Worcester Cathedral
Guild of Bellringers

CREATING A WELL BALANCED RING
Part 2 - Clappering

In our quest to make the heavy twelve at Worcester a more balanced ring, over a period of months we first altered the swing times of several of the bells (see Part One) and then looked at their clappering. The back bells had been vastly improved with the introduction of Jim Wheeler's wooden-shafted clappers between 2005 and 2015 and whilst there was no plan to replace all the others (!) there were obvious possibilities to improve their performance.

For lumps of metal bashing other lumps of metal, clappers are quite complex, or at least their movement is. Some quite tricky maths describes the action of a swinging object inside another swinging object but most of this is irrelevant to the practical steeplekeeper. Getting the clappering right breaks down into two, semi-related, issues – how long the clapper takes to strike the bell when it is rung and the timing difference between hitting one side (the handstroke) and the other (the backstroke) – 'oddstruckness'. This paper deals with the first of these.

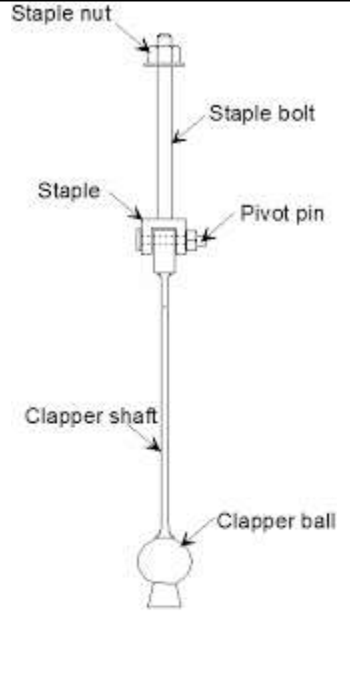
The **Clapper Strike Times** depend on the action of the compound pendulum of the bell and clapper working together – how fast the bell swings and how fast the clapper moves when 'thrown' by the bell. *Thus it is important to have the bell swing times correct before contemplating changes to clappers*.

These strike times depend upon two variables, how fast the clapper moves on its own - the **Clapper Swing Time** – and how fast it is thrown by the bell, dependent on the leverage the bell has over it which is the **Clapper Throw** (CT).

CLAPPER SWING TIMES

How fast a clapper swings depends on its length, and rather crucially, lubrication at the pivot. One usually assumes that the design characteristics have been considered by the bellhangers, though that does not mean they are optimum.

The steeplekeeper can do quite a lot about the ease of movement however – a year before starting this exercise we removed the twelve wrought iron clappers and staples, dismantled, cleaned, lubricated and then re-installed them. The pivot pin of the 8th was found to be broken and had to be replaced by Whites. The back four bells have wooden-shafted clappers with pivots in ball-races which need no such attention! We did, however, clean and lubricate the old clappers for these bells so that they are available for an emergency.

		
Clapper & Staple Assembly Courtesy ODG	8th clapper & staple with broken pivot pin	8th clapper repaired

We measured the clapper swing times by using a stopwatch to count a number of swings with the bell down. Friction can have quite an effect on this measurement – you can get 10-15 full swings (there and back) from an old style clapper but well over 25 from the wooden-shafted ones which pivot on ball-bearings. For example, our 11th clapper takes 45.8 seconds for 25 swings which means 1 full swing takes 1.832 seconds or 1832ms. Compared to the Bell Swing Time of 2060ms that is 89%.

Alan Hughes advised us that the clapper swing time should be about 90% of the bell swing time. If the bell swing times are set up correctly this ratio will put the strike times in the right ball-park but no more than that. We regard this is as a useful measure but not a target on its own.

When we looked at this ratio for the bells with all-metal clappers it went as high as 94% - which confirmed the sluggishness of the 8th. The same ratio occurred in the 9# which had been a fast turning bell with a very slow clapper - the change we'd made to the bell's swing time now means that the bell and clapper times are in alignment.

