

TROZE

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By Ronald S Hawkins

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Troze is the journal of the National Maritime Museum Cornwall whose mission is to promote an understanding of small boats and their place in people's lives, and of the maritime history of Cornwall.

'Troze: the sound made by water about the bows of a boat in motion'
From R. Morton Nance, *A Glossary of Cornish Sea Words*

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The Falmouth Time Ball

Ronald S Hawkins

When told that longitude had been ‘found’, Sir Isaac Newton is said to have replied that he never knew it had been lost! Whether playing the pedantic scientist or displaying a sense of humour he was making a valid point. It was easy for cartographers to divide the globe with great circle lines running through the poles and to show them on their charts but it was difficult for mariners to establish their position in relation to them. Similarly, after the pursuit of red herrings such as the earth’s magnetic field, the solution became apparent but the means was not available. As the earth turns through 360 degree each day, longitude could be equated to time so it was only necessary for the mariner to know how his local time differed from his departure time to know his longitude. Some form of reliable clock was needed. While famously this was eventually solved by Harrison who developed his chronometer, even the best could not keep perfect time.¹ In the nineteenth century time signals, either visual or audible, allowed the accuracy of the shipboard chronometer to be checked and for a period they were seen as essential aids to navigation. This article seeks to establish the events around the decision to establish a time signal at the Cornish port of Falmouth and to follow its construction and operation. It will set out the arguments used by supporters and show what resistance the proposal faced. The events at Falmouth will be set in the context of national debates over the establishment of time signals for the benefit of mariners.

Time signals can take a number of forms either audible or visual. The most usual audible method, before the advent of radio, being the firing of a gun; its advantage being that it did not depend on line of sight whilst the disadvantage was that the sound took a measurable time to travel to the observer. On the other hand a visual signal had the advantage that it was seen instantaneously by the observer but its use was dependent on a line of sight. At Falmouth the signal eventually chosen was a time ball, that is a sphere, which could be dropped at an appointed hour. It was situated on the Tudor tower of Pendennis Castle overlooking both the harbour, Carrick Roads and the Bay.

Its westerly geographical position and commodious, safe harbour meant that Falmouth always looked outward to the sea to drive its growth and prosperity. It was chosen as the base for the Post Office long distance overseas Packet ships. When the advance of technology meant that this operation was lost, it continued to service the growing mercantile trade but also expanded its interests into ship repairing, shipbuilding and tourism. Towards the end of the nineteenth century as the first deep water port on entering the English Channel Falmouth benefitted from the practice of vessels calling for telegraphed discharge orders which associated its name with the familiar Charter Party clause ‘for orders’. While it never became a significant exporting port for the Cornish industrial hinterland, its growth as a port was such that by 1870 it was necessary to establish a Board of Harbour Commissioners by Act of Parliament to regulate maritime activity.² A Chamber of Commerce had already been formed in 1865 to promote the growing commercial interests of the town.

There is no detailed or comprehensive survey on the history of time signals or, more specifically, time balls. They are barely mentioned by histories of navigation.³ A seminal paper on the invention and early development of the time ball, and one that does have some relevance to the present study, is that by Bartky and Dick.⁴ Previous published material on the Falmouth time signal is limited, being only brief passing references which are misleading or in error.⁵

The main primary sources used here are the Harbour Commissioners' Archives and contemporary newspapers. Establishing the timing and sequence of many early moves at Falmouth is made difficult by the fact that none of the Chamber of Commerce records from this period survive. Fortunately, they were available when Baker wrote a history of the Chamber of Commerce. To increase the uncertainty the Chamber did not allow the press to attend their meetings until 1896.⁶ Contemporary technical articles which were published in various journals; these proved particularly useful in understanding the original design, the telegraphic transmission of time signals and release mechanisms.⁷ No detailed research has been undertaken in the National Archives for this article, and there will be more material relevant to the Admiralty and the Greenwich time signals. In particular they may throw more light on the correspondence between the Chamber of Commerce and the Devonport Dockyard Superintendent, local copies of which have been lost.⁸

Why Time Signal?

The middle decades of the eighteenth century saw advances in technology which allowed the culmination of two differing approaches to solving the problem of longitude. One, an elegant, astronomical and mathematical solution proposed by scientists used the movement of the moon against other heavenly bodies as a clock, and the other, more practical, approach proposed by a Yorkshire carpenter turned clockmaker was an accurate, reliable chronometer carried on board ship.⁹

Harrison and the clockmakers that followed him provided a convenient means of keeping time at sea. But chronometers were expensive, as much as £80 each in the 1780s, and, therefore, their use was slow to spread. It was not until the second half of the nineteenth century that they became at all common on board merchant ships. When they were carried it was necessary to check their accuracy as even the best could not keep perfect time in all conditions for months on end. So, before a voyage they needed to be 'rated', that is to have their 'going', or their daily rate of losing or gaining, measured by an Observatory or instrument maker using a transit circle to observe accurate time. During the voyage the only means of checking the accuracy of a chronometer was by the difficult and complicated lunar observations. These were championed by the Astronomer Royal and taught and practised until the beginning of the twentieth century. The only alternative was a call at a port where a time signal was available or where the longitude was known. Williams sums up the dilemma and points to the answer as follows:

In ships which traded between ports without time signals the accumulative nature of chronometric error was a serious disadvantage of the instrument, equally, in the early years when the longitude of lesser ports was not known with adequate precision there was nothing but the lunar distance.¹⁰

During the second half of the nineteenth century this deficiency was addressed. A daily time signal able to be seen or heard by ships in port allowed a chronometer to be rated without the disturbing and potentially hazardous need to send it ashore. The most frequently used was a Time Ball. Eventually around 150 were installed worldwide. Superseded in the 1920s by wireless signals, very few survive, now operated largely as tourist attractions.

Early Time Balls

As early as 1818 Captain Robert Wauchope of the Royal Navy realised that some form of time signal, visible from vessels in port, would be a convenient and efficient method of checking chronometers without the need to take them ashore. He proposed a plan 'for communicating time by means of telegraphs'.¹¹ His description clearly shows the catalyst for the idea. He would have been familiar with the system of shutter telegraph stations established by the Admiralty across southern England during the 1790s, and realised that transmission was instantaneous between stations within sight of each other. Their efficiency was such that in 1805 the Admiralty could send a one o'clock time signal down the Plymouth Shutter Telegraph and have it acknowledged in three minutes, a distance of 200 odd miles each way.¹² Wauchope saw that the system could be used to give an accurate time check to local observers. The principle of a shore based observer determining the time and transmitting it by some form of visual signal was thus established.

By the time the Admiralty were ready to undertake trials at Portsmouth in 1829 his plans had progressed to the point of using of a dropped ball as the most accurate means of indicating a time signal. An engraving of his design was published in the *Edinburgh New Philosophical Journal* for that year (see Fig 1). He used two balls, four or five feet in diameter, constructed of black canvas and iron wire. An iron rod (AB) secures the top ball and passes through the diameter of the lower, moving ball. A segment of the top ball is cut off so that when they meet no daylight can be seen between them. Once it is hoisted, the halliard of the lower ball is secured to the release mechanism. The downhaul has a weight fixed to the end of it and about four feet from the ground. This has the effect of adding weight to the ball but avoids the extra force when it reaches the bottom of its fall. The operator releases the ball manually; an instantaneous release being achieved by means of a pivoted lever pulling a pin from a hole in a plate attached to the end of the halliard. He would obtain the time from an accurate watch on the table before him or through observing a signal sent from the Portsmouth Observatory some distance away; the time ball itself being placed on a platform at the waters edge. An interesting point is that Wauchope's description indicates that he did not expect the time to be taken from the instant the balls separated but when the lower had fallen a distance of its own diameter, that is, when it reaches the bottom of its fall. He reckoned this to be four-tenths of a second and suggested that the halliard be released four-tenths of a second before the true time. Seeking such accuracy does seem to be splitting hairs given the reaction times of observers, particularly as chronometers and the watch he intended using to time the drop would only be registering half seconds.

