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Magnetism and chronometers: the research of the Reverend George Fisher

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Abstract. Although largely remembered as an astronomer, the Reverend George Fisher (1794–1873) played a significant part in studying the performance and possible improvement of marine chronometers in the mid-nineteenth century. Appointed astronomer to the Royal Navy's Arctic expedition of 1818, while on the voyage Fisher carried out research into the effects of magnetism on the accurate running of chronometers on board ship. By this time, chronometers were standard equipment on many ships and their reliability was a matter of importance to all mariners. Fisher's published findings from this research led to considerable contemporary debate, and also influenced the work of others in the field. Moreover, as papers held at the National Maritime Museum show, he carried on his chronometer research in later life, making further contributions to the subject that have remained somewhat neglected.

The National Maritime Museum (NMM) holds a substantial collection of papers formerly belonging to the Reverend George Fisher (Figure 1), as well as many of his instruments. About half of this collection consists of papers and workbooks relating to Fisher's later career at the Royal Hospital School, Greenwich (which was housed in buildings that now form part of the NMM site), while the remainder relate to his scientific research while serving as a chaplain in the Royal Navy. The research for this paper has drawn on these papers and on the results of Fisher's voyages to the Arctic under the command of Captain David Buchan in 1818 and Captain William Edward Parry in 1821.

Previous discussions of Fisher's life have largely focused on his astronomical research,[1] a tendency that derives from the obituary published in the *Monthly Notices of the Royal Astronomical Society* in 1874. This anonymously written piece concentrated on a limited range of Fisher's research, such as measuring the length of pendulum vibrating seconds to determine the figure of the Earth and his work on the aurora borealis.[2] Yet the obituary ignored Fisher's early work in which he was the first to study the effects of magnetism on chronometers. This paper examines Fisher's research on this topic and seeks to explain the debate that arose from an article he published in 1820. Fisher's chronometer work has been previously considered by Brooks, who placed the

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I would particularly like to acknowledge the helpful comments of Richard Dunn and Jonathan Betts on earlier drafts of this text, as well as Pieter Van Der Merwe for the references relating to Fisher's later academic career.

1 In particular A. McConnell, 'Fisher, George (1794–1873)', *ODNB*, Oxford, 2004 (online edition: http://www.oxforddnb.com/view/article/9495, accessed 23 June 2007).

2 Anon., *Monthly Notices of the Royal Astronomical Society* (1874), **36**, 140–4.

Figure 1. The Reverend George Fisher. © National Maritime Museum, Greenwich, London.

1820 paper in the context of other contemporary studies of magnetic influence on chronometers.[3] Brooks did not, however, consider Fisher's later research on the topic. This paper seeks to redress this by looking at his research in the 1830s, which included the possible use of glass balances and balance springs for chronometers.

George Fisher

Fisher was born in 1794 at Sunbury, Middlesex, to James and Henrietta Fisher. His father was a surveyor who died when George was only three years old. At the age of fourteen George took a job with the Middlesex Insurance Company where he gained a reputation as a diligent and hard worker. He also showed scientific talent, and with the support of well-known figures including Sir Humphry Davy, Sir Joseph Banks and Sir Everard Home he was able to enter St Catherine's College, Cambridge, in 1816 to read Natural Sciences. Fisher's period at Cambridge was not an easy one, however: his studies were interrupted by illness and by appointments to two British naval expeditions. As a result he did not graduate with a BA until 1821, gaining his MA in 1825.

Although the two naval expeditions prolonged his Cambridge studies, they had a lasting effect on Fisher's life, leading in particular to his first published article on the effect of magnetism on chronometers.[4] Fisher also wrote much of the scientific appendix to Parry's journal of his second voyage in search of the North-West Passage, which

3 R. C. Brooks, 'Magnetic influence on chronometers, 1798–1834', *Annals of Science* (1987), **44**, 245–64.

4 G. Fisher, 'On the errors in longitude as determined by chronometers at sea, arising from the action of the iron in the ships upon the chronometers', *Philosophical Transactions* (1820), **110**, 196–208.

presented further chronometer observations as well as the results of other experiments that Fisher had undertaken.[5] His contribution to Arctic expeditions and exploration was formally recognized by the Navy when they named Cape Fisher on the south-western end of Winter Island in Foxe Basin in the Canadian Arctic.[6] In addition to the published works arising from his Arctic voyages, the NMM collection contains later unpublished work, included in this study to assess Fisher's overall contribution to chronometer research.

