GLASGOW TIME SIGNALS

WILLIAM B. BLACK, DAVID CLARKE, Glasgow University

1. *Introduction*

As world-wide trade grew in the 18th and 19th centuries, serving the vibrant locations of activity with accurate time became more and more important. This was particularly apposite if the local commerce relied on ocean-going vessels. Safe sea voyages depended on the navigational skills of the captain who determined the location of his cargo-burdened ship in terms of latitude and longitude as calculated from on board astronomical measurements with reference to the exact times of the observations. The story of how determinations of longitude at sea became more reliable, particularly through the development of accurate marine chronometers, has been well told by many authors with popular accounts given Sobel and Dunn & Higgitt.[1]

The city of Glasgow with its port on the River Clyde enjoyed growth through trade in raw cotton and its local manufacture into cloth. In addition, the sugar importation from the West Indies and tobacco from Virginia in the USA, with its re-export to Europe, added to its burgeoning prosperity. Pig iron and timber from the Baltic also contributed to the city's industrial development.[2] The importance of providing accurate time for this shipping activity was very much appreciated by the local citizens involved in such commerce.

As a consequence of a maritime disaster in 1707 off the Isles of Scilly, the British Government established the Board of Longitude in 1714 with the aim of solving the problem of knowing time at sea.[3] Proposed strategies to obtain what was later to be known as Greenwich Mean Time (GMT) while on voyage involved eclipse observations associated with Jupiter's satellites, or application of the lunar-distance method as proposed by Nevil Maskelyne, this requiring mariners to carry tabulated predictions of the moon's position. The necessary tables of information were carried in the annual production of *The Nautical Almanac* overseen by Maskelyne who by 1765 had become the Astronomer Royal. As the observations underpinning the

published tables were made at the Royal Observatory, Greenwich, its meridian became the accepted fiduciary reference for measurements of longitude by the Royal Navy, and used on British Admiralty Charts. Eventually, at an international conference in Washington in 1884, the Greenwich meridian was formally adopted as the International Prime Meridian, carrying the fiduciary angle (0^o) of longitude.[4]

Rather than relying on lunar observations which are not always possible particularly around the new moon phase, it was obvious that the best method to determine the local longitude was to have accurate time always to hand. This had been recognised by the Board of Longitude and a prize of £20,000 was offered to the first person to produce a reliable watch that would meet the requirements of navigators. After many years' work, a self-taught carpenter, John Harrison, produced his fourth and successfully famous example (H-4) of a reliable time piece in 1759.[5] Since then, skills of manufacturing stable chronometers improved steadily. This progress was encouraged through a scheme commencing in 1822 under the auspices of the Greenwich Observatory whereby established clockmakers could submit their instruments for testing. The Admiralty offered prizes according to the one which had kept the best time over the year by purchasing it for £300 with the second best bought for £200. Later, the prizes were extended to the best three pieces with adjustments made to the monetary values of the awards. The trials were terminated by the newly appointed Astronomer Royal, George B. Airy, in 1836. Four years later they were reinstated with the results published annually in an appendix to the document known as *Greenwich Observations*. Trials and testing of chronometers continued in various forms well into the twentieth century.[6]

Before embarking on any voyage, it was important that a ship's chronometer should be set accurately to GMT and that any daily drift in its time keeping be known. This could be done by reference to time obtained at a local astronomical observatory equipped with a transit telescope. The procedure would entail either taking the ship's chronometer to the observatory, or checking with the port authority's display of a chronometer synchronised to an observatory's master clock. Many ports provided a time signal each day either by operating a time ball at the quayside or by firing a large gun. Both these visual and audible schemes were experimented with in Glasgow over a period of about five years.

The aim of this paper is describe how the provision of time came to the general Glasgow public and to the shipping at the quayside. It will deal with the conflicts that arose in the decision making processes of erecting a time ball and then operating a system of time guns. In setting up these enterprises there was much local debate and argument. One of the factions involved financial matters; a local chronometer manufacturer had concerns over the protection of commercial interests in which investment had already been made, and expanding telegraphic companies were keen to increase their revenue from use of their lines and cables for transmitting time signals. Even to-day intercity rivalry between Glasgow and Edinburgh occurs in many areas but it was very much to the fore over which city would supply Glasgow with the master time signals, particularly for the operation of the time gun. Edinburgh had more operating experience over transmission connections with telegraphic cables, but Glasgow had a legal commitment to central government to supply time to the city. In addition, there was friction over the natures of the observatories of the two cities and their associated academic institutions; Edinburgh was supported by central government finance, while Glasgow was solely reliant on funding from its College. Glasgow's angst over Edinburgh's political scientific power was very much aired. There were concerns over the autocratic behaviour of the Astronomy Royal for Scotland, Charles Piazzi Smyth, ensconced in Edinburgh. Over the period of the debacles, the Regius Chair of Astronomy in Glasgow was occupied by John Pringle Nichol at the time of the establishment of the time ball and then by Robert Grant at the time of the experiments of time guns. Differences in the characters of these two men in approaching the various contentious issues are readily seen. Finally, development involving the running of a city and a port depends on the persuasions of local politicians with inputs made by people of business and other interested citizens. Recorded proceedings of the Glasgow Council show the usual procrastinations of committee decision making. The general public were very much kept informed of all the developments through the local newspapers by announcements of the experiments, by reports of City Council meetings and by inputs from the College. The public also made their feelings known by their contributions through strongly worded letters published in the newspapers.

2. *The Glasgow Scene*

Glasgow Colle(d)ge was founded in 1451. Although the establishment later became known as Glasgow University, the title of 'College' tended to remain through the period covered by the earlier part of this paper. Astronomy has been included in the University's teaching curriculum for over 560 years.[7] Its first observatory was established in 1757 and located in the Old College grounds off High Street, following the bequest of instruments from a Glasgow graduate and successful Jamaican business man, Alexander MacFarlane. By 1830, although the Macfarlane Observatory continued to be maintained by the College, it was in poor state for providing time as its meridian aspect had suffered from the building of St John's Church in 1819.[8] In the meanwhile, the *Glasgow Society for Promoting Astronomical Science* was formed to oversee the building of a public funded observatory in 1810 on Garnethill, nearer to the harbour. By the early 1820s this had become defunct and in 1824 the land was put on sale, with the buildings demolished soon after. At its establishment, a 14-inch telescope had been bought from and tested out by the famed William Herschel who visited Glasgow in 1811. Following the closure of the Garnethill Observatory, this instrument was sold to the Board of Longitude and shipped in 1829 to the Cape Observatory in South Africa.[9]

Around 1829 the Clyde Navigation Trustees, who were responsible for the operation of the city harbour, had provided four clocks at key points and employed a man named Alexander Mitchell to maintain them.[10] Nothing is known, however, as to whether these clocks displayed seconds' fingers, or how well they were regulated, or what source was used to ensure their accuracy. They were located at the following sites:

Corner of Jamaica St and Broomielaw
Finnieston Quay
River Police Office in Robertson St
Court House

The local astronomical scene was revitalised on 6 February 1836 by the appointment of 31 year old John Pringle Nichol (see Fig. 1) to the Regius Chair of Astronomy at the College. He brought a new enthusiasm for the subject to the city. As a result of his public lectures which attracted audiences of 1000 people, on 16 December 1836, the old *Glasgow Society*, now renamed the '*Friends of Astronomical*

Science in Glasgow', held a grand dinner with 200 people in attendance in the former Town Hall in the Trongate.[11] This resulted in a proposal that a body known as the *Astronomical Institution of Glasgow* (*AIG*) should be established with the aim of building an observatory away from the pollution of the city to replace the failed venture of Garnethill. The following year saw economic depression and by January 1838 only £1195 had been raised through subscription, the target figure being £2000. By 30 May of the same year the project had become a joint one involving the public organisation and the College; the *AIG* agreed to provide the building with the College being responsible for obtaining the necessary observatory equipment but financed by the *AIG*. Nichol soon took to the task of acquiring instruments, but in a somewhat profligate way. A transit telescope purchased from Ertel of Munich, Germany, had engraved scales in gold rather than silver.[12] It was resolved to complete the building of the new observatory by 1840 to coincide with the British Association Meeting scheduled to be held in Glasgow. To supplement the finances, a Memorial to the Lords Commissioners of the Treasury was despatched to London applying for grant of £1500.[13] The application was referred to the Royal Astronomical Society and the Astronomer Royal, George B. Airy, for their inputs and they seized on references to the increased shipping on the River Clyde. In compiling the submission, Nichol also mentioned that a transit circle by Ertel was on order, enabling observations to be conducted that would result in the ability to maintain accurate time within the observatory. Thus, when the grant was agreed, it included a proviso that transit observations would be carried out regularly and be used to provide correct time for relaying to ships on the Clyde.

The chosen site for the new observatory, the third for the city, was at Horselethill, on the side of Dowanhill, just south of the Great Western Road. It was surrounded by open country at this time, being some three miles from the city centre.[14] The facility, complete with a residence, was opened in 1841 and two years later a sidereal clock by Bryson of Edinburgh was purchased, providing improved support to undertake accurate transit observations. Unfortunately, partly through miscalculations on the annual costing of the land and on Nichol's extravagances in purchasing equipment, financial problems began to affect the project. In 1845 the situation was resolved with the College taking over all the responsibilities of operating the facility. A settlement was made with the shareholders of the *AIG* with

concessions made to the original subscribers in terms of returned monies and access to the facilities. On 18 March 1845, a letter was despatched from Her Majesty's Treasury with a directive for the College to accept "all the obligations and conditions to which the properties of the Institution are liable to the Crown, thereby relieving the Institution of its responsibility".[15] At this point the provision for providing accurate time to the Clyde was solely in the hands of the College.

Although Horselethill's location was superior to both the original MacFarlane Observatory at the Old College and that of city's public observatory at Garnethill, it was at some distance from the harbour and not in its line of sight. Without provision of visual signals or a telegraphic cable, the method to provide the transmission of time involved a College servant travelling into the city and carrying a chronometer synchronised with the observatory's master clock. The main purpose of the exercise seemed to be to check and correct the clock of the city's Royal Exchange. There is no evidence that Nichol strongly pursued a facility for displaying accurate time at the quayside. Criticisms of Nichol by his peers suggest that he lacked practical expertise and that his energies were geared more to literary endeavours in which he had great success.[16] Nichol was not skilled in making observations and had difficulties in operating the Ertel transit telescope. It was not as robust as the English designs and he voiced concerns about the quality of its objective lens[17].

Over the same period as the establishment of the Horselethill Observatory, Duncan McGregor became a well-established chronometer maker in Glasgow. He started his business in Greenock in 1836 and opened premises in Clyde Place on Glasgow's quayside in 1844, trading as D. McGregor & Co. from 1856 onwards (see Fig. 2). The company submitted a chronometer numbered 138 which was purchased for £47 5s in 1844 by the Admiralty under the testing scheme outlined earlier.[18] Results for this time piece were noted in *Greenwich Observations* of 1847.[19] The company had invested in establishing a transit telescope for use on its premises which overlooked the harbour and they offered a time service to the ships tied up there.[20] As related below, Duncan McGregor & Co. became a major player in the controversies of the establishment of time in Glasgow.