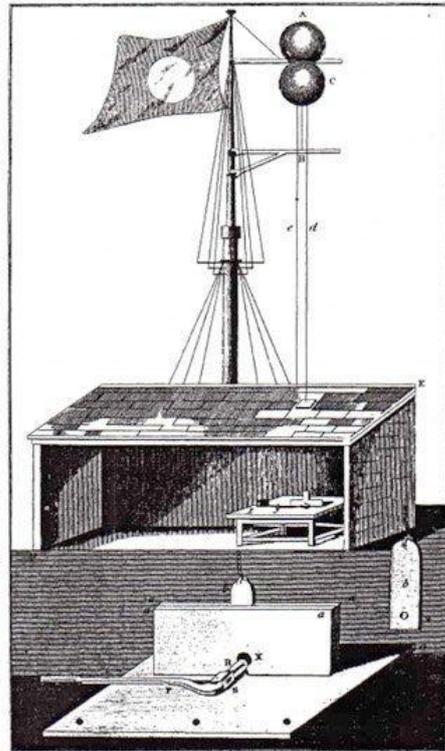


Figure 1: **Robert Wauchope, 'Plan for ascertaining the rates of chronometers by signal',**

Source: ***Edinburgh New Philosophical Journal*, viii (1830) pp. 160-62**

The Portsmouth tests proved successful enough for Wauchope to lobby, not only the Admiralty but both the American and French governments, on the benefits of extending the system to other locations. There was little immediate response; not until 1833 did the Admiralty pass his proposal for a signal at the Greenwich Observatory to the Astronomer Royal George Airy. An Admiralty notice described both its usefulness and its operation. It would be visible to vessels in adjacent reaches of the river and from most docks. Airy took personal responsibility for the design and construction of the time ball. This resulted in a structure more refined and robust than Wauchope's Portsmouth design. A single ball rose and fell on a pole erected on top of the Observatory which passed through its centre. It could therefore be heavier, allowing more immediate movement when released. The required damping system to prevent damage at the bottom of its fall could also be more easily provided. As at Portsmouth the operator dropped it manually. Not until 1852 was the release mechanism connected electrically directly to the Astronomical Clock. The benefit of this design was quickly realised and the great majority of subsequent time balls followed it (see Fig 2).

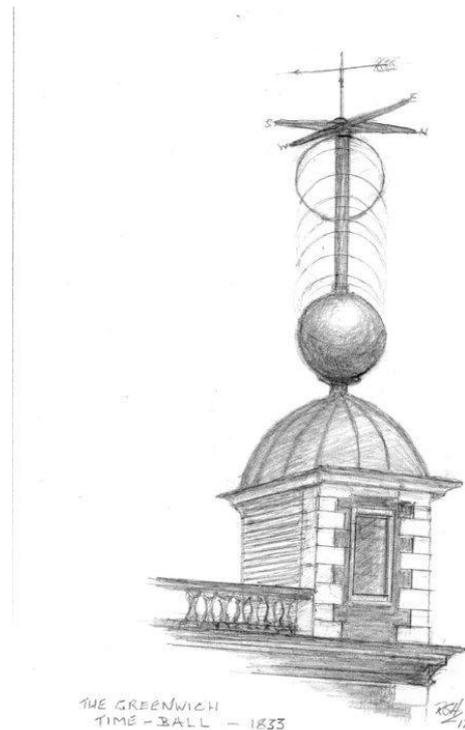


Figure 2: **Greenwich Observatory Time Ball,**
Source: Sketch by the author based on photographs

At that time it was necessary to calculate the time locally, so the earlier time balls were attached to observatories, such as that at Liverpool in 1845, overseas at Sydney in 1855 and the US Naval Observatory at Washington in 1845. The development of the electric telegraph in the 1850s, together with accurate astronomical and synchronized clocks, allowed the signal to be established at more remote locations. An important early time ball was that at Deal overlooking the Downs which was dropped on an electric signal being received from Greenwich through the Admiralty and railway telegraph lines, the only other signal to be controlled directly from Greenwich.

A Time Ball for Falmouth

Falmouth was late in the day amongst British ports in establishing a time signal for the benefit of shipping, and then it was only after many years of discussion. An 1896 editorial in the *Falmouth Packet*, the local weekly newspaper, refers to attempts being made 'years ago'.¹³ Perhaps these were in response to a 'complaint from many shipmasters and others chiefly interested' as claimed by the Chamber of Commerce in support.¹⁴ Certainly shipping interests were instrumental in prompting action in other ports such as the approach in 1884 by the Superintendent of the Royal Mail Steam Packet Company to the Southampton Harbour Board.¹⁵

From the evidence available there is no doubt that it was the Chamber of Commerce which initiated and led the campaign for a time signal, seeing it as at a facility that would attract more shipping to the port. Equally clearly it was the Harbour Commissioners, the only body in the port able to charge dues to offset the cost, which formed the resistance. Ironically the Chamber had been instrumental in setting up the Harbour Commission. In 1868 it became apparent that a form of statutory authority was needed over shipping activity in the port. In the following year the necessary Parliamentary Act failed because of incompetence on the part of the Chamber's agent. The ensuing delay and

increased cost led to the Town Council becoming involved which caused more acrimony and confusion. Amid accusations of misappropriation of funds and counter claims of 'vindictive malevolence' two alternative Bills were presented to Parliament. The Town Council's sought to invest all authority in the Corporation whilst that promoted by the Chamber proposed to create an elected Harbour Board representative of all interested parties. The latter won the day. To facilitate the passage of the Bill the Chamber had not requested to be represented on the Board. A shrewd tactic that had little effect on the outcome since no fewer than ten of the original sixteen members of the new Harbour Board were also members of the Chamber of Commerce.¹⁶

It was from such fractious history that the campaign for a time signal at Falmouth was fought. By 1878 the Chamber of Commerce was actively campaigning and took the decision to send a Memorial to the Borough MPs showing the advantages a time ball or gun signal would be to shipping.¹⁷ Early in that year they were also in a position to write to the Harbour Commissioners enclosing particulars of the expenses incurred by the Newcastle and Gateshead Chamber of Commerce in setting up a gun signal at North Shields. At that time the Chamber had an open mind as to the type of signal for Falmouth, merely stating that 'a time ball or gun at Falmouth would be greatly appreciated'.¹⁸ They referred the matter to the Harbour Board as they could not fund either method themselves. A positive response might have been expected from the statutory body seen as being responsible for looking after the interests of shipping using the port. In this though they were disappointed as the Board decided it did 'not see its way clear to so large an expenditure as that involved in the proposed measure...'.¹⁹ In Southampton, following an initiative by the Royal Mail Line, the Harbour Board worked with the town authorities to establish a time signal. In contrast, either by choice or default, in Falmouth the Chamber of Commerce had become the lead body and, for that matter, the sole agency pressing for a time signal. Moreover, those Harbour Board members who were also members of the Chamber of Commerce took contrary views when faced with the prospect of spending money when asked to support innovation.

In 1880 the Board of Trade showed an interest in the situation at Falmouth and asked the Harbour Commissioners for details, if any, of the means of enabling masters of ships to ascertain exact Greenwich Mean Time. Their response was not encouraging, and carefully worded:

That the Clerk replies that the subject referred to was last year fully discussed and considered by the Board. That they obtained an estimate of the cost of providing means of ascertaining exact Greenwich Mean Time but found that the outlay and annual expenses consequent thereupon was greater than they could bear.²⁰

Ironically, the estimate they claim to have obtained must have been the original provided by the Chamber of Commerce. It seems the Secretary was just as selective in his wording of the minutes which make no mention of the discussion. The *Falmouth Packet* reporter, with his ear for a good quote, was more forthcoming:

...it was observed that Messrs. Cox and Co., of the Falmouth Foundry rendered very material service to the town by the use of their "hooter" which was used several times a day. Very good time was kept at the foundry, and the exactitude with which the "hooter" sounded was very creditable, and something for which the town should feel indebted to the firm.²¹

At this distance it is difficult to interpret such a remark. At best it could be seen as a tongue in cheek response to perceived official interference in local matters, but, at worse, it could show a lamentable lack of understanding as to the nature

of time signals and of their importance to mariners in a body charged with administering the Port of Falmouth. On reflection, and because of the considered wording in their reply to the Board of Trade's request, we should, perhaps, take the more charitable view that it was a light-hearted remark in a forum concerned with spending public money wisely. Nevertheless, it does provide an illuminating insight into mind sets in an age when precise time-keeping was not given as much emphasis as today.