The marine chronometer

The chronometer was developed primarily as an instrument for determining longitude. Since longitude is a measurement in the direction of the Earth's rotation, a difference in longitude between two places can be thought of as the difference in their apparent local times as determined by the sun's position. Knowing the times both where a ship is (from the sun) and at some reference point (such as Greenwich) would allow one to calculate the difference in local times and thus the difference in longitude between the current position and the reference. So one way of determining longitude would be to carry an accurate timekeeper, which maintained the time at the reference point. The principle of longitude determination by timekeeper had been understood since the sixteenth century, but it was not until the second half of the eighteenth century that the work of John Harrison, John Arnold and Thomas Earnshaw made it a practical reality.[7] Overseeing this period of development was the Board of Longitude. This body had been established as a result of the 1714 Longitude Act in response to demands from the public, naval officers, the merchant marine and British commercial interests for a solution to the longitude problem. The act famously followed the loss of around two thousand lives, when part of Sir Cloudesley Shovell's fleet was wrecked off the Scilly Isles in 1707, Britain's worst maritime disaster to that time. Although the cause of the disaster is still debated, it was felt by some contemporary observers that it could have been avoided if Shovell had been able reliably to determine the longitude.

The new board was given funds to support and encourage research into the longitude problem, with a maximum prize of £20,000 for a practical solution, if proven successful to within well-defined limits of accuracy. Ultimately this prize went to John Harrison for his invention of an accurate marine timekeeper, although the board also encouraged and rewarded many others, including the mathematician Tobias Mayer, who produced reliable lunar tables in 1755. With tables like Mayer's, mariners were able to establish longitude by measuring the moon's position with a sextant, or similar instrument, relative to one of the stars listed, using this as a sort of clock to determine the time at the reference point. This was known as the lunar-distance method of longitude

5 W. E. Parry, *Appendix to Captain Parry's Journal of a Second Voyage for the Discovery of a North-West Passage from the Atlantic to the Pacific*, London, 1825.

6 C. R. Markham, *The Arctic Navy List, 1773–1873*, London, 1875, 16.

7 For more detail on the development of the chronometer see W. E. May, 'How the chronometer went to sea', *Antiquarian Horology* (1976), 9, 638–63; R. T. Gould, *The Marine Chronometer: Its History and Development*, London, 1922, 54–78; W. Andrews (ed.), *The Quest for Longitude*, Harvard, 1996.

determination. The Royal Observatory at Greenwich had been founded principally to put this method into practice. The necessary navigational tables were published annually in the *Nautical Almanac* from 1766, with each edition incorporating tables for three years ahead.[8] The board also took on other roles. From 1819, for example, it offered rewards for progress towards the North-West Passage and the North Pole, although only one of these was ever given out, when Parry's expedition reached 113° west in 1820, for which the board awarded £5,000.[9]

The main problem with the lunar-distance method, however, was that a clear night was required for accurate observations and even then the moon could not always be seen, being, for example, invisible at night around the new moon. Moreover, the calculations required to reduce a lunar-distance observation to a longitude were complex and time-consuming. Although reliant on a more costly instrument, the chronometer method thus had the advantage of relative simplicity and reliability, although sufficiently clear weather for an observation of local time was still needed. The importance of testing and improving this new technology for the Royal Navy meant it soon found a place on voyages by explorers such as Cook in the Pacific Ocean.[10] By the nineteenth century the widespread use of chronometers sustained an age of British naval exploration. Yet the new technology was not without problems. Although Cook was extremely impressed with the timekeeper Kendall number 1 (an exact replica of Harrison's prize-winning H4), donated by the Admiralty to test on his second voyage to the Pacific from 1772 to 1775, he noted that its rate decreased during the expedition.[11] The rate is the amount by which a chronometer gains or loses time compared to mean solar time. If this rate is constant for a specific chronometer, then with a correction applied to any reading it can be reliably used for determinations of longitude. Conversely, if a chronometer's rate cannot be relied upon (if the rate changes in an unpredictable way), then the problem of accurately determining longitude remains, since there is no way of ascertaining the correction to apply to a specific reading. This was another area in which the Board of Longitude found a role, since as well as offering financial rewards, the board supported British voyages of exploration, in particular by supplying instruments, including chronometers. In these cases the chronometers came with instructions to test their rates during the voyage as part of a continuing programme to assess their reliability.