3. *Time Balls*

While tied up in port, mariners might take their chronometers to have them checked against a land-based master. Chronometers remained delicate instruments and there was always a reluctance to have them transported any distance away from ship, even if carried in their protective wooden boxes. The timepiece would be away from its vessel for some time under the supervision of key personnel who might be more gainfully employed on board. In addition, the service incurred a not inconsiderable charge. In 1859 the fee of McGregor & Co. was 5 shillings per chronometer.[21]

To overcome these inconveniences, and to provide an instant reference time signal available to all, in 1818 Capt. Robert Wauchope RN, a Scots naval officer, submitted a paper to the Admiralty suggesting a means "for communicating time by means of telegraphs".[22] Apart from a polite acknowledgement, Wauchope received no encouragement, a second submission in 1824 receiving identical treatment. Then, in late 1829, a member of the Admiralty Board observed chronometers being brought ashore in rough weather from an anchored warship at Greenwich to be checked at the observatory there. Commenting on the risk of damage to such delicate instruments and the gross inconvenience involved, his aide reminded him of Wauchope's earlier submissions. These were then recalled for further examination with the result that a trial was introduced at Portsmouth. Details of his proposals with a drawing of the system were published by Wauchope early in 1830.[23] In his plans he described the use of metal and canvas spheres, hoisted to a yardarm and dropped at a specific time each day. By situating the system where it would be visible across an entire harbour or anchorage, it would be possible for mariners to check the accuracy of their chronometers quickly, without cost and while remaining aboard their vessels. The exercise proved successful and four years later a time ball was established at the Royal Greenwich Observatory. Initially Wauchope had specified a system with two vertical spheres, plus a large one minute warning flag, but the latter and one of the spheres were dispensed with in the later construction. A single ball drop became the norm for all successive systems. Another modification was suggested by Wauchope within a month of his paper being accepted and the experiment agreed. Originally he had proposed that the time signal be given at 12-00 GMT, but this was around the time of the solar meridional transit when observatories would be busy carrying out their own midday observations and checking their own master clocks. He therefore suggested that the execution of the time signal be deferred by one hour and a one o'

clock drop at 13-00 hours local time was adopted universally except in the United States. Wauchope's letters, writings and proposals for his system simply referred to as a 'One o' Clock Time Ball' have been documented by Bartky & Dick and summarised by Aubin et al.[24] Wauchope promoted his idea around the world, particularly for the St Helena–Cape of Good Hope station in South Africa and on the home front for Liverpool and Edinburgh. Operation of a time ball in Liverpool began in 1845; although the Edinburgh authorities took up the idea at about the same time, various delays held back the official signal operation until 1854 (see later).[25]

4. *The Scottish Scene*

Accurate operation of a time ball required it to be in direct connection with a master clock under the auspices of an observatory capable of carrying out regular accurate transit observations. Being adjacent to the Observatory, the Greenwich ball was initially operated manually but advances in technology allowed it to be 'dropped' automatically by electric signal under control of the master clock. By 1841 the first electric telegraph systems were in operation and, within six years, they had spread across most of the United Kingdom, linked primarily to the development of railways. This provided the opportunity for the transmission of an instant accurate time signal across the network, subject to the limitations of the reliability of the transmission wires. Also in 1841, Alexander Bain, born in Watten between Thurso and Wick in Caithness, Scotland, invented an electric clock system, whereby a master instrument could control the accuracy of several slave pieces located remotely, again utilising telegraphic signals.[26] The principle of this invention was to play a significant role at a later stage in the provision of accurate time for clock face displays at distant locations.

Around 1849 Charles Piazzi Smyth, formally proposed the erection of a time ball in Edinburgh to provide an accurate signal for shipping lying in the Forth estuary. It was not until late 1853 that it was tested and then becoming officially operational on 20 March 1854. It was erected on top of the Nelson Monument below Calton Hill. At the time of the commissioning, Smyth discussed the problems of dropping the massive ball quickly and applying a cushioning system to prevent it deconstructing and damaging the supporting column.[27] Activated by an electric signal from the Royal Observatory on Calton Hill, the ball had to be hoisted into position manually

and the timing of its 'drop' dependent only upon the accuracy of the master clock. During 1852 the Royal Observatory at Greenwich had obtained a Shepherd master clock, which was used to transmit a daily time signal across the railway telegraph network throughout the major cities of the country. Because the Edinburgh master clock might drift slowly during periods when transit observations were prohibited by local inclement weather, Smyth arranged to have the telegraph line from the nearby railway station extended to the Calton Hill Observatory.[28] Accordingly, the Greenwich signal could be used as a standby according to the confidence he had in the Edinburgh master clock, this dependent on the frequency of the local transit observations made over the previous nights.

During the initiating phase of the establishment of the Edinburgh time ball, Sir Thomas Brisbane had taken a participatory interest in the operations.[29] Sir Thomas, a native of Largs in Ayrshire, had studied astronomy at Edinburgh University and retained an abiding interest in the subject throughout his life. Following military service in the Napoleonic Wars, he had been Governor of New South Wales, Australia, from 1821 to 1825. During his extensive travels, he had taken a strong interest in navigation especially having experienced a near calamity at sea in 1795 as a young man.[30] On his many later voyages he maintained his own reckoning and was shocked once, when comparing that of the ship's master, he found the two readings differed by as much as 500 miles. At the time, an average of 900 vessels were lost each year, of which he considered 9 or 10 were due to chronometer inaccuracies, or lack of knowledge for their correct use.[31] He therefore considered the provision of accurate time signals at ports to be an urgent priority.

With the obvious success of the Edinburgh time ball, Brisbane submitted an appeal to the Clyde Navigation Trust in Glasgow, suggesting they follow suit and erect a time ball to cover the harbour at Glasgow.[32] Records of the Royal Observatory Edinburgh also note that Glasgow had been encouraged to set up a similar system to that at Calton Hill.[33] Brisbane's suggestion was remitted to a committee, which reported on 8 June 1854 concluding that no benefit could follow from such an action; Brisbane was informed that his submission had been rejected.[34]

Undeterred, he waited until the autumn of 1855, when the annual British Association for the Advancement of Science Meeting was held at the Glasgow College. As President of the Royal Society of Edinburgh, Brisbane had close involvement with the meeting's organisation and took the opportunity to promote his

support for time balls. At his own expense he had a model time ball set up within a lecture room in the College, connected to Edinburgh by telegraph. Observatory records at Edinburgh for 12 September 1855 report: "The necessary arrangements for dropping a Time Ball in Glasgow being in process of being made."[35] The local daily Glasgow newspaper commented on the forthcoming experiment noting that the Edinburgh to Glasgow Railway would keep the telegraph line clear for the required brief period around 13-00 hours for the daily drop signal.[36] At the meeting, the demonstrations proved to be successful and in a letter to Sir George Airy, Professor Smyth wrote:

> Furthermore our lines of wire from the Obs[y] to the Railway were tested during the Association week by carrying out also at Sir T. Brisbane's expense, his favourite desire of introducing Time Ball signals to the notice of the people of Glasgow.
>
> Extra batteries having therefore been brought up here, & temporary wires laid down in Glasgow from the Telegraph Station to Section G room in the College a large model Time Ball was dropped every day during the Association week, by the Edinburgh Obs[y] Mean Time Clock.[37]

In addition, on 13 September, Smyth read a paper to the meeting's delegates on the subject of time balls, in which he pressed for a system to be erected either at Glasgow or Greenock.[38] Never slow to promote himself or the Royal Observatory Edinburgh, Smyth proposed that it could be controlled remotely from there like the model. Nichol was present at the lecture and, perhaps recognising the need to be diplomatic, Smyth acknowledged that the Glasgow Observatory could be used as an alternative source for the signal. In endorsing Smyth's lecture, Nichol reinforced this by suggesting that a connection to the Horselethill Observatory might be made at little expense. Although the experiment received considerable press coverage, there appears to have been no immediate reaction from the Clyde Trustees, their subsequent meetings during the year making no mention of the subject. At some point a little later, however, the Tidal Harbour Commissioners made comment on the lack of a time ball, pointing out that the other developing west coast port, Liverpool, had invested in one as well as at Edinburgh.

5. *The Glasgow Time Ball*

5.1 *The Decision Process*

Among the new people elected to the Glasgow Council in November 1855 was William Allan, partner in the bonded warehouse firm of Allan & Poynter; he was invited to act as a Clyde Trustee. Like all new incumbents to such positions, Allan appears to have been anxious to make his mark at an early stage. As early as 1846 efforts had been made to introduce a new Sailors' Home but it was almost a decade before construction commenced. Located on the Broomielaw on the quayside, at the corner with James Watt Street, it was designed by J. T. Rochead. A circular tower was planned to be over the main entrance at the junction of the streets and Allan saw this as an opportunity to press for the erection of a time ball. It appears he may have held informal talks with Rochead to establish the suitability of the tower, and the architect considered it to be a superior structure to the Nelson Monument in Edinburgh. On Tuesday 1 July 1856, Allan notified his fellow Trustees that he planned to raise a motion at their next meeting, proposing a committee be established to consider setting up a time ball.[39] Specifically he intended that they should concentrate on the utilisation of the Sailors' Home tower but another Trustee, Bailie Peter Clouston, considered this would be too restrictive. Although the Trustees voted in principle for the time ball, some may have had reservations about the tower as a site, and that the remit should be broader. Allan considered the tower the best option but, probably sensing stronger opposition if he persisted, agreed that he was "not wedded to the spot".[40] As an adjunct to Clouston's comments, Andrew Fowler suggested that inclusion of a clock on the tower would be beneficial, a proposal that was greeted warmly by his colleagues, but never implemented.

With agreement in principle on the time ball plan, Allan visited Edinburgh to study their installation, having it demonstrated by Mr Wallace, Smyth's assistant, the astronomer himself being abroad on one of his many expeditions. The construction cost was £200 but, being located in a Royal Observatory, this had been defrayed by the central government, a situation that would not be repeated in Glasgow. Wallace was convinced, however, that a similar ball could be built in Glasgow for a modest amount. Like that in Edinburgh, it could be connected remotely by telegraph wire to an observatory but the cost could be reduced considerably by mounting a master clock within the same building. This was the option that had been preferred in

Liverpool and had proved successful. There, a person was under contract to maintain chronometers and the time ball had been added without additional charge. Wallace was not aware if this applied in Glasgow but, if not, he considered the annual maintenance charge would be modest. The proposal was approved on 5 August 1856 at the Clyde Trust meeting formed to progress the matter under a small committee headed by Allan.[41]

The first step was to approach the directors of the Sailors' Home for their agreement that the tower could be utilised. Again it appears that this was ground that Allan had covered unofficially before the formal approach and no objection was made to the proposal. With the matter settled, the way was clear to have John Ure, the Trust Engineer, prepare a plan and obtain the cost of construction.[42] The estimate was ready by 18 November, when Allan presented details to the Trustees.[43] Alexander McKenzie had produced the lowest tender for construction at £250 and this was accepted. Manufacture of an astronomical clock and additional timber would add a further £100, and, with an estimated maintenance figure not exceeding £40 per annum, the project was approved for progression.

Perhaps mindful of the failure of the College to fulfil its requirement to provide accurate time to the port of Glasgow, early in 1857 Nichol had a letter published criticising the proposal for a time ball at the Sailors' Home. This drew a sharp response from Allan at the Trustees' meeting on Tuesday 7 April, suggesting that Nichol "seemed to speak at random".[44] The letter commenced with Nichol admitting he had no knowledge of the proposed arrangements but insisted the time ball must be connected to an astronomical clock, with an indication of true Greenwich Time. In addition it might have been connected by telegraph wire to the clock at Horselethill Observatory or that at Edinburgh. All of this appeared quite reasonable and Allan responded by briefly explaining the existing arrangements. He confirmed that an astronomical clock was being placed in the Sailors' Home to control the operation and that it would be set to Greenwich Time. The Trust's sub-committee had considered connection to the Glasgow Observatory at Horselethill but this would have increased costs by three times the present total, so the idea was discarded. Similarly, connection to the Calton Hill Observatory would require obtaining exclusive use of the telegraph of the Edinburgh to Glasgow railway for a short period every day, again introducing an additional cost. With his usual deference to the Royal Observatory, Nichol appears to have suggested that Smyth could have been

consulted. Of course, Allan had endeavoured to do so, but had only been able to speak to Smyth's assistant, as related earlier.