It is worth noting that for fourteen years the Board of Trade had been involved in an argument that very much mirrored nationally what was happening at Falmouth. Following the success of the early time signals, Greenwich Observatory launched an initiative to establish an hourly time ball signal at Start Point so that outbound vessels from East Coast and North Sea ports would be able to establish a sea-going rate for their chronometers. The intentions of the scientists may have been admirable but the more practical, potential users were less enthusiastic. It was an idea beyond the existing technology. Most telling of all though was the reluctance of relevant bodies to finance the scheme. The Board of Trade itself declined, using very much the same argument as the Falmouth Harbour Commissioners, feeling they could not justify the use of the Mercantile Marine Fund, by Statute limited to funding 'seamarks', for the benefit of the limited users of the Start Point scheme. For their part the Admiralty also pleaded lack of funds. In 1875 the issue was put to rest and was eventually resolved by the arrival of wireless technology. The Greenwich Observatory proposals though were to have an impact on later developments at Falmouth.²²

At Falmouth there seems to have been little progress for seventeen years, though there must surely have been many informal discussions, and, perhaps, a more substantial initiative. Is it significant that the Ordnance Survey of 1893 shows a semaphore turret on the main roof of the Castle and the Hydrographic Survey for the same year notes 'a time ball is dropped at Pendennis Castle at 1 pm GMT'?²³ It is possible that there was a hope that a time ball would be funded by the Admiralty, when the signal station was established. Clearly the lack of any ready funding was preventing progress but there were also technical matters which needed to be considered. With sufficient resolve this need not have been an insurmountable problem. Falmouth may have been remote from any major observatory but as early as 1812 Mr. Howells, chronometrician to His Majesty's Packets, had advertised his intention to build a Transit Room with an instrument by Troughton. Evidence of a Transit Room has not survived but it is clear the Packets' chronometers were serviced and rated at Falmouth by Mr. Howells' successor, William Goffe, a local chronometer maker.²⁴ This does show that chronometers were rated at Falmouth well before the era of time signals. In any case, by the 1880s the telegraph and synchronized clocks were available as a means of overcoming the distance problem. Even then though, to complete the circuit, it would still be necessary to fund a link between the Post Office and Pendennis Castle, the preferred location.

However, in the spring of 1896 circumstances allowed both the financial and technical problems to be addressed and the Chamber of Commerce took up the issue with renewed vigour. They had clearly been making detailed preparations. There is evidence that, at this stage, they were in communication with the Admiralty authorities, extracting from them a promise to cover the expense of sending the current from the sympathetic clock at Mount Wise, which had been installed in 1886, as well as the capital cost of providing a line from Falmouth Post Office to Pendennis Castle.²⁵ Drawings had been produced and forwarded to the Admiralty, who were in due course to reply that they 'appeared to be entirely satisfactory and indicates that the Time Ball is similar to that at Mount Wise which works well'.²⁶

The momentum could not now be resisted. Even national policy was playing a part; during the 1890s the Admiralty was becoming more and more concerned over the growing threat from France and Germany to Britain's naval supremacy. The *Falmouth Packet* of 16th May 1896 carried an editorial supporting the scheme. It pointed out that an attempt made years ago had ultimately to be abandoned through the lack of a connection with the telegraph system. Now this impediment was removed by the Admiralty's support and the cost to Falmouth would be less than a hundred pounds. It believed the Chamber was right to ask the Harbour Board to defray the cost, urging it, 'in the interests of the local shipping trade which it so admirably manages', not to hesitate.

Whatever the enthusiasm generated, it was clear little more progress would be made without the support of the Harbour Board. It was essential to have their financial backing and, if possible, for them to take over the running of the project. They were after all the body charged with managing the affairs of the harbour for the benefit of shipping and with the authority to collect fees. With the intention of furthering these aims a delegation from the Chamber of Commerce met with the Harbour Commissioners on the 19th May 1896.²⁷ They put forward what were now the well rehearsed arguments in favour; that the Admiralty had accepted the cost of sending the signal from Mount Wise, and now, apparently, the War Department was ready to facilitate the erection of a signal – which presumed it to be at Pendennis Castle. All of which left Falmouth needing only to fund the materials and cost of construction. These costs were now given as £75 for apparatus similar to that at Mount Wise, with a further £8 required for the wire to connect the Castle with the Post Office. In a direct appeal to the interests of the Harbour Board it was pointed out that 'no doubt more vessels would call at Falmouth' because of the availability of a time signal. Despite acknowledging the benefits it would bring to shipping the Harbour Board's initial reaction was both cautious and parsimonious. In the words of the Chairman, 'expense would be the chief thing'. This concern was quickly focused on working expenses and maintenance. The Chamber were not so definite on these as they had been on the construction costs, only suggesting that the coastguard would help and that ongoing costs were likely to be small.²⁸ The matter was eventually referred to the Harbour Committee which after lengthy discussion recommended that the Board acceded to the request to defray the initial costs provided it could be done efficiently and at a cost to the Board of no more than £100.²⁹

Even now there were symptoms of a lack of direct control and responsibility as the project was subjected to prevarication and manoeuvring. The Chamber of Commerce was still the driving force and contact organization. The Admiralty were clearly keen to have the benefit of a time signal at a strategic port and had indicated their willingness to cover the major part of the running costs as well as paying for the Post Office to connect Pendennis Castle with the telegraph system – provided that is that it was definitely arranged to erect a time ball in that position. Similarly the Harbour Commissioners had eventually and reluctantly agreed to defray the initial costs to a maximum amount of £100. But the Commissioners were not willing to take over the running of the apparatus. So the question remained as to who would supervise the construction and manage the day to day operation. The Chamber, when pressed on the issues of operation and maintenance by the Harbour Commissioners, had rather dismissed the problems, expressing the hope that the Coastguard would be cooperative and that the Post Office might maintain the batteries free of charge. At the June Quarterly Meeting it appeared that even the exact location was still an outstanding issue.³⁰ Yet the Chamber did continue to take initiatives and actively press the project forwards, in effect taking the necessary control, initially perhaps by default, but eventually more implicitly. The available records of their meetings indicate no formal

motion to take this step. Again at the June Quarterly Meeting there was discussion as to whether they or the Board should continue with the negotiations and tenders. Yet again the point was made that the Board was the most appropriate body to take control of the project, but in the end they could do no more than invite the Harbour Commissioners to join a small joint sub-committee and ask them whether they wished the Chamber to continue negotiations with the Admiralty and Post Office. For its part the Harbour Board was quite willing to accede to both requests.³¹

By the end of 1896 the negotiations appeared to be finally reaching a conclusion. In December the Admiralty confirmed that the Post Master General had been authorized to spend £10 on a line between Falmouth Post Office and the Castle.³² By February 1897 the Chamber of Commerce was able to place a notice in the *Falmouth Packet* inviting tenders for the erection of a time ball apparatus on the tower at Pendennis Castle. This seems to have been merely a necessary formality. The chosen contractor turned out to be Mr. Blight, who during the previous year had been providing the Chamber with various estimates for the work to assist them in their negotiations. He must have started work promptly as by the middle of May the Time Ball Sub-Committee was able to report that the time ball would be in working order by Jubilee Day, that is the 21st June. It would have been an auspicious day to inaugurate the signal but neither the contractor nor the committee members were unduly optimistic. At some stage a problem had been encountered when the original mast proved to be unsuitable. Eventually, a piece of Oregon pine was obtained from Plymouth. By the middle of June the mast was indeed erected but Mr. Blight was now doubtful whether he could complete the whole of the work by Jubilee Day.³³ In the event the official opening ceremony was held on the 27th August 1897 when the ball was formally dropped for the first time. On that day a gathering of Civic, Chamber of Commerce and Harbour Board representatives who were treated to, in the words of the *Falmouth Packet* report, 'a soupcon of speeches'. It seems though that regular working did not begin for a few more days as the daily current to activate the signal was not commenced until 1st September.³⁴

Technical matters

A few photographs, for example Figure 3, and a non-technical sketch of the release mechanism in the report of the 1913 Committee of Inspection (Fig. 4) are all that remains to show the construction of the Falmouth Time Ball. A set of drawings and specifications must have been prepared under the auspices of the Joint Committee during the campaign in order for Mr. Blight to provide them with estimates of costs. When contractors were invited to bid the designs were available for inspection and were submitted to the Admiralty who found that the arrangements appeared to be 'satisfactory and indicates that the Time Ball signal is similar to that at Mount Wise which works well'.³⁵ This description of it as 'similar' is useful as a blueprint of the Mount Wise Time Ball 'as fitted', and drawn in 1915, has survived (Fig. 5). It almost certainly represents the arrangement in use some twenty years earlier when that at Falmouth was being planned.³⁶ Together with what is known more generally about the electrical and telegraph circuits of time signals, it is possible to describe the structure and working of the Falmouth Time Ball with a good degree of certainty.