Ensuring the accuracy and reliability of chronometers was essential. Considerable skill was involved in their manufacture, the 'elite branch of the British watch making industry'.[12] Competition between manufacturers was also fierce. John Arnold and

8 P. Johnson, 'The Board of Longitude 1714–1828', *Journal of the British Astronomical Association* (1989), **99**, 63–9, 66; D. Howse, *Greenwich Time and the Longitude*, London, 1997.

9 Johnson, op. cit. (8), 68.

10 J. Cook, *A voyage to the Pacific Ocean: undertaken, by the command of His Majesty, for making discoveries in the Northern Hemisphere: to determine the position and extent of the west side of North America … performed under the direction of Captains Cook, Clerke, and Gore, in His Majesty's Ships the Resolution and Discovery, in the years 1776, 1777, 1778, 1779, and 1780*, London, 1784.

11 Cook, op. cit. (10), 4.

12 A. C. Davies, 'The life and death of a scientific instrument: the marine chronometer, 1770–1920', *Annals of Science* (1978), **35**, 509–25, 524.

Thomas Earnshaw, for example, both published pamphlets criticizing the work of other watchmakers and publicizing inventions that, they claimed, improved the performance of their own chronometers.[13] Similarly, Thomas Mudge junior was moved to challenge potentially damaging criticisms of his father's work by Nevil Maskelyne, fifth Astronomer Royal, and published two works questioning Maskelyne's assessment.[14] It is within this culture of competition and constant striving to improve the performance of chronometers, therefore, that one should view the work of George Fisher.

Fisher's first voyage, 1818

George Fisher's contribution to the debate over the accuracy of chronometers began after he was appointed astronomer to the 1818 Arctic expedition. The British government was by then sensing threats from Russia's Arctic explorations, in particular the prospect that Russian vessels might infringe British interests in North America. This perceived threat led John Barrow, second secretary of the Admiralty, to order a major expedition to the Arctic since he had been informed by the whaling captain William Scoresby that retreating ice in the polar regions might allow easier passage there.[15] Barrow, a well-known geographer, later became principal patron both of Arctic voyages of discovery and of other naval explorations across the globe.[16] Barrow's proposal for the 1818 expedition had two aims: to attempt to discover the North-West Passage, which would allow British ships easy access to the Pacific, and to reach the North Pole. The search for the North-West Passage was assigned to Captain John Ross and that for the North Pole to Captain David Buchan, with each given two ships to command. Writing in the same year, Barrow boasted that no other polar expedition had 'been fitted out on so extensive a scale or so completely equipped in every respect as the two which left England this year'.[17]

Having been recommended by the Royal Society, George Fisher was assigned to Buchan's ship HMS *Dorothea*. His orders regarding the scientific research to be carried out were both broad and extensive, with a strong emphasis on testing the rates of chronometers, particularly in the cold temperatures of the Arctic. Besides this, Fisher was to study and record the variation and inclination of the Earth's magnetic field and test the extent to which it was affected by atmospheric electricity. The *Dorothea* was

13 E. G. Forbes, 'The origin and development of the marine chronometer', *Annals of Science* (1966), **22**, 1–25, 13–22.

14 T. Mudge the younger, *A Narrative of Facts relating to Some Timekeepers Constructed by T. Mudge for the Discovery of the Longitude at Sea, Together with Observations Upon the Conduct Of the Astronomer Royal Inspecting Them*, London, 1792.

