Q and the "Grand Mother" Clock continued (Part 2)

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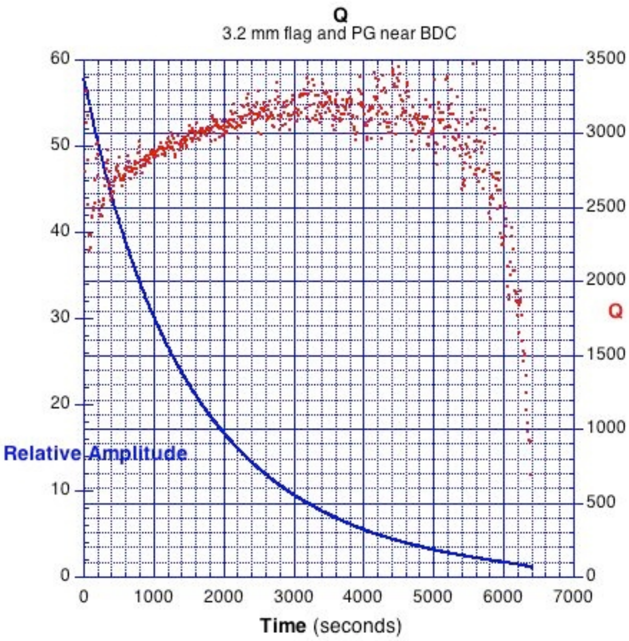
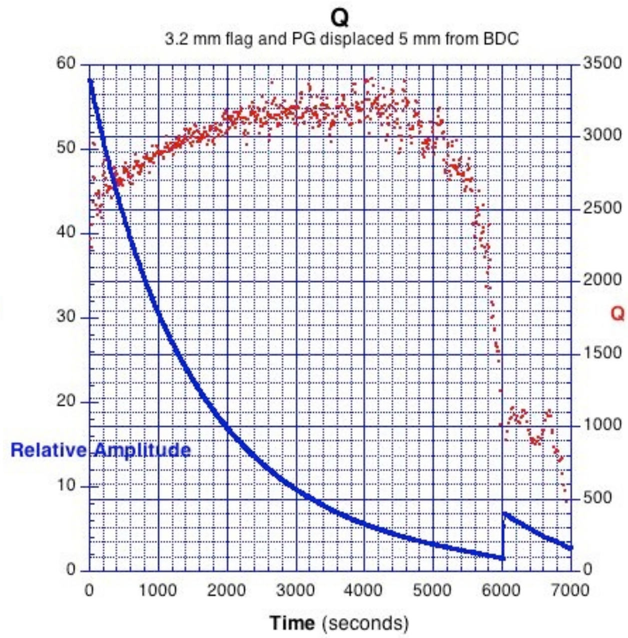
Data Collection Using a PhotoGate

Though many know the two principal assumptions regarding the use of photogates, I must emphasize them, especially, as I failed to account for one of them in the previous article. They are the errors due to improper placement of the PG and the flag's finite width. I had examined the effect of moving the PG off BDC one mm with a one mm width flag and found little difference in the calculated continuous Q. There is, of course, an increase in the number of doubled beat values at the end of the decay when the PG is displaced. To approximately quantify the off BDC effect I, using a 3.2 mm flag fond the continuous Qs of two trials one near BDC and the other off five mm, graphs of which are below:



