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TIME-KEEPING IN THE ANTIPODES: A CRITICAL COMPARISON OF THE SYDNEY AND LYTTELTON TIME BALLS

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Abstract: Maudslay, Sons & Field built the time ball apparatus for Sydney, New South Wales (NSW) in 1855, and to hoist the ball they used a rack and pinion that was developed from the mechanism found at Edinburgh and Deal. Sydney's time ball became operational in 1858, following completion of Sydney Observatory (which included a time ball tower). Henry Russell, the NSW Government Astronomer, modified this apparatus to a limited extent during the 1870s, but most principal features were retained. The apparatus for Lyttelton, New Zealand, was ordered in 1873 and shipped from London in 1874 by Siemens Brothers. It, too, had to await completion of the necessary tower, and became operational in 1876. Both Antipodean time balls were still working in 2009. In this paper it is demonstrated that the apparatus at Lyttelton is a replica of the 1855 design used in Sydney, despite the long interval between their dates of supply. The only surviving note in Maudslays' records about an 1873 time ball indicates provision for the Cape of Good Hope and an association with Siemens. A time ball was installed at Alfred Docks in Cape Town during 1873, but available evidence indicates that it was unlikely to have been built by Maudslays. It is suggested that Maudslays' 1873 apparatus was instead sold to Siemens Brothers who installed it at Lyttelton. No Siemens records showing the supply of time balls to other locations at this time have been found.

Keywords: time balls, Maudslays, Siemens, Sydney Observatory, Lyttelton Timeball Station, Cape of Good Hope

1 INTRODUCTION

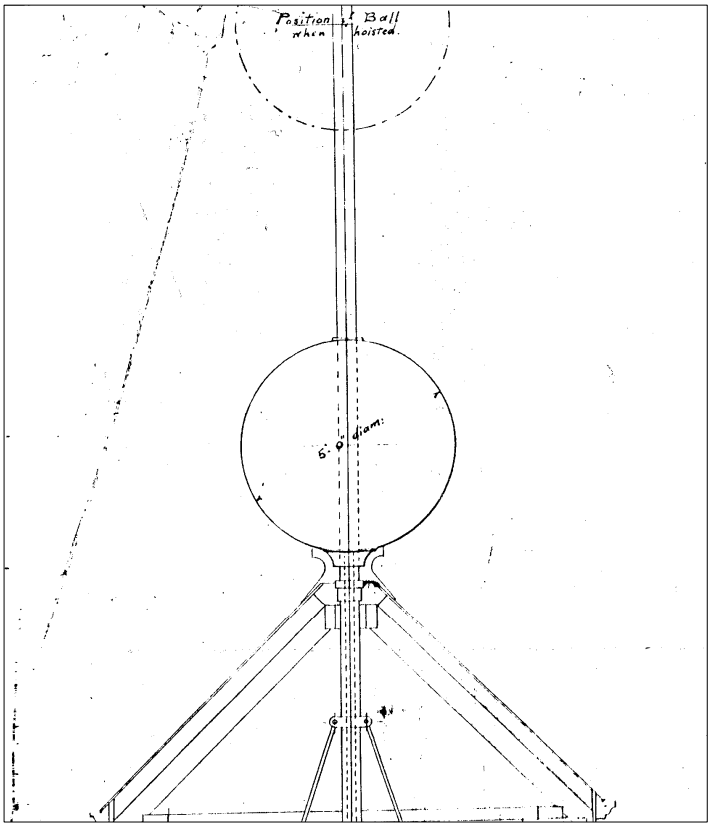
The time balls at Sydney (Australia) and Lyttelton (New Zealand) are two landmarks that are famous locally, and they provide a reminder of maritime history when precise measurement of time using ships' chronometers was critical to determination of longitude. Their mechanisms, both fine examples of Victorian engineering, are still working. The aim of this paper is to explore why they are almost identical, despite supply by two different companies in England with an interval of nineteen years between shipments; Maudslay, Sons & Field (abbreviated to Maudslays in the following discussion) built the apparatus for Sydney in 1855, while Siemens Brothers shipped the apparatus to Lyttelton in 1874. Records of both companies concerning time balls are sparse, but recent work has thrown light on their contributions and business activities at the time of supply. Histories of the Sydney and Lyttelton time balls are outlined, based upon historical sources.

Kinns and Abell (2009) sought to establish the influence of Maudslays on the development of time balls in Australia. A brief history of Henry Maudslay and the company he founded is given in a Maudslay Society brochure, published in 1949 and amended in 1956. A letter from Henry Russell (1899), the NSW Government Astronomer, to Sir Charles Todd in Adelaide was thought to be the only surviving evidence in Australia of Maudslays' supply to Sydney. Confirmation has now been found in the Todd correspondence, archived in Adelaide (Todd, 1899a; 1899b). The Sydney time ball became operational on 5 June 1858, following completion of Sydney Observatory. Henry Russell, the NSW Government Astronomer, modified this apparatus to a limited extent during the 1870s, but most principal features, including the rack and pinion mechanism and the casing, were retained (Russell, 1899). The Sydney design provided the basis for the apparatus that was installed in the new Customs House at Newcastle, NSW. It became operational on 21 February 1878 and incorporated Russell's Sydney modifications and other improvements, which included an open structure for the mechanism casing. It was manufactured by Potter & Sons of Sydney in 1877 (Kinns and Abell: 78-81).

The history of the Lyttelton time ball station is described in an informative booklet, published by the New Zealand Historic Places Trust in 1979. According to this booklet, Siemens Brothers shipped the apparatus for Lyttelton from London in July 1874, following an order placed in March 1873 (Bremner and Wood, 1979: 15). Siemens had become a principal supplier of telegraphic equipment, with heavy commitments to supply and install telegraph cables at the time. The Lyttelton time ball also had to await completion of the necessary tower and it became operational on 23 December 1876 (*ibid*: 23). It was restored faithfully during the 1970s.

The Sydney and Lyttelton time balls are both included in the 1898 list of time signals for mariners. The Sydney ball was specified as having a diameter of 5 ft. and a drop of 10 ft. (List of time signals, 1898: 26-27), but although the corresponding parameters for Lyttelton were not indicated (List of time signals, 1898: 28-29) they were in fact the same. The two time ball mechanisms are remarkably similar, especially when known modifications to the Sydney apparatus after 1870 are taken into account. Drawings, photographs and other records are compared in this paper. The similarity suggests strongly that Siemens bought the apparatus for Lyttelton from Maudslays. It also suggests that no significant design development in time balls had taken place at Maudslays during the nineteen years that elapsed between the supply of the Sydney and Lyttelton time balls.