15 B. M. Gough, 'British–Russian rivalry and the search for the north-west passage in the early nineteenth century', *Polar Record* (1986), **23**, 301–17, 308.

16 A. Savours, *The Search for the North West Passage*, London, 1999, 39; F. Fleming, *Barrow's Boys*, London, 1998.

17 J. Barrow, *A Chronological History of Voyages Into the Arctic Regions; Undertaken Chiefly for the Purpose of Discovering a North-East, North-West or Polar Passage Between the Atlantic and Pacific*, London, 1818, 364.

Figure 2. Frederick William Beechey, *Expedition Beset in the Ice off Red Hill. June 14th 1818*. Both Fisher's ship *Dorothea* and the expedition's second ship *Trent* are shown in this image from Beechey's account of the expedition (National Maritime Museum, no. PAD6116). © National Maritime Museum, Greenwich, London.

equipped with apparatus especially for this purpose. There were also orders to study any currents and tides the expedition might encounter and to take samples and measure the depth of the sea.[18] Finally, if the expedition succeeded in reaching the North Pole, Fisher was also instructed to supervise the capture and collection of animal, plant and mineral samples, to measure the dip of the horizon with his dip-sector and compare his instruments' performance over ice and sea.[19]

Ultimately Buchan's expedition was unsuccessful. Before the ships set sail, John Franklin, who commanded the second ship on the expedition, HMS *Trent*, had noted in his journal that he felt they should have had more whalers on board since they had more experience of the polar seas than he and his crew.[20] As it turned out, the ships ran into difficulty to the north of Norway near the island of Spitsbergen, where they spent the winter. Returning to Britain the following spring, the expedition had failed even to threaten Scoresby's 1806 record for the most northerly latitude reached (81° 31′ north), let alone reach the North Pole (Figure 2). It is unlikely that the mission could have succeeded: the journey is only possible using a modern steel-hulled icebreaker, very different from the 1818 expedition's wooden vessels.[21] Yet this apparent failure increased the importance of Fisher's presence. As Barrow had explained, even if it failed in the primary objective of reaching the North Pole, the scientific investigations performed during the journey would make the effort worthwhile.[22]

Indeed, the winter spent on Spitsbergen did benefit Fisher's research. In Frederick William Beechey's account of the voyage, the sole published report, Fisher wrote up the results of many of his experiments. This included detailed research on determining the figure of the Earth through the length of the pendulum vibrating seconds, as well as

18 F. W. Beechey, *A Voyage of Discovery Towards the North Pole: Performed in His Majesty's Ships Dorothea and Trent Under the Command of Captain David Buchan R.N., 1818; to which is added, a summary of all the early attempts to reach the Pole*, London, 1843, 9–10.

19 Beechey, op. cit. (18), 17–19.

20 John Franklin's journal, January to 2 June 1818, Scott Polar Research Institute (SPRI), MS 248/270, 3.

21 Savours, op. cit. (16), 43.

22 Barrow, op. cit. (17), 367.

Figure 3. Chronometer no. 326, by John Arnold and Son, 1797, formerly owned by George Fisher. This is likely to be one of the chronometers referred to in Fisher's notes on the 1818 voyage (National Maritime Museum, no. ZAA0067). © National Maritime Museum, Greenwich, London.

recording the temperature of the sea.[23] But it was not for these results that Fisher's work became well known. Rather, it was his research on chronometers, published in the *Philosophical Transactions* upon his return, which brought him to wider attention.[24]

'On the errors of longitude'

Although Fisher did not identify the specific chronometers he used for his research on the *Dorothea*, he did note that he had four chronometers made by Arnold (Figure 3), two by Earnshaw and one each by Pennington, Baird and Barraud.[25] No serial numbers for any of these instruments were given, but in an account of his preparations Franklin itemized the four chronometers on board the expedition's second ship, HMS *Trent*: Earnshaw 364, Pennington 150, Baird 1733 and Arnold 2149. The last had been given to Franklin by Captain Buchan, and was presumably on test from the Admiralty, as

