Issue 10 • Spring 2010



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SPIDERS AND PIGEONS: ON THE GREAT COURT

By Hugh Hunt

This is a double anniversary year for the Great Court Clock. It was 400 years ago in 1610 that the clock was first installed. Its dial was small and modest, but in 1726 our masterful master Bentley had it replaced by something grander. The 1610 clock is still running in the tower of Orwell's village church.

As Graham Chinner reported in *The Fountain* of Autumn 2009, the Bentley clock mechanism was coincidentally replaced a century ago, in 1910, thanks to a bequest from Lord Grimthorpe. His "double three-legged gravity escapement" was made famous in 1859 when installed in the Great Clock in Westminster ("Big Ben"). In the 50 years that followed, the design was adopted and perfected by all the best turret-clock makers.

J. Smith of Derby built our own precision timepiece. For its 100th anniversary we have set up a web page at www.trin.cam.ac.uk/clock so that anyone can monitor its accuracy. We have also devised an engineering-student project to see if we can help Smith's mechanism to attain still greater accuracy.

At the heart of the monitoring system is a tiny infrared beam that is interrupted every 1½ seconds by the swing of the pendulum—once per "tick". The signal is recorded by a PC which also records the one-pulse-per-second output of a GPS receiver—accurate to 10 nanoseconds, so they say. A computer compares the ticks with the GPS to compute the drift of the clock and the amplitude of the pendulum's swing, producing a new data point every three seconds. A weather station also records temperature, barometric pressure and humidity. Data is uploaded to the website every three hours.

This system, which has been running since April 2009, has given invaluable help in regulating the clock and recording much interesting data.

For example, you can watch how the clock is regulated day by day. This is done by placing small brass weights on a platform halfway up the pendulum. The regulation constant

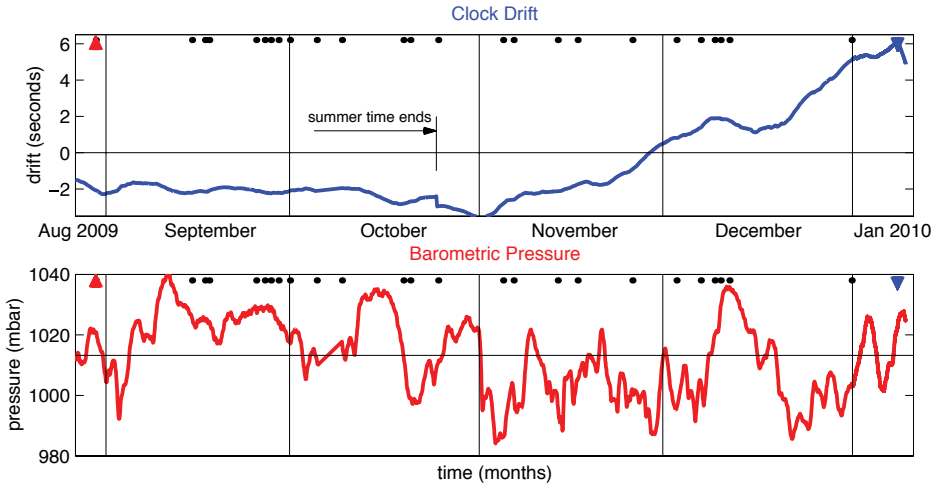


is 104 milliseconds per day per gram. Our smallest regulation weight, at 5ms/day, is 50mg —not much heavier than a grain of rice.

Data for the months of April – July 2009 are shown in the graph below. The red diamond indicates that a regulating mass was added to the pendulum in early September. For the next three months the clock kept time with remarkable accuracy, to within one second (most wrist watches will not keep time to better than one second per week).

Unfortunately, the regulation didn't stay perfect for long. Something clearly happened late in November and December, causing the clock to gain several seconds in less than two months.