Maudslays' company records were largely destroyed after liquidation of the firm at the end of the nineteenth century (Maudslay Society, 1956: 20). There is, however, an indication that there was a relationship with Siemens for time ball supply in 1873. Possible options for this relationship are explored.



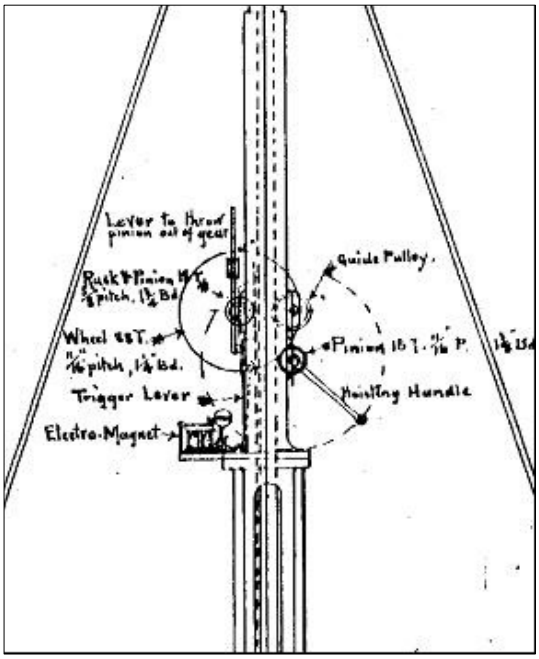


Figure 1: The 1894 time ball at Alfred Docks (courtesy: Gabriel Fagan)

2 TIME BALLS SUPPLIED BY MAUDSLAY, SONS & FIELD

Maudslays developed a wide-ranging general engineering business (Petree, 1934), which complemented the main work of marine steam engine supply. Petree (1967) drew heavily on twelve notebooks dating between 1842 and 1883 by Charles Sells, who was Maudslays' chief draughtsman for forty-eight years. The only reference to time balls is a list on the final page of the last note-book (Sells, 1878-1883):

Greenwich	1833
Edinburgh	1852
S Foreland (Deal)	1853
N. S. Wales (Sydney)	1855
C of Good Hope (Siemens)	1873

The time ball at Greenwich used a chain hoist, but those at Edinburgh, Deal and Sydney used rack and pinion hoists. Although it was planned originally that the Deal time ball would be installed on the South Foreland lighthouse, Astronomer Royal George Biddell Airy decided that it would be better located at the semaphore tower at Deal. The above dates are of construction, rather than first operation. Interpretation of the final entry for 1873 is key to this paper.

The need for a heavy ball and development of appropriate arrangements for controlling deceleration, in order to ensure reliability and availability in all but extreme weather, were described by Charles Piazzi Smyth in an 1853 paper concerning the Edinburgh time ball (Smyth, 1853). Piazzi Smyth (1819–1900) was the second Astronomer Royal of Scotland, and served in that capacity from 1846 to 1888 (Brück and Brück, 1988). He was responsible for provision of the time ball on top of the Nelson Monument at Calton Hill in Edinburgh, a location that allowed it to be seen easily from Leith Docks. This was Maudslays first apparatus to use a rack and pinion hoist for the ball, followed by Deal and then Sydney.

Sir Charles Todd (1899b) wrote that he saw the Sydney apparatus under construction in Maudslays' workshops before he left for Adelaide in 1855, and he also noted that it was modelled on the Deal apparatus. The systems at Deal and Sydney use the same principles of operation, but there are design differences, described later, which show development between 1853 and 1855. The original drawings for Sydney have been lost, so the original design has to be inferred from knowledge of later alterations.

2.1 Time Balls at the Cape of Good Hope

Maudslays contract list includes a time ball for the Cape of Good Hope in 1873, with a reference that suggests Maudslays had an arrangement with Siemens. The first time ball at the Cape Observatory had been erected in 1836 (Bartky and Dick, 1981); a second became operational on 14 October 1853 (Notice to Mariners, 1853), constructed because the original was no longer readily visible from Table Bay. The first time ball had been established by Thomas Maclear (1794–1879), Director of the Royal Observatory at the Cape from 1834 to 1870 (Gill, 1913). It had a diameter of 5 ft. and slid upon a rope projecting from a flagstaff. It was said to have had a probable error that had been reduced to 0.1 sec by 1852 (Maclear, 1852). Maclear (*ibid.*) was defensive about its availability, feeling obliged to point out that the signal had failed on only seven occasions between 1 January and 7 July 1852: four due to weather, two while the transit instrument was being repaired and one "… because the establishment was engaged upon a more urgent duty." Gill (1913) records the introduction of other time

signals after the electric telegraph came into use: "… a time ball was dropped at the Docks in Cape Town; a Disc at the end of an arm was dropped at Simons Town, and similar Discs at the Light House, Port Elizabeth and at East London." The 1898 list of time signals indicates that there was still a disc at Simons Town, but by this time there were time balls at Port Elizabeth, Port Alfred, East London and Durban, as well as at Alfred Docks.

The Sells notebook entry for 1873 was interpreted by Petree to imply that Siemens might have supplied the electrical components for Maudslays' apparatus. The electromagnets operating the trigger were, however, a small part of the main apparatus and the telegraphic equipment was external to it. It may have been decided after the order was placed to use a simpler, lighter apparatus at Cape Town; clearly, there was a well-established capability for time ball operation at the Cape Observatory (Gill, 1913), which may have been exploited in local design of replacement systems. Maudslays' 1873 apparatus may then have been sold to Siemens Brothers who shipped it to Lyttelton in 1874 (Kinns and Abell, 2009). Another interpretation of the Sells notebook entry is that Maudslays built two systems in 1873, one for the Cape and one for Siemens. Either possibility would explain the remarkable similarity between the 1855 design for Sydney and the later Lyttelton apparatus.

A time ball was installed on a North Quay warehouse at Alfred Docks in Cape Town during 1873 (Spencer Jones, 1993); this is the only time ball that is known to have been installed in Cape Colony at that time. Cape Town is notoriously windy, so a heavy ball would have been essential for provision of a reliable service (private communication, Jonathan Spencer Jones, 27 February 2009). The Alfred Docks site was redeveloped during the 1890s and "In 1894 a new time ball was erected in a much more conspicuous position near the Resident Engineer's Office of the Cape Town Docks." (Gill, 1913). Its elevation was increased later, by extending the tower. There do not appear to be any surviving records of the 1873 arrangement (private communication, Gabriel Fagan, 17 March 2009). It was, however, the principal time ball for Table Bay in the first and second editions of the Admiralty list of time signals (1880 and 1888). It was listed as having a drop of 6 ft., the diameter being unspecified; its latitude and longitude were 33° 54′ 27″ S and 18° 25′ 15″ E (List of time signals, 1880: 8-9). According to the 1898 list, the 1894 time ball retained the 6 ft. drop, but there was a small adjustment or correction to its latitude: 33° 54′ 24″ S and 18° 25′ 15″ E (List of time signals, 1898: 22-23).

