

Petto's Cross-Detent Escapement: Its Origins, Function, and Applications

By Peter Toot

The use of clocks to find longitude had been proposed as early as 1530 by the Flemish astronomer Gemma Frisius, but timekeepers of the era and for centuries thereafter were not sufficiently precise for the task. Increased shipping and imperial ambitions in the 18th century heightened the need for a reliable method to determine longitude while at sea (Betts 2017, 6). In a remarkable period of innovation from 1740 to 1800, many of the greatest technical minds of England and the Continent focused on developing portable timekeepers that were both reliable and accurate. It was John Harrison's well-documented H4 of 1759 that first proved portable mechanical timekeepers were capable of the precision necessary for navigation. The subsequent invention of the detent escapement was one of the most important advancements for precision timekeeping during this period. In 1784, James Petto of London created his own unique variant of this escapement. Petto's Cross-detent, as it became known (often abbreviated as simply Petto's Cross), combined many of the best features of the competing designs of the era. Although it saw only limited use in marine chronometers, it later found much favor in tourbillon watches.

Characteristics of Detent Escapements

To better understand Petto's Cross escapement, we must first examine the defining characteristics of a detent escapement. A detent escapement has three distinctive features: first, a single impulse is given by the escape wheel once per oscillation of the balance wheel; next, the balance's supplementary motion is detached from the escapement; and finally, lubrication is unnecessary at the point of impulse.

The first of these characteristics defines how the escapement impulses the balance wheel. The balance wheel must receive energy from the escapement to maintain its motion, but impulses from the escapement also disturb the stability of the balance wheel and therefore its rate. The benefit of a balance wheel that receives one impulse per oscillation is that it remains undisturbed for a greater portion of its amplitude.

The second defining element of the detent escapement, the balance wheel's detachment from the escapement during much of its motion, benefits the timekeeper in the same way as the first feature. In contrast to verge or cylinder escapements, the detent escapement is not in frictional contact with the balance wheel during its supplementary motion. This permits a free and more regular oscillation of the balance, resulting in more accurate timekeeping.

The third important characteristic of the detent is its freedom from lubrication at the point where the escape wheel tooth engages the impulse pallet. While improvements in lubricants have reduced the importance of this characteristic, oils of the 18th century were susceptible to significant variations in viscosity due to temperature fluctuation and decay. This change in viscosity significantly affected the rates of escapements that required lubrication, such as the cylinder and the lever. The escape wheel and the impulse pallet of a detent escapement, in contrast, are moving in overlapping circular paths. The limited sliding action of the escape wheel tooth as it delivers an impulse to the impulse pallet requires no lubrication.

Two styles of detent escapements became prominent in the period: the spring detent, favored by English makers, and the pivoted detent, preferred by Continental producers. In both versions, a locking jewel is set in a narrow piece of metal. The jewel swings in a small arc to release a tooth of the escape wheel and then returns to the lock position to block the next tooth. In the spring detent, a portion of the detent itself is thinned and treated so it becomes a spring, and the arc the locking jewel travels is centered upon the point where this spring section flexes. The discharging roller on the balance staff contacts the detent horn and lifts the detent away from the banking to release the escape wheel tooth. When the discharging roller passes the detent horn, the force of its integral spring returns the detent to the banking position where it receives and stops another tooth of the escape wheel. It is upon this configuration that Petto based his innovative design.

Development of the Petto's Cross-Detent Escapement

Pierre LeRoy (1717-1785), a French horologist described by Rupert Gould as “the father of the chronometer as we know it,” took many of the first steps towards the creation of the detent escapement. In a series of designs presented to the Academie Française des Sciences from 1748 to 1769, he developed and implemented the ideas of a single impulse per oscillation and detachment of the balance during supplementary arc. In the early 1780s, John Arnold (1736-1799) and John Earnshaw (1749-1829) in London, and Ferdinand Berthoud (1727-1807) in Paris, developed designs for detent escapements that built upon LeRoy's ideas. Arnold's and Earnshaw's spring detent designs contained fundamental differences and James Petto would choose the best from each for his escapement design.

James Petto was a worker in Earnshaw's shop in London. His name is frequently misspelled with a single “t” as “Peto,” possibly in part because Earnshaw erroneously wrote it that way (Osterhausen 2001, 250). The authorship of the idea of Petto's Cross is, like so many things in horological history, surrounded by controversy. Earnshaw claims that he outlined the idea of the escapement to Petto, pointing out the flaws in Arnold's escapement and explaining how the passing spring could be placed at the back of the escapement (Gould 1978, 137). Whether it was Petto who actually invented this arrangement or not will probably never be clear. What is known is that Petto left Earnshaw's shop soon after the escapement was developed. He began working for Earnshaw's competitors, John and Miles Brockbank, who would use Petto's escapement in marine chronometers and pocket chronometers.