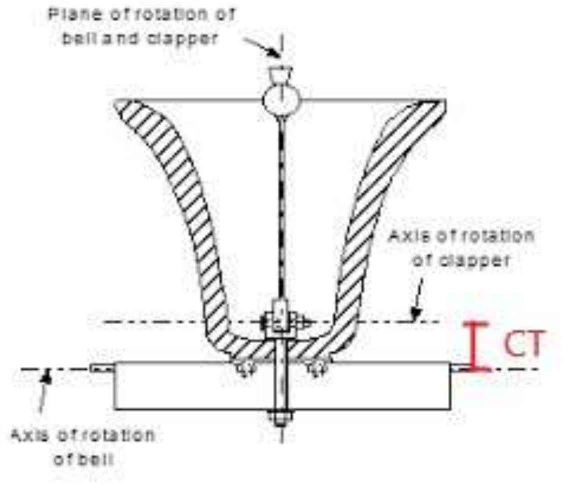
CLAPPER THROWS

This is the vertical distance between the centre of the clapper pin in the staple and the centre of the bearings. That is, the difference between where the bell pivots and where the clapper pivots *(see diagram).* This is **critical to the speed of the clapper within a swinging bell**, and is most obvious to the ringer when raising the bell – it is the only leverage he has in making the clapper move differentially from the bell when it is chimed, that is, ‘throwing’ it to the upper lip of the bell to get it up ‘right’. Increasing the CT accelerates the clapper, decreasing it slows it down, so chiming a bell with a large clapper throw is easier than with a small one.

We were advised that the CT’s should either be all the same for a ring or gradually increase in line with the bell weights, the figure of **5½” (13cm)** being suggested as an optimum. The Worcester ones were quite perverse, with the treble at nearly 19cm running down to the 8^{th} at 10.5cm. The 5^{th} was particularly short and did not even fit into this ‘reverse’ pattern! This immediately suggested one reason why the middle bells felt slow. In doing our adjustments to strike times we did not make any specific length of CT a target, but used it as confirmatory data of other measures.

The CT has more effect upon the Strike Time than the clapper’s swing time does, because the bell exerts more force on the clapper than it creates itself. This is why the 90% rule is not the most important aspect of clappering and in fact really only determines how easy it is to get the bell up ‘right’, not how well it rings when up.

As it turned out, we were in the fortunate position of needing only to speed up clappers - increasing the CT’s by packing out the staples from the bells. The smaller adjustments, increasing the CT by up to 1cm (½“), could be implemented without any change to the clapper but did usually require a longer staple bolt. For the larger adjustments the clapper had to be shortened in order to keep the strike point of the ball in line with the strike point on the soundbow of the bell. Luckily we have access to a forge and a Jim Wheeler!



CLAPPER THROW (**CT**) is the distance between the centre of the bearings and the centre of the clapper’s pivot in the staple.

Typically this is about 13cm (5 ½ “)

