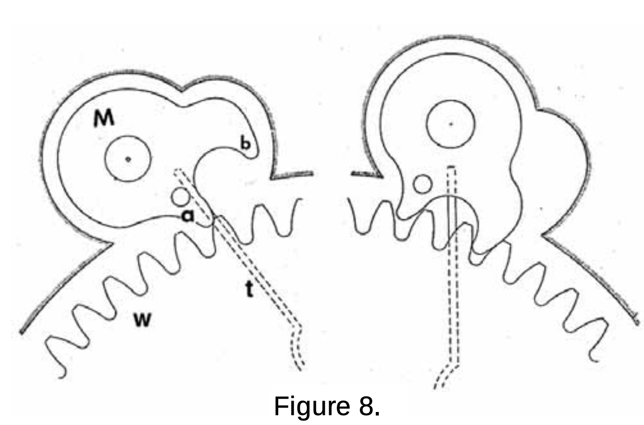


Figure 8.

nearly constant torque. It is probable that fusees were not adjusted in most cheaper watches or after replacing a mainspring, but even so the fusee would significantly improve isochronism.

Dirt and thickening oil also alter the behavior of the balance, and high-quality watches still need to be adjusted for isochronism, but if a watch is wound and serviced regularly, it is not much of a problem.

As we can see from Figure 7, an ordinary up-down indicator displays the same information as a dynamograph; all we need to do is have the same indicator move over a scale, which represents the mainspring torque instead of using a scale marked in hours. In both cases there is a direct relationship with what is actually being measured, the number of turns of the barrel, and in both cases we are being shown information that is only needed by the most disorganized and habit-free people. To illustrate this point, Figure 9 shows an Audemars Piguet "Edward Piguet Tourbillon" watch with both; the pointer at 10 is the power reserve indicator, and the pointer at 2 is the dynamograph. It is easy to see that the same mechanism (counting mainspring turns) can be used simply by changing the scale marked in the dial.

NAAS, ED., *GRAND COMPLICATIONS* (TOURBILLON INTERNATIONAL, 2005).

Figure 9.
Audemars Piguet.

So, is a dynamograph something different? Unfortunately, it is very difficult to contact the company; they provide no "contact us" facility on their website, and very few agents provide e-mail addresses. After several e-mails to and a telephone conversation with an Australian agent, I had learned nothing. This didn't surprise me because it is unlikely watches produced in very small numbers will be found in small countries with few millionaires. (I believe only 20 copies of the watch in Figure 9 have been made, so its distribution is very limited.)

However, there is an Internet site for owners of complicated watches called thepurists.com. A search on that site yielded two vague explanations:

"A winding gauge on the barrel determines the position of the dynamograph needle on the dial." This seems to suggest it is an up-down indicator; substitute "reserve power indicator" and the sentence has the same sense.

"The torque indicator is based on the strength difference between a reference spring and the barrel spring." This statement refers to the torque indicator on some Richard Mille watches. However, it is much more interesting and is the principle on which the dynamometer used by Berner is based. (Richard Mille does provide a "contact us" on the company's website, but repeated requests for information failed to elicit a response.)

It is actually quite easy to explain the principles of a reference spring gauge.

If we remove the tooth **b** from the click shown in Figure 8, there is nothing stopping the click from being pushed out of the way of the winding wheel teeth, thus allowing the mainspring to run down. Such a click can be used, but the click must butt up against a fixed stop to prevent unwinding, as in Figure 10.

We can create a dynamograph by replacing the stop in Figure 10 by the reference spring **r** in Figure 11. Now the torque of the mainspring, which is trying to turn the wheel **w** counterclockwise, is resisted by the balancing force of the spring **r**. The higher the torque the further **r** bends and the further the click rotates clockwise; like any spring, the force produced by **r** increases as it is deflected. (Note that the torque indicator must be on the barrel arbor. If it was on the barrel, it would absorb all the power going to the train and the watch could not run.)

Such a mechanism is too simplistic, but it could be improved by having two or three teeth on the click and weakening the reference spring so the click rotates far enough to be useful without impairing the safety of the locking of the winding wheel. This idea has one virtue. When the mainspring is fully wound, the reference spring bends the greatest amount, and as it does so the mainspring unwinds a little. So it behaves just like the recoil click in Figure 8. Indeed, the mainspring can never be fully wound.

Thanks to the efforts of Olivier Mory, I managed to get a diagram and animation of the Richard Mille system, which appears to be the same as I have described. According to Olivier, the indicator hand is driven from the two-toothed click, which acts as a pinion.