2.1.1 The 1894 Time Ball at Alfred Docks

The mechanism for the 1894 system no longer exists, but original drawings are available and a replacement system was designed by the Department of Mechanical Engineering at the University of Cape Town and was commissioned in November 1997 (Victoria and Alfred Waterfront, website). The overall restoration of the waterfront site was undertaken by Victoria and Alfred Waterfront (Pty.) Ltd., with Gabriel Fagan as the architect.

Figure 1 shows the design of the 1894 apparatus, from drawings made in 1898 (drawings used to restore the tower and construct the new time ball apparatus for the Waterfront site were received from Gabriel Fagan on 21 March 2009). The time ball clearly had a diameter of 5 ft. and a drop of 11 ft. The drawings expose an ambiguity in the Admiralty lists of time signals: the reported time ball drop can mean either the vertical drop of the ball centre from its raised to its rest position, or the distance from the bottom of the ball in its raised position to the top of the ball in its rest position. Thus the drop is recorded as 6 ft. at Alfred Docks, using the second definition, while it is recorded as 10 ft. at Sydney using the first, more intuitive, definition. Compilers of the Admiralty lists were probably unaware of the ambiguity. The second definition is likely to have been used for all time balls in Cape Colony, so the 1873 time ball is also likely to have had a drop of 11 ft.

The drawings of the 1894 mechanism show that it was similar in principle to that supplied for Deal in 1853, but it was of lighter construction. The rack and 18-tooth pinion had a pitch of only 16 mm whereas Maudslays' systems used a 10-tooth pinion and 24 mm pitch. It used a single guide wheel opposite the pinion, as at Edinburgh and Deal. This design was changed for Sydney, with a pair of guide wheels on each side of the rack. The small pitch and tooth size for the rack at Alfred Docks suggests that the ball and rack would have been considerably lighter than those at Edinburgh, Deal and Sydney. The descent was cushioned using an air-filled cylinder with an escape valve to provide damping, as in all Maudslays' mechanisms.

If the 1873 apparatus had been supplied by Maudslays, it would have been based on the 1855 design for Sydney, not the earlier design for Edinburgh and Deal. It would be surprising in those circumstances if the 1894 apparatus had then reverted to the earlier design.

3 TIME BALLS SUPPLIED BY SIEMENS

The principal biographies of Sir William Siemens and Siemens Brothers (Pole, 1888, and Scott, 1958) do not include any mention of time balls. Time ball supply would have been a minor business activity in relation to design, supply and installation of submarine telegraph cables. Siemens Brothers submitted a proposal in April 1873 to the governments of New South Wales, Queensland and New Zealand for provision and operation of telegraph cables between Singapore and Normantown and from Sydney to New Zealand (*Nelson Examiner and New Zealand Chronicle*, 1873), but this does not appear to have been accepted. The main preoccupations of Siemens Brothers during 1873 and 1874 were supply of the Direct United States and ill-fated Platino-Brasiliera cables, and commissioning of the cable-laying ship *Faraday* (Scott, 1958: 37-39). These major projects carried huge financial risk, with the future of the company depending on a successful outcome. It would not be surprising in these circumstances if Siemens decided to subcontract provision of a time ball apparatus to an established manufacturer, electing to act as systems integrator for their client. Maudslays was the obvious choice.

Maudslays and Siemens Brothers would have been well aware of each other's capabilities; indeed, Maudslays' Joshua Field, FRS, had been a proposer in the successful recommendation for William Siemens' fellowship of the Royal Society during 1862 (Pole,

1888: 129). Siemens does not have any record of time ball supply by either the British or German companies, other than for Lyttelton (private communication, Alexandra Kinter, January-March 2009).

Table 1: Time balls extant in 1898, having a diameter of 5 ft and a drop of 10 ft.

Country	Place	Location
Great Britain	Greenwich	Royal Observatory
Great Britain	Deal	Semaphore Tower
Great Britain	Edinburgh	Nelson Monument, Carlton Hill
Australia	Sydney	Sydney Observatory
Australia	Newcastle	Customs House
New Zealand	Lyttelton	Time Ball station
Germany	Wilhelmshaven	East Tower of Observatory
Germany	Bremerhaven	SW of lighthouse
Germany	Bremen	Harbour Office Tower
Germany	Cuxhaven	E of lighthouse
Germany	Hamburg	Kaiser Quay
Germany	Swinemunde	120 yds E of tower of New Navigation House
Spain	Cadiz	San Fernando Observatory

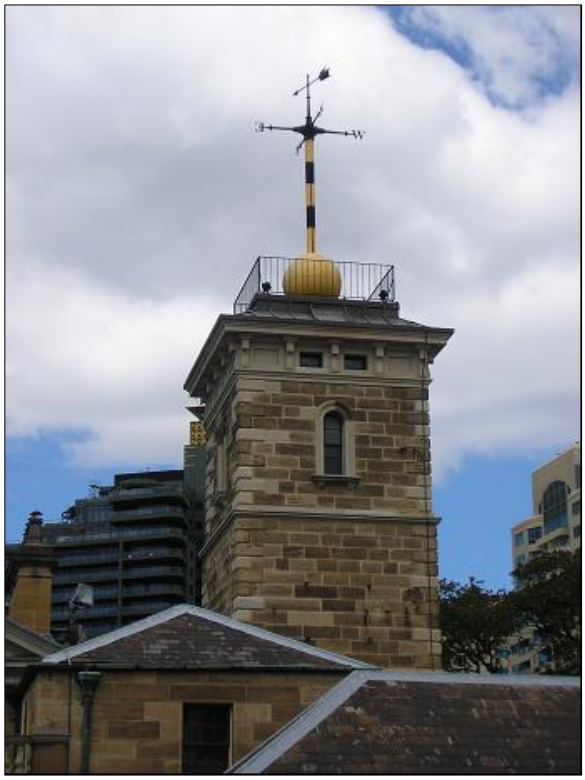


Figure 2: The tower and ball at Sydney on 27 March 2007.

4 ADMIRALTY LISTS OF TIME SIGNALS

The 1898 Admiralty list of time signals has 154 entries, including 94 time balls. In most cases, the list gives the diameter and drop of the ball, but as we saw when considering the 1894 design at the Alfred Docks in Cape Town there is ambiguity in the meaning of 'drop'. Other time balls existed in 1898, but were excluded from the list if they were not useful to mariners, because of location or accuracy. Various other devices were listed, including chronometers held in shore establishments that could be accessed for calibration, discs and moving arms, as well as guns that provided audible signals. All dimensions are given in the original Imperial units. This list formed the basis of a study by the New Zealand Historic Places Trust to show the status of time signals and to provide additional information about their origin (see Wright, 2007).

