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(D)W5, a Free Pendulum Clock

David Walter describes his deluxe version of Philip Woodward's remarkable regulator

(D)W5, **1**, is an emulation of Philip Woodward's well-known W5. Philip has described W5 in his book *My Own Right Time* (MORT), and in a series of articles 'W5 for Emulation' beginning with the February 2004 issue of the *HJ*. The articles inspired (D)W5 and ultimately provided the name.

A Brief Description of W5

W5 was a new concept in precision horology and may be the first advancement in mechanical horology in the last 100 years. It is an all-mechanical free pendulum clock working on the same principles as the Shortt clock, in which a free pendulum is impulsed by a dropped weight timed by a slave pendulum, and the rate of the slave pendulum is regulated by the rate of the free pendulum through a feedback mechanism. Unlike the Shortt, the two pendulums in W5 are dissimilar, with the slave a half-seconds pendulum and the periods of the free and slave pendulums in the ratio 30:21. This was done to avoid the tendency of nearby same-period pendulums swinging in the same plane to lock into synchronism, but it puts the two pendulums at the appropriate phases of their swings every 30 seconds for the impulse mechanism to work properly.

W5 has an escapement designed by Philip Woodward that provides impulses to both the free and slave pendulums, thus he chose to name it a 'double gravity escapement'. This escapement is not to be confused with that of Lord Grimthorpe also known by this name. A detailed description of the operation of the W5 escapement is given later.

(D)W5 Design

I was commissioned to create a version of W5 using my own design ideas while retaining the scientific concepts of the original. This proved much more difficult than it would appear. After carefully studying the *HJ* articles and MORT, then learning a new mechanical concept, especially the idea of the 'hit and miss' synchronizer for the two pendulums, (D)W5 gradually came to life on the drawing board.

Philip's original W5 has a single main plate with most of the train behind this plate while the remontoire and the gravity escapement are in the front. (D)W5 is mounted on a heavy, solid mounting plate attached to the case back. The two feet for supporting the movement and the suspension brackets for supporting the gimbaled knife-edges are also fitted to this mounting plate.

Both pendulums are mounted on inverted tungsten carbide knife-edges, the 'V' portions of the knife-edge suspension fitted into INVAR blocks which themselves are attached to the top of fused silica pendulum rods. The bobs are a tungsten alloy.

The free pendulum bob is supported at its centre by a fused silica sleeve and a brass sleeve sized to provide temperature compensation. Barometric compensation is provided by an aneroid with compensating disc fitted under the pendulum bob. The furniture below the bob is supported on a short length of threaded INVAR. The upper part of the INVAR extension was turned to just fit inside the hollow pendulum rod and is cemented in place.

The main movement plate is solid, while the front plate is skeletonised as much as possible. The front plate is attached by four pillars to the main plate and held with the large specially made blued steel screws that have become a feature of my designs.

1. (D)W5, as yet un-cased, fitted to a pine back board.