With the help of thepurists.com, I located a very interesting site with 3D animations of various confabulations, including the dynamograph. This site, http://www.zvisuel.com/montrespassion/english/, requires javascript and a 3D plugin (which you can get

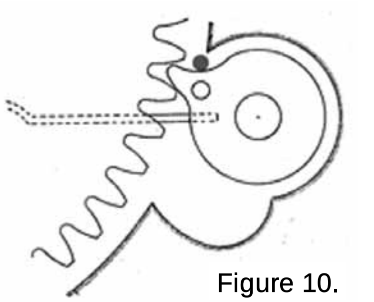


Figure 10.

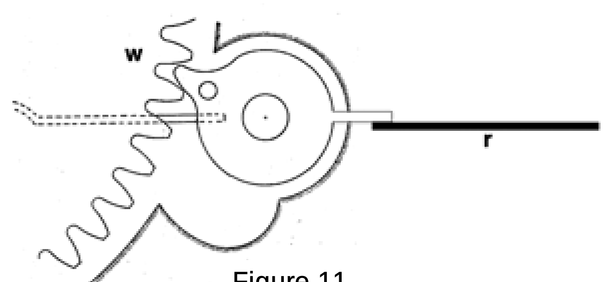


Figure 11.

from http://www.cult3d.com/download/download.asp), but browsers don't always tell you; I spent many happy minutes clicking on options with nothing happening at all, until I tried another web browser that condescended to tell me about the plugin! Although the dynamograph animation is confusing, hard to understand, and probably wrong in detail, the principle is the same as that which I have described. Figure 12 shows my attempt to explain it.

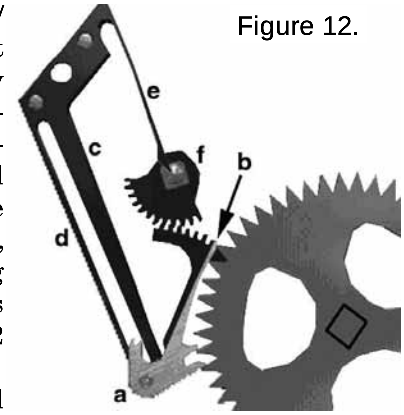


Figure 12.

The wheel squared on the barrel arbor turns clockwise during winding. The click **a** has a tail **b**, which limits its motion when the torque of the mainspring attempts to turn the wheel counterclockwise. The torque of the mainspring is counterbalanced by the reference spring **c**. When the mainspring is fully wound, the mechanism is in the position shown, with **c** flexed the most and holding the tail **b** against the wheel. As the mainspring runs down and its torque decreases, **c** moves to the left and the click rotates, lifting the tail away from the wheel. This movement of the click is transmitted by **d** and **e** to the rack **f**, which rotates anti-clockwise, turning the second rack underneath **b** which moves the dynamograph hand. Arms **d** and **e** are shown as part of the reference spring **c**, but this does not make sense. I assume they are arms of a lever pivoted under the reference spring. The tail **b** is unnecessary, but it does prevent the mainspring being released if the reference spring should break.

Assuming Audemars Piguet and Richard Mille make very accurate reference springs, then we do have a miniature dynamometer. But how accurate is it? As you can see from Figure 7, torque changes very slowly and the perturbations (caused by friction and slight variations in strength along the length of the spring) are extremely small. Indeed, unless the dynamograph indicator hand is very large and the scale on the dial very finely divided, short-term changes will not be visible. Anyway, even if they can be seen, the watch owner would have to look continuously at the indicator or they would be missed—not practical while driving. It is obvious that the indicator in Figure 9 could only show gross changes, in which case it is no more accurate nor more useful than an ordinary up-down indicator. (The writer on thepurists.com is well aware of this, noting: "The tightly coiled winding spring can still stick to itself ... creating uneven dips in the power supply. ... The dynamograph function however ... does not measure nor adjust these peaks and valleys; it simply shows if the torque being supplied is within a particular range."

Despite this, a dynamograph does have a use. You can observe the behavior of your mainspring and wonder why Audemars Piguet didn't resolve the issue completely by putting in Geneva stop-work or, even better, a fusee.

Sonnerie and Minute Repeater

Longcase clocks have very loud bells. Back in the "good old days" a home might have only one clock and it had to be loud so that it could be heard from any room. More to the point, if the clock was in a hall and you were in the study, you could not see the time and had to rely on audible chimes. And if you were outside at night with no street lights or candles, a watch that chimed or was a repeater could be very useful. But that was a century or more ago. These days (with electric lights, luminous hands and dials, and digital bedside clocks) they seem a bit pointless. But not entirely.