4.1 Accuracy of Data

The 1880 list has fewer entries, but can be used to judge the accuracy of the specified latitude and longitude, as well as other information such as the time ball drop distance. There are many corrections between the 1880 and 1898 lists, those for Sydney and Lyttelton being typical of locations remote from Greenwich. The actual time ball location was not changed in either case. In the 1880 list, the latitude and longitude of the Sydney time ball are given as 33° 51′ 54″ S and 151° 12′ 42″ E (List of time signals, 1880: 12-13), whereas in the 1898 edition they are 33° 51′ 41″ S and 151° 12′ 23″ E (List of time signals, 1898: 26-27). The corresponding data for Lyttelton are 43° 36′ 40″ S and 172° 44′ 17″ E (List of time signals, 1880: 14-15) and 43° 36′ 42″ S and 172° 44′ 50″ E (List of time signals, 1898: 28-29). The changes in listed latitude and longitude are 13″ and 19″ at Sydney and 2″ and 33″ at Lyttelton. The currently-accepted values for Sydney and Lyttelton are 33° 51′ 34″ S and 151° 12′ 16″ E and 43° 36′ 24″ S and 172° 43′ 35″ E respectively. Not surprisingly, changes between 1880 and 1898 are much smaller for facilities in Great Britain: 3″ and 2″ at Deal; and 3″ and 0″ at Edinburgh.

The time ball diameter and drop are often listed, but not always correctly. For example, the Lyttelton drop is given as 16 ft. in 1880, but is unspecified in 1898, yet it was always 10 ft. The first entry may be a typographical error, '10' and '16' being easily confused. The 5 ft. diameter is not specified in either edition. The Lyttelton time ball is listed as being at "The Custom House" in 1880, but at "The Observatory" in the 1898 list. The terms Signal Station or Time Ball Station were also used to describe the same location (Wright, 2007).

4.2 Time Balls of 5 ft Diameter and a Drop of 10 ft

Time balls supplied by Maudslays all had a diameter of 5 ft. and a drop of 10 ft. After 1852, they used heavy rack and pinion mechanisms, which required installation in a substantial building. Many other time balls in the 1898 list had similar diameters and drop heights. The time ball at Lyttelton had a diameter of 5 ft. and a drop of 10 ft., although these parameters are not stated in the 1898 list. The diameter of the Edinburgh ball is also not stated in the list, but it was 5 ft; the 10 ft. drop is stated.

Time balls in the 1898 list that are known to have had a diameter of 5 ft. (1.5 m) and drop of 10 ft. (3 m) are included in Table 1. Many were in Germany.

4.3 Time Balls at German Ports

The first time ball in Germany was at Cuxhaven in 1875 (Lexikon, 1888). The time ball at Kiel had a diameter of 5 ft., but the drop was listed as 11 ft. There was another 5 ft. diameter ball at Neufahrwasser, but with a reduced drop of 7 ft. (List of time

signals, 1898: 36-39). Other German time balls used a drop of 10 ft. and are therefore included in Table 1. The only location outside the British Empire and Germany that is known to have used a 5 ft. diameter ball with a 10 ft. drop was Cadiz.

It was decided in 1873 to use a standard time ball apparatus for German ports (The time ball column at the Alte Liebe, website). The ball diameter of 5 ft and preferred drop of 10 ft were probably chosen in the light of British experience. The balls were all listed as black in 1898. The time ball drop in Germany was triggered using an electric telegraph signal. The apparatus for German ports was designed by Hugo Lentz, Leiter der Cuxhavener Wasserbauinspektion, who received a patent for the design. That appears to rule out design, and probably supply, of German time ball systems by Siemens, explaining the absence of any company records to that effect.

5 THE TIME BALL AT SYDNEY OBSERVATORY

Figure 2 shows a photograph of the Sydney Observatory tower and ball, taken on 27 March 2007. The ball was originally black, but was painted yellow for the Millennium celebrations. The ball itself is not the original design; it was changed during the 1870s.

5.1 The Letters Between Russell and Todd

A letter written by Henry Russell (Director of Sydney Observatory) to Sir Charles Todd (Director of Adelaide Observatory) includes criticisms of the original apparatus in Sydney and a brief description of the principal modifications that Russell made to it during the 1870s (Russell, 1899). These were: (1) Replacing the original ball, which had zinc plate nailed to wooden ribs, with a new one made of Muntz metal; (2) Replacing the wooden shaft which supported the rack with an iron shaft; and (3) Changing the trigger mechanism to make it direct acting.

Russell (*ibid.*) also remarks that

> The one we have in Newcastle was made in Sydney and is much better than the original in every way. The cast iron bore was replaced by four wrought iron corner pieces which leave the machinery all open and reduces the cost. It has been nearly 20 years in its place and has never cost anything for repairs.

The Newcastle time ball had actually been in operation for over twenty years at the time the letter was written. In his response Todd (1899b) commented:

> It may interest you to know that I very carefully inspected the Time Ball at Maudsleys (*sic*) in 1855 before I came out to Australia. It was then considered a very fine piece of work; but I quite recognised the objections you mention from its being too much closed in.

The present Sydney mechanism retains the features mentioned in Russell's letter. Not surprisingly, there have been various repairs and additions since the letter was written more than a century ago. For example, the pinion has been replaced on more than one occasion, because the teeth were stripped when it was not withdrawn correctly before release. Sydney now has a modern electric motor drive to raise the ball, but the underlying arrangement was not altered and the capstan can still be used.

5.2 Costs of Time Ball Systems

Todd (1899a) recalled that the 1855 Sydney apparatus had cost £500, while Russell (1899) thought that the 1877 apparatus for Newcastle, which was made in Sydney, had cost £400. Russell (*ibid.*) also thought that £200 would have been sufficient in 1899. Todd (*ibid.*) mentioned the relatively low cost of the apparatus for Semaphore in 1875, which served Port Adelaide. That apparatus, with a chain hoist, is likely to have been built in Adelaide to Todd's design (Kinns and Abell, 2009).