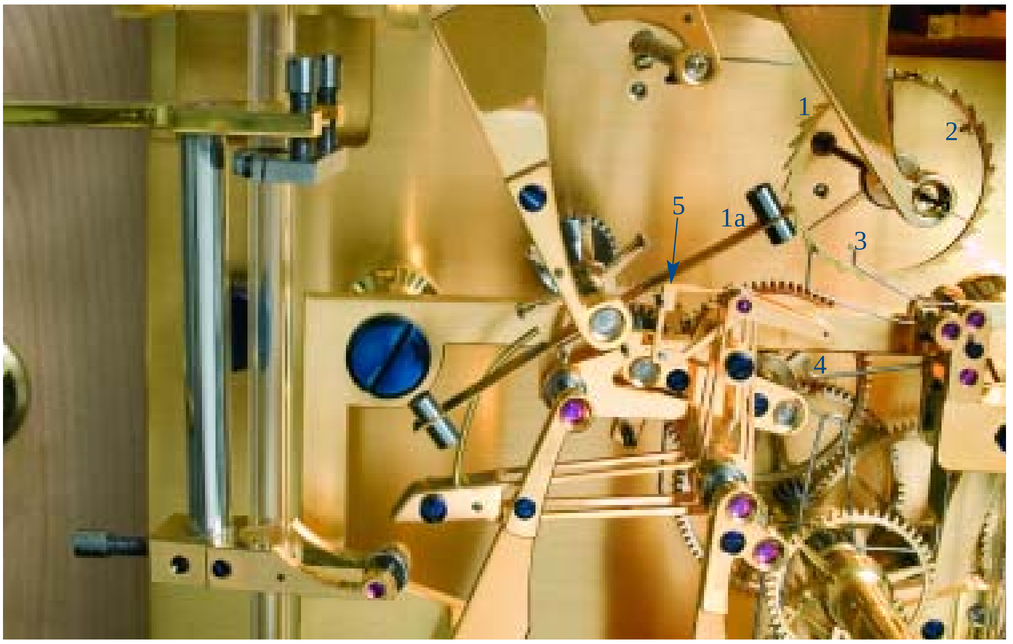
The remontoire, count wheel, escapement, and levers are all fitted under bridges, some of which are on the main plate with others fitted to the front plate. All bridges are pinned and numbered over a corresponding number on the plate.

Because of the demands of this clock, friction must be kept to a minimum. All the train and escapement pivots are jewelled and have jewelled end stones where possible. There are 64 jewels including the barrel and front center wheel pivots. To further reduce the frictional load the size of the pivots has been kept small. The train pivots are 0.82 mm while the escapement pivots are 0.63 mm. The barrel pivots are 6.35 mm and have matching jewels 2.60 mm thick. Clear jewels and clear cap jewels have been used for the train while red jewels have been used throughout the escapement. This is to highlight the unique features of (D)W5.

It was decided in the beginning to take advantage of modern materials now available for the pendulums, fused silica is used for the pendulum rods, the knife edges have been cut by EDM from tungsten carbide while the bobs are a 3:1 tunsten:copper alloy. Tungsten was chosen as it is twice as heavy as brass providing the pendulum with more inertia.

A final touch has been to matte gold finish the three main plates, supporting feet and the suspension brackets, and bright gold finish all the wheels, escapement parts and the bridges. There was a stage in making this clock, when the brass plates were polished, that the reflections were so confusing it was almost impossible to see the escapement in action.

The seconds and main dials are of glass onto which the characters have been sandblasted from the rear then filled. The Arabic numerals were copied from the dial of a quarter repeating Breguet pocket watch. The hands are of my own unique design. I have coined the name 'David's hands' to describe them, and all three hands are balanced, polished and blued.



2. Detail of the mechanism. For explanation see text.

Making (D)W5

The main and front plates are of 1/8" brass, the bridges have been cut and machined from rectangular bar stock. The wheels have been cut from 3 mm, 1.6 mm or 0.80 mm hard brass; the pinions have been cut from oil hardening silver steel (drill rod). The train for (D)W5 has one more wheel than is usual after the centre wheel, to achieve the correct rotation of the remontoire permitting it to gather and lock the gravity lever after impulsing the free pendulum. This requires small diameter and tooth count wheels with unusually large counts for the pinions.

The train is: centre 80, third 72 (pinion 20), fourth 40 (pinion 24), remontoire pinion 28 and remontoire wheel 7 pins.

The locations of the count wheel, **1**, in **2** (which carries the seconds hand) and the remontoire wheel in relation to the centre wheel are crucial to the proper functioning of the finished clock. The count wheel must be poised and as light as possible. The secret of W5 running successfully lies in the count wheel being very free and light. Philip commented: 'the count wheel must be able to spin freely when blown on with a light breath'. The count wheel has a 0.018" sapphire rod pressed into a nib near the rim to trip the gravity lever drop. The pivots are not oiled.

Once the train was finished it could be planted, the jewels pressed into the plates, and the jewelled endplates fitted. All the endplates are numbered to their location.