Nichol had also stated that time had been transferred regularly from the Horselethill Observatory to the clock mounted within the Royal Exchange, with which Allan agreed. However, he said that study of the records there would show that this clock sometimes varied by ten seconds in a week. By contrast McEwan, a fellow Trustee, owned a clock that had not varied more than two seconds in five years. It appears to have been comments made by Nichol on the operations of McGregor & Co, the local nautical instrument making business, which offended Allan who referred to them as being a great libel. The professor noted that ship-owners expected their masters to provide chronometers at their own expense and he suggested that such time pieces were useless. He considered that they were very imperfect instruments, whose operation varied according to temperature and masters used sightings of headlands or hailed a "chance Yankee as he passed".[45] In response Allan claimed that Glasgow chronometer makers had facilities to calibrate their instruments equal to those available at the College, so they were considered reliable.[46] No large vessel left the river without at least one chronometer aboard, and sometimes two, supplied by the owner. In further support of the safety record relative to accurate navigation, he pointed out that Glasgow ships enjoyed identical, if not better, insurance rates than the remainder of the market.

At the April 1857 meeting of the Clyde Trustees, Allan reported that the clock had been established within the Sailors' Home and it was hoped the ball would be in place within the present month.[47] Nichol raised another issue in June with a letter to the Lord Provost, then chair of the Trustees, querying why the proposals at the British Association Conference two years previous had not been adopted. Apart from a brief acknowledgement this second intervention by Nichol was ignored. The Sailors' Home had been officially opened on 26 Jan 1857.[48] Throughout this same year the regular meetings of the Clyde Trustees made comment on its opening and on details for the operation of the time ball. By October 1857 the time ball had been installed and functioning with its daily drop.[49] All of Nichol's attempted interventions had been ignored, particularly in relation for his desire to have the University Observatory supply the time to control its functioning. It had been just over ten years since he had accepted the remit for the College to fulfil the obligation to the Crown to provide time

to the harbour but, at this point, he was only regulating the clock in the city's Royal Exchange which itself was a poor time keeper.

5.2 *Description of the Glasgow Time Ball*

Although Rochead considered the tower construction more suitable than the column at Calton Hill in Edinburgh, it was recognised that it would require internal modification to absorb the stresses imposed daily by the dropping ball.[50] At third floor level a cast iron ring was constructed, one side being supported by the tower wall, while two strong pillars held up the other side. These pillars continued down to the foundations of the building, with a series of stays and crossbeams providing further strength. At first floor level four strong girders supported the tower itself, on which a series of beams had been laid to form a platform. In its centre was a 9-inch diameter vertical iron pillar, supporting a circular staircase and with further diagonal beams adding to stability. This led up to a landing on which the machinery for the ball itself was positioned. In the centre was a vertical iron cylinder housing a piston attached to the ball. Another circular stair, braced identically to its lower partner, led to a second landing. Centrally on this was an extension of the cylinder, the section having a narrow vertical slot cut in one side. Within it was a long mahogany rod, acting as a piston, extending both above and below the cylindrical section. Fitted to the rod was a metal rack, with a wheel and pinion arrangement to enable the ball to be raised vertically prior to its operation. The ball itself was attached to the top of the mahogany rod and rested on a tarred moulding on the centre of the roof of the tower. It weighed 10 cwt and was designed to fall about 8 feet when released. It was constructed of a series of mahogany rings. Crossing each other at right angles, these formed a sphere which was covered with zinc sheeting to protect it from the weather. Comments on the time ball weight and the drop height have been made by Clarke & Kinns.[51]

On the ground floor of the home, at the rear corner of the shipping office, was the astronomical clock that controlled the ball, its body bolted to the floor.[52] The final cog wheel made one full rotation in 24 hours. As it reached the end of its rotation at 13-00 hours a weighted lever fell into a notch on its edge. A second wheel rotated once per hour and had an identical notch and lever, this falling into place as it completed the rotation leading up to 13-00 hours. The two levers filled a gap and

when a third wheel, rotating once per minute, completed its last rotation at 13-00 hours, a projection allowed the completion of an electric circuit, with the current passing to the ball mechanism. The clock was rated to have an accuracy of $^{1}/_{10}^{th}$ of a second per day. Directly above the figure 60 on the seconds dial was a slot, through which protruded a thin trigger plate, made of gold, inclined at an angle of 8° to the second hand, which also was made of gold. Concentric with the minute wheel, and revolving with it, was a wheel, notched in three places, above which was a lever, connected to the trigger. At 12-55, when the second hand reached 60, the lever dropped into the first notch, allowing the trigger to come into contact with the second hand. This completed a circuit producing a bright spark indicating that the operator should raise the ball to the midpoint on the external vertical mast, so sending a preparatory signal to those watching in the harbour. Then at 12-58 the lever dropped into the second notch, repeating the electrical spark, enabling the operator to hoist the ball to the truck of the mast, where two levers dropped into notches in the rod under the ball, holding it in position. At 13-00 hours the minute wheel lever dropped into the third notch, automatically transmitting an electric current to an electro-magnet, opposite the upper levers. This pulled both out simultaneously, permitting the ball to fall. Initially the ball fell sharply with the air beneath being expelled through the aperture in its upper section. Once the mahogany rod dropped into the bottom part of the cylinder, it compressed the air there, causing it to act like a cushion and its descent was retarded gradually until the ball returned to its housing in the roof. To cushion the descent further, a moveable plate was secured to the bottom of the mahogany rod by spiral springs, these compressing as the ball settled.

The designs of the ball and its clock were undertaken by Alexander McKenzie, a former telegraph engineer for the Edinburgh to Glasgow Railway, who had moved to London and established his own business. The construction was by Thomas Colquhoun of St Vincent Street, Glasgow. Maintenance and daily operation were undertaken by Duncan McGregor & Co., their premises in Clyde Place being almost directly opposite the Sailors' Home across the river. One of the partners of the company, M. McN. Walker, acted as overseer of the operations which were carried out under an annual contract running from 1 July each year with the following requirements:

To furnish observations required to keep the time ball regulator at Greenwich Mean Time.

To attend daily and set the regulator at absolute Greenwich Mean Time.

To furnish and maintain the chemicals required in forming the magnetic connection between the regulator and time ball.

To attend daily for the purpose of putting the battery in action, hoisting the ball, seeing that it drops accurately and generally to see that the whole apparatus is kept in proper working order. [53]

Each morning two of the company's staff, one being mentioned earlier as William Church, an instrument maker, crossed the river to supervise the activation of the ball. The transit telescope used to check of McGregor's chronometers was situated on the roof of their building, being mounted on a block of polished marble, thereby providing it with a stable base little influenced by vibration. The marble itself had a central vertical slot between which the telescope was mounted, this being aligned to enable the instrument to traverse the plane of the meridian, permitting stars to be checked according to their altitude at the time of meridional passage. Armed with a chronometer checked against the latest observations, the men walked to the Sailors' Home and inspected the clock. It was fitted with a spring mechanism that was attached to the pendulum so permitting adjustment without disturbing the hands of the clock itself. A horizontal rod passed through the casing at the rear of the clock to which was attached the end of a spring. The spring itself encircled the bar for one turn with its other end connected to a bar at the back of the pendulum. On the outer end of the rod was a knurled head, which was rotated to adjust the diameter of the spring as required. Within the case, part of the rod had been manufactured with a screw thread, cut into a section, which connected with a stud projecting from the bar at the rear of the pendulum. Should the clock be noted to be running slow (i.e. $^{2}/_{10}^{th}$ of a second) the spring was adjusted to make the pendulum move faster for a short period until this deficit was corrected. With the clock checked, the men climbed into the tower, using their chronometer to ensure that they raised the ball to its warning levels at the correct time. Following a successful operation, after having spent between 1½ and 2 hours on site, the team returned to Clyde Place.[54]

5.3 *Criticism and Opposition*

Although the ball appears to have been put into commission without serious problems, the Clyde Trustees' meeting of Tuesday 5 January 1858 saw the first

concerns arise.[55] Allan revealed that the final cost of the ball and clock was £626 12s 1d, while McGregor & Co. were to receive £60 per annum for maintenance of the system. The original estimate for the installation he claimed had been £350, including £50 for the strengthening work on the tower. An extra £200 had been required for cabinet work and other fittings, while the increased maintenance cost covered the provision of replacement parts. Bailie Taylor expressed disquiet at this increase in costs, recalling that the original estimate was £200, Allan responding that this was not so, although study of the earlier reports suggest the original £350 included £100 for cabinet fittings, now shown as additional. When Ure and he had visited Edinburgh to inspect the ball there, they were advised it had cost upwards of £500 and so based their own estimates on this figure. Nothing more was heard on the matter until a year later when on Tuesday 1 February 1859, a new Trustee, Charles Kidston, appointed by the Clyde ship owners, raised the matter once more.[56] He intimated his intention to bring forward a motion at the March meeting, seeking non-renewal of the maintenance contract when it expired.

At the meeting of Tuesday 5 April 1859 the matter arose again.[57] By this time Kidston's attitude towards the entire concept of a time ball had hardened. He announced it to be a "sham" and, even if correct, was not required in the harbour, and so proposed its removal. As an alternative, consideration could be given to moving it to Greenock, where it might be of use to vessels lying nearer to the mouth of the Clyde. He had spoken to several ships' masters, all of whom preferred to send their chronometers to McGregor & Co. for calibration. Allan responded by introducing an amendment that the ball be retained. He reminded members that the Tidal Harbour Commissioners had considered such an item essential and also that Liverpool was in the process of adding two more at their port as he spoke. In response to Kidston's conversations, he had a memorial signed by over 40 ships' masters supporting the ball. Allan's amendment was backed by another councillor, William Rae, but the ship owners immediately closed ranks, George Smith and James Allan, both prominent representatives, endorsing the proposal by Kidston. Then a third councillor, David Dreghorn, indicated the dangers of a little knowledge. He stated that he had seen the ball in action and noticed that it was controlled solely by one man, operating with a watch in his hand. In the event the Trustees took the tried and tested route on such occasions, they appointed a committee to look into it.[58]

The unrest and heated discussions provided Nichol with the opportunity to press once more the case for the ball to be controlled from Horselethill Observatory. He did so by writing to Dreghorn on 18 April 1859, ostensibly expressing concern that it might be decided to withdraw the time ball.[59] He considered its role went far beyond providing masters with a check on their chronometers. It also gave the Broomielaw "an exact indication of Greenwich time", an action that was important to everyone involved in rating chronometers in Glasgow. He considered that the ball did not provide an advantage over the clock at the Royal Exchange, which could be used by chronometer makers to calibrate their products but it was essential that "the ball ought to be dropped immediately and directly by an electric current proceeding from the transit-clock of some adequate observatory". Although apparently more circumspect than his earlier letter, he went on to claim that "no intermediate action by portable chronometers or otherwise can be considered admissible". Then, rather disingenuously, he proceeded to state that it was "of no consequence from what observatory such a current proceeds; it may be a public one, it may be a private one; it may be in Glasgow, it may be in Edinburgh; the only essential is that the observatory be *adequate*". Nichol then defined what he considered as being adequate:

> It must possess a telescope of considerable size.
>
> This instrument must be placed on a stone pillar, or between stone pillars.
>
> Must be detached from other buildings.
>
> Means must exist for the frequent examination and valuation of the errors of the instrument.
>
> Must be employed as constantly as our climate will allow on the fundamental stars.
>
> Every observation must be reduced and corrected.