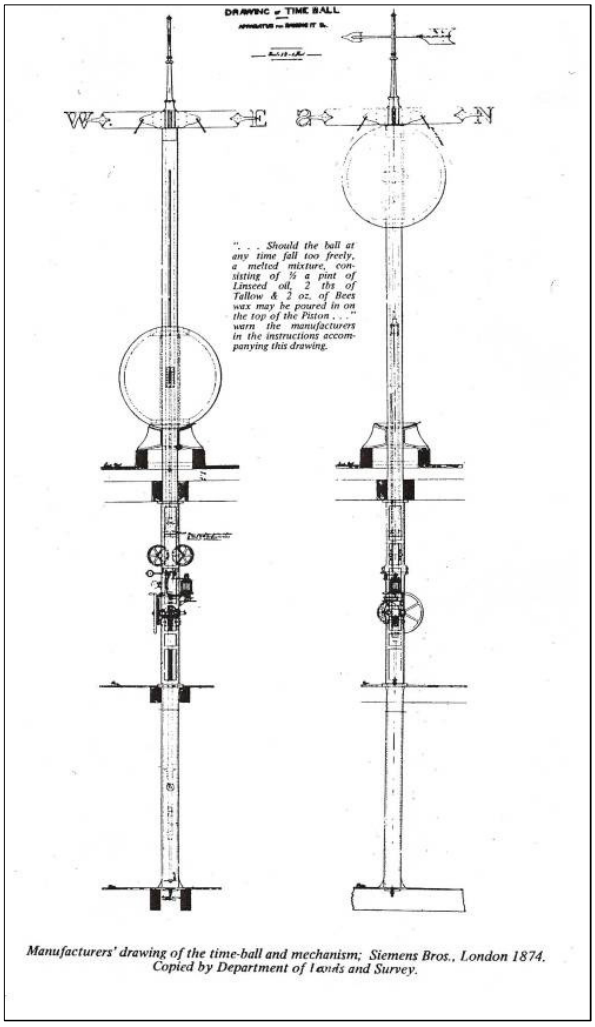


Figure 3: The 1874 Siemens drawing for Lyttelton (courtesy: NZ Historic Places Trust).

6 THE TIME BALL AT LYTTELTON, NEW ZEALAND

Booklets about the Lyttelton time ball were published by The New Zealand Historic Places Trust in 1979. Two versions are available, both entitled *The Lyttelton Time-Ball Station ...* The preliminary version contains the manufacturer's drawing, reproduced in Figure 3. The second, longer version (Bremner and Wood, 1979) includes several photographs and also a three-dimensional sketch of the mechanism in place of the drawing. The following quote from Bremner and Wood (1979: page 15) shows how the project came to fruition:

> Canterbury's time-ball project was backed by two Australians in the Provincial Council, who had a long-term interest in shipping. Businessman and farmer J.T.

Peacock was the son of a Sydney shipowner who had a fleet of ships in Lyttelton, and Henry Webb, Provincial Secretary, had come to Lyttelton initially to take control of the Peacock shipping business. The old Sydney time-ball would have been a familiar sight to both of them.

At a Council session in November 1870, Peacock proposed: 'That a respectful address be presented to His Honour the Superintendent requesting him to place upon the Supplementary Estimates a sum sufficient to erect a time-ball and tower at the port of Lyttelton.' The motion was passed, and Webb contacted the Telegraph Department in Wellington who requested a quotation from London for a ball and its machinery and also a special clock: the ball was to drop automatically, released by an electric current which was to be switched on at the correct time by an astronomical clock. Electricity was one of Webb's many interests – he had demonstrated the first electric light in Lyttelton.

Webb's interests in lighting and telegraphy would have made him aware of the important contributions by Siemens Brothers in these areas.

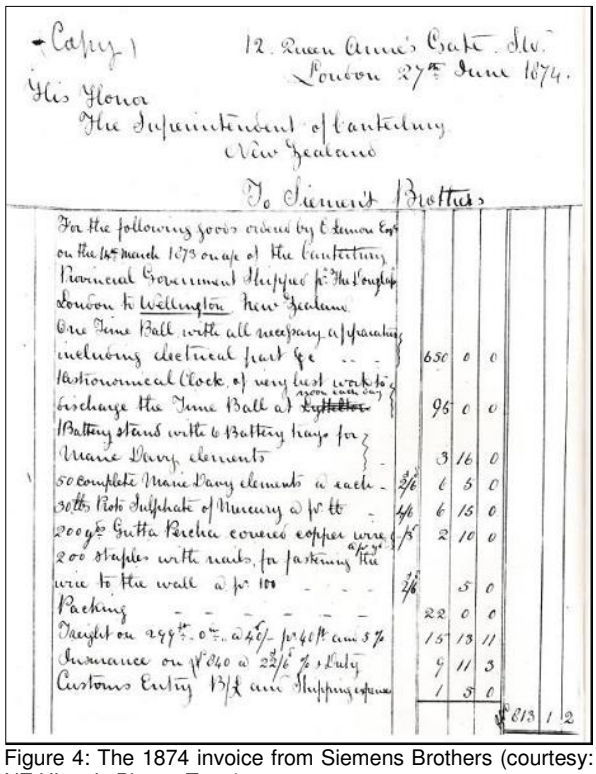


Figure 4: The 1874 invoice from Siemens Brothers (courtesy: NZ Historic Places Trust).

6.1 Cost of the Lyttelton Time Ball

The Telegraph Department in Wellington ordered "… one time-ball with all necessary apparatus and one astronomical clock …" from London on behalf of the Canterbury Provincial Council. Fifteen months later, in June 1874, the Council voted £750 to pay for them. The complete apparatus was supplied by Siemens Brothers to the Superintendent of Canterbury, NZ, as shown in the invoice that is reproduced in Figure 4.

The time ball apparatus was ordered on 14 March 1873 and invoiced on 27 June 1874. A shipping advice note bears the same date and "One Time Ball with all necessary apparatus including electrical parts" cost £650. The "Astronomical Clock of very best work to discharge the Time Ball at noon each day" cost £95. Other items brought the total to £813-1s-2d.

The original quotation had been for "… about £500". Interestingly, that is Todd's (1899a) recollection of the cost of the 1855 mechanism for Sydney, supplied by Maudslays. The apparatus and clock, which was made by Edward Dent & Co., London, were shipped by the *Douglas* in July 1874. Siemens' invoice for £813-1s-2d was sent to Canterbury's London agent who was shocked at the price, but paid promptly nevertheless.

The apparatus was unpacked in April 1876 and installed in the new tower at Lyttelton in September of that year. The Lyttelton time ball finally became operational on 23 December 1876. It was the third time ball in New Zealand, those at Wellington and Dunedin having become operational in 1864 and 1868. The time ball at Dunedin (Otago) provided a weekly service only and was of secondary importance. Only the Lyttelton apparatus has survived in New Zealand.