23 Beechey, op. cit. (18), 333–9.
24 Fisher, op. cit. (4).
25 Fisher, op. cit. (4), 200.

were the Earnshaw and Pennington chronometers.[26] The Baird chronometer was sent by a Mr Daniel Moore, although no reason is given for this. It is likely that Moore was the barrister of that name from Lincoln's Inn who was a member of the Royal Society (elected in 1810),[27] as well as secretary of the Geological Society of London.[28] Most of the chronometers were supplied by the Admiralty on behalf of the Board of Longitude, following the usual procedure of the time.[29]

Fisher's published paper began by disproving the received theory that the rates of the chronometers were affected by the ship's motion. He had observed instead that they continued to accelerate despite the ships becoming encased in ice. It was only once Fisher had removed the chronometers from the ships and placed them on land, while the expedition wintered on Spitsbergen, that they began to return to their normal rates.[30] Instead, Fisher concluded that the chronometer rates were being affected by magnetism, which he could reasonably attribute to one of three different sources. The first was geological magnetism, particularly from basaltic rocks, but these were not common on Spitsbergen where Fisher made his observations, so this possibility could be discounted. The other two factors were terrestrial magnetism and shipboard iron. During the 1818 voyage the Arctic seas would predominantly have been under the influence of dip (the vertical element of the Earth's magnetic field), rather than the relatively weak horizontal force from the Earth's field evident there, so again this would only have been a minor factor. Shipboard iron, however, including stoves, iron rods, chains and anchors, all of which were magnetic due to their manufacture, did seem likely to have a significant influence.

On the expedition's return to England Fisher carried out a series of experiments to test his new theory that magnetic influences affected the chronometers' rates by placing a magnet within the plane of the balances of four chronometers. He varied the position of the magnet for each, concluding that placing chronometers aboard ship should be done with due consideration of nearby magnetic materials that might affect the chronometers and that onshore rating could never be reliable since the subsequent influence of magnetic elements on the ship would alter the rate of the chronometers. Brooks has noted that Fisher's appears to be the first published proposal for rating chronometers *in situ*, although he suggested that it was probably not the first time such a call had been made.[31] However, there is no evidence of such a suggestion in the Minute Books of the Board of Longitude before Fisher sent his paper to them in 1820. In response, the Board thanked him for his work and recommended that he present it to the Royal Society, in whose journal it was subsequently published.[32]

26 John Franklin, Account of Preparations for the British Naval North Polar Expedition, 1818, SPRI, MS248/270. Moore also sent his chronometer on Franklin's overland polar expedition in 1819.

27 Certificate of Election of Daniel Moore (*c*.1760–1828), Royal Society, MS EC/1810/06.

28 H. B. Woodward, *The History of the Geological Society of London*, London, 1907, 6.

29 May, op. cit. (7), 656.

30 Fisher, op. cit. (4), 202.

31 Brooks, op. cit. (3), 248.

32 Board of Longitude minutes, 1 June 1820, Cambridge University Library (CUL), MS RGO 14/7.

The chronometer balance and spring

Fisher's suggestion that magnetic influences could affect the performance of chronometers was perfectly plausible given the methods of construction used. The oscillatory system in a chronometer, the 'beating heart' which actually keeps time, consists of a balance which swings under the influence of its balance spring. A typical chronometer balance completes 345,600 of these cycles a day. If it is inconsistent by just eight of those swings it will be inaccurate by up to two seconds by the end of the day and would be considered a poor timekeeper. In most chronometers of Fisher's period the balance had bimetallic rims made of brass and steel for temperature compensation, while the balance spring itself was usually made of hardened steel. Although many other parts in the chronometer's movement were also made of steel, it was these two critical elements that were principally affected by magnetic forces. Any tests using strong bar magnets close to chronometer balances and springs would affect their rate and probably cause irreversible magnetic 'damage' to the oscillatory system. Gain or loss of time by a chronometer was not in itself a problem. If it were known that the instrument would gain thirty seconds in a day then that became its rate (+30 s/d); a mariner could apply this to his calculations when checking the mean time for the chronometer. The particular problem that Fisher was observing was an irregularity in the rates. In his case, the chronometer rates were accelerating, rendering any readings from them unpredictable.