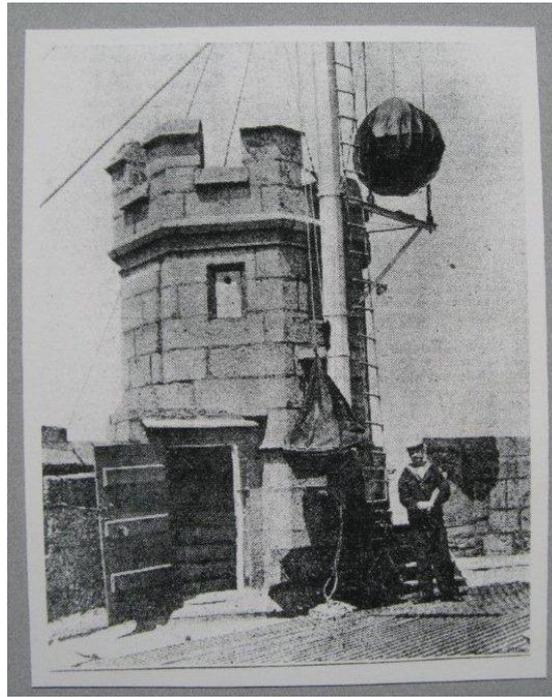


Figure 3: **The Falmouth Time Ball**
 Source: Anon, *Disappearing Coastguard Stations*, 1909

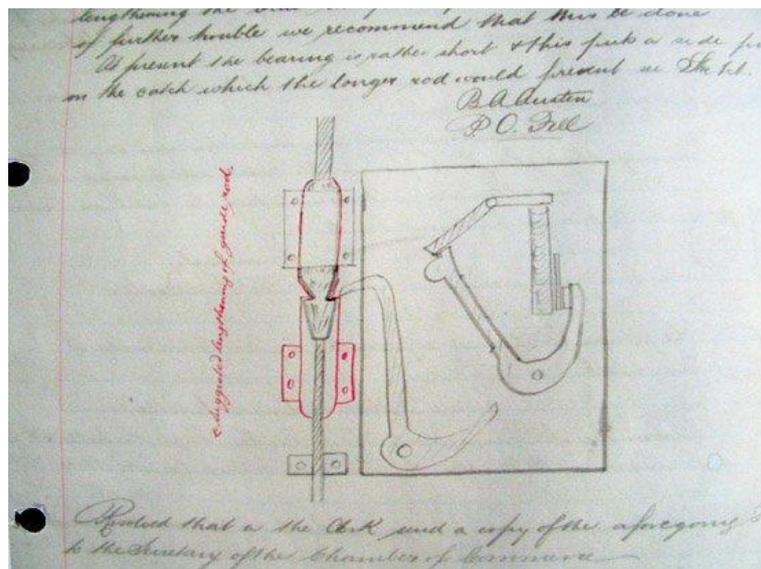


Figure 4: **The Falmouth Time Ball**
 Source: NMMC: Harbour Committee Minute Book

In view of this affinity it will be instructive to first look at the history of the Mount Wise time signal in a little more detail. Plymouth has a long history of time checks. The earlier time check through the Admiralty shutter telegraph system has already been mentioned. Nevertheless, Plymouth continued to keep local time, 17 minutes behind GMT, until 1860, even after the arrival of the electric telegraph in 1852.³⁷ What was probably the first time signal at Mount Wise is described in 1861 as 'a Cone, made of canvas, 4 $\frac{1}{2}$ feet in diameter and painted black, is suspended below the flag on the flagstaff'. The time signal was given by the collapse of the cone, which when not in use hung closed on the flagstaff.³⁸ Following the developments by Wauchope and, particularly following

the Greenwich Ball, this was a primitive and unsatisfactory arrangement. As part of the 1861 proposal for a time signal on Start Point already mentioned, it was envisaged that a sympathetic clock would be installed at Devonport to control both the local and Start Point signals. The preferred site at Plymouth was the Devonport column but Mount Wise was proposed as a more economic location. The plan envisaged a mast forty feet high on which a skeleton ball, five feet in diameter would slide – in other words a similar apparatus to that at Greenwich.³⁹ As a consequence of the scheme being abandoned in 1875 it seems Airy's proposed design for the Mount Wise Time Ball was never followed up. However, a synchronized clock was installed in November 1886. There are then references to it being used in conjunction with the hoisting and dropping of a time ball as well as the firing of a one o'clock gun.⁴⁰

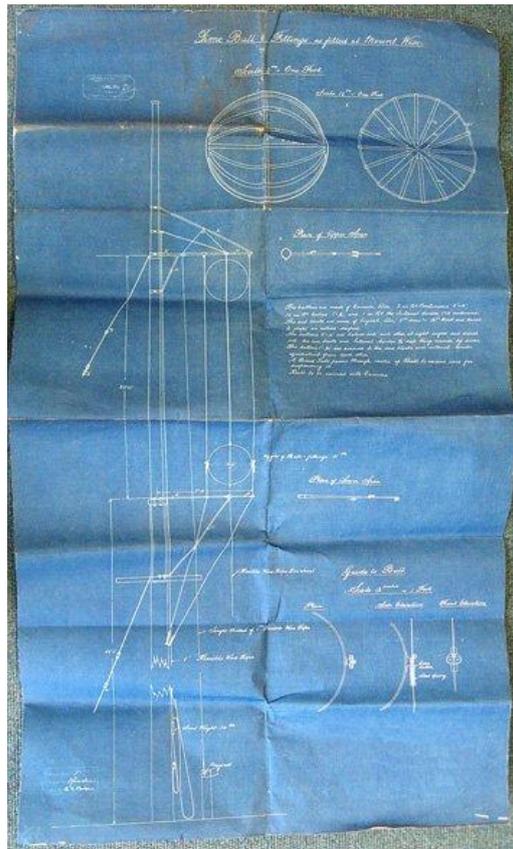


Figure 5: **The Falmouth Time Ball**

Source: Cornwall Records Office, reproduced with their permission

The 1915 blueprint (Fig.5) shows what must have been the time ball established at that time; a ball 3' 6" in diameter, rising and falling between two guide wires stretched between spurs attached to the Mount Wise signal mast. It is constructed from elm battens secured to end blocks turned to the spherical shape on the outside and strengthened with an internal, equatorial binder. A brass tube passes through the centre of the ball to receive the detent wire. It was covered with canvas and, with its fittings, weighed 31 pounds. The upper, stationary ball, used by Wauchope on his prototype has been dispensed with, possibly at the expense of some accuracy. It was critical that observers could note the instant the ball started to move and Wauchope's approach of having two spheres touching at their poles was a neat solution when viewed from any direction. At Mount Wise only the upper spur provided a reference point which would have been difficult to see from certain directions. The running rigging was of one inch flexible wire

rope, except that when the ball was hoisted ready to fall the detent wire holding it was only a single strand of such rope. This would be sufficient to hold the weight of the ball for the necessary short period and cause the least possible friction during the drop. Handling the drop efficiently and safely was at the heart of time ball design. The ball had to be of sufficient weight to move instantly and swiftly when released and yet had to be stopped without damage. At Mount Wise it was arrested by a combination of a 14 lb counterweight and steel springs fitted to the bottom of the guide wires. For this system to work correctly these features had to be adjusted accurately. The counterweight needed to take effect just before the ball hit the spring stoppers and even then the action would have been sudden. Another limiting factor at Mount Wise, and subsequently at Falmouth, was that the ball had to be hoisted by hand without any mechanical aid. Professor Piazzzi Smyth, the Scottish Astronomer Royal, points out the obsolescence and limitations of this approach:

The earliest signal-balls which were made, though provided with ropes passing over pulleys by which they are enabled in their descent to raise a series of weights in order to check in a gradual manner the velocity of their fall, were yet invariable found, after a short time, to pull or smash themselves to pieces. Steel springs were next tried to break the force of the concussion, but were pretty sure to be themselves snapped...⁴¹

Professor Smyth goes on to show that a pneumatic system provided the best means of bringing a heavy ball to a gentle stop; a piston attached to a rod at the bottom of the ball compressed the air in a cylinder. This was used at Greenwich. Therefore, as a result of the archaic system used at Mount Wise, the weight of the ball was limited, which, in turn, compromised the precision of the drop. Perhaps the design of the Mount Wise Time Ball and the Admiralty's professed satisfaction with the working of the signal was to some extent expressing their independence of Airy's ascendancy in such matters.