6.2 Restoration of the Lyttelton Time Ball Tower and Apparatus

The Lyttelton time ball service was discontinued in 1934. The building and apparatus fell into disrepair, but a group of local enthusiasts was formed in 1969 to restore the famous landmark. They suffered an early setback when vandals damaged the mechanism, smashing the manual gearwheels and stealing the electromagnet. The electromagnet was never recovered, but the Siemens Brothers nameplate was found in nearby scrub; it has since disappeared again. A replica of the electromagnet was made using a photograph of the original. Some new parts for the mechanism were made during the restoration by local engineering firms and it was possible to raise the ball again in December 1969. Restoration of the tower was a difficult and ultimately very expensive challenge; in the meantime, the restored mechanism was protected against corrosion. The project was finally completed in 1978. Figure 5 shows the ball in its raised position on 14 March 2009.

7 THE WELLINGTON TIME BALLS

It has been noted that the design of the apparatus which used to exist at Wellington was identical to that for Lyttelton (Clibborn, 1975), so it would also have been identical to that found in Sydney. The plan seen by Clibborn was probably for the 1888 Wellington time ball.

The first Wellington time ball became operational on 9 March 1864 and was installed on the roof of the Wellington Custom House, next to the Provincial Observatory (Ward, 1928; cf. Eiby, 1977). Ward records that the ball was black and made of metal. Early press notices gave its location as 41° 17′ 01″ S and 174° 49′ 15″ E (e.g. *Evening Post*, 1866). The Custom House ball was stated in the 1880 edition of the list of time signals to be red and white, with a drop of 12 ft.; the diameter was not specified. Its latitude and longitude were given as: 41° 17′ 15″ S and 174° 47′ 45″ E (List of time signals, 1880: 12-13). These co-ordinates should be more authoritative, but differ significantly from those given in earlier local press notices. The difference in longitude is particularly marked. A photograph taken in the late 1860s and now in the H.N. Murray Collection in the Alexander Turnbull Library in Wellington suggests that the ball

drop was considerably larger than 12 ft., possibly because the alternative definition favoured at the Cape of Good Hope was used; it also shows that the ball was then a dark colour. By 1873, the apparatus had become worn and the service was unreliable, so repairs had to be made after less than ten years (Stock, 1873). The time ball was relocated in 1888 (Wellington's Maritime Heritage Trail, website).

The second Wellington time ball was listed as being on a "Staff on square tower at inner end of Railway Wharf." Its latitude and longitude were then 41° 16′ 50″ S and 174° 46′ 55″ E (List of time signals, 1898: 28-29), which should be about 750 m north and 1130 m west of the Custom House location given in the 1880 list. There may, however, be a significant longitude error in one or both locations specified in the Admiralty lists. The ball diameter, colour and drop height were not stated. This second Wellington time ball was destroyed by fire in 1909 (Wright, 2007). A photograph entitled "Wellington's latest Conflagration. - The Last of Captain Edwin's Tower and Time Ball" (*New Zealand Free Lance*, 1909) shows the exposed framework of the tower and an apparent rack and pinion system. It was not replaced and the apparatus is now lost.

8 COMPARISONS OF THE SYDNEY AND LYTTELTON TIME BALLS

Table 2 shows a comparison of some principal mechanism components at Sydney and Lyttelton. It includes dimensions of: the rack and pinion, the upper and lower guide wheels, and the casing. Dimensions are all to the nearest mm.

The rack at Lyttelton has a pitch of 24 mm and a width of 38 mm with a 10-tooth pinion. The rack at Sydney was re-backed with an iron shaft by Russell, replacing the original wooden shaft which is still extant at Lyttelton. The Sydney 10-tooth pinion is known to have been replaced on several occasions. The rack dimensions are the same to 1 mm accuracy. A precise measurement showed that the Lyttelton rack has 24.3 mm pitch, exactly as at Edinburgh (private communication, Bruce Carr, 18 April 2009).

The Sydney and Lyttelton time ball mechanisms have cast iron casings. Each casing has a square section, with the same breadth and depth of 270 mm (10⅝ in.). The arched apertures for access to the rack and pinion also have similar dimensions. The aperture at Lyttelton is now covered by a modern perspex window, which can be removed when necessary.

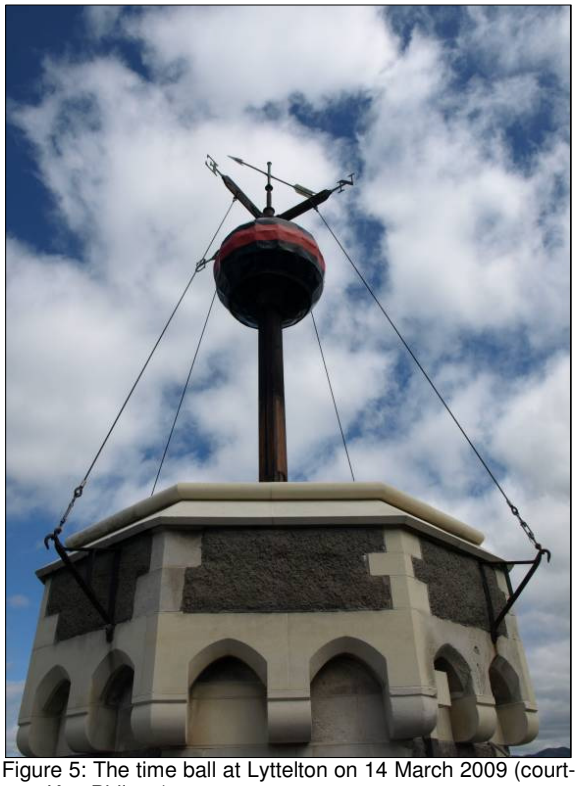


Figure 5: The time ball at Lyttelton on 14 March 2009 (courtesy: Ken Philpott).

The upper and lower guide wheels at Sydney and Lyttelton are identical, given small tolerances in manufacture and measurement. The inner width of the guide wheels is 84 mm (3 5/16 in.).

Pairs of photographs allow comparisons of particular design features. Figure 6 shows the layout of the gears, Figure 7 the trigger mechanisms and Figure 8 the upper guide wheels. The compass arms on top of the mast are compared in Figure 9.

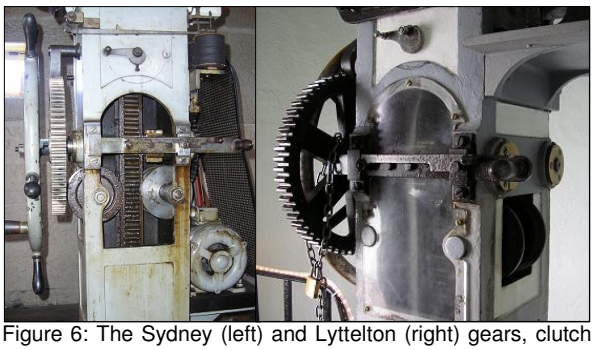


Figure 6: The Sydney (left) and Lyttelton (right) gears, clutch and aperture.