However, Fisher's conclusions regarding the changing rates were not shared by Edward Sabine, his fellow scientist on the joint expedition. Sabine had been assigned to Captain Ross's search for the North-West Passage and given the same scientific instructions as Fisher.[33] To protect against shocks, the chronometers under Sabine's supervision were suspended by steel spiral springs from the ceiling of Ross's cabin, where there would also be less risk of interference.[34] In his research notes Sabine recorded similar results to Fisher, with the rates of all but one of his chronometers accelerating during the voyage, yet he came to different conclusions.[35] In a letter to a friend he attributed the chronometers' accelerated rates to rough seas, noting a particularly large wave that struck his ship. He also complained that Captain Ross lit fires in his cabin, causing temperature changes that might also have affected the rates of the chronometers.[36] The symptoms being observed in these tests were almost certainly attributable to a then unknown phenomenon to which new chronometers were often prone, known as acceleration. This effect is still not fully understood, but many new chronometers accelerate their rate, even when in stable and still environments. This may have accounted for some of the problems encountered in these trials.

33 J. Ross, *A Voyage of Discovery, Made Under the Orders of the Admiralty, in His Majesty's Ships Isabella and Alexander, for the Purpose of Exploring Baffin's Bay, and Enquiring Into the Probability of a North-West Passage*, London, 1819, 9–11.

34 Ross, op. cit. (33), 198.

35 E. Sabine, 'Chronometers: Determination of Latitude and Longitude: Account of Performance on Isabelle Voyage', the National Archives (NA), BJ 3/62.

36 Edward Sabine to 'My Dear Friend' (possibly James Rennell), 22 June 1818, SPRI, MS862;BJ.

Rather than chronometers, Sabine's main research concentrated on the effects on the ships' compasses of magnetism caused by iron. This was of increasing interest to the Royal Navy, particularly after the observations by Matthew Flinders during his voyage to the Pacific in 1801–3. Flinders had found that he obtained varying compass readings at different locations on board his ship and attributed the variations to the magnetic influence of iron in the ship's construction, claiming credit as the first to do so,[37] although Fanning notes that this had previously been suggested in 1538 by a Portuguese sailor, Don João de Castro.[38] Sabine's work was published in 1819 in the *Philosophical Transactions* with another paper in the same volume by William Scoresby, who had come to similar conclusions. Both suggested that the presence of magnetically sensitive materials could have significant effects on the accuracy of compasses.[39] Such was the interest in this area that two of the captains on the 1818 expeditions, Ross and Franklin, also took notes on the subject. Ross published his thoughts in his account of the voyage.[40] He and Sabine had argued over the credit for the scientific results of the expedition, hence both published results, while Franklin's went unpublished. Both made similar observations and suggested that compasses should be placed at different locations around the ship in order to determine and eliminate the consequent inaccuracies.[41] Magnetic influences were to become an even greater problem in the following decades, following the launch of the first iron steamship the *Aaron Manby* in 1821 and the construction in 1860 of HMS *Warrior*, the Royal Navy's first iron-hulled battleship, marking the beginning of the ironclad navy. The quest to ensure the accuracy of compasses on the new iron ships resulted, among other things, in a long-standing dispute between Scoresby and the seventh Astronomer Royal, George Airy.[42]

Surrounded by such interest in the effects of magnetism on compasses, it is unsurprising that Fisher considered its effects on chronometers. He was not the first to consider the effects of magnetism on timekeepers. In 1798 Samuel Varley, a London watchmaker and jeweller, had published an article examining the ways in which magnets affected his watches.[43] Varley observed that he was able to alter the rate of a watch by placing a magnet on its balance, noting 'that watches of considerable price, and from the hands of excellent workmen, often perform no better than a plain one of inferior workmanship and of much lower price'.[44] Davies has further suggested that Varley's

37 M. Flinders, *A Voyage to Terra Australis in the years 1801, 1802 and 1803; Vol. II*, London, 1814.

38 A. E. Fanning, *Steady as She Goes: A History of the Compass Department of the Admiralty*, London, 1986, p. xxii.

39 E. Sabine, 'On irregularities observed in the direction of the compass needles of HMS Isabella and Alexander, in their late Voyage of Discovery, and caused by the Attraction of the Iron Contained in Ships', *Philosophical Transactions* (1819), **109**, 112–22; W. Scoresby, junior, 'On the anomaly in the variation of the magnetic needle as observed on ship-board', *Philosophical Transactions* (1819), **109**, 96–106.