The remontoire bridge had to be made tall and long, tall because the remontoire wheel with its five pins must be in alignment with the ear of the gravity lever and the locking detent, long because there is a fly, **1a** in **2**, perhaps better named an 'inertial damper', fitted to the upper end of the shaft. This damper is necessary to disperse the residual energy when the train is locked after lifting the gravity lever. The two grey metal counterweights seen at the ends of the damper are made of pure tungsten, used for its density, almost twice that of lead.

The gravity lever and locking detent locations are also critical. Philip Woodward specified the correct position to 0.001". It may seem strange for a clock to require the precision of a watch, but W5 is no ordinary clock.

Philip designed W5 around sound and very precise scientific principles with the aim of creating a very accurate, all-mechanical timekeeper. To further this, the positions of the pendulums, both horizontally and vertically, are crucial to proper functioning, as is the correct placement of the remontoire wheel.

The exact locations of the suspension points of the pendulums caused me some difficulty. Philip used suspension springs on his W5; I chose to use knife-edges to avoid the associated problems found with spring suspensions. To work in the manner I wanted, the INVAR blocks for the pendulums needed to be held in gimbals, but there was too little space available for the usual large gimbals as made by Berthoud. As I was using fused silica for the pendulum rods, I could not fit the knife-edges into the rods as has been done by many Viennese makers. I was able to create for each pendulum a pair of 'L' shaped brackets supporting gimballed knife-edge frames large enough to allow the pendulum rod with its INVAR block and fitted tungsten carbide 'V's to pass through.

The free pendulum has a threaded shaft with a brass disc above the INVAR support for micro regulation. One turn of the disc equals about 1/10 of a second per day, replacing the usual weight tray on the free pendulum rod.

Near the top of the free pendulum is a Shortt type safety lever. This is pivoted on hardened steel conical screws sitting on a hardened steel table attached to the fused silica rod. The safety lever is counterbalanced at the top to hold the impulse roller bracket at the bottom of the short INVAR rod against the pendulum rod.

How it Works

Very few people seem to understand the operation of (D)W5, though Philip has described it several times in the past. Many who have read the description still

Photography by Bill Taylor ASC

have not grasped it all, so I shall attempt to explain in my own words.

It all begins with the slave pendulum, which indexes the count wheel to which the seconds hand is attached. This action is performed by the centre wire of the three pivotted on the wires block mounted on the slave pendulum. This is a half seconds pendulum, but as it indexes the count wheel only on its swing to the left, it delivers true seconds.

The count wheel (**1**, in **2**) is turned until the sapphire pin (**2**, in **2**) comes into contact with the tip of the 'S' shaped upper wire (**3**, in **2**). When this 'S' wire is pressed down by the count wheel, another wire fitted into the same pivoted base comes into contact with the base of the 'hook' (**4**, in **2**), the lowest of the three wires. By benefit of a multiplying effect, the hook is lifted to engage the nose of the gravity lever when the slave pendulum is swinging to the right. The hook draws the gravity lever to the right and unlocks the ear (**5**, in **2**) of the gravity lever which falls to rest on its banking. The ear is pivoted at the top left of the gravity lever opposite to the nose.

The slave now begins its journey to the left and will gently lower the hardened tip of the gravity lever (**6**, in **3**) onto the impulse roller (**7**, in **3**) of the free pendulum, thus receiving its impulse. As soon as the tip of the gravity lever touches the impulse roller, the hook on the slave pendulum is released and the slave pendulum has no knowledge of further events and swings to the right with enough added energy to maintain its motion.

The impulse roller on the free pendulum is now in exactly in the right position by the magic of science to accept the tip of the offered gravity lever. The gravity lever must be placed on the 'dead roll' portion of the impulse roller and not at, say, the 2 o'clock point. The impulse roller completes its 'dead roll' with the gravity lever resting on top. As the free pendulum swings to the left the gravity lever rolls down the impulse roller, providing an impulse through a tangential force of 2.69 grams. The free pendulum is once again fully detached from the movement.

After the impulse has been given to the roller, the gravity lever is free to fall a little farther to its banking. As it does this, the notch (**8**, in **3**) in the ear of the gravity lever touches a pin (**9**, in **4**) on the remontoire. This is a most unusual action, and W5 is possibly the only escapement that is unlocked by a percussive action.