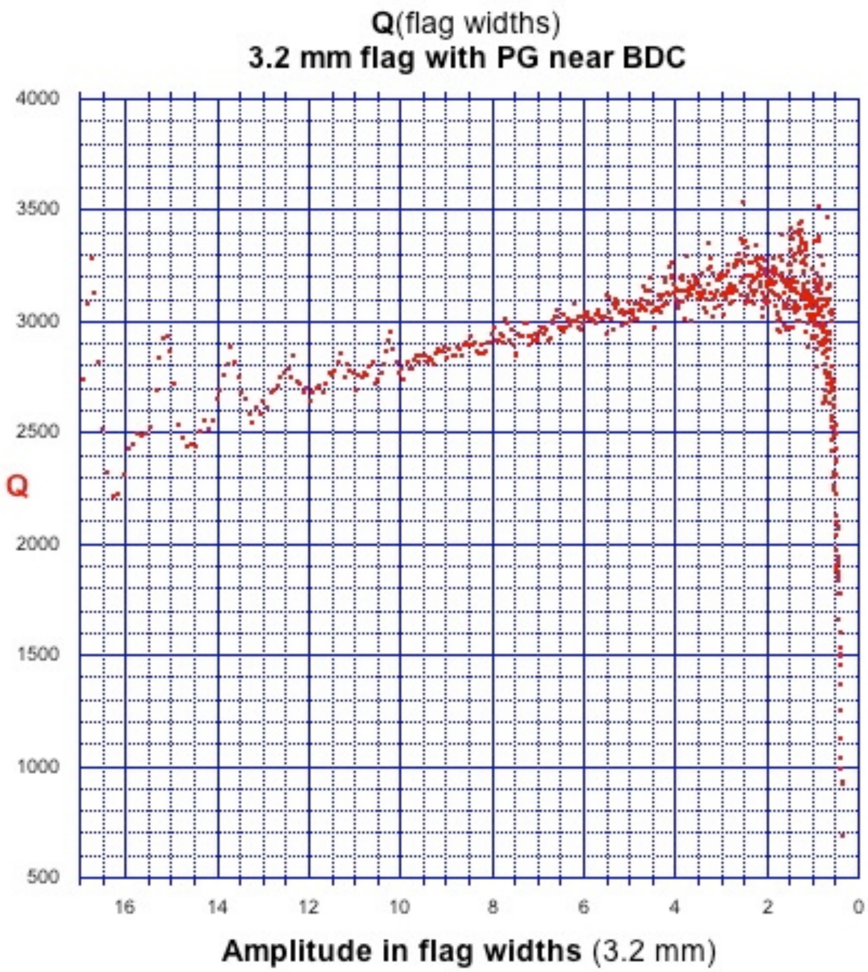


The MicroSet was set at time 10 and the relative energy and energy differences each smoothed with a five point window to obtain the data for the graphs.[1] Because I am able to set the PG within approximately five μm, I had ignored PG displacement as a source of error until B. Mumford collected data near BDC and displaced a half inch. He found the Q at BDC ~ 9k reduced to 8k.[2] The formula, easily derived, that gives the expected error as a function of the amplitude measured linearly (beat plate) and the displacement is: $Q_{(\text{PG displaced})} = Q_{(\text{PG@BDC})}(1 - \frac{\text{displaced distance}^2}{\text{amplitude}^2})$ Before continuing I must examine the other assumption, *i.e.* failure to account for the finite width of the photogate's flag. I had

[1] My formula HSN 2007-4

[2] personal communication

ignored this because the roll over due, I thought, to da Vinci dissipation occurred so early in time. I was apprised of this error by Douglas Drumheller[3] who has derived an "advanced" algorithm that corrects for the finite width. He found my Q is accurate "by eye", for amplitudes greater than twice the flag's width. As a result I tried to find da Vinci dissipation in the clock's pendulum, freely decaying, using a 0.4mm flag. Possibly there, but so noisy not convincing. Therefore, I now often plot Q as a function of the amplitude in flag widths. For example, next is the first graph's Q data plotted as a function of the flag width.



Note the roll off beginning at approximately two flag widths.

Da Vinci dissipation in the Grand Mother Clock

Finally, occasionally mentioned in the horological literature is the running or going Q[4]. I've not found in the literature any direct measurement, but Woodward measured one of his clock's actuating force and using it concluded it was approximately 2k. Since the free pendulum's was 8k, "... some three quarters of the loss are, so to speak, internal to