The photographs of the Falmouth Time Ball shows that it does closely follow the Mount Wise design. The ball appears to be of a similar construction and size and, therefore, comparable weight, and runs between two guide-wires set up on spurs projecting from the signal mast. It is also possible to see a weight attached to the end of a lanyard and what could be springs at the bottom of the guide wires. This would be a similar arrangement to that at Mount Wise. The ball is in the bottom position and there is a little slack in the wire which does suggest it has not stopped the ball before it reached the bottom spur. On the other hand the distortion of the ball towards its upper pole may have been caused by jerks from the counter weight as much as the pull of the halyard when it was being hoisted; proof of the fine adjustment necessary if this arrangement is to work properly.

In contrast, more is known about the detent and release mechanisms of the Falmouth Ball than that at Mount Wise. In February 1913 a Committee of Inspection was convened to investigate continuing failures. Their conclusion was that the 'connection of the clutch with the catch on the guide rope was worn' and that it was mainly by chance that the ball was released. The report included a rough, non-technical sketch of the mechanism (see Fig.4).⁴² It shows that the detent wire holding the ball in preparation for the drop was fitted with brass sleeve in way of the clutch which had a rebate cut into it to form a catch. The clutch holding the ball was in the form of a pivoted hook bearing on this ridge. Its instantaneous release was ensured by a weighted lever striking its other arm and knocking it clear of the rod. The working of the arrangement for releasing the weighted lever is not clear from the sketch and, as drawn would not work. Figure 6 is an attempt to reconstruct how it might have worked, based on the sketch and the arrangement used at Greenwich.⁴³ A signal received through the telegraph line would switch power from the batteries into the circuit to activate

the electro-magnets setting in motion the levers and allowing the weight to fall and disengage the clutch. The clutch arrangement together with the telegraph connection and batteries would have needed to be housed undercover and a hut was apparently constructed for this purpose. However, the photograph taken in around 1909 does not show any such hut. The Mount Wise blueprint merely shows some form of clutch attached to the end of the detent wire, which may be similar to the arrangement at Falmouth – the scale of the drawing being too small to be certain, and shows it was held by a magnet housed in a small case at the bottom of the mast. Nevertheless, ancillary equipment such as batteries and the sympathetic clock must have been housed undercover – presumably in the signal station.

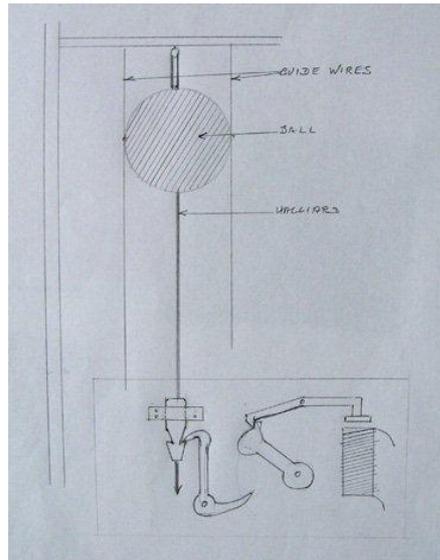


Figure 6: **The Falmouth Time Ball mechanism**

Source: Drawing by the author based on a sketch in the Harbour Commissioners' Minute Book

By 1896, and, even by the 1880s, time balls had proliferated and appropriate mechanisms to control them must have been familiar to engineers. Engineering firms such as Maudslay Sons and Field had erected time balls around the world. In addition, patents had been granted to several inventions addressing the issues involved in hoisting and releasing the ball, notably to William and Lancelot Smith in 1873 and William Lake in 1882. It must be said though that this knowledge and experience was directed towards the Greenwich System, therefore the design of the Falmouth time ball was developed without the benefit this expertise. It was usual for authorities planning to establish a time ball to seek advice from Greenwich.⁴⁴ At an early stage the Falmouth Chamber of Commerce sought advice from a fellow organization but the more immediate input must have been from Devonport. We know that the drawings were submitted to the Admiralty at Devonport for comment and that they found them to be similar to the Time Ball at Mount Wise. As a result Mount Wise and Falmouth became part of a very small group of time balls - the only two found so far – which were not derived from Wauchope's initial design feature of having the ball rise and fall on a metal pole. It seems that this situation may have come about because of the strained relationship between Airy, the Astronomer Royal, and the naval authorities following their opposition to the Start Point proposal. During the 1870s he had been critical of the Portsmouth time signals where the Admiralty were protective of local observatory facilities and manual operation whilst Airy

wanted to replicate the Deal system.⁴⁵ This animosity must have influenced the design of the Mount Wise Time Ball when it was erected in 1886; the Admiralty developing their own design, although Airy's proposal for a synchronized clock was adopted. And when the Chatham Barracks were being built contemporary with the establishment of the Falmouth Ball, the Admiralty did consult with the Astronomer Royal and followed the Greenwich pattern. Unfortunately, the Falmouth Chamber of Commerce must have consulted Devonport before this relationship with Airy thawed. The evidence available suggests that some knowledge of the release mechanism at Greenwich was available to the designers at Falmouth; whether this came from the Admiralty at Plymouth or directly from Greenwich is not known. Who the designer was is unknown; Mr. Blight, the eventual contractor may have produced the drawings for the structure but could he have designed the electrical circuits, detant and release mechanisms? Could they have been purchased commercially? Unfortunately, evidence of any payment for them is not available.

Operational matters

The time ball was dropped at 1300 GMT and, to avoid confusion, this practice was continued when Summer Time was introduced in 1916.⁴⁶ The electric signal was controlled by the synchronized clock at Mount Wise and was received through the Post Office telegraph lines and the direct line from Falmouth Post Office to the Castle. The daily procedure was for the ball to be hoisted to its upper position and the release mechanism set at five minutes before the hour. No dedicated attendant was employed to look after the Signal; for most of its life the Coast Guard duty lookout performed these few necessary operational functions. Though, when the Coastguard was mobilized by the Navy during the Great War, it was necessary to come to a similar arrangement with the military authorities. In the event that the ball failed to drop it would be kept up for about twenty minutes and then slowly lowered.⁴⁷

So, the apparent straight forward act of dropping the Ball required several pieces of equipment to work smoothly and a number of operations to be performed by distinct personnel, all of these being at different locations; the clock at Mount Wise had to be working, the signal had to be put through the switchboard by the Post Office clerks at Plymouth and Falmouth, the ball had to be hoisted and the release mechanism set, both the electrical and mechanical release apparatus had to work properly and, finally, the ball had to fall instantaneously and speedily. Each of these functions was under different control; the Admiralty at Mount Wise, the Post Office at Plymouth and Falmouth, and, at Pendennis Castle, the Coastguard and, later, the Army.⁴⁸ Figure 7 is a schematic drawing of the telegraph and electrical circuits involved.