This slight pressure on the remontoire pin releases the locking detent (**10**, in **3**), which permits the remontoire pin in contact with the notch in the ear to lift the gravity lever. As the gravity lever is lifted, a pin on the lower portion of the ear comes into contact with, and lifts, the locking detent, which intersects with another pin on the remontoire wheel and locks the escapement.

Once the escapement is locked by the locking detent the gravity lever is free of the train and is merely resting against the remontoire pin which lifted it into place.

4. Detail of the mechanism. The change of angle may resolve some difficulties. For explanation see text.

The action of the synchronizer spring comes into play when the gravity lever falls after impulse and unlocks the detent. The lower tail of the locking detent touches the left tail (**11**, in **3**) of the synchronizer spring, causing the right side of the synchronizer spring to flick up. The synchronizer spring is pivoted between the gravity lever and the center wheel, the right hand portion of which (**12**, in **3** and **4**) ends in an upstanding tail that is close to a down-pointing tab on the wires' block of the slave pendulum.

If the action is a 'miss' the synchronizer spring will flick up and drop back to its banking. When it is a 'hit' the upstanding tail will intersect with the down-pointing tab (**13**, in **4**) on the wires block. It will be a 'hit' only if the slightly slow rate of the slave pendulum has allowed it to fall behind sufficiently for the tab to catch the synchronizer spring before the spring drops.

As the slave pendulum is swinging to the right the synchronizer spring will expand, stop and pull the slave pendulum, slightly

3. Detail of the mechanism. For explanation see text.

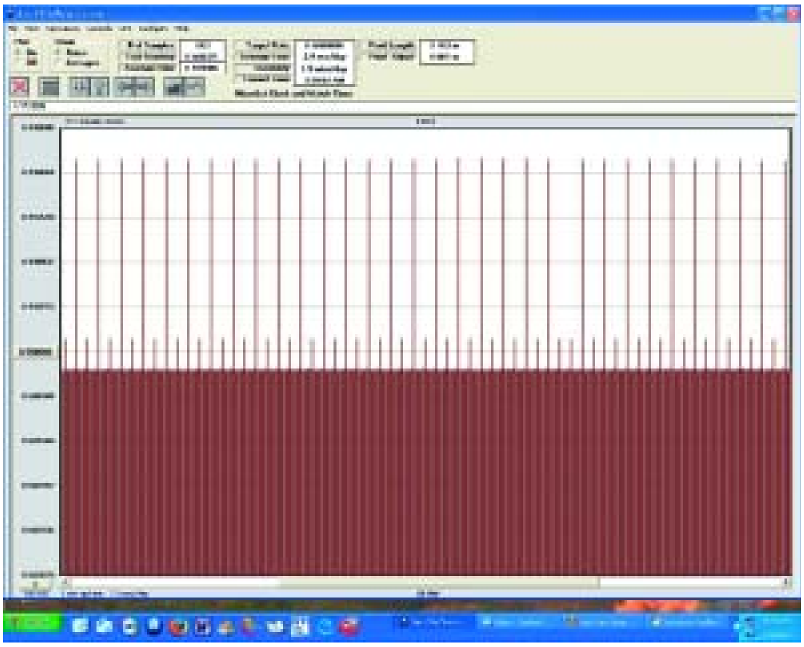
accelerating its rate and bringing it back into synchronization with the free pendulum. The slave pendulum must have a losing rate because the mechanism can correct its rate in only one direction. Were the slave to be accurately regulated or fast, the 'hit and miss' system could not work, causing the W5 system to fail.

My slave pendulum has a losing rate of some 30 seconds per day. As it is corrected at every second impulse, i.e. once per minute, it shows accurate seconds. The ideal setting is one hit, one miss, although several misses can occur without failure of the system. A screen grab from the MicroSet timing system, **6**, clearly shows the hits and misses of the slave pendulum. The hits are the tall spikes and indicate a gaining rate.