Diagram courtesy of ODG

RECORDING DATA

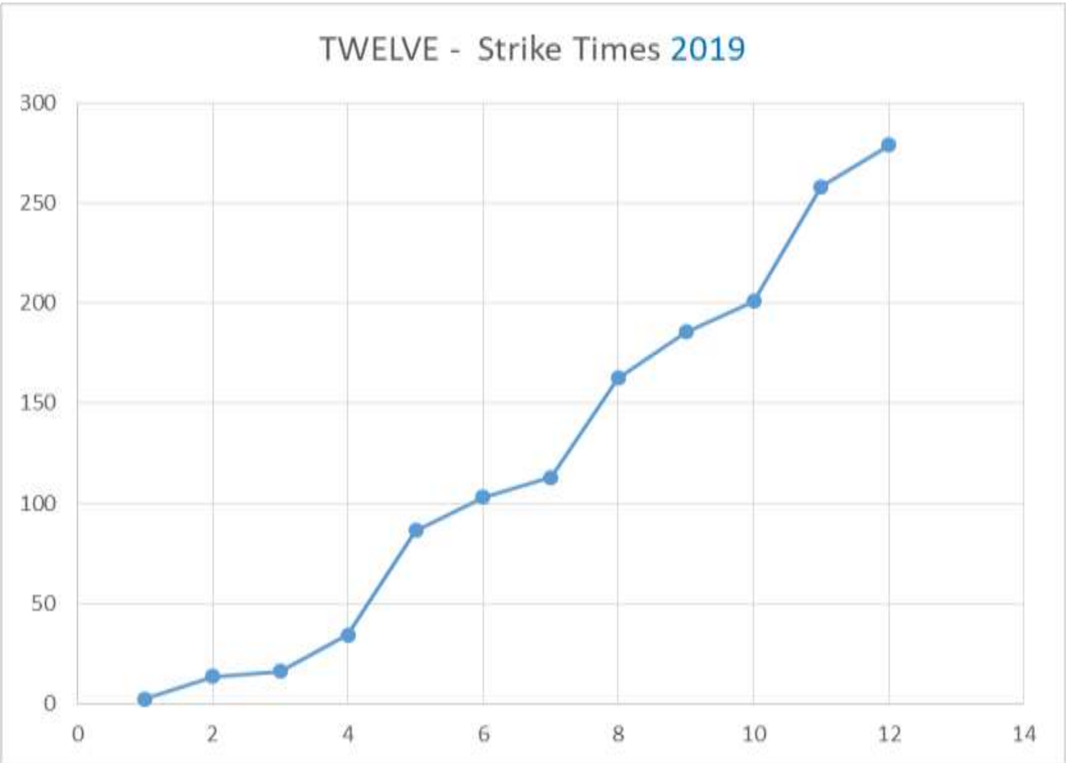
The whole exercise of altering bell swing times and clapper strike times relies on collecting and recording data in order to make informed decisions. We keep paper and electronic records of these and all ‘standing’ data, such as rope details, stay sizes, clapper details, &c and of reasons for changes in these. All this is made available on the Guild website. This process allows for some ‘peer review’ and will also provide useful information to our successors.

We log all steeplekeeping activity, and produce at least one detailed report per year of that activity to the Guild and Chapter.

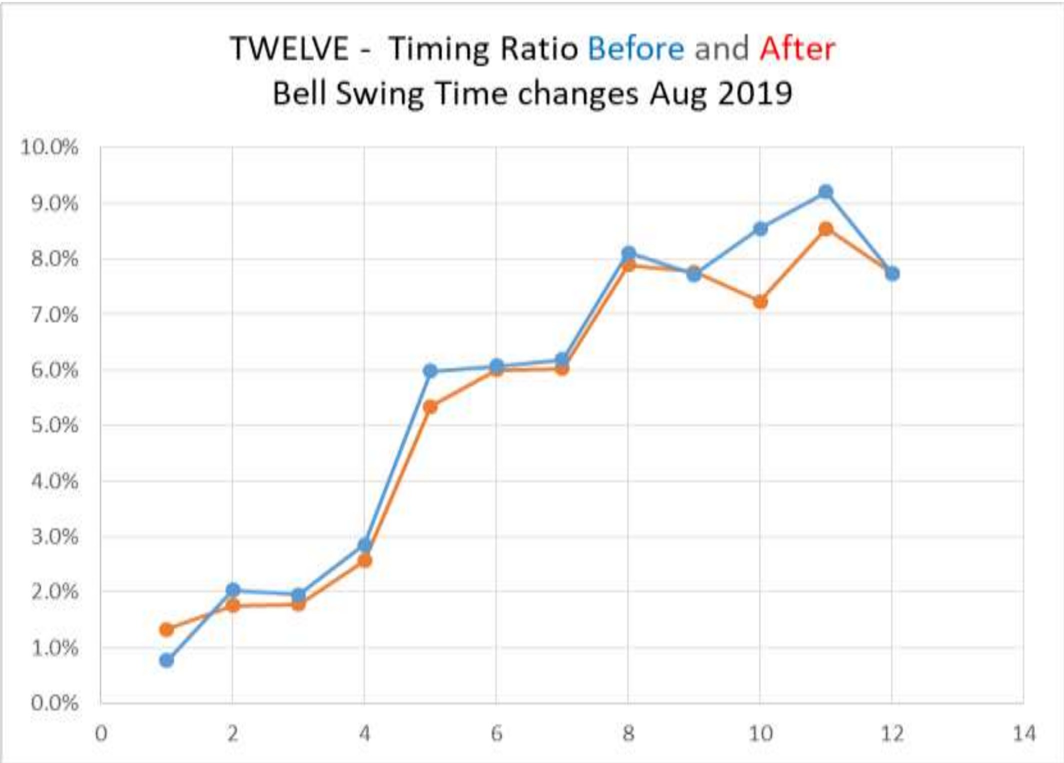
This process, of recording data, is vital to making 'things work'. If we make changes and they are improvements we know what we did. If we get it wrong we can go back to where we were. All basic stuff but plenty of people don't do it.