Petto's Cross design was elegant, whatever its origins were. It took the best aspects of Arnold's and Earnshaw's design and joined them in a single escapement. The strength of Arnold's spring detent escapement, Figure 1, was the locking of the escape wheel as it rotated away from the base of the detent spring. This meant that the detent spring was held in tension when the escapement was locked. Earnshaw's version, Figure 2, held the spring in compression during lock because the escape wheel rotated toward the base of the detent spring.

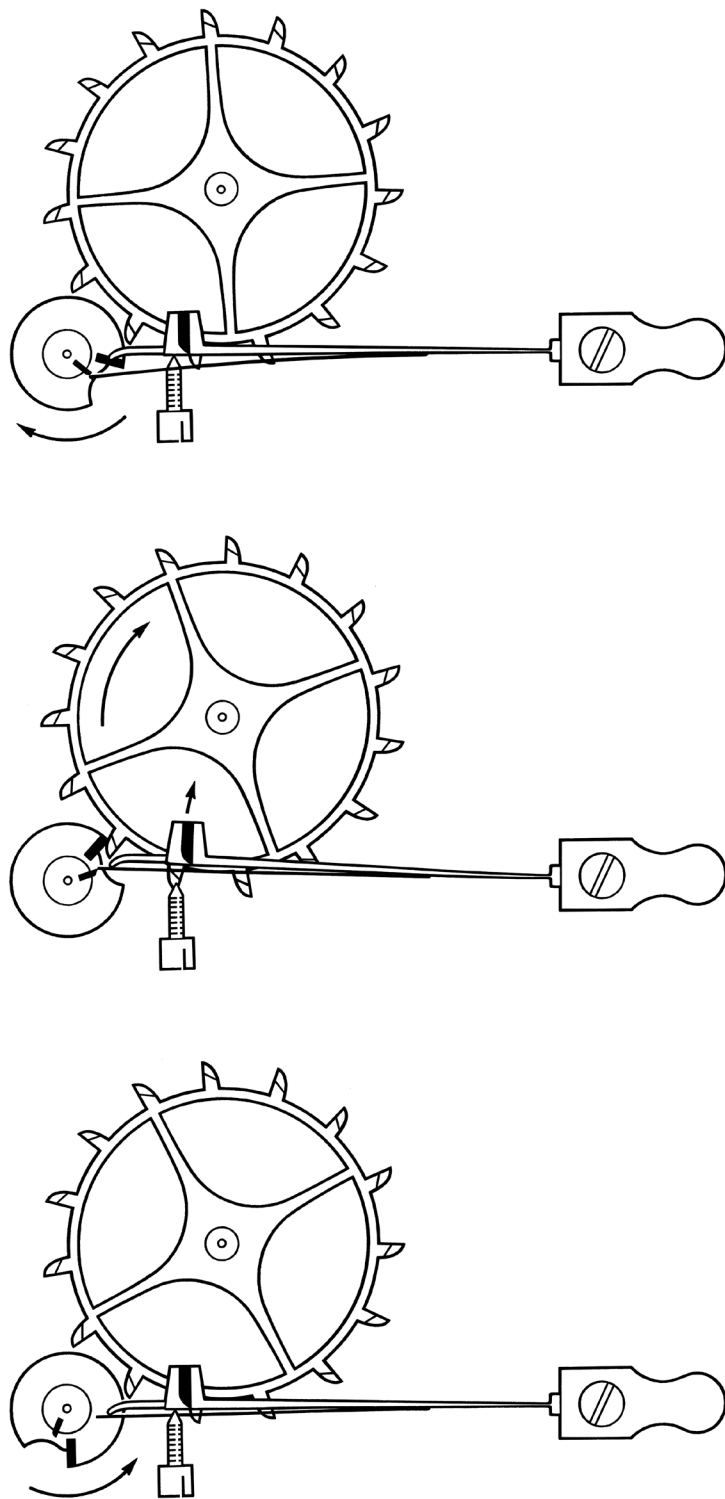


Figure 1. Arnold's spring detent escapement.
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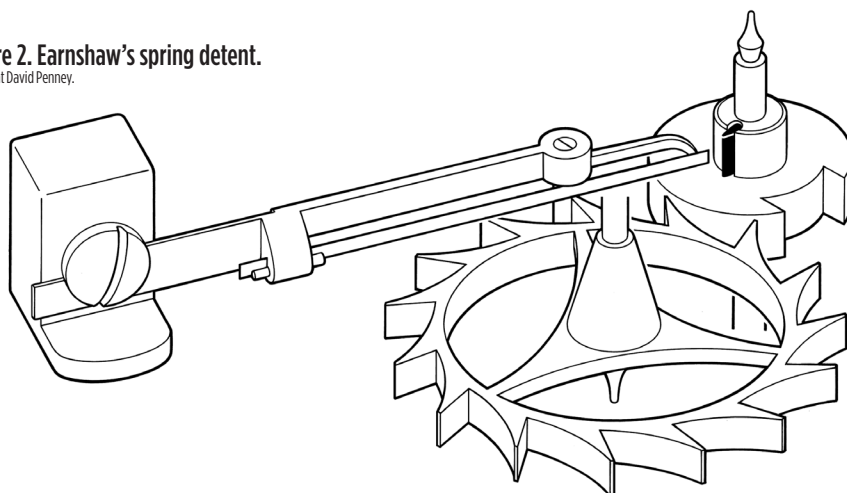
John Arnold, for one, had concerns that a thin and delicate detent spring held in compression might buckle under the pressure of the escape wheel, especially if additional forces such as an external shock were applied (Randall and Good 1990, 58). By shifting the passing spring 180° from its position in Earnshaw's design, Figure 2, Petto was able

to change the direction of the rotation of the discharge pallet during unlocking. This allowed the escape wheel to rotate away from the base of the spring, and in this form Petto created a spring detent that locked the escape wheel in tension instead of compression.

While Arnold's design allowed for the spring to be held in tension, it used epicycloidal escape wheel teeth, which were a major drawback. The sliding action of the tooth on the impulse jewel created friction and so required lubrication. Earnshaw used pointed escape wheel teeth that pushed with their tips against the impulse pallet as they moved through the impulse angle. This meant that it did not need to be lubricated, liberating the escapement from the uncertainties of lubricants.