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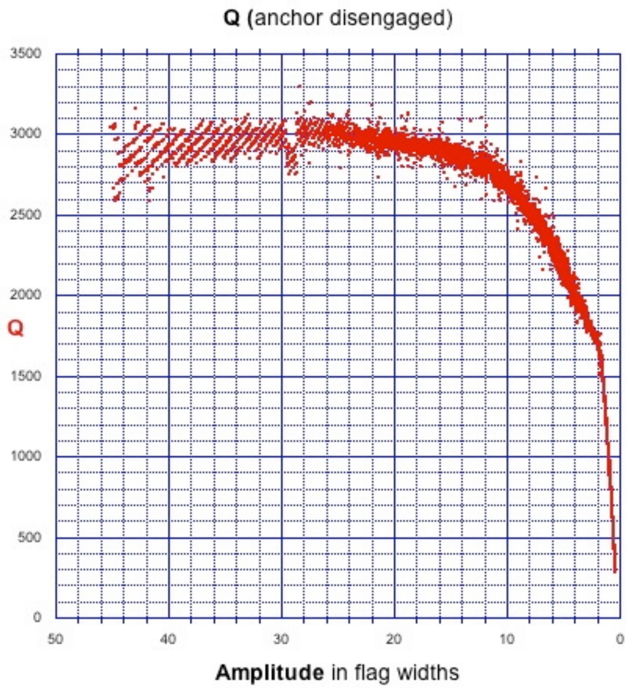
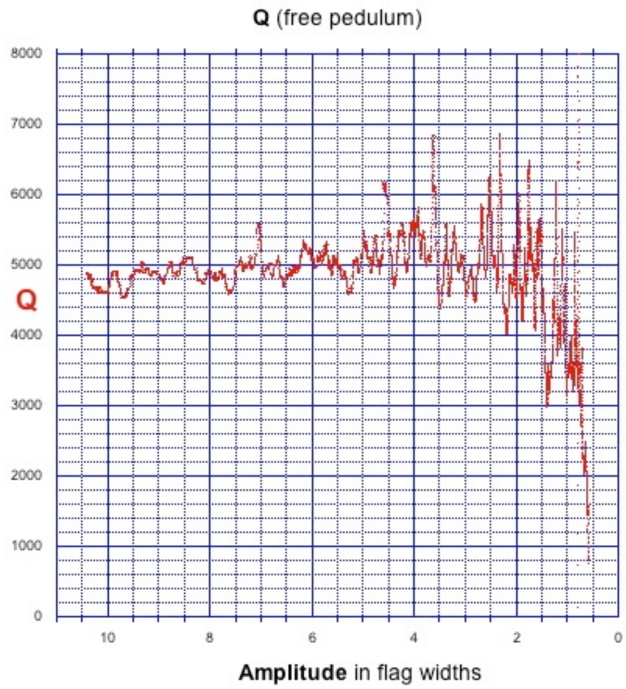
[3] personal communication.

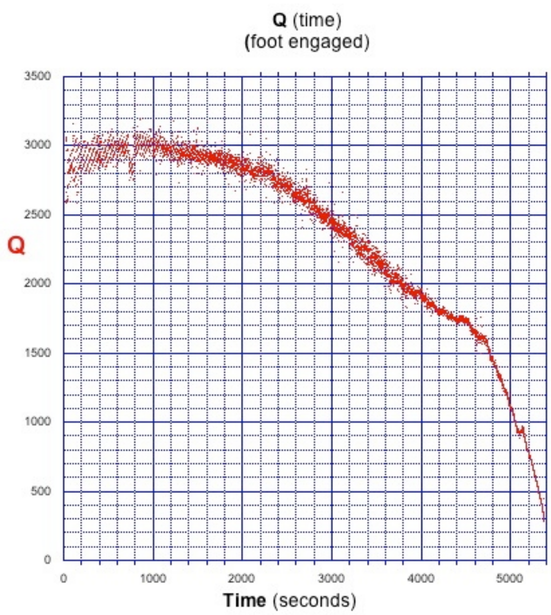
[4] "loaded Q" p. 46 Woodward on Time

the clock."[5] I've measured some of the "loaded Q" of the GM clock by installing the anchor with its integral, engaged with the pendulum, split foot. Below (left) is the result with the anchor well above (disengaged from) the escape wheel, as a result the decaying pendulum drives the anchor with a resulting friction in the bushings and the





split foot. To the right is shown the last ~ ten flag widths of the same pendulum freely decaying with the expected greater Q. Determination of the dissipation type requires the Q found as a function of the time. So next is the foot engaged Q plotted as a function of the time.



One may now see all three dissipations. I estimate the going amplitude at approximately 30 flag widths or ~ 800 s in the graph on the left. I haven't concluded whether the friction in the rest of the clock affects the Q. However, the system Q[6] of weight driven clocks are easily found. I intend to discuss this, *inter alia*, in part three.

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http://www.cleyet.org/

[5] *loc. cit.*

[6] more properly the efficiency, as it includes all the dissipation in the "works" in addition to the pendulum.