CLAPPER STRIKE TIMES

As shown on this graph the **strike times** were anything but a smooth line. These are mean strike times, making any oddstruckness between handstroke and backstroke irrelevant. They were taken on 4 Sep 2019, after the Bell Swing Times had all been adjusted. *(The y-axis is milliseconds less 300).*



Whilst making our adjustments in order to smooth this line out we also started to use another metric, the ratio of the **Strike Time to the Bell Swing Time**. (As this is something of a cumbersome title it is abbreviated on the graphs to **Timing Ratio**). It doesn't take much thought to realize that this captures in one number the essence of what the ringer experiences – how long his bell takes to move and how long it takes to sound. For Worcester this is in a range of about 18-26% and the graph of this ratio captures, in more vivid style, how much adjustment the clappering required. Just to check whether our swing time adjustments (see Paper 1) had messed up this measure we compared it before and after those changes were made. Only in the case of the 10th does it appear to be significantly different. *(The y-axis is percentage less 17).*



The **changes to clappering** needed were thus quite extensive, covering 7 of the 12 bells, as well as two of the semitones.

FIFTH - In Dec 2019 we had this shortened by 2cm, courtesy of Jim Wheeler, and on re-installation increased the CT, packing out the staple with a thick plastic washer. These two changes speeded up its strike time by 29ms. Whilst shortening the clapper decreased its swing time we noted just how much difference the CT made to the strike time – with different thicknesses of washers we could achieve a range of 15ms.

NINTH - We made adjustments to the throw of the 9th in two stages, necessitating some shortening of the clapper – we able to do this work on site as it is a wooden-shafted one. (We have a workbench, industrial vice and a pillar drill installed in the belfry!) The staple bolt had to go to the forge for lengthening because it was insufficient to allow the increased CT we were looking for. The strike time went down by 24ms.

ELEVENTH - Later we adjusted the 11th CT but did not need to change the clapper, achieving a reduction of 23ms.

EIGHTH – As with the 5th the increase in CT we were looking for required the clapper to be shortened by 2cm. The combined effect lowered the Strike Time by 30ms, the largest adjustment we had made. Finally this bell stopped being the sluggard of the ring!

Dec 2029 - Tenor clapper with wedge broken from ball
This is the original 2005 design with a solid counterbalance

TENOR - Just as we were making good progress a major unplanned addition to the work was created when the clapper ball of the tenor broke during a quarter peal attempt on 23 Dec 2019. This was the second (heavier) ball used on this clapper and had done 8 ½ years' work, whilst the first had lasted 5 ½ years. The breakage seemed to be due to a casting flaw rather than the design of the wooden-shafted clapper and was like fractures in other similar clappers. For various reasons, the repair turned into a complete replacement with an adjustable counterbalance like the ones we have on the 10th and 11th. We were hoping that the clapper strike time would be near the 579ms of the broken one but even after some initial adjustment it was a rather faster 555ms.

So it does need slowing down, either by adding further to its counterbalance or reducing the clapper throw which requires a new staple. All three versions of the wooden-shafted clappers used in this bell have been hung on the old staple so it is a good opportunity to upgrade to an adjustable one. The timing shown on the graph represents where we want it to be at 577ms when circumstances allow us to do this work.

One oddity is that the old SG clapper used as a temporary replacement for two months has a similar strike time to the new clapper but the bell was harder to ring. It would be good to know why this is so.

