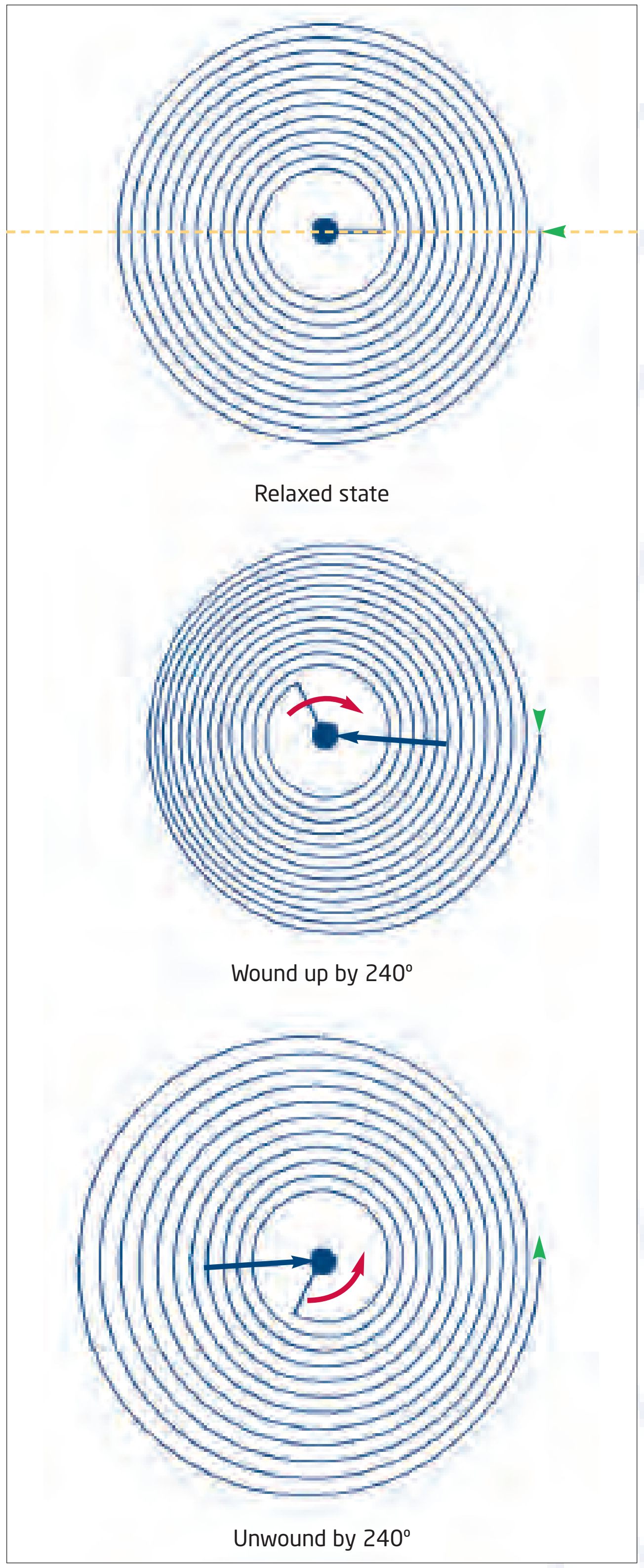
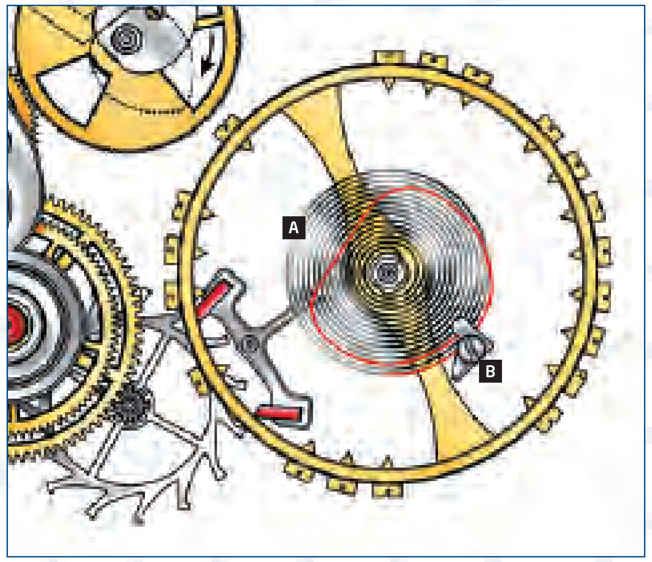
A Matter of Balance

The heart of any mechanical watch is the balance. Precision timekeeping depends on the regularity of its swing. The 3 or 4 hertz (Hz) balance most commonly used in modern watches makes more than half a million swings a day, so that even the slightest error in each swing can have a profound cumulative effect. The fact that watches perform as well as they do is a tribute to the work of generations of scientists, engineers and watchmakers, particularly in the first half of the last century...