Table 2: Key dimensions at Sydney and Lyttelton (courtesy: Nick Lomb, Bruce Carr and Ken Philpott).

Sydney				Lyttelton			
Component	Dimensions in mm			Component	Dimensions in mm		
	No. of teeth	Width	Diameter		No. of teeth	Width	Diameter
Pinion on rack	10	40	80	Pinion on rack	10	40	80
		Width	Pitch			Width	Pitch
Rack		39	24	Rack		38	24
		Width	Diameter				
Upper guide wheels	Outer	99	332	Upper guide wheels	Outer	103	330
	Inner	84			Inner	84	
Lower guide wheels	Outer	100	150	Lower guide wheels	Outer	97	149
	Inner	84			Inner	84	
		Width	Depth			Width	Depth
Main casing		270	270	Main casing		270	270

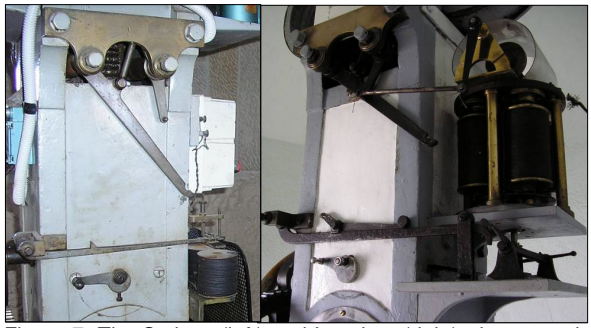


Figure 7: The Sydney (left) and Lyttelton (right) trigger mechanisms.

The rack and pinion arrangement is the same, but the outer gears and capstan differ in detail. The outer gearwheel and pinion have 80 and 15 teeth at Sydney, but have only 62 and 10 teeth at Lyttelton. The Lyttelton gears have the same number of teeth as at Edinburgh and Deal, so Sydney is the exception. The 6-spoked capstans differ in detail, that in Sydney having radial handles as well as a handle on one of the spokes. The original Lyttelton drawing shows a handle at the capstan periphery, now positioned on one of the spokes. The capstan at Edinburgh does not have radial handles, while that at Deal is similar to Sydney. Clearly, details like this are easily changed to suit the operator and may have been modified during the working life of the system. The electric motor, drive belt and gear for hoisting the ball are modern additions at Sydney, but the hand capstan can still be used.

Figure 8: The Sydney (left) and Lyttelton (right) upper guide wheels.

The sliders for the rack pinion, which act as simple clutches at Sydney and Lyttelton, are identical. This applies also to the brass plates on the back and front of the casing that support the trigger levers and roller catches for the rack. The pinion is engaged with the rack in the Lyttelton photograph, but is withdrawn to the right at Sydney, prior to the drop (see Figure 6).

Figure 9: The Sydney (left) and Lyttelton (right) compass arms (Lyttelton photograph courtesy Ken Philpott).

The trigger mechanisms (Figure 7) are significantly different. The Lyttelton mechanism is more complicated, with an extended series of levers between the electro-magnets and the ball release catches. This is likely to be the original arrangement at Sydney that was criticised by Russell (1899) as being "… complicated and clumsy in the extreme." His modifications to the Sydney apparatus give a much more direct link between the electromagnets and the release catches. A link from the right hand roller catch lever to the upper electromagnet contacts is still present at Lyttelton, but the link has been disconnected at Sydney.

The E-W and N-S compass bearing indicators are remarkably similar (see Figure 9). The arms themselves are more substantial at Lyttelton, but the letters and their fittings to the arms appear to be the same. The ball at Lyttelton still has a wooden frame and zinc plating, as supplied to Sydney in 1855, whereas Sydney now has a Muntz metal ball. This wooden frame is noted in the most recent documentation about Lyttelton (New Zealand Historic Places Trust, website). Ball construction of zinc plate on a wooden frame was used previously at Edinburgh and Deal.

The arrangement of the piston in the vertical cushioning cylinder below the casing is not visible, but the Sydney design was inspected when the time ball at the Newcastle, NSW customs house was being restored (McDonald, 2000). The 0.3m diameter piston is made of 0.1m thick rubber and is fitted with a bleeder valve to adjust the rate of descent. The bottom of the cylinder is filled with 7 litres of soapy water to act as a buffer and, presumably, to provide lubrication for the rubber (Kinns and Abell, 2009: 75). The use of a rubber piston and soapy water may have been Russell innovations. The arrangement at Lyttelton is generally similar, but the piston is made of metal with a leather cap seal and there is no apparent provision for water at the bottom of the cylinder in Figure 3.

The present slotted mast at Sydney is made of metal and has a circular section, while the slotted mast at Lyttelton is made of wood with a square cross-section. Russell probably modified the Sydney mast at the time the ball was changed; early photographs show a mast with a square cross-section (Pickett and Lomb, 2001: 20). The mast at Lyttelton is similar to that at Edinburgh.

9 TIME BALL DEVELOPMENT FROM EDINBURGH TO SYDNEY AND LYTTELTON

There were substantial changes in the detailed arrangements for the rack and pinion hoists from Edinburgh and Deal to Sydney, which can be seen in the surviving mechanisms.

The casings at Edinburgh and Deal were made of wrought iron, with corner pieces and bolted plates. The casing at Sydney was cast as an integral structure, presumably to give greater rigidity. That applies also to Lyttelton. Many features of the mechanisms at Edinburgh and Deal were changed for the Sydney apparatus. One of the most significant changes was to the guide arrangement for the wooden shaft. Other changes to the trigger and catch arrangements are also obvious.

9.1 Deal and Edinburgh

Figure 10 shows photographs of the Edinburgh and Deal casings and mechanisms. The designs are similar, although the capstan is on the opposite side of the casing to the external gears at Deal, with differences in the capstan handles that are not unlike those between Sydney and Lyttelton. The mechanism at Deal is no

longer used for hoisting the ball, but it can still be seen in the Deal museum following restoration; a modern mechanism is now used to operate the ball. The original electric trigger at Edinburgh has been substituted by a manual rope pull, smoke from the Edinburgh Castle gun having replaced the time ball as the primary signal. The Edinburgh tower and apparatus, including the ball, are undergoing restoration in 2009; some parts of the apparatus are in poor condition, but it is essentially complete in its original form.