Nichol then turned to the mention that the clock was "electrically controlled" and from his remarks it appears not only had he not visited the Sailors' Home but had not examined the Edinburgh system. He claimed that the only function of electricity was to transmit the signal from the transit clock necessary to activate the precise dropping of the ball, precisely the function obtaining in both cities at this time. Again he ended his letter by proposing that the Trustees seek the opinion of Smyth but added three other names, Sir Thomas Brisbane, John Hartnup, Director of the Liverpool Observatory, and George B. Airy, for consultation.

Four days later Allan responded to Nichol's letter to Dreghorn, again through the pages of the *Glasgow Herald*.[60] He confirmed that the conditions Nichol detailed in relation to the time ball existed, apart from the connection to a remote observatory. He acknowledged that connection with Greenwich was possible, the initial cost being £5 for the installation of the necessary relay. Added to that, however, would be the expense of laying a telegraph line from the Royal Exchange, where the Glasgow telegraph exchange was located, to the Sailors' Home, this being considerable. He reminded Nichol that the connection to the College Observatory had been considered but would require extensive upheaval along the city streets at some expense, so this idea was discarded. Allan conceded that a time ball at Liverpool had been operated through a telegraph link to Greenwich but this had been abandoned due to unreliability. He related that the Liverpool balls were dropped manually but that Hartnup was proposing the installation of two more, which would operate as per Glasgow, using a transit clock adjacent to the time balls. Indeed this had been reported in the *Glasgow Herald* only ten days earlier.[61] The Glasgow clock had a losing rate not exceeding $^{2}/_{10}^{th}$ of a second per day, this being rectified daily just before the system was activated to ensure accuracy of the ball drop. The data used to ensure this were accurate and provided from "a transit instrument situated in an adequate observatory, located scarcely two hundred yards distant". By contrast the Exchange clock was known to show an inaccuracy of five to ten seconds, sometimes gaining and at other times losing, while it is corrected only once per week. Allan supported Nichol's suggestion that Smyth be consulted and that operation of the time ball should not be discontinued, requesting that the Professor continue to press his fellow Trustees on the matter. Although he made no reference to Brisbane in his response, a few days later, Allan confirmed that he had spoken to him within the previous two months, Brisbane had expressed great satisfaction with the Glasgow time ball.

When Nichol read Allan's letter, he immediately sent off correspondence both to Airy and Hartnup, enclosing extracts from it.[62] Both men replied on 27 April 1859 and Nichol forwarded these, with a covering letter to Dreghorn. The latter had them published in the *Glasgow Herald* on 4 May.[63] The Astronomer Royal, Airy, corrected some of the statements made by Allan. He stated that the time ball at Liverpool, controlled from Greenwich, continued to operate and did so "with perfect accuracy".

Later, however, he qualified this by admitting that it did fail from time to time, although claiming this to be rare, through defective insulation, damp weather and other unspecified reasons. Airy confirmed that the Greenwich ball was dropped by galvanic clock and had been controlled in this way for several years, confirming by this statement that the mechanism was closely similar to that at Glasgow. Diplomatically Hartnup made no mention about the Greenwich controlled clock, perhaps suggesting that he was less enthusiastic about it than the Astronomer Royal. He confirmed that a new time ball was being erected on top of the Victoria Tower overlooking the Liverpool harbour entrance and would be controlled from the local observatory, further evidence that the Greenwich system might not be perfect. He acknowledged that in 1837 it had been found that the Greenwich Time obtained from various celebrated chronometer makers with transit instruments was "found to differ sufficient to cause a wreck". Then he made brief mention of an alternative that was being considered at Liverpool, this being the use of the observatory clock to control all the public clocks in the city, a method which would gain more prominence within a few years. In his covering letter to the *Herald*, Dreghorn rather ambiguously appears to endorse Hartnup by suggesting "there can be little difficulty in placing Glasgow under the system to which Mr Hartnup alludes, as already existing and about to be greatly extended and perfected in London and Liverpool." [64]

In his covering letter Nichol responded to two further points made earlier by Allan.[65] Firstly he was emphatic on use of "electric currents", which he claimed should pass directly from the transit clock to the ball machinery and set it in action automatically. He considered there was no place for intervention by "a man with a watch", no matter what part of the process it took place. These would be a fair comment but, at this time, all of the time balls in operation required manual intervention to raise them prior to their operation. Therefore, in this respect the Glasgow system did not differ from those at the other locations. Even should the raising of the ball be controlled electrically, the intervention of "a man with a watch" would be necessary at some point, if only to monitor the accuracy of the transit clock against the astronomical observations. Secondly he raised the issue of an "adequate observatory", stating that he hoped the Trustees would verify the assertion about McGregor's premises. Connection by telegraph over the 200 yard distance should be simple along with a requirement "to secure the records of the working of the

institution be regularly kept, and remain open to examination". Although he appears to be conceding that there was the possibility McGregor's equipment might be accurate, this was not so as seen in his disparaging remark about it to Airy. By this he refers to the observations being "kept by a watchmaker, who has a rickety (observatory) in the top of his house". By referring to him as a "watchmaker" he belittled the skills of McGregor, who, as described earlier, had submitted a chronometer for examination by Greenwich in 1844, and which was praised highly for its accuracy and reliability, with the Admiralty purchasing it. Likewise it is doubtful if he had any personal knowledge of the quality of the equipment and its location within the large building occupied by McGregor in Clyde Place. In conclusion, after repeating his suggestion that Smyth be consulted, he acknowledged that there may be some justification in the criticism in relation to the Royal Exchange clock and he promised to take steps to correct this.[67]

By this stage Nichol's health was in decline, which may have influenced him during all his correspondence over the time ball issues. It must have been known that he was not in the best of health as he had taken recuperative treatments for laudanum addiction.[68] He died on 19 September 1859 at Rothesay.

Nichol's successor at the College was Professor Robert Grant (see the sketched portrait in Fig. 3) who saw the establishment of accurate time to all public places in Glasgow as one of his priorities. Probably unwittingly, he caused controversy by stating in a report dated July 1861 that the College Observatory was responsible for providing weekly information to check the accuracy of the time ball and seemingly appeared to think that this was actively the case.[69] It looks as though he had not appreciated that McGregor & Co. had the formal contract for operating all aspects of the time ball. Being the holiday period, it was almost a month before any response appeared, coming on 5 August from Walker of McGregor & Co.[70] He considered Grant's comment implied that his company was unable to make their own accurate calculations and reiterated that they had a very accurate transit telescope and associated equipment in their observatory at Clyde Place. It appeared that John Rollo, who had been an assistant to Nichol for eighteen years, had been in the habit of visiting McGregor's Observatory each week en route to checking the Royal Exchange clock. While there, the opportunity was taken to cross-check their chronometers, it being found in a few instances that the College Observatory instrument was in error.

Walker did not consider this implied that this telescope was other than accurate but suggested the problem came from errors in calculation of the results at the College.

The spat continued on 14 August, Grant also having been on holiday but responding sharply on his return.[71] Now knowing that McGregor & Co. had been paying Rollo for several years in relation to his weekly visits, he felt that they must have been considered valuable for the company to make regular remuneration. In relation to the College's instruments, he assured the public that his transit telescope with a 6½ inch aperture was capable of observing stars of the smallest magnitude, "even in the daytime".[72] He considered its accuracy superior to the smaller instruments that McGregor possessed but acknowledged that they all had less than ideal conditions in Glasgow. Although he could not speak for the period prior to his appointment, since that date every effort had been made to ensure that all errors were eliminated, perhaps an implicit acknowledgement of Nichol's previous shortcomings. By 21 August and very upset, Walker defended McGregor & Co. writing that they had been carrying out detailed observations for more than thirty years with great reliability.[73] He acknowledged that when they expanded their premises a few years previously into an adjacent building at Clyde Place, they had arranged for the initial visits from Rollo. This was to enable them to cross-check their results until certain that their instruments were calibrated correctly. Aware that the College technician had only a modest salary, McGregor & Co. decided to continue his visits, providing a small fee for the privilege. Finally Grant responded again on 28 August with a sharp rebuttal, claiming that Rollo had never worked for him.[74] Rollo was employed by the College but when Grant arrived he received approval for funding to employ an assistant under his personal control. He engaged a Joseph Wood for this role and, with his work taken over by the new technician, the College decided to dispense with Rollo. Technically Grant was correct over Rollo's position but it was a clear case of splitting hairs with a devastating outcome for Rollo who had given the best part of his life to the service of the College.

From there on, the Glasgow time ball continued to operate under the maintenance of McGregor & Co. for about five years until the middle of 1864.[75] Other local events then affected the way by which public displays of time came into practice. Although inoperative in the 1870s, the time ball remained visible (see Fig. 4) but was dismantled soon after, leaving the distinctive tall tower on the building as a landmark. The Sailors' Home itself was demolished in the 1970s.

6. *Time Guns*

6.1 *Early Implementations*

Operations of one o'clock time ball signals at commercial ports needed installations offering good visibility, not always ensured particularly around harbours with large numbers of steam powered vessels. An alternative was required to cover those times when conditions were poor. The firing of a gun as a means of indicating a specific time was in practice at some locations at the turn of the 17th century. As early as 1806, a cannon had been used in Cape Town to provide a noon-time signal.[76] Following the establishment of the time ball in 1854, Edinburgh also adopted firing a gun, coinciding with the dropping of the ball. The one o'clock gun of Edinburgh still operates daily as a tourist attraction.[77] In 1861 Professor C. Piazzi Smyth arranged with the Castle authorities for a gun to be connected by telegraph wire to the Calton Hill Observatory, so that the same electrical signal generated at 13-00 hours for the time ball could be used to fire a gun on the ramparts of the Castle. With the speed of sound being slower than that of light, there were delays in receiving the noise of the detonation according to the distance from the gun. The distance from the Castle to the shipping activity located at Leith was about two miles, with the harbour suffering delays of several seconds in receiving the acoustic signal. To overcome problems of time delays, maps were printed with superimposed circles on them, giving the time delay of the noise of the gun at various distances from the Castle. Time guns were established in other ports including that of Liverpool in 1867.