Why did Petto not simply replace the epicycloidal teeth of Arnold's design with straight teeth of Earnshaw's escapement and thus have an oil-free escapement that held the detent spring in tension? The answer can be seen in the form of Arnold's escape wheel. Because his detent had to pivot toward the center of the escape wheel to unlock due to the direction of rotation of the discharge roller, it required an escape wheel built on two levels with the teeth above the rim. This was necessary so that the locking jewel could pass over the rim as it moved through the unlocking phase. Petto's design unified an escape wheel built on a single level with the lubrication-free escapement of Earnshaw's design and Arnold's locking of the detent spring in tension.

Figure 2. Earnshaw's spring detent.
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Function of Petto's Cross-Detent

The most obvious characteristic that distinguishes Petto's escapement from those by Earnshaw and Arnold is the placement of the unlocking/passing spring opposite the detent itself, Figure 3, such that the detent, balance staff, and passing spring are in a straight line. The passing spring, detent horn, and discharging jewel all function in the usual manner. However, this configuration allows for unlocking the escapement with the balance rotating in the opposite direction in contrast to the traditional spring detent. This, in turn, means that the escape wheel is rotating away from the foot of the detent; therefore, the detent spring is in tension, not compression, when in the locked position, as mentioned previously.

In Figure 3, the escape wheel is stopped by the locking jewel of the detent blocking an escapement wheel tooth and the balance assembly is shown at its center line. From this position, we can follow the functional sequence of the escapement as the balance swings counterclockwise on its supplementary arc, detached from any engagement with the detent.