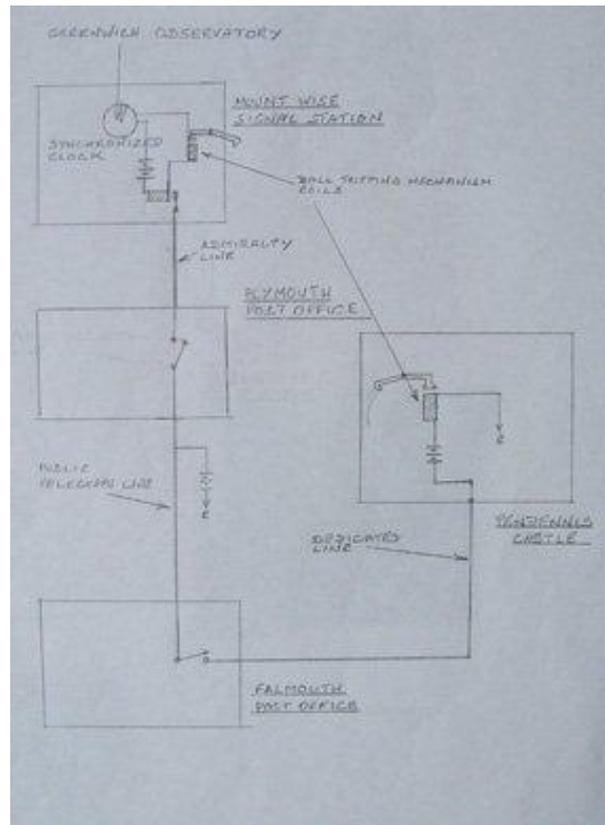


Figure 7: **The Falmouth Time Ball mechanism**

Source: Drawing by R Hawkins based on information from *The Greenwich System of Sympathetic clocks and the Distribution of Time-Signals, The Observatory 1885* and the Harbour Commissioners' Minute Book

Furthermore, the smooth working of the time ball apparatus depended on regular maintenance and it is not clear who was responsible for this. Initially it was hoped that the Post Office would undertake the maintenance of the batteries free of charge although the contractor did submit a quote.⁴⁹ Later communications with the Post Office suggests that they did in fact undertake the routine maintenance.

It is clear there were many opportunities for fault or error. There were occasions when no current was received, for instance because the synchronized clock at Mount Wise was out of service or through the failure of Post Office personnel to make the connections.⁵⁰ There were also numerous occasions when the Ball failed to drop although a current was received. These resulted either from the design and maintenance of the apparatus, despite the Admiralty's assertion that it was similar to that at Mount Wise which gave 'entirely satisfactory, service', or the exposed position of the mast.⁵¹ The report of an inspection carried out by a joint sub-committee in 1913 illustrates the nature of the problems experienced at that stage of the operation.⁵² They examined the mechanism closely and carried out successful drops by hand or by means of the electric current supplied by the batteries. However, when the pulse was received from the telegraph line the ball failed to drop. The general view was that the connection of the clutch with the catch on the guide rope was worn but the recommendation they made - lengthening the brass rod forming the catch so that it could be held between a further guide and so avoiding the weight of the ball to cause an horizontal force on the catch - suggests a design fault. It is not possible to say whether this small feature of the designed differed from that at Mount Wise. Figure 4 shows the suggested modification outlined in red. Finally, even

when the current was received and the release mechanism worked smoothly, the ball would catch in the rigging when the wind was from certain directions.⁵³

It was, perhaps, inevitable that the Falmouth Time Ball was going to have a significant failure rate, although opinions did vary as to the exact figure. Between March and September in 1904 the Harbour Commissioners thought it to be 16 percent whilst the Chamber of Commerce reckoned on only 10 percent. On the other hand the Coast Guard reported to the Secretary of the Chamber that it had only failed to drop twice; a claim that was greeted with cries of 'absolute rubbish'.⁵⁴ Clearly the Coast Guard were not comparing like with like; they were, no doubt, only concerned with their own duties and responsibilities and failures from other causes were no part of their report. Problems, teething troubles or not, had become apparent at a very early stage in 1897. Within two months the *Falmouth Packet* was reporting that the time ball had 'refused to obey orders on Tuesday' because of a lack of electric current.⁵⁵ The following month it was reported at the quarterly meeting of the Chamber of Commerce that '...the signal was suffering from some of the irregularities inseparable from the early days. Last Sunday a number of persons were waiting watch in hand, but it did not fall until five minutes too late owing to a defect in the Post Office apparatus which has since been rectified. It is only fair to the contractor to say that the signal itself works all right.'⁵⁶ The weight of available evidence does suggest that the most persistent problem was a failure to receive the electric signal for whatever reason. It continued to be prone to human error; even in 1912 the clerk at Falmouth Post Office could still forget to switch it through.⁵⁷

There were also faults in the design of the time ball apparatus itself. From comments made at a Chamber of Commerce meeting in 1904 it is clear that repairs had already been carried out with a guarantee being given by the contractor that it would work without trouble for six months. The three failures that did occur during that period were, again, the result of a failure to receive a current. Numerous entries in the Harbour Committee Minute Book and various newspaper reports show that a similar rate of failure persisted over the years and that a generous proportion of them were due to problems with the electric signal. On at least one occasion the Post Office engineer investigating the problem was unable to account for the failure but thought it might have been caused by the Ball catching in the rigging owing to a gust of wind.⁵⁸ By the outbreak of war there were signs that the mechanism itself was beginning to deteriorate. The inspection, already mentioned above, carried out in February 1913 had highlighted possible wear and tear and in 1916 the Chamber of Commerce requested drawings of the time ball and its appliances at Mount Wise from the Admiral Superintendent at Plymouth and made enquiries as to the cost of a replacement at Pendennis.⁵⁹ Also for a fortnight during October of that year it was reported that the Ball was not hoisted as it was out of order before being repaired and reinstated towards the end of the month.⁶⁰ It seems that the war, and, no doubt, the inevitable arguments over financial responsibility prevented further progress on a replacement being made.

The outbreak of war presented a further range of problems effecting the operation of the time ball. The Coastguard, a naval auxiliary, was mobilized by the Admiralty to man the fleet and this resulted in the signal being discontinued for a while. Fortunately the War Office was as accommodating as the Admiralty had been and took over responsibility at Pendennis for operating the ball for a payment of 2/6d a week.⁶¹ The initial custodian was a Bombardier Barfort who was replaced by Rifleman Rayson in June 1917. Wartime conditions though did mean that military needs took precedent; in February 1917 the Army reported that for the present the time ball would not be hoisted owing to a signal being shown in its place.⁶² It was also during this period that the introduction of

Summer Time meant a decision had to be made on the timing of all time signals. To avoid confusion and frequent amendment notices it was decided to continue making them at 1 pm GMT throughout the year and communications to that effect were received from both the Admiralty and the Board of Trade.⁶³

There is no doubt that the frequent failures soon dampened enthusiasm for the Time Ball, focused resentment within the Chamber of Commerce over funding and compromised its integrity. Even as early as 1904 members of the Chamber felt able to make remarks such as ‘amongst those people to whom he had spoken he found considerable indifference as to the continuance of the time ball’ and that the ‘uncertain action of the apparatus destroyed its effectiveness altogether’.⁶⁴ Some twelve years later moves were made to replace the unreliable apparatus.

Financial Matters

The financing of the operation was similarly fragmented. Despite their lack of enthusiasm for a Falmouth Time Signal the Harbour Commissioners did finally agree to defray the initial costs up to a limit of £100, but they continued to resist suggestions that they should, as a statutory, fee charging body, pay the operating expenses. It was not until 1906 that they began making a regular annual payment to the Chamber of Commerce. The Chamber itself, despite being the leading agency arguing for its establishment and then, by default, having to supervise its operation, made little financial contribution from its own funds. The extras incurred during construction were paid by subscriptions from members and, in the early years, individual members apparently covered essential costs as they arose out of their own pockets. In fact, at an acrimonious debate in 1904, when the future of the Time Ball was thought to be very much in the balance because the maintenance costs were more than the Chamber could bear, it was revealed that the Chamber itself was slightly in debt.⁶⁵ By far the largest contributor was the Admiralty. Without them covering the cost of transmitting the daily signal the time ball would not have been erected and could not have been continued. It was their eventually decision in 1920 to abandon this policy that meant the inevitable end of the time signal at Falmouth.

Telegraph line, Falmouth P.O. to Pendennis Castle	£10 * Paid by the Admiralty
Construction Contract	£75
Extras to Contract	£11
Hut to house equipment	£15
Total	£111

Table 1: **Expenses**

Source: NMMC: Harbour Commissioners Minute Book No.5 p.218; *Falmouth Packet* 18th September 1897, details of construction costs given in report on Chamber of Commerce quarterly meeting.