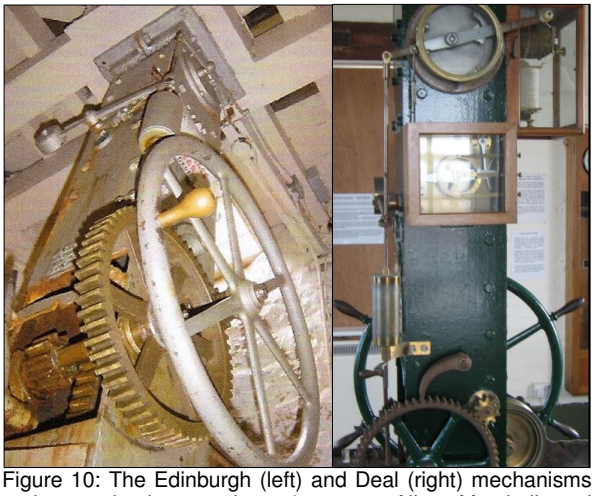


Figure 10: The Edinburgh (left) and Deal (right) mechanisms and wrought iron casings (courtesy Allan Marshall and Michael Kinns respectively).

A single guide wheel opposite the pinion was used for the rack at Edinburgh and Deal, as shown in Figure 11. This was changed at Sydney and Lyttelton to a design that used two pairs of guide wheels, one either side of the rack (see Figure 8). Another important change was in the catches for the rack. These were linked using gear segments at Deal and Lyttelton, but this arrangement was changed to lever-linked roller catches at Sydney and Lyttelton. The Edinburgh and Deal quadrants are shown in Figure 12, together with a photograph of one of the catches engaged with the wooden shaft at Edinburgh. The inspection holes for the catches are below the gear segments.

The Edinburgh casing is narrower than at Sydney and Lyttelton, with 251 mm sides. The capstan has the same diameter, with a single handle at the periphery as in the original Lyttelton drawing in Figure 3. The manufacturer's plates can still be seen at Edinburgh and Deal, but the plate at Sydney is absent. The plates shown in Figure 13, both indicating an 1853 date, suggest that Maudslays received a Royal Warrant between the deliveries to Edinburgh and Deal.

Allowing for tolerances in measurement and manufacture, the bronze rack at Edinburgh has the same 24.3 mm pitch ($^{23}/_{24}$ in.) and 38 mm tooth width as at Sydney and Lyttelton. It is backed by a wooden shaft, having a width and depth of 64 mm with bevelled corners that engage with the single guide wheel. The metal base for the teeth extends the full width of the shaft and is 13 mm thick. The rack itself is made in sections; the wooden shaft and its metal rod extensions connect the ball to the piston. The same basic rack design was used for Sydney and Lyttelton.

Figure 11: The Edinburgh guide wheel (courtesy: Allan Marshall).

10 CONCLUSIONS

Maudslay, Sons & Field built the time ball apparatus for Sydney in 1855, and used a rack and pinion mechanism to hoist the ball. It became operational in 1858, following completion of Sydney Observatory with its time ball tower. Maudslays' mechanisms and casings at Edinburgh and Deal are similar to each other, but the design was developed further for Sydney. Henry Russell, the NSW Government Astronomer, modified the Sydney apparatus during the 1870s, but most principal features were retained.

Figure 12: The Edinburgh (top) and Deal (bottom) gear segments and catches (courtesy Allan Marshall and Michael Kinns respectively).

The apparatus for Lyttelton, NZ was ordered in 1873 and shipped from London in 1874 by Siemens Brothers. It, too, had to await completion of the necessary tower and became operational in 1876. It has been demonstrated that the apparatus for Lyttelton is a replica of the original 1855 design for Sydney, prior to Russell's modifications, suggesting strongly that Siemens Brothers bought it from Maudslays in 1873. There are no Siemens records of time ball supply at any time, other than to Lyttelton, so it was not an ongoing business for the company. In 1873 and 1874 Siemens was heavily involved in supplying submarine

cables and commissioning the cable-laying ship *Faraday*, so it would have been easier for them simply to buy an existing time ball apparatus from another company with an established record of production.

Figure 13: The Edinburgh (top) and Deal (bottom) Maudslay, Sons & Field plates (courtesy Allan Marshall and Michael Kinns respectively).

The only surviving reference to a Maudslays 1873 time ball is in the last notebook of Charles Sells, and indicates provision for the Cape of Good Hope and an association with Siemens. The first time ball at Alfred Docks in Cape Town was installed on a North Quay warehouse in 1873. Admiralty lists of time signals published in 1880 and 1888 show that the Alfred Docks installation was then the official time ball for Table Bay, and was operated by an electric telegraph signal from the Cape Observatory. It was superseded in 1894 by a new system after site redevelopment; this later design was similar to that used at Deal, but of lighter construction. When the site was developed again during the 1990s, it was possible to design and build a working system based on the 1894 drawings. Unfortunately, no records relating to the 1873 design have survived in South Africa, but it would be surprising if the design for Sydney had been used, when the 1894 design is essentially a reversion to the design for Deal.

The available evidence indicates that one time ball system is likely to have been built by Maudslays in 1873, using the 1855 design for Sydney. It may have been intended originally for Alfred Docks in Cape Town, but a lighter system was probably preferred and Maudslays' apparatus was no longer needed there. Instead, it was bought by Siemens Brothers of London who installed it at Lyttelton, New Zealand. Thus, the apparatus at Lyttelton is an 1873 reproduction of the original 1855 Sydney design, whereas the present apparatus at Sydney includes later modifications.

The rack and pinion mechanisms built by Maudslays between 1852 and 1874 have all survived.

11 ACKNOWLEDGEMENTS

Many gave freely of their time and energy to assist with this investigation. Bruce Carr and Jan Titus of Lyttelton (NZ) gave unstinting support throughout. Ken Philpott of Christchurch (NZ) measured the Lyttelton apparatus and some of his photographs feature in this paper. Measurements by Dr Nick Lomb, Curator of Astronomy and Timekeeping at the Sydney Observatory, allowed a full comparison of the two mechanisms. Alexandra Kinter, archivist at Siemens, conducted searches of company records which showed that the Lyttelton supply was not part of ongoing Siemens business in either England or Germany. Jonathan Spencer Jones and Gabriel Fagan supplied valuable information about the history of the Alfred Docks time ball in Cape Town. David McDonald of Edinburgh World Heritage and Alan Wilson of James Ritchie & Son (Clockmakers) Ltd. provided key information about the first rack and pinion mechanism and ball to be supplied by Maudslays. Allan Marshall took many informative photographs of the Edinburgh time ball apparatus, some of which are reproduced in this paper. Dr Michael Kinns visited the Deal Museum and photographed the apparatus there. Their help is greatly appreciated.

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