6.2 *The Glasgow Guns*

Apart from curiosity over Edinburgh's gun, its implementation does not appear to have drawn any immediate interest in Glasgow but, on 26 September 1863, Glaswegians were advised that they also were to have a time gun.[78] The original announcement appeared in the *Scotsman*, an Edinburgh based newspaper lacking a wide circulation in Glasgow at that time.[79] It was intended that operations would commence either on 25 or 26 September. The firing was to be on an experimental basis and was the enterprise of Nathaniel Holmes, manager of the United Telegraph Co., in association with Professor Smyth.[80] As it turned out

Professor Grant had been in contact with the city authorities during the previous two to three years in respect of laying down a telegraphic cable to the city centre from the University's Horselethill Observatory. He was given the courtesy of adding a letter to the announcement of the time gun experiments.[81] In his submission he described the success of the city of Liverpool whereby several of the public clocks were controlled by dedicated telegraphic cables connected to the local observatory. Grant promoted this kind of system for Glasgow as it was superior to a once a day gun signal, allowing accurate time to be displayed continuously to the second at any location. In respect of the proposed time gun experiment he commented that "This method no doubt has much of a sensational character, which cannot fail to recommend it to popular feeling, but on grounds of real utility, the methods practised at Liverpool appear to be vastly preferable, more especially when the question relates to a great and rapidly extending commercial city, where the ear is assailed by the continuous din of the traffic of the streets, and the noise connected with a multitude of public works". [82]

A 32-pounder cannon was provided for the Glasgow experiment by the shipbuilding company of Robert Napier of Govan.[83] Obviously an elevated location would be required, but there was no clear position within Glasgow that matched the site of the Castle Esplanade at Edinburgh. Eventually an open area at Garnethill was chosen, the site belonging to the City Bank It overlooked Sauchiehall Street and could be entered from Renfrew Street at the west side of the McLellan Galleries. Because there were numerous buildings in the area, both domestic and commercial, it would not be possible to fire the gun with a full charge. Holmes acknowledged that the site was temporary, having preferred a position in the West End Park, but thought to be too far from the harbour. Consideration was given to Gilmorehill, the present day location of the University of Glasgow, as being suitably elevated to permit using a full charge of 6 pounds. Provided the gun was placed facing the city, although 3 miles away, it was considered that the report should be heard across the whole centre without difficulty. Like its Edinburgh counterpart, the gun was to be connected by telegraph wire to the Calton Hill Observatory. The wire was laid by the Electric Telegraph Co. and utilised those running adjacent to the Edinburgh to Glasgow railway line. Exclusive access to transmission was offered for the brief period of the daily firing. Edinburgh had used a friction tube as a detonator, this proving

unreliable during its early operations, so the recently introduced Wheatstone Electro Magnetic Exploder would be provided for the Glasgow gun.[84]

The announcement that time gun experiments were to be conducted immediately triggered a brief exchange of letters in the *Glasgow Herald* related to the source of accurate time for providing the signal. It commenced with that of 30 September by F.G.Taylor, a customs official, who considered any astronomical observations from a site between Bridge St and Dale St would not be accurate.[85] Of course this related to the premises of McGregor & Co., the contract holder for the operations of the time ball as described earlier. Their shop with an observatory on its roof was situated on Clyde Place between both noted streets. Taylor considered such measurements required absolute stability and the supervision of an astronomer. Having been granted authority to respond by his employer, William Church wrote a letter that was published on 5 October 1863.[86] He stated that their transit telescope was used to take measurements of numerous stars, producing any differences of determined time all within a few tenths of a second of each other, and regular comparison with the generated time from the College Observatory confirmed the reliability of their equipment. As related earlier, he made mention of the fact that, on one occasion, it was the Observatory's chronometer that was in error when a joint check was made with McGregor time at the Royal Exchange; the conveyor (Rollo) had to return to the Observatory to put the matter right.

Meanwhile the gun had commenced operating at Garnethill on 1 October but proved ineffective, the small charge preventing it being heard within the city centre or along the Clyde over the noise of the traffic.[87] In an effort to overcome this, on 7 October the charge was increased, but this brought complaints from the residents of the area. In particular, one (signed T. Fugit) reported that several of his ceilings had cracked as a result of the concussion, while in another house a young boy had a narrow escape when a large section of plaster fell in the room where he was.[88] There were several schools within the vicinity and, despite being advised of the firing, the children were frightened badly by the event. In view of this it was decided to seek a new site and the Forth & Clyde Canal Company were approached for one in the Port Dundas area. It was agreed that it could be placed on Hamiltonhill, just north of the canal offices, and on one of the highest points overlooking the city.[89] It was moved there in the ensuing week and at 13-00 on

Wednesday 14 October, the cannon fired at full charge.[90] The speed of the move to the new location prevented distribution of revised maps with overlay circles indicating time delays across the city according to the distance of the gun, but posters were placed in various premises, indicating the delays at key locations. It was noted that it took 6 seconds for the sound to reach the Royal Exchange and 7 seconds to be heard on the Broomielaw.

The discussion on the relationship between the time signals and their generation as a result of astronomical observations received a new participant on 12 October, under the pseudonym of 'Tempus Verum'.[91] He came down firmly on the side of Taylor and the College Observatory, accusing Church of appearing "to be in a passion". Contesting Church's assertions over vibrations, he claimed that they must affect the operation equipment at the premises of McGregor & Co. at Clyde Place as it would be possible only to observe the meridian mark during the day, when traffic is heaviest. The term "a few tenths" also raised comment, as he considered it to be ambiguous. Tempus Verum referred to " 'Vega' as a high star and 'Spica' as a low star" and, if he observed them he would expect they would display the "same clock error *within one or two tenths* to the extreme". Should this be greater, he implied the instrument would have been out of adjustment. In the final lines of his letter, Tempus Verum compared the involvement McGregor & Co. with the time ball as an "incongruity akin to a hairdresser interfering with mechanics, or a dairymaid with politics". Within two days Church had returned to the fray, stung by the writer's "vulgar impertinence" in his implications about the operation of the time signal.[92] Church claimed his main objective was to show that McGregor & Co. carried out their remit efficiently and that their Observatory should not be disparaged. He assured his opponents that frequent comparisons were carried out during the day, verifying that the instrument was in no way affected by vibration.

Although the correspondence to date had concentrated primarily on local affairs, on 30 October an editorial in the *Glasgow Herald* raised wider issues.[93] Its content origins came from several concerns voiced elsewhere by the newly appointed Professor of Astronomy at Glasgow, Robert Grant. The first related to what was considered as intrusions by an outside party in establishing the time gun with the firing signal coming from the Royal Observatory Edinburgh under the direction Professor C. Piazzi Smyth. As part of the establishment of the

Observatory in Glasgow, its operations carried an obligation "to furnish the shipping of the Clyde with the correct time" and Grant had been in negotiation with the Town Council on several occasions over this service.[94] The second issue related to a more political concern that Smyth appeared to be over-promoting himself in his position as Astronomer Royal for Scotland despite the existence of an Astronomer Royal at Greenwich, covering all of Great Britain. He appeared to be using his position to gain funding from the national purse for himself and for the Royal Observatory Edinburgh. Since the establishment of the Horselethill Observatory in Glasgow, the running costs, including any salaries of observing assistants, had to be met locally. By contrast, following the transition from being a private body to assuming its new status in 1834, the Royal Observatory Edinburgh, under the control of the local University, was totally financed by central government.[95] Hand in hand with this, the honorary title of Astronomer Royal for Scotland was assumed by the Director of the Observatory. Not appreciating that the position carried this official banner that Smyth used to his advantage, the *Herald* demeaned his title in no uncertain manner ridiculing it as a pretentious nonsense. It was suggested that it was on a par with a title such as "her Majesty's Painter for Scotland or her Majesty's Jeweller for Scotland – there being scores of such titles, which mean nothing, to be found in the west end of London, as well as at Windsor, the Isle of Wight, Edinburgh, Glasgow, and Aberdeen".[96] Later the paper carried a correction on the status of his Royal appointment, but without any apology.[97]

To seek a publicly funded salary for the Royal post was considered unacceptable by the *Herald*, particularly in view of Smyth's lack of courtesy to his Glasgow counterparts on the time gun question.[98] It appears the first that Grant learned of the proposal to establish a time gun was on 24 September when it was announced in the press, and he considered it an unacceptable intrusion by Smyth. Although Glasgow was not fulfilling its formal commitment to Clyde shipping, Grant had been quick to write to the Lord Provost that "under no circumstances whatever, will the University consent to forego this engagement; or permit the usurpation, by any other observatory, of the duties which it imposes".[99]

Response to the Editorial in the *Glasgow Herald* came on the following day from Nathaniel Holmes, manager of the United Telegraph Co.[100] He revealed himself as the prime mover in installing the gun at Glasgow along with Smyth.

Holmes provided explanation on the genesis of the project, following the apparent success of the Edinburgh time gun. At a recent meeting of the British Association at Newcastle it had been agreed to establish a gun there, controlled from Edinburgh. With the United Telegraph Co. having an extensive network throughout Glasgow and agreement made with the Magnetic Telegraph Co. for use of their link from Edinburgh for a maximum of four minutes per day, he considered a gun could be established in Glasgow without significant expense. Lack of proper consultation by Holmes with the Glasgow authorities and the announcement that Napier was to provide a gun took Professor Grant off guard, his chagrin being reflected by the population at large through letters and articles published in the *Glasgow Herald*. Ever optimistic, Holmes indicated that he hoped to install another gun at Greenock in the near future, to assist shipping lying off the Tail o' the Bank. Further aims were to have guns sited at Port Glasgow, Helensburgh and Dunoon to give extensive cover over all the Clyde anchorages. He also promoted the notion that it was easier to check the time carried by any chronometer by responding to the noise of a gun rather than transferring gaze of a public clock face to that of the chronometer at a particular instant. He considered it unjust for blame to be heaped upon Smyth as the organisation of the system had been his own responsibility. In doing so he had not intended any insult either to Glasgow University or to Grant, whom he referred to as the "esteemed professor". His sole aim had been to limit any additional expense by utilising existing systems throughout, including that at the Calton Hill Observatory. Although this letter appears to have been an attempt to placate Grant, he ruined it by concluding that the gun was necessary, stating that Glasgow "had been more than two years already thinking about time but so far without any practical results".[101] This ignored completely the time ball on the Broomielaw and, although Holmes may have "forgotten" courtesies towards Grant, as a fellow professional it would be expected that Smyth should have not done so. This does seem odd as Grant and Piazzi Smyth's father, Admiral W.H. Smyth, were friends having collaborated on the translation of Arago's famous two volume work '*Astronomie Populaire*'.[102]

The movement of the time gun to Hamiltonhill, overlooking the Clyde from the north, proved less than successful, continuing to remain unheard over large parts of the centre of the city. Apparently the problem was a combination of

background noise and topography, the many dips and hollows resulting in the detonation being masked. To counter this, Holmes fitted a small gun on the roof of his company's premises at 15 St Vincent Place (see Fig. 5). This was also linked to the signal from Edinburgh to synchronise with the gun fired at Hamiltonhill.[103] This system commenced operation on 29 October and, on 3 November, James Smith of Jordanhill, in the Glasgow suburbs, wrote to the *Glasgow Herald* detailing his experience of it on Saturday 31 October.[104] He owned a pocket chronometer which had been dropped and damaged a few years previous but repaired by McGregor. Following this he had found it maintained time with great accuracy and he carried it to check the time gun signals. In relating his story, Smith appeared to provide some implicit support for the technical ability and standards of the chronometer maker. Prior to 13-00 hours, Smith had compared the time shown on his chronometer with that indicated on the clock within the Royal Exchange and also the jeweller's premises of James Muirhead & Son in Royal Exchange Square. When the gun fired he recorded that his chronometer coincided exactly with its indication, while the clock at the Exchange was three seconds slow and that at Muirhead's was five seconds slow. He made no mention to whether he applied any sound delay time corrections. He considered this proved the need to have a distinctive accurate time signal on a daily basis controlled from an observatory, whether it was in Glasgow or in Edinburgh he had no preference. He felt, however, that it would be necessary to place a time gun at the harbour as the only way to ensure the same degree of precision there.