Timothy Treffry



The upper drawing shows the balance spring in its relaxed state at the midpoint of the balance swing. Note that if a line is drawn across the centre of the relaxed spring (top), each part above the line is slighty shorter than the parts below, so the centre of gravity of the spring lies below the balance staff (black) to which the inner end of the spring is fixed. The outer end is fixed to the stud (green arrow). When the balance staff turns clockwise the coils are bunched to the left pulling on the stud and putting a lateral pressure on the staff as indicated. The situation is reversed when the staff turns anticlockwise. These drawings, by Dr Philip Woodward, were first published in the *Horological Journal* and are reprinted with the permission of the British Horlogical Institute.



The balance spring of the Lange Datagraph (opposite page) has a Breguet overcoil A. In the drawing of the escapement (above) the outer end of the spring has been highlighted in red so that it can be seen more easily. After it passes under the stud B it is bent up over the spiral, passing close to the centre before ending in the stud. Note the stud is fixed to the balance cock.

Swing theory

A child on a swing swings back and forth under the influence of gravity, momentum, and regular inputs of energy. A watch balance behaves in a similar way, with the escapement delivering the energy and the balance spring taking the place of gravity. As the balance is driven in one direction the coils of the spring tighten until the balance stops at the end of its swing and the power in the spring drives it back. As the balance passes the central point of its swing, momentum, and a little extra push from the escapement, carries it on until the dilation of the coils becomes powerful enough to stop the balance and drive it back again. As the balance swings the alternate opening and closing of the coils of its spring drives the balance towards the midpoint of its oscillation. The problem is that it is difficult to prevent gravity rearing its, in this case, ugly head. If the balance assembly is slightly 'out of balance', the force of gravity may act on the eccentric mass. It will not have any effect when the watch is horizontal, but at all other times it will, and this can affect timekeeping. The effect will vary with the orientation of the watch, with the force of gravity sometimes assisting, and sometimes opposing the swing of the balance[1].

[1]This is why, as part of the COSC performance test, a watch is rated 'in positions' as well as at different temperatures. No watch is perfect and timekeeping depends on the wearer's life-style. If you are at a computer keyboard much of the day your watch will spend a lot of time more or less horizontal, 'dial up'. When walking about it will often be on edge 'crown down'. If you take it off at night, do you leave it flat or on edge; and which edge? This is why, ideally, you should have your watch adjusted after you have worn it for a while and kept track of its performance. The watchmaker will want to tell you what your watch does on his timing machine, but that is not really the point, it should really be adjusted according to what it does on your wrist. Sadly the local watchmaker has all but disappeared.

(Far left) Movement of the Henry watch. The unique Straumann double balance spring escapement module is positioned by the two screws (blue arrows) and can be exchanged for servicing if required greatly reducing the time for which the owner must relinquish his watch. The outer ends of each of the two balance springs are fixed to the studs (green arrows). The 4-day power reserve indicator is above right. The escape wheel is in hardened gold and does not require lubrication.

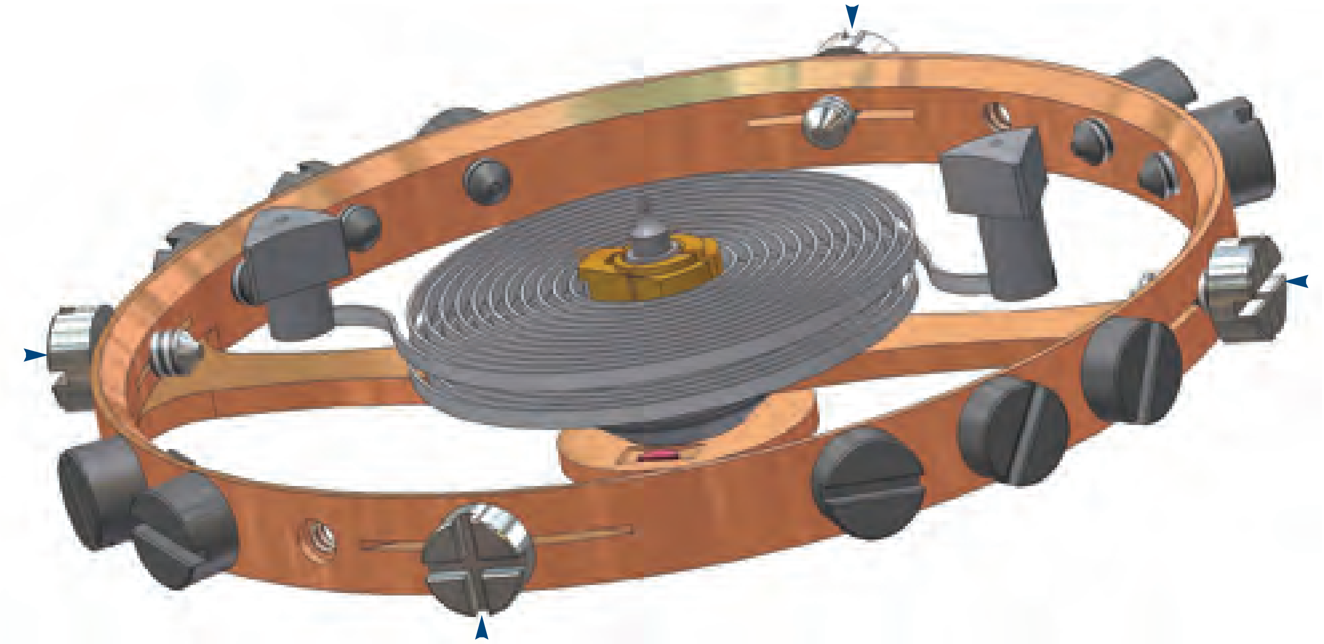
(Left) The rose gold white dial version of the Henry watch (Reference 324.607-004). This watch is also available in platinum with an anthracite dial (Reference 324.607-006).