A useful application of these features would be if you went to a particular restaurant in Sydney, after spending the day happily trying to work out the equation of time. Here diners are fed in pitch blackness so that they are not distracted by the surroundings and can concentrate on the smell, taste, and texture of the food and drink. In this situation, with hands covered in bolognese sauce from groping for your plate and your lap drenched by the glass of wine you knocked over, a grande sonnerie would be a godsend. However, a repeater would be at grave risk from all the culinary fluids.

In contrast, a repeater is far more useful than a sonnerie in church. Although humans are very good at performing habitual tasks, such as winding watches, they are pretty poor at remembering occasional activities. Presumably, the owner of a sonnerie watch allows it to chime most of the time; otherwise, it would be pointless to have it. Consequently, it is highly likely that quiet moments of prayer and meditation will be interrupted by the Westminster chimes gleefully announcing that it is 10:45! Cinemas and other places need signs reading "Please turn off your grande sonnerie and your mobile phone."

Indeed, a minute repeater has some potential to be useful, especially for the blind. But have you ever used one? It takes ages for the gongs to be struck up to 32 times and considerable concentration to count them. And by the time you have worked out the time, it will almost certainly be one minute later and you will be wrong anyway.

Before going on, it is worth noting that many things are normally in one state and the other state is exceptional. For example, the oil light in a car is only on when there is no oil. Of course, if the light bulb has blown, then it will not come on when needed and you will have a rather serious repair bill; this is why lights should always be on when everything is OK and off when there is trouble. The reverse is also true, and some things are normally on and very rarely off. As we have seen, the normal state of a sonnerie is the wrong one, which is why a repeater or an alarm is much better.

Chronographs

This is a wonderful confabulation because it is so visible; all the extra dials, hands, and pushers make it obvious, even to the most ignorant, that this is a complicated watch. Not only that, because the mechanism is not hidden under the dial but exposed on the top plate, a simple display back will reveal all its wonders. But is it useful?

First, it should be noted that a very accurate watch is not needed. Assume your watch is really poor and has a rate of +30 seconds, or about 15 minutes per month. Then the error in timing an event lasting 15 minutes is 0.3125 seconds. Now, considering that you are not a professional timer and you are using a wristwatch, this error is almost certainly less than the error introduced when starting and stopping the hands. For example, the biggest problem with using a tachometer scale is working out just when to press the pushers as mile or kilometer markers flash past you. So any chronograph will be perfectly satisfactory for normal use, and for serious tasks you will most certainly have a special-purpose, high-precision electronic timer. This is why the advertisements showing F1 racing car drivers wearing particular brands of chronographs have always puzzled me.

Second, what do you want to time? Pulse? No, any old watch with a seconds hand is perfectly satisfactory, and because a person's pulse changes quite quickly, an exact measurement is meaningless. Speed? Maybe, if you are in a vehicle without a tachometer and moving past well-defined distance markers, but that situation doesn't occur very often. Distance? All boys enjoy working out how far away lightning is by measuring the time it takes the thunder clap to arrive. The facts that the speed of sound varies depending on atmospheric conditions and that we don't really need to know the answer to the nearest foot somewhat detract from the value of using a chronograph. Races? Yes! We can time our children as they run in the 50-yard dash at primary school.

Multiple Time Zones

Displaying more than one time zone is quite simple, but it actually has some use. When I have gone on holiday in England, knowing the time at home in Hobart enabled me to avoid telephoning people at 3 a.m.

Because of time zones it is possible to just have two hour hands and many watches do that, using the second hour hand or an hour disk to show the appropriate hour through a window. Some manufacturers either don't understand time zones or hope the buyers of their watches don't. They produce GMT watches, implying something special about Greenwich time and suggesting the watch can only show this zone. But GMT is just a time zone like any other and has to be set relative to the local time shown on the main hands. Perhaps owners of such watches who live in London use the GMT display for local time and set the main hands to somewhere else?

Actually, an hour hand by itself is not sufficient. The time zone for South Australia is GMT + 9-1/2 hours. There are only five such odd time zones in the world, but if you are buying a very expensive watch and live in or visit these countries, I would hope it could cope. (My nice Longines perpetual calendar is very clever. Because it is so accurate, the normal hand-setting position only moves the hour hand, ensuring the minute and seconds hands stay on the correct time and, consequently, it can only be adjusted in 1-hour increments. Most of the time this is fine, but it cannot cope with South Australia.)

So, separate hour and minute hands are necessary. In which case, why call it a time zone or GMT watch? You could set the other hands to any time you want, such as true local time for your boyfriend's longitude.

Perpetual Calendars

For me a perpetual calendar is a useful confabulation; indeed, it is so useful it almost deserves to be called a complication. I am always forgetting to adjust the day of month display on my watch, and I frequently date checks and letters incorrectly. Having a watch that always shows the right day of month is a godsend for me. Again, the problem is the lack of regularity and hence the lack of habitual behavior.