One might suppose that low winter temperatures were the likely cause, but our clock is fitted with a temperature compensated pendulum—as has been common practice for three centuries. Barometric pressure is a less obvious influence. Close inspection, however, shows that the clock slows down during



THE PRESSURES CLOCK

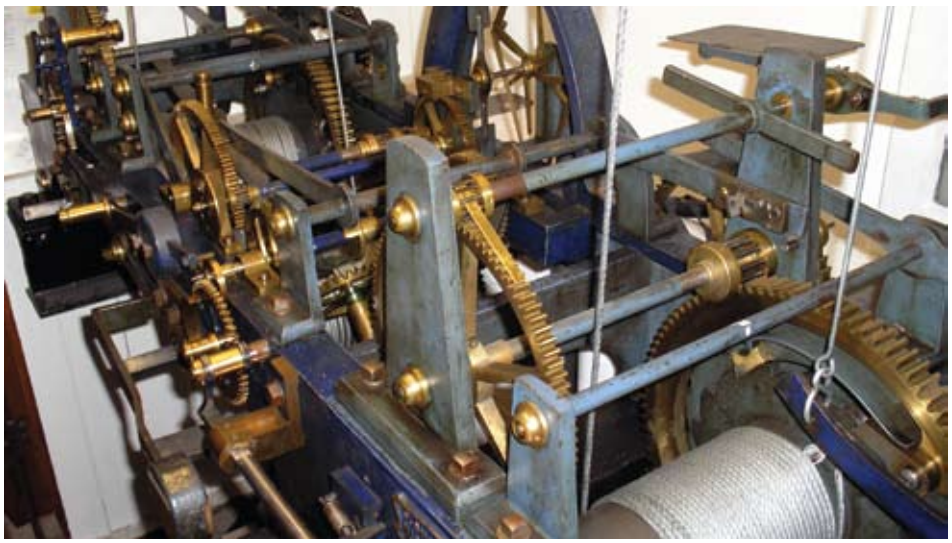
periods of high pressure, and that it was an extended period of low pressure that had caused the acceleration.

Three effects are at work here. The biggest is buoyancy, because the pendulum bob displaces air whose density depends on air pressure. The weight of the displaced air reduces the apparent value of the gravity constant *g* and therefore the period of the pendulum's swing. For more than a century we have known that pendulum clocks lose time at a rate of around 10ms/day for every millibar rise in barometric pressure.

Two other effects to consider are the aerodynamic drag on the pendulum as it swings, and the mass of the boundary layer of air that the pendulum carries along with it.

The little black dots in the graph indicate other interesting events. For instance, in October the clock had to be put back an hour at the end of Summer Time. The pendulum continued to swing during this adjustment but it was not driven. The change in the breadth of the pendulum's swing caused the recorded drift to shift by about half a second. A similar "glitch" came in March, as will happen in March and October of every year.

But what of the flurry of black dots in late September and early December? These glitches seemed inexplicable. It appeared that they always occurred around quarter-to-the hour. The minute hand is horizontal then and rising. We also noticed that pigeons gather in large numbers around the clock dial, especially when the sun shines. The black-painted south-facing dial must be a warm place to sit. The glitches occurred only in daylight hours.



Is it therefore possible for pigeons to stop the clock by sitting on the minute hand? A quick calculation of power balance can help us decide. Suppose a pigeon weighing 1 kg is sitting on the minute hand at a distance of 50 cm from the pivot. The hand would be rising at about 1 mm/sec and would therefore require about 5mW (milliWatts) of power to lift it. The clock is driven by an 80kg weight which falls 9 metres in 7 days, equivalent to 12mW of power. It seems that there is only just enough power to lift a single pigeon. A couple of pigeons could easily stop the clock.

Three consecutive pigeon-events occurred around 10.45am, stopping the clock for a total of 4 minutes on 8 December. This was in the middle of the Admissions Interview season. Already nervous candidates might have thought that their punctuality was being tested as a fiendish new admissions test!

There are other events that can only be understood if you go to the website to see the graphs. I am convinced, for instance, that a spider spinning its web around the pendulum rod caused the clock to gain 300 milliseconds overnight on 3–4 May 2009. During this "spider" incident, a scatter plot of "going" vs "amplitude" shows a beautiful straight line with a gradient of –580ms/day for every 1mm change in the amplitude of pendulum swing. This agrees perfectly with small-amplitude pendulum theory.

What of the future? The original motive for setting up all this instrumentation was to try to detect the tidal variations in gravity due to the moon and the sun. To do this it looks as if we need to devise a barometric compensator for the pendulum, and this will be part of a new student project in 2010–11. Look out for our results in the Autumn issue of *The Fountain*!

But perhaps we should sort out the pigeons and spiders first…

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