Gravitational pull

It is possible to balance, or 'poise', the balance wheel itself, either by precision manufacture or by adjusting the screws sometimes placed in its rim. But the addition of the balance spring always poses a problem. The spring forms a spiral[2] and its centre of gravity is not at the centre of the spiral[3]. This eccentricity worsens as the coils tighten and loosen when the balance swings. As a result the centre of gravity of the spring, and therefore the balance, wanders about.

The outer end of the spring is attached to the watch plate, usually via a stud on the balance cock, and the inner end is fixed to the balance staff. As the balance swings so that the coils tighten, the end of the spring pulls on the cock. As the balance swings the other way the coils open up and the end of the spring pushes the cock. These forces produce an alternating lateral thrust on the balance pivots increasing friction and wear.

[2]It is not a strictly Archimedean spiral, where the coils get closer together towards the centre, but (perhaps appropriately) is more like a Swiss Roll, where the jam 'coils' are evenly spaced by the cake. This is due to the way balance springs are made. Three lengths of flat spring wire are wound together, heat treated, and later separated. This leaves the coils of each spring two thicknesses apart when relaxed. [3]Because the radius of curvature of each part of the spring is different a line across the centre of the spring will cut it into unequal halves.



A drawing of the balance and twin balance springs of the Henry watch by Moser. The triangular ends of the two studs to which the outer ends of the springs are attached, can be seen in the photograph of the movement fitted to a bar attached to the centre of the balance assembly. Note the 4 timing screws (arrows) in this free-sprung balance. These are adjusted in pairs to regulate the rate by altering the moment of inertia of the balance. The threaded portions are slightly tapered, as are the holes that receive them. The slot in the balance rim associated with these screws allows the holes to be 'springy' so the screws are gripped tightly and will not move during the running of the watch. This is a point of quality carried forward from 19th century Moser watches.

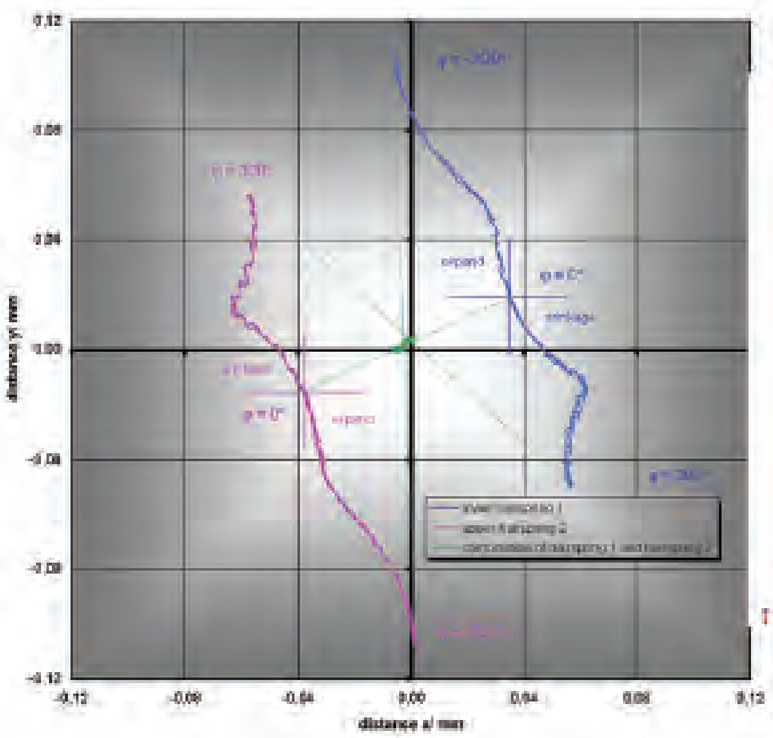
(Below) The Audemars Piguet Millenay Tourbillon in the 'Tradition of Excellence' series. With perpetual calendar, 7-day power reserve, dead-beat seconds and a completely new escapement, its double balance spring (above) went almost unoticed. Note that the studs (A stud for upper balance spring and B stud for lower balance spring) to which the outer end of each spring is fixed are opposite sides of the balance centre and that each spring spirals in an anti-clockwise direction towards the centre.