This positive tone was not to last, the first untoward incident arising on Monday 9 November, the scheduled day of operation for the third small gun, placed as Smith had suggested at the Broomielaw. A gunshot was heard at 12-20, however, originating from St Vincent Place.[105] It appeared that the charge had detonated prematurely and had to be replaced. Then at 13-00, although the guns at Hamiltonhill and Broomielaw fired as required, that at St Vincent Place failed to do so. It appeared that the electric signal was received but the fuse detonated at the top of the gun rather than within the vent. The Hamiltonhill site fired a 6 pound charge, allegedly audible over a range of five miles, although it was reported on that date it was heard only in the quieter streets and in some of the suburbs. The two smaller guns, probably signal cannons, similar to those

mounted on steamers at this date, used only a 3 ounce charge and were intended to be audible up to a distance of 1000 yards.[106]

Holmes had been absent in London, but on 17 November he travelled to Greenock to have a meeting with the Provost and other interested parties with the aim of providing a time gun there.[107] This was agreed to commence on 21 November on an experimental basis, also using the Edinburgh signal, with the telegraph line of the Glasgow & Greenock Shipping Co. being utilised for three minutes daily, to provide the onward link from Glasgow.[108] The Greenock Harbour Trust provided a site on Allison's Quay at Albert Dock for the gun, the weapon itself being a 32-pounder cannon; McGregor & Co. fitted the necessary electrical detonating equipment.[109] As it was on an experimental basis, a Captain Farquhar RN of the Clyde guardship HMS *Hogue* agreed to supply a gun to perform the operation, which fired for the first time on the agreed date.[110] Soon after a response came from H.M.Tatum at the War Office which carried responsibility for such weapons. On 5 December he advised Holmes that it was normal to use 24-pounder 24cwt guns for such signals and the Earl de Grey and Ripon, Secretary for War, had agreed to their supply. However any ammunition would require to be sourced through the Royal Arsenal at Woolwich and would incur regular expense.[111]

Holmes' correspondence not only produced criticism in Glasgow but resulted on 20 November in a letter from Liverpool, written by R. L. Jones.[112] He was a former station master at Chester who had patented improvements to Bain's original electric master clock system cited earlier. He considered that a considerable number of guns would be required to provide an effective service in Glasgow and that the stroke of a bell would be as effective within the confines of the city. Similar to Grant's proposals, the authorities in Liverpool had been exploring the possibility of controlling public clocks with an electric signal from the city's observatory. In 1860 the original 13 feet long two-second pendulum of the clock in the Victoria Tower which stood in a prominent position along the river Mersey, had been replaced by a one-second version controlled by the Jones' electromagnet mechanism, operating from the observatory one mile distant, and since then had been accurate to within one tenth of a second. Refuting Holmes'

comments about the weight of snow on clock hands causing inaccuracies, Jones reported that this standard of accuracy had been maintained in all weathers and conditions. In addition the mechanism had been utilised for the operation of a time ball for the checking of chronometers. The system had been extended to include smaller clocks placed in shop windows and one at the Exchange Piazza, which was claimed to be consulted as much as fourteen times daily. In terms of cost, not having details of the figures for the guns, he could not give comparison. However, given the continual requirement for gunpowder, cleaning and charging, along with their renewal over time, he suggested that it was probable the master clock system was more economical in the longer run.

Events then took an interesting turn when Holmes was charged and brought to court over the firing of his gun at St Vincent Place.[113] Henry Monteith & Co., textile manufacturers, had premises in the area in George Square and Queen St. and had written to the police, complaining about the daily detonation and demanding action be taken. In consequence Holmes was charged with contravening Section 158 of the Glasgow Police Act 1862 and brought to trial in front of Bailie George Grant at the Police Court on 25 November 1863. It was claimed that, on Monday 15 November, Holmes had "wantonly discharged a cannon or other firearm" from 15 St Vincent Place "to the annoyance or danger of passengers or persons carrying on business in the neighbourhood". Holmes argued that the cannon was not "wantonly" discharged and demanded that the complainers prove it was an annoyance. Although the local beat sergeant described horses at the cab stand in St Vincent Place reacting slightly when the gun discharged, he admitted no complaint had been made to him concerning this. The Procurator Fiscal, John Lang, claimed that burning wadding from the gun was caught by the wind and could prove a hazard to textiles or other soft goods, lying waiting for loading. The area had a high level of commercial traffic, including lorries loaded with hay or tow, while some had gunpowder aboard. The last commodity appears to be unlikely as to do so in this manner would have been a severe contravention of existing explosive regulations. Holmes responded that he had counted over 200 people gathering to listen to the detonation and, as it took place at an advertised time, he did not consider it wanton. In further support of his case he provided the bench with the names of 45 people with businesses in

the area who considered the gun beneficial. Ultimately it was decided that there was no case to answer and, as the operation was an experiment granted by the Corporation, it should be permitted to complete its period of operation.

In the interim Smyth had added fuel to the fire with a report on 14 October 1863 to the Board of Visitors to Edinburgh University.[114] This contained several statements that were inaccurate, including a suggestion that the Glasgow citizens had considered the 1855 time ball demonstration at the British Association Meeting in the College and "did not have enough to fully interest" them. When Wheatstone's magnetic exploder had been proved reliable "the strong common sense of Glasgow's citizens immediately perceived the super efficiency of the new system". His report also mentioned that the gun had been moved from its original position. The reason given for doing this showed acumen of which any modern political spin doctor would be proud. He claimed it had been done due to positive local responses, allowing the charge to be increased "from 2lbs to 8lbs".

6.3 *The Glasgow Response*

Smyth's report had implications that had to be refuted as they were seen to be very damaging both to Grant and the Glasgow College Observatory.[115] It lead to the Senate of Glasgow University issuing a strong rebuttal of the whole time gun project in the form of a letter dated 11 December 1863, with one of the signatories being William Thomson (Lord Kelvin).[116] At this time the College had submitted a memorial on its Observatory to the Treasury of central government, detailing the actions that had been taken, or those proposed to comply with the requirements of the original grant, with the aim of seeking finance for an assistant to Grant. Obviously mute acceptance of Smyth's remarks would be damaging to their case and could lead to withdrawal of support.

The first intimation to the College of the introduction of the gun had been posted in the *Glasgow Herald* of 25 September and, although it was claimed they did not wish to raise the discourtesy shown by Smyth, displeasure was recorded in the Senate's rebuttal of the Edinburgh project.[117] The first issue dealt with was the claim that the time ball experiment at the British Association Meeting of 1855 had indicated that the University of Glasgow assented to permanent transmissions from Edinburgh. This was not so, the University had merely provided the courtesy of facilities for the period of the conference event. Secondly it was

claimed that Glasgow representatives had approached the Calton Hill Observatory in the autumn of 1863 to provide the city with a time gun controlled from Edinburgh. There was no evidence that such an approach had been made, only a verbal approach by Holmes to the Lord Provost being acknowledged. It noted, however, that Holmes had sought permission to fire an experimental time gun within the city and had been advised that the Telegraph Company could do so at its own risk. It would be required to make good any damage incurred and, if complaints were made to the police by any inhabitants, they would "give such a complaint their consideration". Thirdly, once the gun was operational, Smyth claimed that the citizens of Glasgow had confirmed their preference for control of the system to be from Edinburgh and provided a schedule to support this. Again there was no evidence that anyone other than Holmes had endorsed Edinburgh's control of the enterprise.[118]

The Senate admitted that the requirement to provide time signals had not been met previously, partly due to the lack of a the general facility of a large refractor but, with the commissioning of the Ochtertyre telescope on 30 April 1863, this had been remedied. The second problem had been the rural situation of the new Observatory on Horselethill, three miles from the centre of Glasgow with no telegraph facilities available to transmit any signals and this remained under consideration. The third component was the availability of a clock suitable for transmitting the signal but, thanks to the support of local benefactors, such an instrument had now been purchased from Charles Frodsham & Co. of London.[119]

At this point and at its own expense, the University established a telegraph wire from the Horselethill Observatory to the College Buildings in the High Street, permitting the clock in the tower (see Fig. 6) to be controlled remotely. The system was proved over the Christmas period of 1863 with an announcement made of its success early in the new year.[120] At this time Grant prepared a Memorial dated 28 December 1863 to the Lord Provost renewing his offer to have the University Observatory control the time ball and, if required, the time guns, as well as expanding the control to other public clocks within the city.[121] Grant obviously saw the advantages of having a system that would provide the means of controlling public clocks continuously with their bell chimes giving a signal on each hour, rather than simply providing an inconvenient once per day signal with inherent time delay problems. In addition he promoted the idea of installing slave

clocks with large sweep fingers displaying time to the second (see Fig. 7). Nonetheless, operation of the time ball or the time gun could still continue if the Council desired. Grant declared his remit as simply being one of generating accurate time for the city; how it was to be used was for others to decide.

On 13 January 1864 an editorial in the *Glasgow Herald* covered the whole history of the time gun issue, requesting the Council to " 'take such steps as may appear expedient for co-operating with the University in tendering the admirable instrumental appliances, and the resources in general, of the Observatory practically available to the public,' for the purpose of conveying correct time to the city with which it is so closely connected".[122]

Two minor notes appeared in the *Glasgow Herald* around the same time. The first was a concern expressed by Mr Baxedale of the Manchester Philosophical Society by reporting that the American Civil War had demonstrated that artillery could affect the weather.[123] He claimed that experience of sustained bombardments had indicated that they induced rain. The other was an observation by 'JD' who advised that he and a friend had heard the time gun distinctly while standing in Castlecary railway station, some fifteen miles from Glasgow.[124] There was no mention about the time delay that the signal would have suffered.

While Grant's operations and proposals were being considered, it was not until 15 January 1864 that Holmes responded both to the news about the connection to the University clock and the Senate's earlier letter. He claimed that as a result of the actions of himself and Smyth, the "army of talented professors" and Observatory at Glasgow had wakened "from their long repose, startled, dismayed and rebuked".[125] They recognised that the work should have been carried out by them and now could only copy and "not originate". The Edinburgh establishment and Smyth were financed by central government to which Glasgow citizens contribute through their taxes. Therefore to introduce a separate system would mean that they were "paying double". He continued to argue that clocks could not provide an accurate time in the manner of time guns, claiming errors that crept in would not be rectified, even when the master clock was adjusted. Not content with voicing his frustrations over the lack of support in Glasgow, Holmes used a reference to the Newcastle time guns to disparage the Royal

Observatory at Greenwich. This institution had taken over control of the signal to Newcastle in November, dispensing with his services at the same time and, since doing so, it had failed several times, in contrast to the total reliability when operated from Edinburgh. This proved to be a final salvo from Holmes as he announced that the time gun experiments at Glasgow and Greenock were to cease on Saturday 6 February.[126] He considered them as being successful but implicitly acknowledged the lack of local support by stating they could continue only if the various authorities were prepared to make the "necessary pecuniary arrangements". This was followed two days later by a letter from Smyth, addressed to R. S. Symington, Holmes' manager in Glasgow.[127] It congratulated him on the reliability of the test and claimed that until gunpowder was replaced, no better method of signal could be found than the gun. Smyth considered this would never change, even though the use of master clocks was being introduced successfully in several other cities. A formal acceptance that Glasgow University would provide telegraphic signals to the city to control a variety of public clocks was declared on 5 March 1864 a Glasgow Herald editorial.[128] One of the first public clocks included in the scheme was the in the tower of the church of St George Tron and a photograph of it forms Fig. 8. Developments of the control and display of other public clocks in Glasgow soon followed, the system controlled from the University Observatory for some fifty years. In addition to the transit observations made at the University's Observatory serving as the source of the local generation of GMT, from measurements made over a twenty year period, Grant produced the *Glasgow Catalogue of 6415 Stars* in 1883, followed by a second catalogue in 1888.[129] From these data he was able to determine the proper motions of nearly one hundred stars and provided a detailed discussion of forty-three of them.[130]

7. *Conclusion*

As with many cities around the world, during the nineteenth century Glasgow strove to provide time for its river harbour and its citizens involved in commerce. This was in an era when the study of Astronomy was very much geared to positional measurements of stars and their cataloguing, well before the concepts of physical processes within the cosmos were at the forefront of research. The need to carry accurate time to calculate the position of a ship using on board

astronomical measurements was readily appreciated by the majority of directors of commerce involved the movement of cargoes by sea.