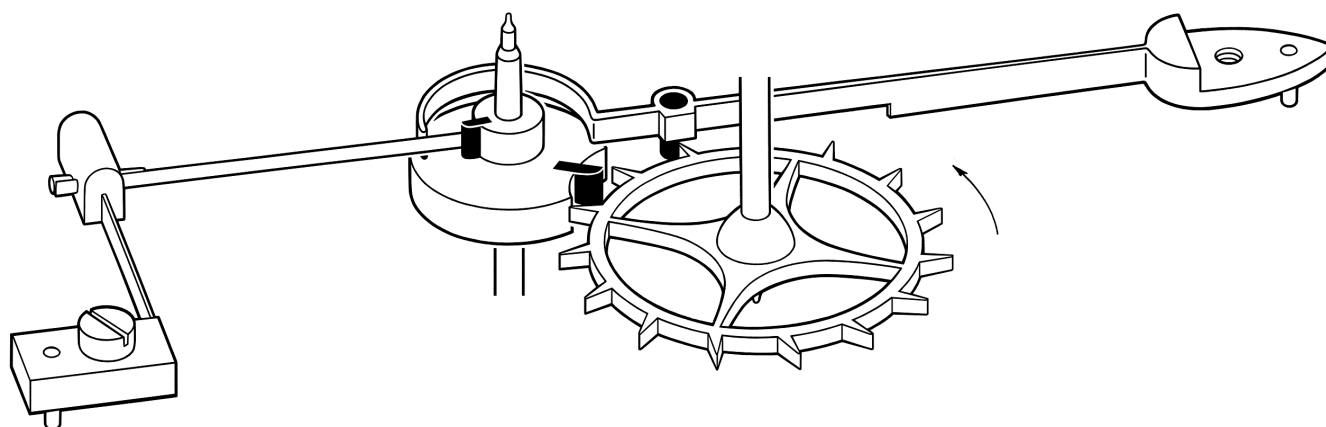


Figure 3. Petto's Cross spring detent escapement.
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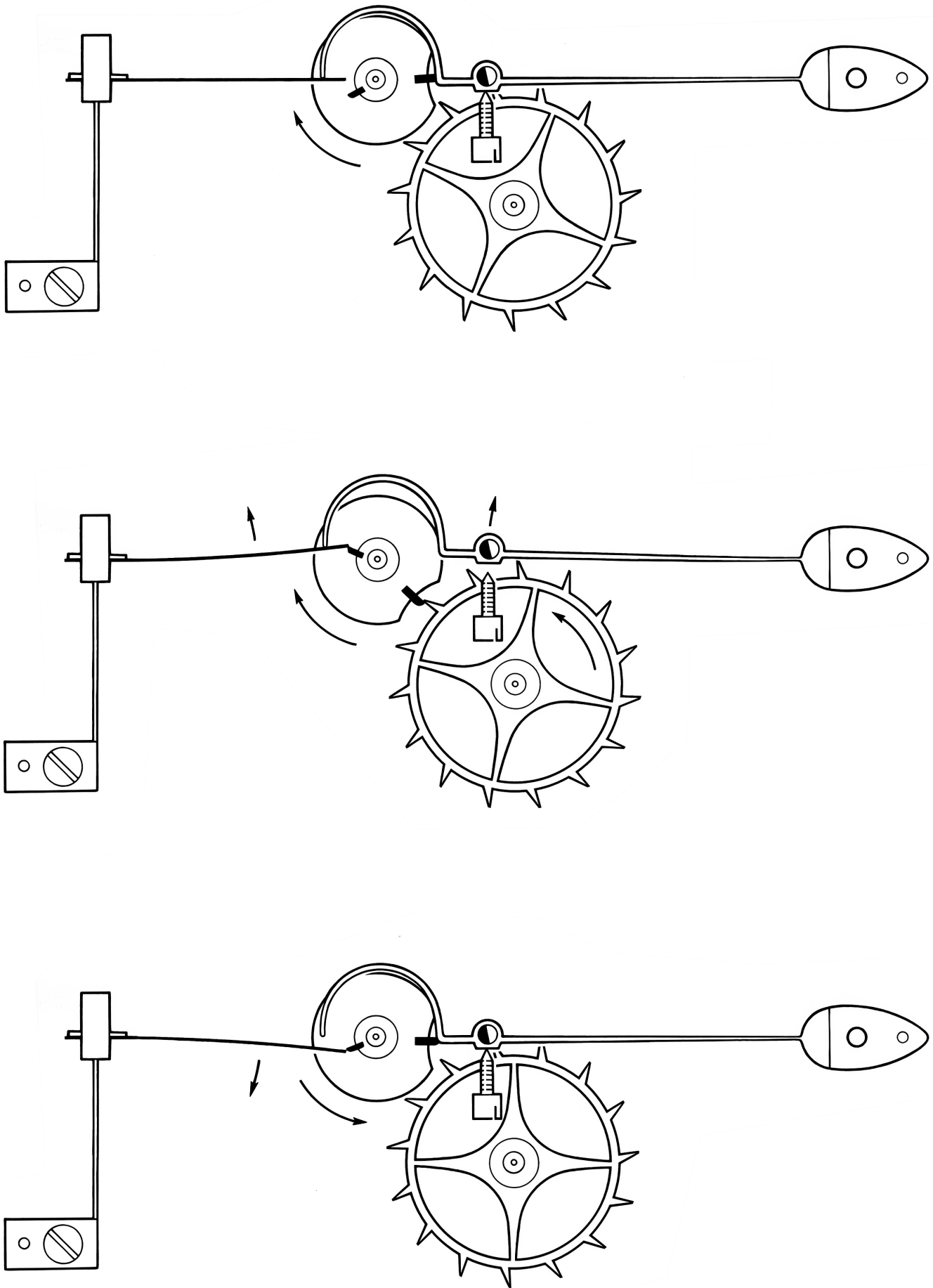