However, a perpetual calendar usually includes more that is useless than useful. The IWC "Portuguese Perpetual Calendar" watch in Figure 13 displays the year, the month, the moon phase (for both hemispheres), the day of month and the day of week (together with a seven-day power reserve superimposed on the day of month at 3). Now think carefully and answer these questions truthfully: How many people do you meet who do not know what month it is? How many people do you meet who do not know what year it is? How many people do you meet

NAAS, ED., *GRAND COMPLICATIONS* (TOURBILLON INTERNATIONAL, 2005.

Figure 13. IWC.

who do not know what day it is? You may know a totally disorganized person who does not know the day of week, but this is almost always by choice and utter disinterest in such a trivial matter. Such a person does not need this information any more than all the ordinary people you know. And how many people do you meet who need to know the moon's phase and are not capable of having a quick look at the sky at night? And why would you want to know anyway?

The most ingenious perpetual calendar is probably the Patek Philippe mechanism that has a full 400-year cycle and never needs to be corrected; it contains a wheel that rotates just once per cycle. Presumably, if you had one it would be supplied with enough spare parts so that it could be refurbished in 300 years' time; by then it would probably be showing signs of wear.

Alarms

At last something that is actually useful. Indeed, among my friends only one has a watch with a complication that is used, and it is an alarm; admittedly, a cheap Seiko Bellmatic, but an alarm nonetheless.

It seems that the desirability of a feature has nothing to do with its usefulness but is related to its rarity in other timepieces such as clocks and ordinary watches. (There is an exception to this rule, the chronograph. But the chronograph is a special case because of all its visible whirly bits.) So, because an alarm is actually useful and virtually everyone has one in the form of a bedside alarm clock, very few complicated watches include it.

An alarm is a good design. It is normally off, as it should be, and requires a special effort to use. So it is very unlikely that an alarm will create havoc by sounding inappropriately. However, for an alarm to work it must be loud and raucous; something that quietly plays a tuneful lullaby is unlikely to be successful in rousing you. But the last thing a watch owner would desire is to have his exquisite timepiece start clanging noisily, assuming such a small, delicate object could be noisy. However, the unexpectedness of the sound means it would probably alert the wearer in a meeting or a cinema even if it has little chance of waking him up.

Why Have a Complicated Wristwatch?

Watches with the features we have looked at are very popular, and it seems that demand outstrips supply. Why?

Do you use a portable valve radio? Unless you are at least 60 years old, you probably don't know what a valve is, let alone a valve radio. When did you last play a 78 record on a record player with replaceable steel needles and a horn speaker? Both of these technologies have been superceded by far better iPods and CDs. But people collect them as passionately as people collect watches.

I am sure you can think of many other things that are now obsolete. And the mechanical wristwatch, complicated or not, is one of them. Why use an extremely expensive mechanical device that is fragile and costly to maintain when you can have a far more accurate quartz watch for one hundredth of the cost? A watch that is often so cheap that it isn't even worth replacing the battery; if it stops, throw it away and buy another. I have a minute repeater (it tells me the time on request in a pleasant, female American voice) with alarm (it crows like a rooster at the set time) with a calendar (which is probably perpetual as implementing one using digital integrated circuits is trivial) and which costs $49. There is no equation of time, which is a great relief. Of course, if you want to, you can spend five or ten thousand times as much and get a less accurate mechanical watch with the same features.

One explanation for the popularity of these watches is given in the last sentence of the introduction to the book *Grand Complications* (Tourbillon International, 2005). This book is a buyer's guide to complicated mechanical wristwatches, providing photographs and brief descriptions of particular watches and giving information on how to contact the manufacturers. There are no prices, but that doesn't matter, because if you are going to buy one of these watches, you presumably have a spare quarter million dollars and are not going to quibble about a few thousand.

Anyway, the last sentence of the introduction simply reads "Indulge."

Another explanation is that they are collectible. As a reviewer put it: "Watches are generally collected as 'toys' or as art. The basic idea of collecting flies in the face of utility." So, on the surface indulging in complicated wristwatches is irrational. But so too is listening to a symphony by Beethoven. Indeed, the incredible complexity of music and the superb workmanship in mechanical watches are exquisite demonstrations of man's ingenuity and inventiveness, which go far beyond mere questions of utility.

About the Author

Richard Watkins collects mechanical watches from before the quartz revolution. He was described as a "saint" by a respectable fellow, and he wrote this article to show that he is actually a "minor devil." And, in case you are wondering, the restaurant actually exists.