Glasgow's quest for the running of a local time service began with the building of its third Observatory at Horselethill initiated by public subscription and established round about 1840. For its completion Professor Nichol obtained a government grant with the condition that the Observatory should supply accurate time particularly to the quayside of the river Clyde so enabling ships' masters to check their chronometers before embarking on sea voyages. Shortly after its opening, the operations of the Horselethill Observatory suffered financial problems and the University agreed to take over complete responsibility for its running. For the next ten years, Professor Nichol made little progress satisfying the government remit with activity limited to taking a chronometer from his Observatory once a week to the Royal Exchange to regulate its public clock which suffered from an irregular rate. In the meanwhile a local nautical supplier, Duncan McGregor & Co., established a transit telescope in his premises close to the quayside enabling ships' masters to check their chronometers for a fee.

Following the establishment of a one o'clock time ball in Edinburgh under the direction of Piazzi Smyth, the Astronomer Royal for Scotland, a demonstration was arranged within the Glasgow College by Sir Thomas Brisbane in 1855 to illustrate how the signal might be operated electrically by telegraph. A few years later, some members of the Clyde Trustees realised that the city's port was being left behind in terms of the lack of provision of a time service. After much debate and with confusion over its cost and on how the signal would be generated, a one o'clock time ball was established on the tower of the newly built Sailors' Home. Discussions on its design and operation were made by men of commerce who had no direct astronomical knowledge. It was decided that an accurate clock should be housed in the Home to control the timing of the ball drop with the operation maintained by McGregor & Co. This was a fly in the ointment for Professor Nichol with his long responsibility to provide time to the city. Fifteen years previously, he had been the 'darling' of the community in offering charismatic lectures and establishing a public observatory chiefly for the purpose of providing time. He appeared to have lost favour with the decision makers of the city's Council Members. This might have been caused by the mishandling of finances at the establishment of Horselethill Observatory resulting with the public

shareholders being paid off, or by living more remotely away from the city centre within the Observatory with his isolation exacerbated by illness and laudanum addiction. Although he had suggested the laying of a telegraph line from the Observatory to the city centre, it was not done with powerful conviction and the Trustees baulked at its cost. He lobbied George B. Airy at Greenwich and Professor Hartnup of Liverpool for support, but the decision had been made to operate the time ball using the services of a private company rather than a more professional astronomical observatory. The time ball seemed to operate successfully for about four years although there was continual disquiet by some members of the City Council as to its efficacy and its running costs.

Shortly after the establishment of the time ball in 1859, Professor Nichol died and the Regius Chair of Astronomy was taken by Robert Grant, a person of much stronger resolution. Although he did not seem to challenge the running by McGregor & Co. of the time ball, the government's remit for the University to provide time for shipping on the Clyde was at the forefront of his mind and he was in communication with the authorities over its implementation. In September 1863 it came as a shock for him to be side-lined by an initiative of Nathaniel Holmes of a telegraph company to operate one o'clock time gun experiments using a signal from the Royal Observatory Edinburgh. For a period of about four months chaos reigned over the project with several guns being employed at different locations but with none being successful in overcoming the general hub-hub of the city. Several members of the general public made their voices heard over the shortcomings of the project and on the choice of where the controlling signal should originate. The local daily *Glasgow Herald* was the vehicle for the discussion and unrest with several letters and editorial articles which could be considered as libellous. The operation of the time gun unleashed the passionate rivalry which has always existed at some level between the cities of Edinburgh and Glasgow. The situation was further complicated in that McGregor & Co. had a financial interest in providing the one o'clock signal. Grant was resolute that the local source of the time should originate from the Horselethill Observatory and administered by the University. He also advocated that the dissemination of time would be better served by having clocks with a long finger sweeping out the seconds under dedicated telegraphic control rather than generating a signal either by a ball drop or by the firing a gun just once per day. With the Glasgow Council

slow to respond, the University Senate sanctioned the laying of a cable from Horselethill to the Old College in the High Street.[131] With the success of this venture, the time guns fell silent and were abandoned. Shortly after, other turret clocks in the city, as well as slave clocks along the river Clyde, were connected to a dedicated time network taking advantage of rapidly expanding electric telegraphic communication systems. With Professor Grant's tenacity, a time service grew rapidly throughout the city. Grant claimed that it was not his responsibility to decide on the form of the display, whether it be a time ball, a gun or clock faces, but only to supply time from the Univsersity's Observatory. In the end it was self-evident that clocks with chimes or with sweep fingers giving time to the second would have superior usage and the telegraphic service from Horselethill drove several tens of displays in the city and along the Clyde. Overall the period from 1855 to 1863 demonstrated how business men with their commerce, academically trained astronomers and the man in the street had influence in setting up a time service. The machinations reveal the complexities and passions of decision making when various bodies and institutions are involved. Grant's system operated for some 50 years until its replacement by a nation-wide wireless radio service.

Acknowledgements

We wish to thank the staff of the Mitchell Library in Glasgow for their generous help in providing access to the archived copies of the *Glasgow Herald*.

REFERENCES

Many of the references relate to the Minutes of Meetings of the Clyde Navigational Trust. These documents have unfortunately been lost but extracts were reported at the time in the local daily newspaper, the *Glasgow Herald.* Other 'Letters to the Editor' and 'Editorial Comments' are also referred to and for brevity this newspaper is simply referred to as *GH.*

1. Sobel, D. *Longitude*. (Fourth Estate, London, 1995) and Dunn, R., Higgitt, R. *Finding Longitude: How ships, clocks and stars helped solve the longitude problem.* (National Maritime Museum, 2014).

2. See the article by Gordon Jackson in *The Glasgow Story* from the internet site: www.theglasgowstory.com in the section headed 'Industrial Revolution' and the page headed 'Trade and Communications'.

3. There are many books and papers relating the history of the Board of Longitude but the story is told simply by Peter Johnson in 'The Board of Longitude 1714-1828', *Journal of the British Astronomical Association*, 99, (1989), 63-69. The operation of the finances of The Board have been described and collated by Derek Howse in 'Britain's Board of Longitude: The Finances, 1714-1828'. *The Mariner's Mirror*, 84, (1998), 400-417.

4. International Conference Held at Washington for the Purpose of Fixing a Prime Meridian and Universal Day. October, 1884. Protocols of the Proceedings. Washington, D.C. Gibson Bros., Printers and Bookbinders, 1884. The document can be found on the internet site: https://www.gutenberg.org and can be read as an e-book free of charge.

5. Sobel, *op. cit.* (ref. 1).

6. See the article of Graham Dolan on the internet site: http://www.royalobservatorygreenwich.org/articles.php?article=1040 for the Royal Greenwich Observatory - Rates of chronometers and watches on trial at the Observatory, 1840-1915, (from the appendices of *Greenwich Observations*).

7. Clarke, D. *Reflections on the Astronomy of Glasgow*. (Edinburgh University Press, 2013).

8. Chapman, R. *The topographical picture of Glasgow in its ancient and modern state, with sketches of a tour to the lakes and romantic scenery in the shires of Dumbarton, Argyll, and Perth, and the Falls of Clyde.* Glasgow: R Chapman, 1820, p.166..

9. Warner, B. 'The William Herschel 14-foot telescope'. *Monthly Notes of the South African Astronomical Society*, 46, (1987), 158-63. See also Board of Longitude Papers – Public Record Office: PRO 28.

10. Letter from Alexander Mitchell to George Knight Esq. T-CN12/516, Glasgow City Archives – Mitchell Library. The letter is undated.

11. Glasgow University Manuscript 117/27402. A Report of the Proceeding at the Dinner of Friends of Astronomical Science – 16 Dec 1836. Glasgow University Archives.

12. A copy of Ertel's correspondence with Nichol and the transit telescope invoice listing the gold scales are given in Clarke, *op. cit.* (ref. 7), pp. 166-167.

13. Coutts, J. *A History of the University of Glasgow (From its Foundation in 1451 to 1909)*, (Glasgow: James MacLehose , 1909), p. 389.

14. An more complete account of the establishment and operation of the Horselethill Observatory can be found in Clarke, *op. cit.* (ref. 7), pp. 152-169. Nichol's contributions to the development to astronomy in Glasgow have also been described by Roy, A.E. 'Glasgow and the Heavens'. *Vistas in Astronomy*, 36, (1993), 389-407.

15. A copy of the transcript of the letter from C.E. Trevelyan from the Treasury Chambers, London, to the Principal of the College of Glasgow is given in Clarke, D. *op. cit.* (ref. 7), p.159.

16. A potted biography of Nichol and his literary achievements can be found in Clarke, D. *op. cit.* (ref. 7), Ch.6 – *A Professor of Eloquence* ; Other insights on Nichol's life as narrated by his son can be found in Knight, W. A. *Memoir of John Nichol, Professor of English Literature in the University of Glasgow*. (Glasgow: James MacLeHose & Sons, 1896).

17. Royal Astronomical Society. 'Report to the Council to the Thirty-ninth Annual General Meeting of the Society'. *Monthly Notices of the Royal Astronomical Society*, 19, (1859), 141.

18. For the detail of the purchase of McGregor's chronometer by the Admiralty, see Clarke, D. *op. cit*. (ref. 7), p. 266.

19. Rates of Chronometers on Trial for Purchase by the Board of Admiralty at the Royal Greenwich Observatory, Greenwich, 1847. Author: Airy, G.B. Greenwich Observations in Astronomy, Magnetism and Meteorology made at the Royal Observatory, Series 2, Vol. 7, pp. F1-F9.

20. Brown, James. *Sketches on the Clyde. No.I. Gourock. No. II. West Kilbride. No. III. Hamilton. And Guide to the Watering Places and Chief Resources of the Clyde*. Glasgow (1862), pp. 12-14.

21. *GH* – 9 April 1859. A short article which includes mention of the charge made for checking a chronometer while in Glasgow's port. Letter from William Church dated 6 April 1859.

22. O'Byrne, W. R. *A Naval Biographical Dictionary*. (London: John Murray, 1849). p. 1261.

23. Wauchope, R., Captain, R.N. *Edinburgh New Philosophical Journal*, 8, (1830): 'Plan for ascertaining the Rates of Chronometers by Signal', pp.160-2 and 'Description of the Signal Post for Instantaneous Signals', pp. 289-91.

24. Bartky, I.R., Dick, S.J. 'The First Time Balls'. *Journal for the History of Astronomy*, 12, (1981), 155-164. See also the summary in Aubin, D., Bigg, C.H., Sibum, H.O. *The Heavens on Earth*. (Duke University Press, 2010).

25. Kinns, R. (2011) 'The Early History of the Edinburgh Time Ball and Time Gun'. *International Journal For the History of Engineering & Technology*, 8, (2011), 264-90.

26. Gunn, R. P. *Alexander Bain of Watten, Genius of the North*. (Wick, 1973). The article has been archived and can be downloaded from the internet site: http://www.electricclockarchive.org using 'Search ClockDoc'.

27. Professor Piazzi Smyth. 'Remarks on the Erection of the Time-Ball of the Royal Observatory, Edinburgh'. *Monthly Notices of the Royal Astronomical Society*, 14, (1853), 23-25.

28. *ibid*.

29. Kinns, *op. cit*. (ref. 25).

30. Thomas Makdougall Brisbane. *Reminiscences of General Sir Thomas Makdougall Brisbane of Brisbane and Makerstoun, Bart.* (Edinburgh, 1860), pp. 13-14.

31. Kinns, *op. cit*. (ref. 25).

32. *GH* – 10 March 1854. Glasgow River Trust Proceedings.

33. Royal Observatory Edinburgh (Archive Collection). 'Time Ball & Mean Time Clock' Register: 1854-5.

34. *GH* – 9 June 1854. River & Harbour Trust Proceedings.