Figure 4. Three phases of Petto's Cross escapement action.
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When it reaches the extreme of that arc, it begins its return in the clockwise direction toward the center line of the escapement propelled by the stored energy in the balance hairspring. The discharging pallet (also known as the unlocking jewel), located on the discharge roller fixed to the balance arbor, approaches the passing spring, Figure 2 (phase 1, unlocking). As it contacts the passing spring, which is at rest against the horn of the detent, the discharge pallet lifts the detent. This moves the locking jewel out of the path of the escape wheel, unlocking the escapement and allowing the escape wheel to advance. The escape wheel tooth that then passes closest to the balance arbor catches up with the rotating impulse pallet and pushes against it, delivering the impulse to the balance wheel, Figure 4 (phase 2, impulsing).

After the discharging pallet passes, the detent returns to its banking position where it arrests the further advance of the escape wheel by blocking the next tooth. While this occurs, the balance swings its supplementary arc in the clockwise direction, detached from the escapement.

At the end of its supplementary arc, the balance begins its return vibration, rotating counterclockwise toward the center point, thanks to the force of the balance spring. In its return, the discharging pallet again passes by the tip of the detent, known as the horn, but only touches the passing spring, Figure 4 (phase 3, passing action). The spring flexes from the contact, allowing the discharging pallet to pass without disturbing the detent, which remains in its locked position. The balance continues its arc past the center line to the extreme end of its vibration, detached from the escapement, and the process begins again.

Despite the design strengths of Petto's Cross-detent, it has always received criticism from horologists and horological historians. Earnshaw, having first claimed that he had outlined the idea for Petto, later said the escapement "was like a person going around a house to get in at the back door when the front door stood fairly open to him" (Betts 2017, 213). The historian von Osterhausen (December 2001, 250) suggested that the escapement was developed as a way to avoid paying royalties for the patent that covered Earnshaw's spring detent. And George Daniels berated it, noting that it "contributed nothing to the science of chronometer construction" (Clutton and Daniels 1979, 118).

Petto's Cross was not widely adopted and appeared only in a limited number of pieces. The Brockbanks used it in the production of their standard spring detent watches but only placed it in a small number of marine chronometers. This was possibly due to the extra work required in construction (Gazeley 1992, 309). Later it became clear that spring detents in marine chronometers and detent watches would not typically buckle when held in compression during lock in Earnshaw's design (Gazeley 1992, 309). Although George Daniels had been critical, he did recognize that Petto's Cross was well suited to applications where the detent had to be very small or under some additional pressure (Clutton and Daniels 1979, 51). Because the detent escapement used on a tourbillon carriage must be small and also must absorb the full force of bringing the carriage to a stop after each impulse, Petto's variant proved ideal for this application. In effect, the problem that Petto's design anticipated for marine chronometers only existed under the extra external forces and at the reduced scale of a tourbillon escapement.

Petto's design also provided two minor additional advantages for tourbillon use. The placement of the passing spring on the other side of the balance from the detent offered better weight distribution on a tourbillon carriage. And, in small scale applications, Roger Smith claims that the location of the passing spring of Petto's Cross means that there exists less likelihood of destabilizing the detent spring when the passing spring snaps back against it after the passing phase (*Hodinkee* 2015).

This suitability of Petto's escapement to tourbillon carriages became clear soon after its development. Abraham Louis Breguet used it in a series of tourbillon pocket watches from 1809 to 1819. Daniels asserts that this was an attempt to avoid the buckling of the small detent spring of a tourbillon and also to avoid the increased height of the escape wheel of Arnold's design (Daniels 1986, 327). The Breguet firm released another tourbillon watch, no. 2555, with Petto's Cross in 1824, soon after their founder's death.

More recently, Petto's design has garnered renewed interest by numerous contemporary independent horologists. George Daniels and Gene Clark incorporated it into their unique tourbillon watches, and David Walter created a tourbillon clock using Petto's Cross.



Conclusion

The spring detent escapement played a major role in making portable, mechanical timepieces highly precise. James Petto gave his name to a variant of this escapement designed to address the potential problem of detent spring buckling in marine chronometers, but time showed that detent buckling was not an issue in that format. It later became clear that by incorporating the best features of Arnold's and Earnshaw's designs to address the anticipated problem of buckling, Petto had created an escapement that was admirably suited to tourbillon escapements in watches.

All drawings courtesy of David Penney, www.AntiqueWatchStore.com

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