In conclusion I will say (D)W5 is very robust. I have moved and transported it twice in the last week for an exhibition. Each time it was set up there was no problem with getting it running. As a visitor said to me: 'it really wants to run'.

Acknowledgement

During the creation of this clock Philip Woodward has been a great supporter and a veritable fountain of assistance, digging into his notebooks when I had questions, making suggestions and even mulling over my own ideas. I could not have hoped for more cooperation and would like to express my deep gratitude to him.

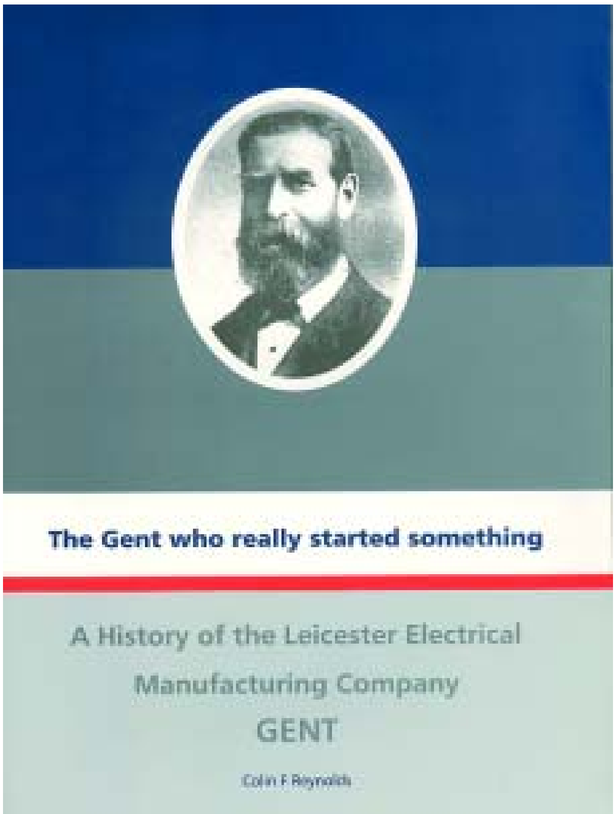


6. A screen-grab of the MicroSet timing system showing the hits and misses of the slave pendulum. The hits are the tall spikes and indicate a gaining rate. The slave pendulum has a losing rate of some 30 seconds per day. As it is corrected at every second impulse, or once per minute, it shows accurate seconds. The ideal setting is one hit, one miss, although several misses can occur without failure of the system.

BOOK REVIEW

The Gent who really started something

Colin F Reynolds A4, 142 pages, published by the author*, £7.50 plus £2.20 postage in the UK or £4 to Europe.



Most readers will be aware of the 'Pulsynetic' clock systems made by Gents of Leicester. Colin Reynolds spent his working life with the company and has produced this unusual and fascinating work. While it will not tell you how to service or repair a 'Pulsynetic' clock, but it does give a detailed history of the company and its development from the early production of electric bells and indicator panels, via telephones, to electric clocks and fire detection equipment, as well as the vicissitudes of frequent changes of ownership during its later years.

Colin has had the advantage of access to company records, and the memories of retired workers, as well has his own lifetime working there. This is a social as well as a company history, any reader who has worked in manufacturing will appreciate the story of how a company changes over the years as markets and manufacturing techniques develop.

Gents were not without their share of disasters. Starting in typical Victorian premises with small separate shops, at the end of the 19th century the company built a new factory on the American system (i.e. a 'Big Shed') only to have it totally destroyed by fire a few years later. I certainly had never realised that, at one period, Gents actually made very up-market radiograms as well as being a large producer of electric cable.

Just prior to and during the second World War Gents produced the bulk of the Air Raid sirens for the government as well as being involved in the manufacture of 'ASDIC' submarine detection apparatus and other electronic equipment for military use. Many contemporary photographs illustrate the text, these show the buildings, the people who worked there and the shop conditions under which they laboured. Even as late as 1936, the machine shop was a forest of belts driven from overhead line shafts.

J K Nicholson

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