35. Royal Observatory Edinburgh. *op. cit.* (ref. 33).

36. *GH* – 14 September 1855. Part of the Report on the British Association Meeting.

37. Letter from C.P. Smyth to G.B. Airy, 15 October 1855, Royal Greenwich Observatory (RGO) 6/613, Section 16, Leaves 163-5.

38. *GH* – *op. cit.* (ref. 36). Report of Smyth's proposal to establish a time ball in Glasgow.

39. *GH* – 2 July 1856. River Trust Proceedings: Proposed Time Ball.

40. *GH* – 6 August 1856. River Trust Proceedings: Time Ball on the Sailors' Home

41. *ibid.*

42. *GH* – *op. cit.* (ref. 39) ; *GH* – 3 September 1856. Report of the Clyde Trustees Meeting.

43. *GH* – 19 November 1856. Reports of the Clyde Trustees.Meeting.

44. *GH* – 8 April 1857. River Trust Proceedings: Letter from Prof. Nichol re Time Ball.

45. *ibid*.

46. *ibid*.

47. *ibid*.

48. *GH* – 22 January 1857 – Article describing the opening of the Sailors Institute.

49. *GH* – 8 June 1857; *GH* – 24 August 1857; *GH* – 7 October 1857; *GH* – 9 October 1857. All references are Reports River Trust Procedings.

50. *GH* – 24 August 1857 Reports of the River Trust Meeting.

51. Clarke, D., Kinns, R. 'Some New Insights into the History of the Glasgow Time Ball and Time Guns'. *Journal of Astronomical History and Heritage*, 15, (2012), 59-87.

52. *GH* – op. cit. (ref. 49); Brown, *op. cit.* (ref. 19); Complete details and drawings of the clock mechanisms can be found in 'The Glasgow Harbour Time Ball'. *The Practical Mechanic's Journal* III (second series), (London: Longman, Brown, Green Longman and Roberts,1858), pp.179-80.

53. Letter of 14 December [no year given] to George Knight. T-CN12/514 (Glasgow City Archives – Mitchell Library).

54. *GH* – *op. cit.* (ref. 48); *GH* – 9 April 1859; 'The Glasgow Harbour Time Ball', *op. cit.* (ref. 52); Brown, *op. cit.* (ref. 20).

55. *GH* – 6 January 1858. Report of the Clyde Trustees Meeting of 5 January 1858.

56. *GH* – 2 February 1859. Report of the Clyde Trustees Meeting of 1 Februay 1859.

57. *GH* – 6 April 1859. Report of the Clyde Trustees Meeting of 5 April 1859

58. *GH* – 18 April 1859. River Trust Proceedings.

59. *GH* – 12 April 1859. Letter from Prof. Nichol to David Dreghorn.

60. *GH* – 22 April 1859. Letter from William Allan to the Editor of the Glasgow Herald.

61. *GH* – 22 April 1859. Report on the use of the clock within the Sailors' Home.

62. Nichol, J.P. Letter dated to G.B. Airy dated 26 April 1859 – RGO archives 6/515, Leaf 75.

63. *GH* – 4 May 1859. Letter from David Derghorn to the Editor of the Glasgow Herald.

64. *GH* – *ibid*.

65. *GH* – *ibid*.

66. *GH* – *op. cit.* (ref. 61).

67. *GH* – *op. cit.* (ref. 63); Kinns, R. 'Time balls, time guns and Glasgow's quest for a reliable local time service'. *Journal of Astronomical History and Heritage*, 14, (2010), 145-164.

68. Nichol, J.P. *Memorials From Ben Rhydding: Containing The Place, Its People, Its Cures.* London: Charles Gilpin; Edinburgh: James Nichol (1852). A reproduction of the text is available from BiblioLife Publishers, India.

69. *GH* – 11 July 1861. Glasgow Observatory Report by Prof. Grant.

70. *GH* – 5 August 1861. Letter from N. Walker to the *GH* Editor.

71. *GH* – 14 August 1861. Letter from Grant to the *GH* Editor.

72. *ibid.*

73. *GH* – 21 August 1861. Letter from N. Walker to the *GH* Editor.

74. *GH* – 28 August 1861. Letter from Grant to the *GH* Editor.

75. Invoices from D. McGregor & Co. to George Knight Esq. dated 1858 to 1863. T-CN12/535, Glasgow City Archives – Mitchell Library.

76. Cdr W B Bisset. Cape Town's Time-Guns. *Scientia Militaria, South African Journal of Military Studies*, 14, Nr. 4, (1984), 67-71.

77. The Edinburgh One o'Clock Gun. See the web site: http://www.royal-mile.com/castle/oneoclockgun.html for the details.

78. *GH* – 26 September 1863 (a). Article entitled 'The New Time Gun'.

79. *The Scotsman* – 24 September 1863. A transcript of the announcement that the Edinburgh Observatory intended to control the firing of a Time Gun in Glasgow on an experimental basis is presented in Clarke, D. *op. cit.* (ref. 7), pp. 233-234.

80. *GH* – *op. cit.* (ref. 77).

81. *GH* – 26 September 1863 (b). Letter of R. Grant to William Euing of the Royal Exchange, Glasgow – Proposed Transmission of Greenwich Time From Glasgow Observatory.

82. *ibid.*

83. *GH – op. cit.* (ref. 76).

84. *The Scotsman – op. cit.* (ref. 78).

85. *GH* – 30 September 1863. Letter to the Editor by F.G. Taylor entitled 'Time-Gun – Time-Ball Glasgow Observatory'.

86. *GH* – 5 October 1863. Letter to the Editor by W. Church entitled 'The Glasgow Time-Ball'.

87. *GH* – 7 October 1863. Article entitled 'The Time-Gun'.

88. *GH* – 9 October 1863. Letter to the Editor by T. Fugit entitled 'The Time Gun'.

89. *GH* – 12 October 1863. Short Report on the use of Hamiltonhill under the article entitled 'The Time Gun'.

90. *GH* – 15 October 1863. Note is made that the cannon was fired at full Charge in an article with a header entitled 'The Time Gun'.

91. *GH* – 12 October 1863. Letter to the Editor by Tempus Verum entitled 'The Time-Gun and Glasgow Observatory'.

92. *GH* – 16 October 1863. Letter to the Editor by W. Church entitled 'The Glasgow Time Ball'.

93. *GH* – 30 October 1863. Article by the Editor entitled 'The New Time-Gun'.

94. *ibid.*

95. See the website www.roe.ac.uk/roe/history.html for 'A brief history of the Royal Observatory Edinburgh'.

96. *GH – loc. cit.* (ref. 93).

97. *GH* – 23 November 1863. A Note by the Editor.

98. *GH – loc. cit.* (ref. 93).

99. *GH* – 29 September 1863. The Observatory and The Time Gun.

100. *GH* – 31 October 1863. Letter to the Editor from Mr Nathanial J. Holmes.

101. *ibid.*

102. Smyth, W.H. (Admiral), Grant, R. 'A translated and edited version of Astronomie Populaire by François Arago'. (London: Longman, Brown, Green and Longmans – Vol.1, 1855; Vol. 2, 1858).

103. *GH* – 10 November 1863. Article with the header 'Time Gun'.

104. *GH* – 4 November 1863. Letter to the Editor by James Smith entitled 'The Time Gun'.

105. *GH – loc. cit.* (ref. 103).

106. *GH – loc. cit.* (ref. 104).

107. *GH* – 14 December 1863. Article entitled 'The Time Guns'.

108. *GH* – 16 November 1863. Article with the header 'The Time Gun'.

109. *GH* – 16 October 1879. Article entitled 'New Time Signal for Greenock'.

110. *GH – loc. cit.* (ref. 103).

111. *GH* – 21 May 1864. Annual Visitation of the Observatory of the Glasgow University.

112. *GH* – 20 November 1863. Letter by R.L. Jones of Liverpool.

113. *GH* – 26 November 1863. Article entitled 'The St Vincent Place Time Gun'.

114. *Telegraphic Journal* : A Weekly Journal of Electrical Progress - 16 January 1864. An anonymous article entitled 'On time and Time Guns'. Vol. 1, pp. 29-30. (Truscott, Son & Simmons: London). In addition to presenting Smyth's Report on the operation of the Edinburgh Time Ball and Time Gun controlled by the Calton Hill Observatory, the author rues the fact that London appeared to be far behind the more northern cities of the country noting that "true time is scarcely to be had".

115. *ibid*.

116. *GH* – 12 Dec 1863. A Letter from the Senate of the University of Glasgow with the heading 'University of Glasgow on Time Signals'

117. *ibid*..

118. *ibid*.

119. Report of The Professor of Practical Astronomy in the University of Glasgow Addressed to the Committee of the Senate Appointed to Visit the Observastory, April 28, 1864. Glasgow University Library Res. Ann. I15-d.5.

120. *GH* – 5 January 1864. Controlling of the Public Clocks by an Electric Current from the Observatory of Glasgow University.

121. Clarke, *op. cit.* (ref. 7), p. 255.

122. *GH* – 13 January 1864. An Editorial reporting on the story of Glasgow's triumph over Edinburgh and the contributions of Professor Grant in supplying the city with GMT from the University Observatory.

123. *GH* – 5 December 1863. Article entitled 'Glasgow time guns favourable to rain or Glasgow climate'.

124. *GH* – 14 January 1864. Article entitled 'Time Guns'.

125. *GH* – 15 January 1864. Article entitled 'The Time Guns'.

126. *GH* – 3 February 1864. Letter to the Editor from Nath.. J. Holmes - 'Discontinuance of the Time-Guns'.

127. *GH* – 8 February 1864. Article entitled 'The Time Guns'.

128. *GH* – 5 March 1864. An article entitled ‘Transmission of Time from Glasgow Observatory. Electric Operations’.

129. Grant, R. *Catalogue of 6415 Stars for the Epoch 1870*. (Glasgow: James MacLeHose & Sons, 1883); Grant, R. *Second Glasgow Catalogue of 2156 Stars.* (Glasgow: James MacLeHose & Sons, 1888).

130. Grant, Professor. The Proper Motions of the Stars. *Monthly Notices of the Royal Astronomical Society*, 43, (1883), 120-46.

131. *GH – op. cit*. (ref. 116).

Fig. 1.A portrait of John Pringle Nichol at his writing desk.

Fig. 2. The emblem of Duncan McGregor & Co., taken from an envelope. [By courtesy of Mrs M. I. Morris.]

Fig. 3. A sketched portrait of Professor Robert Grant.

Fig. 4. The Glasgow time ball c. 1870 on top of the Sailors' Home on the Broomielaw to the left of a mast head of a tied up ship. [By courtesy of Professor Graham Lappin.]

Fig. 5. The premises of 15 St Vincent Place in the city centre of Glasgow, once holding the offices of the Universal Private Telegraph Company. A time gun was placed on the roof at the end of October 1863 and used for a short period on a daily basis.

Fig. 6. The Old Glasgow College tower which housed a turret clock, the first in the City to be connected by telegraph in December, 1864 to the University Observatory at some 4 miles away. The College was demolished in 1871 but the mechanism of the clock was saved and remains on display at the entrance of the Bute Hall at Glasgow University.

Fig. 7. The rear of the seconds' clock, originally at the the Old Glasgow College, showing a seconds' finger which is connected to a full the large sweep seconds' finger on the outer display face. The front face shows the large finger sweeping out time to the second. The mechanism and face are now housed in the West Quadrangle of Glasgow University.

Fig. 8. St George's Tron Church housed the first 'public' turret clock in Glasgow to be connected in 1865 by the telegraph system from the University Observatory three miles away.