Feb 2020 - New tenor clapper. Counterbalance made of plates bolted together

We then had a second setback - the record flooding in and around Worcester disrupted travel and meant a number of work sessions were cancelled. And just as that was all sorted along came the corona virus!

SIXTH, FLAT SIXTH, SEVENTH & SHARP FIFTH - In a small window of opportunity before complete 'lockdown' we were able to get the staple bolts of these four bells lengthened to facilitate changing the CT's of each of them, as well as having the length of the **6b** clapper reduced by 4cm. As with the other bells we took the opportunity to put metric-threaded bolts on and replace the (historic) imperial castellated nuts with split pins which are something of a pain to tighten accurately.

Covid-19 control measures caused all ringing to be stopped and prevented us finishing the job properly. On 24 Mar we put these four clappers back in but had no opportunity to measure the results before leaving the closed cathedral. The timings on the graphs therefore represent the expected outcome for these four bells.

We also recognise that the front end still needs some attention, where small adjustments for the **2nd** (-6ms) and **3rd** (+6ms) would aid the Twelve, the Minor Ten and the Middle Eight. The **2#** really needs about 14ms speeding up to make the Clare Ten and Front Eight spot on.

It is frustrating not to have completed the job but we have made nearly all the major changes and only on-site alterations will be needed once the bells are ringing again.

GRAPHS

All graphs show the **Timing Ratio** as a percentage (*less 17 for display purposes*). Because the project has been interrupted the data for **5#, 6th, 6b and 7th** represents work done by 24 Mar 2020 but not confirmed by measurement and that for the **2nd, 3rd, 2# and tenor** are the targets for planned work when it becomes possible.

For the rings using semitones the changes look like this –

CLARE TEN – 2#, 3, 4, 5#, 6, 7, 8, 9#, 0, E

	The slow 5# and the middle bells have been corrected and the slow 2# will benefit from speeding up.

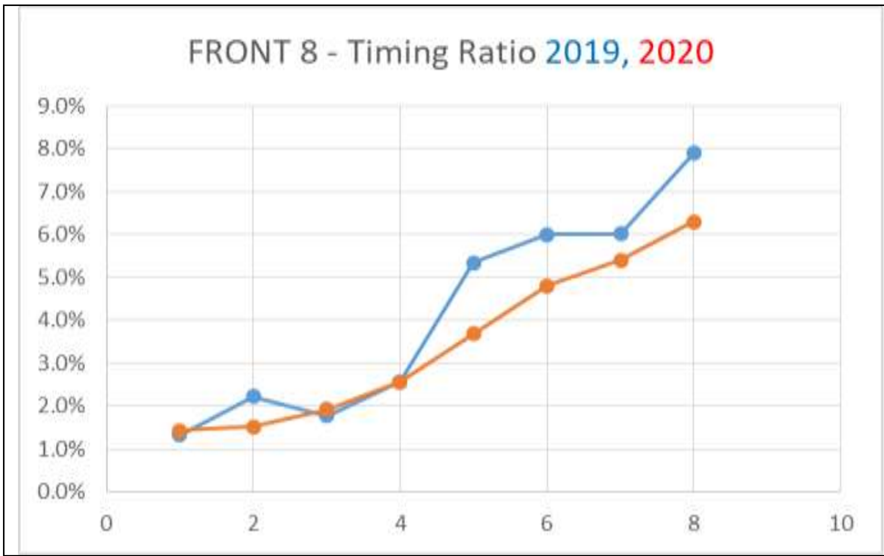
HARMONIC MINOR TEN - 2, 3, 4, 5#, 6b, 7, 8, 9, 0, E

	Removing the slowness of the two semitones helps this ring.

MIDDLE EIGHT – 2, 3, 4, 5, 6b, 7, 8, 9

The changes to all the middle bells including the **6b** are the main event.

FRONT EIGHT – 1, 2#, 3, 4, 5, 6, 7, 8



The adjustments to the middle bells of the Twelve are the main changes speeding up the **2#** also helps.

CONCLUSION

The clapper adjustments necessary to create a cohesive set of strike times for this magnificent ring of twelve were quite extensive. It is surprising that they were needed, especially for a ring all cast together and hung at the same time. One might reasonably conclude that clappering in 1928 was more of an art than a science.