The cost to Falmouth was therefore £101, of which £100 was provided by the Harbour Commissioners, their General Ledger shows one payment of £75 to the Chamber of Commerce on 20th October 1897 and the balance of £25 being made on 16th March 1898.

When it came to operational costs, the chief recurring expense was to the Post Office for sending the electric signal. This amounted to around £32 a year but was defrayed by the Admiralty. It appears their contribution also included a small charge to cover the use of the Coastguard lookout man to hoist and set the ball, and the cost of inspections and maintenance. The total annual costs though run at about £15 above the Admiralty contributions. In the early years the extra cost was covered by subscriptions from individual Chamber of Commerce

members; the Chamber's own accounts were showing a deficit during this period.⁶⁶ Sometime prior to 1904 the apparatus had an overhaul for which the Harbour Commissioners contributed £20.⁶⁷ The financial crisis in 1904 did force the Harbour Commissioners to extend their support beyond the capital and repair costs. Their General Ledger and Annual Statements from 1906 onwards show a £10 annual payment to the Chamber of Commerce. Early in 1920 a much larger payment of £53 10s was made, a sum that perhaps indicates a major overhaul, or up-grade, during 1919. As mentioned, approaches had been made to the Admiralty Superintendent at Plymouth who had provided costings and drawings of the Mount Wise Time Ball and appliances.⁶⁸ Despite accepting a financial commitment the Harbour Commissioners never took over operational responsibility and all of these payments were made to the Chamber of Commerce who must have paid the bills. Only at the very end was any direct payment made and in this case to a Messrs Williams & Co which must have been in connection with the dismantling.

It is possible to make a fair estimate of the total cost of having a time ball at Falmouth between 1897 and 1920. The capital cost was £111, payments by the Harbour Commissioners amounted to £316 whilst the Admiralty's contribution of £710 was by far the largest. If we allow for the personal contributions made to keep it operating in the early years, the total would be around £1,300 to £1,400. Of this it is significant that the Admiralty provided nearly three-quarters whilst the Chamber of Commerce, despite being the lead agency throughout, contributed nothing.

These figures tend to show that the years of prevaricating over the cost resulted in Falmouth getting an economic deal. The Astronomer Royal estimated the capital cost of the new time ball signal at Mount Wise in connection with the Start Point scheme to be £250 and the annual operating cost of the Start Point signal itself as £150 for maintenance and £150 for the salaries of the attendants.⁶⁹ On the other hand perhaps Falmouth's cut price deal was the root of the problems with it.

But could Falmouth's time ball be considered a financial success? In fact, the time ball would have had needed very little influence to return a profit. Allowing the 1900 harbour dues rate of 21p a ton only a little over 6,000 additional tons would be needed to recover the £1,300 costs, a figure which, over the twenty four year life of the time ball represents no more than 260 tons each year – say one extra vessel.

The end of the Time Ball

With the return of peace the Harbour Commissioners decided on a more supportive policy and in November 1919 opened correspondence with the Post Office concerning them taking over 'control of the Time Ball at Pendennis Castle'.⁷⁰ The discussions were protracted. It was not until a year later that a face to face meeting with the Postmaster was held to discuss the rent for the wire circuit between the Castle and the Post Office, but by then the situation had changed. The Commissioners had received the following letter from the Admiralty on 16th November 1920:

I am commanded by their Lords Commissioners of the Admiralty to inform you that the time signal is now issued by Wireless Telegraphy and the time ball is no longer of value for naval purposes. The circumstances which led the circuit to be allowed free of charge in 1896 no longer exist and their Lordships do not feel justified in continuing to pay the rental for the wire circuit to Falmouth Post Office in connection with the time ball.⁷¹

The Harbour Commissioners had never intended to assume the Admiralty's financial responsibility and the Clerk had already informed the Postmaster that, in the changed circumstances, they would be unlikely to continue their support.

That indeed was their response as they retracted their long held position and instructed the Clerk to inform the Chamber of Commerce that they did not now feel justified in incurring the additional expense and to enquire whether the Chamber would pay the rental on the telegraph line. However, there must have been further discussion and second thoughts for that Minute is deleted with a red line and more considered wording substituted. They now felt that, as representatives of the shipping interests of the port, they did not feel the value of the time ball warranted paying more than a nominal rent for its upkeep. Therefore, they resolved that having gone into the question thoroughly they were quite ready to take over the time ball but in view of the fact that a rent would have to be paid for the current, they did not feel justified in pursuing the matter.⁷²

By now the Chamber of Commerce was no more inclined to offer support and, indeed, for the first time they openly expressed opposition. The Chairman proposed that it be advertised for sale saying that it had been nothing of a nuisance since the beginning. His suggestion was seconded with the remark that it would get rid of a very unpleasant subject. It seems the relief generated a frivolous atmosphere; amidst laughter there were remarks such as it should be allowed to remain for the sake of antiquity and that the ball might be used for baseball. In the end it was decided that the Secretary should confer with the Harbour Commissioners as to the disposal of materials.⁷³ Early in the new year the Harbour Committee took steps to dismantle the apparatus and dispose of the materials.⁷⁴ The local newspaper did not record the final drop of the ball.

Conclusions

There is little evidence of a vigorous popular campaign to establish a time signal. Early interest was rebuffed by the Harbour Commissioners who considered the expenditure required could not be justified. The Chamber of Commerce became the lead agency in pressing the case, eventually supported by the local press, on behalf they claimed of many shipmasters and other interested parties. It must be said though that the surviving records provide little evidence of any specific complaints by the shipping community. For instance, there were no letters to the press, although local shipping interests were represented within the Chamber of Commerce – and on the Harbour Commissioners Board for that matter. As a result the time ball at Falmouth was one of the last time signals to be established. This though did not allow it to benefit from improvements made to Wauchope's original design. In fact, its evolution started not with Wauchope or Greenwich but some fifty years later with Mount Wise.

The main argument put forward by the Chamber of Commerce was that the ability to check their chronometers would encourage vessels to call at Falmouth. So many other, variable factors make it impossible to say whether this did happen. In fact there seems to be a fault in the reasoning. Falmouth was not a large exporting port from which vessels tended to start long, oceanic voyages as much trading was coastal. Vessels were more likely to call there 'for orders' at the end of a long voyage having already completed the part when an accurate longitude was most necessary. None of these vessels would have put a premium on checking their chronometers. On the other hand it was a service that might have proved useful to vessels undergoing repairs. As seen, however, it only needed just one vessel to make an additional call each year to cover the costs to Falmouth.

It was only the direct technical and financial support of the Admiralty that eventually led to its establishment. Once it was operational, the Coast Guard, at that time under Admiralty control, provided operational personnel. A time signal at Falmouth clearly supported their strategic plans and this, coupled with a proposed signal station, was a necessary part of Falmouth's designation as a defended port. There was a dialogue between the Admiralty and the Chamber of Commerce well before the successful 1896 campaign got under way, and, though

it is not possible to know who initiated this, it can be argued that the Admiralty had the greatest interest and became the main beneficiaries of the scheme. It very quickly lost any local support once they withdrew.

The unreliability of the time ball only served to enforce local doubts and eventually compromised its value. The original design, the exposed position and the complex operating procedures all contributed to this poor record but were in turn symptoms of a lack of overall control and responsibility. The Chamber of Commerce was the only body willing to take the lead but did not have the structure to manage its operation and was unable to provide financial support, the Harbour Commissioners reluctantly provided financial support but refused to become involved in its operation. Over the years the attitude of the Chamber went from enthusiasm to derision whilst that of the Harbour Board changed from resistance to reluctant acceptance. Only that of the Admiralty remained consistent, allowing their own, and by implication, the national, interests to govern policy.

A number of questions are left unanswered. Firstly, the evidence is not available to discover the reason the Chamber of Commerce sought advice from Devonport rather than the more usual expertise of the Astronomer Royal. That decision would account for the general design but what other professional advice was used for the electrical and release components is not known. Perhaps a more fundamental question though is why did the Admiralty adopt such a different system at Mount Wise?