Equal forces

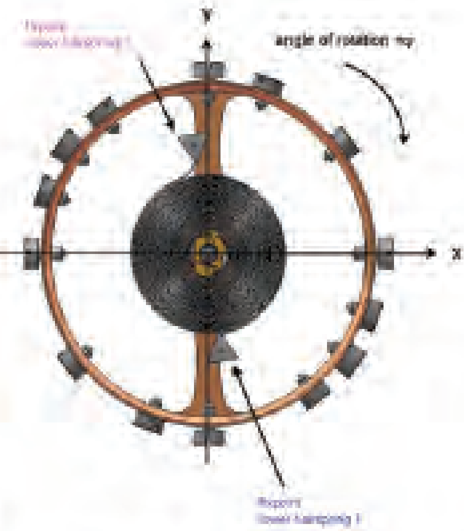
This effects both problems: the wandering centre of gravity and of the lateral thrust can be overcome with a carefully formed Breguet overcoil, in which the outer end of the spring is bent out of the plain of the spring and brought back over it so that the stud is about halfway across the spiral rather than at the edge. If this is done correctly, the coils of the spring dilate and contract symmetrically as the balance swings, the distorting forces are eliminated and centre of gravity of the spring is stabilised. There is however another approach to the solution, which is perhaps intellectually more pleasing.

At SIHH 2006 Audemars Piguet launched its Millenay Perpetual Calendar in the 'Tradition of Excellence' collection. It was a tourbillon with dead-beat seconds and it showcased the company's new escapement. There was so much emphasis on the escapement that the fact that the balance was equipped with two balance springs was scarcely mentioned. These two springs were placed one above the other, but with their ends on opposite sides of the staff. This meant that when the centre of gravity of one was wandering off in one direction the centre of gravity of the other was going the opposite way; completely neutralising the effect. Because the tourbillon is designed to cancel gravitational effects on the balance the twin springs seemed

Straumann Double Hairspring – Centre of gravity (x,y) [mm]



Graph shows the movement of the centre of gravity for the balance springs in the Henry watch as the balance oscillates. One is shown in blue, the other in magenta, the average for the two acting together (green) is very stable and remains so at all balance amplitudes.



The Moser 'Perpetual 1' had established the company's position as a highly innovative maker.

unnecessary. But they did mean that when one spring was pushing the staff one way the other was pushing in the opposite direction, balancing the lateral thrust and reducing friction.

Binary spring system

Presenting its 'Henry' watch[4] at Basel last year, H Moser & Cie highlighted the merits of the twin springs. The previous year the Moser 'Perpetual 1' ('Andreas Strehler', *QP* 25) had established the company's position as a highly innovative maker. The Henry is perhaps a smaller, but significant, step along the same path.

The Henry series has the usual understated elegance of Moser watches. Each looks like a 'simple 3-hander'; there is no mention of its special attributes on the dial. The view of the well-finished movement through the sapphire case back shows that the interchangeable escapement module, which is unique to Moser watches, is engraved: "Straumann Double Hairspring". We also see the power reserve indicator. The power reserve is described as "at least four days". But it is the Straumann connection that gives Moser a particular advantage in the production of a watch with two balance springs.

In 1931 Dr. Thomas Straumann developed a 7-component alloy for the manufacture of balance springs[5]. Precision Engineering AG, a sister company of H Moser & Cie acquired the right to produce Straumann's alloy and now provides an alternative source of balance springs for the watch industry. The double hairspring system in the Henry watch requires that the springs have identical properties and a direct connection with the manufacturer makes this much easier to achieve.

[4]Named after the 1828 founder of the company, Heinrich Moser; unfortunately, to an English ear, the name greatly undervalues the watch.
[5]It was a fracture-resistant, corrosion-free and antimagnetic alloy whose elasticity did not vary with temperature. It was almost identical to the Nivarox now used for balance springs throughout the watch industry. His discovery was so profitable that he founded the Straumann Research Institute, which develops biocompatible alloys for dental and medical implants.

Further information: www.h-moser.com