It would be comforting to think that it would all be done differently now, but would it? It was not until 2005 that any fundamental changes were made to clapper design, and those resulted from an experiment done here at Worcester. Various problems elsewhere suggest that clappering is still very much an approximation rather than an optimisation, with the attendant issues being much more obvious in larger bells.

What has been good is the positive feedback from the local band, both in their comments and in their ringing. We have a band with a wide range of ability and experience, from rounds to Avon Maximus, and it is very noticeable that no matter who is on the ropes the ringing settles into a rhythm much more quickly than it used to. It is not entirely fanciful to suggest that now the bells fit together much better it is easier to ring them properly, and if it is easier to ring them properly we are more likely to create good ringing.

The next (third) paper in this series deals with Oddstruckness.

Bernard Taylor, Steeplekeeper

5 May 2020

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Appendix – Clapper data

The MEAN STRIKE TIMES and their changes are shown in milliseconds. The CLAPPER SWING TIMES are also shown and their relationship to bells' current (adjusted) swing times.

	Clapper Swing Time	% of bell swing time	17-Dec-19 Strike Time	24-Mar-20 Strike Time	Move	
1	1476	90	303	**303**	---	
2	1492	90	314	**314**	---	*
3	1512	90	316	**316**	---	*
4	1540	90	335	**335**	---	
5	1564	90	387	**358**	-29	
6	1596	91	403	**382**	-21	
7	1660	92	413	**402?**	-11	*
8	1688	91	463	**433**	-30	
9	1792	91	486	**462**	-24	
10	1832	89	501	**501**	---	
11	1944	89	558	**535**	-23	
12	2056	88	579	**577?**	New	*
2#	1470	88	320	**320**	---	*
5#	1588?	92	396	**360**	-36	
6b	1600?	91	413	**382**	-31	
9#	1776	91	470	**470**	---	

The table is not complete because no timings were able to be done after installing the altered staples and clappers on the 5#, 6th, 6b and 7th on 24 Mar 2020. The numbers shown with a '?' are what we expect from those changes.

The Strike Time reductions are mostly the result of increasing Clapper Throws. The Clapper Swing Times are not affected by this. However, for the 5th, 8th, 9th and 6b the length of the clappers were changed so their Clapper Swing Times did alter, which contributed to the change in Strike Times.

The asterisks indicate where work still has to be done once we are permitted to access the bells again.

Appendix 2 – Clapper data updated Nov 2020

The MEAN STRIKE TIMES and their changes are shown in milliseconds. The CLAPPER SWING TIMES are also shown and their relationship to bells' current (adjusted) swing times.

	Clapper Swing Time	% of bell swing time	17-Dec-19 Strike Time	3-Nov-20 Strike Time	Move	
1	1476	90	303	**296**	-5	
2	1492	90	314	**310**	-4	
3	1512	90	316	**319**	+3	
4	1540	90	335	**337**	+2	
5	1564	90	387	**358**	-29	
6	1596	91	403	**383**	-20	
7	1660	92	413	**398**	-15	
8	1688	91	463	**433**	-30	
9	1792	91	486	**462**	-24	
10	1832	89	501	**501**	---	
11	1944	89	558	**535**	-23	
12	2056	88	579	**577?**	New	*
2#	1470	88	320	**320**	---	*
5#	1588?	92	396	**360**	-36	
6b	1600?	91	413	**382**	-31	
9#	1776	91	470	**470**	---	

Subsequent to the previous table, the Covid-19 restrictions were partially lifted over the summer and we completed our project to move 5# and 6b in the frame, obviously involving clapper re-installation. The leftover work on the clappers of bells 6 & 7 was completed and the alteration of the staple bolts of bells 1-4 also done. It was good that the times expected in Appendix 1 have largely been achieved. (The changes to the front bells are insignificant and unintentional).

The table above reflects all that work. We now have another Covid-19 lockdown so the **tenor**, (currently at 555ms) remains untouched.

Bernard Taylor
3 Nov 2020