Notes

¹ Dava Sobel, *Longitude*, (London, 1996)

² Alston Kennerley, 'A North West European Shipping Communications and Servicing Hub: Falmouth for Orders, Repair and Supply, 1881-1935', *International Journal of Maritime History*, Vol. XXII, No. 1 (June 2010), 111-138

³ J.D. Williams, *From Sails to Satellites – the Origin and Development of Navigational Science*, (Oxford: Oxford University Press, 1992), is strong on the principles and mathematics and mentions the value of time signals versus lunars, p. 103; W.E. May, *A History of Marine Navigation*, (London, 1973) gives a less mathematical approach. It covers the use of chronometers and lunars with examples see pp.33–36, and the eventual end of lunar observations, p. 40; Peter Ifland, *Taking the Stars – Celestial Navigation from Argonauts to Astronauts*, (Newport News, 1998), approaches the subject through the instruments used and is well illustrated

⁴ Ian R. Bartky and Steven J. Dick, 'The First Time Balls', *Journal for the History of Astronomy*, xii(1981) pp. 155-64

⁵ For instance, www.falmouthport/commercial/html/history/php; A.V. Baker, *The First Hundred Years*, (Falmouth, 1965) ; Richard Lingey, *Fortress Falmouth*, Vol II, (London: English Heritage 2000), p. 88 shows references to the time ball in place 4 years too early.

⁶ Baker, *The First Hundred Years*.

⁷ T. Lewis, *The Greenwich System of Sympathetic Clocks and the Distribution of Time-signals*, The Observatory, Nos 103 and 104, (London, 1885); Piazzì Smyth, *Remarks on the Erection of the Time-Ball of the Royal Observatory*, (Edinburgh, 1853), Both available on www.articles.adsabs.harvard.edu, provided by the NASA Astrophysics Data System. Also, Robert Wauchope, 'Plan for ascertaining the rates of chronometers by signal', *Edinburgh New Philosophical Journal*, viii (1830) pp. 160-62 and 'Description of the apparatus or signal-post for regulating chronometers', *Edinburgh New Philosophical Journal*, pp. 289-91. available at www.archive.org.

⁸ The National Archives (TNA): ADM 174, Navy Board and Admiralty: Plymouth Dockyard Correspondence and Papers, 1690 – 1950 would appear to be promising; The Pond and Airy papers at Cambridge and the Greenwich Observatory Archives at the National Maritime Museum, Greenwich may also contain useful material.

⁹ D H Sadler, *Man is Not Lost – A record of two hundred years of astronomical navigation with the nautical Almanac 1767 – 1967*, (National Maritime Museum and The Royal Greenwich Observatory, London 1968) covers the development and use of Lunar Distances; Sobel, *Longitude*.

¹⁰ Williams, *From Sails to Satellites*, p.103.

- ¹¹ Bartky and Dick., *The First Time Balls*, p. 156.
- ¹² T.W. Holmes *The Semaphore*, (Ilfracombe, 1983)
- ¹³ *Falmouth Packet*, May 19th 1896
- ¹⁴ *Ibid.*, December 9th 1904
- ¹⁵ Caption for exhibition prepared by Susan Hill, Archivist, Southampton City Council (2000)
- ¹⁶ Baker, *The First Hundred Years*; Also. see notes by Ken Williams dated 1977 in the archives of the Bartlett Library, National Maritime Museum Cornwall, Falmouth.
- ¹⁷ Baker, *The First Hundred Years*, p.21
- ¹⁸ Bartlett Library, National Maritime Museum Cornwall (NMMC): Harbour Commissioner's Minute Book 19th March 1878
- ¹⁹ *Ibid.*
- ²⁰ *Ibid.*, 15th June 1880
- ²¹ *Lake's Falmouth Packet*, 19th June 1880
- ²² TNA: MT9/111, Start Point (Time Signals)
- ²³ Lingey, *Fortress Falmouth*, Vol.11 p88. This evidence leads Lingey to make the erroneous statement, at least in respect to the time ball, 'by 1893 the first Admiralty War Signal Station incorporating a semaphore and time ball had been set up on the roof of the Henrician Castle at Pendennis'.
- ²⁴ Tony Pawlyn, *Howells and Goffe – Chronometricians to the Falmouth Packet Service*, (unpublished, 2008), available at the Bartlett Library, NMMC.
- ²⁵ *Falmouth Packet* 23rd May 1896
- ²⁶ NMMC: Harbour Commissioners Minute Book No.5 Letter dated 10th July from the Admiralty to the Secretary of the Chamber of Commerce, p.218
- ²⁷ NMMC: Harbour Commissioners Minute Book No.2 p.169
- ²⁸ *Falmouth Packet*, 23rd May 1896
- ²⁹ NMMC: Harbour Committee Minute Book p.380
- ³⁰ *Falmouth Packet* 13th June 1896
- ³¹ NMMC: Harbour Commissioners Minute Book No.5 p. 178
- ³² *Ibid.*, p. 218.
- ³³ *Falmouth Packet* 20th February 1897; 15th May 1897; Baker, *First 100 Years*, p.29; *Falmouth Packet* 12th June 1897, report on Quarterly Meeting of Chamber of Commerce
- ³⁴ *Falmouth Packet* 28th August 1897, 18th September 1897, report on Quarterly Meeting of the Chamber of Commerce
- ³⁵ NMMC: Harbour Commissioners Minute Book No.5, p218
- ³⁶ Cornwall Records Office, K327. Part of papers removed from Arwenack House in 1972 on behalf of the Earl of Kimberly. It must surely have come to Falmouth during discussions on updating the Falmouth Time Ball.
- ³⁷ Notes provided by Nigel Overton, Plymouth City Museum
- ³⁸ *Nautical Magazine*, July 1861
- ³⁹ TNA: MT9/111
- ⁴⁰ Notes provided by Nigel Overton, Plymouth City Museum
- ⁴¹ Smyth, 'Remarks of the Erection of the Time Ball of the Royal Observatory'
- ⁴² NMMC: Harbour Committee Minute Book
- ⁴³ Lewis, *The Greenwich System*.
- ⁴⁴ See Cambridge University Library Janus project web site, index of George Airy and William Christie papers, www.janus.lib.cam.ac.uk
- ⁴⁵ See, Roger Kinns, *Deal Time Ball & Communication – the Deal Time Ball and its Place in Communication History*, communicated by Mike Kinns. Addelam History Research Group, 2010-11, Available on www.eastkenthistory.org.uk/article:deal-time-ball-communicatiion
- ⁴⁶ Harbour Committee Minute Book, 19th May 1916
- ⁴⁷ *Channel Pilot, Part 1*, (Admiralty 1920).
- ⁴⁸ NMMC: Harbour Committee Minute Book, 4th December 1914
- ⁴⁹ NMMC Harbour Commissioners Minute Book No.5 p.173
- ⁵⁰ *Ibid.*, quote of letter from the Chamber of Commerce, dated 27th May ; Harbour Committee Minute Book, 12th November 1912
- ⁵¹ *Ibid.*
- ⁵² *Ibid.*, 28 February 1913.
- ⁵³ *Ibid.*, 3rd April 1914
- ⁵⁴ *Falmouth Packet* 9th December 1904
- ⁵⁵ *Ibid.*, 9th October 1897

⁵⁶ *Ibid.*, 25th September 1897

⁵⁷ NMMC: Harbour Committee Minute Book 12th November 1912

⁵⁸ *Ibid.*, 3rd April 1914

⁵⁹ *Ibid* 16th July 1916

⁶⁰ *Ibid* 27th October 1916

⁶¹ *Ibid* 29th June 1916

⁶² *Ibid* 2nd February 1917

⁶³ *Ibid* 9th May 1916

⁶⁴ *Falmouth Packet* 25th September 1904

⁶⁵ *Falmouth Packet*, 9th December 1904

⁶⁶ *Ibid.*

⁶⁷ NMMC: The Harbour Commissioners' General Ledger and Annual Financial Statement required under the 1870 Falmouth Harbour Act show this and all the following payments made to the Chamber of Commerce

⁶⁸ NMMC: Harbour Committee Minute Book 16th July 1916

⁶⁹ TNA: MT9/111, Start Pont (Time Signals)

⁷⁰ NMMC: Harbour Commissioners Minute Book

⁷¹ Quoted in NMMC: Harbour Commissioners Minute Book

⁷² NMMC: Harbour Commissioners Minute Book 26th November 1920

⁷³ *Falmouth Packet* 24th December 1920

⁷⁴ *Falmouth Packet* 28th January 1921