40 Ross, op. cit. (33), p. xiii (appendix).

41 J. Franklin, Notes on Magnetism, 1818, SPRI, MS248/275.

42 See A. Winter, '"Compasses All Awry": the iron ship and the ambiguities of cultural authority in Victorian Britain', *Victorian Studies* (1994), **37**, 70–98.

43 S. Varley, 'On the irregularity in the rate of going of time-pieces occasioned by the influence of magnetism', *Philosophical Magazine* (1798), **1**, 16–21.

44 Varley, op. cit. (43), 16.

work was inspired by the performance of the chronometers on Vancouver's expedition to the Pacific between 1791 and 1795.[45] It is possible, therefore, that Fisher read Varley's work and that it inspired him to apply similar ideas to chronometers. Gould has suggested that the chronometer manufacturer John Arnold senior also performed similar experiments before Fisher, but there is no written account of such work, so Fisher can still be judged the first to link magnetism to the acceleration of chronometer rates.[46]

Other theories

Before Fisher's publication, various reasons had been suggested for the changes in chronometer rates observed by ships' captains. The Board of Longitude received several potential solutions to the problem, most of which it rejected. These included suggestions like that of Robert Warters, who assumed that the problem was caused by temperature variations. Sabine thought the same when he criticized Ross for lighting the stove in his cabin. Warters assumed that there was a certain depth across all the oceans (which he guessed as about twelve feet) where the temperature was constant. He thus proposed regulating chronometers by keeping them submerged at this depth in a sealed container.[47] Other proposals included mechanical improvements, such as Grimaldi's proposal which claimed to be a 'simple and mathematical construction'.[48] His new design had no mainspring, weight chain or line, as a result of which, so Grimaldi claimed, it would not suffer from problems such as the chain breaking or deficiencies in the elasticity of the spring.[49] Grimaldi's design was tested by the sixth Astronomer Royal, John Pond, who did not consider it an improvement.[50]

Contemporary criticism of Fisher

The differing conclusions from the two 1818 voyages reflect the fact that Fisher was the leading early commentator on the effects of magnetism on chronometers. A number of Fisher's contemporaries soon responded to his published article. One of the first was the mathematician and optician Peter Barlow, who fairly argued that Fisher's results had been obtained by flawed methods, since the bar magnet he had used was so powerful that it would cause a strong temporary derangement of its latent magnetism, leading to a temporary local pole.[51] Instead, Barlow used a large iron sphere as a magnetic source, and then tested the rates of six chronometers to determine their reaction to its field. Despite criticizing Fisher's methods, Barlow broadly agreed with his conclusions and

45 A. C. Davies, 'Horology and navigation: the chronometers on Vancouver's expedition, 1791–95' *Antiquarian Horology* (1993–4), **21**, 244–55, 254–5.

46 Gould, op. cit. (7), 311.

47 R. Warter's proposal to regulate chronometers by keeping them in the sea, 4 August 1783, CUL, RGO 14/23.

48 Board of Longitude minutes, 5 March 1812, CUL, RGO 14/7.

49 Grimaldi to the Board of Longitude, 2 March 1812, CUL, RGO 14/24.

50 Board of Longitude minutes, 3 June 1813, CUL, RGO 14/7.

51 P. Barlow, 'On the effects produced in the rates of chronometers by the proximity of masses of iron', *Philosophical Transactions* (1821), **111**, 361–9, 363.

even ended with a similar recommendation that chronometers should be placed away from large pieces of iron in order to isolate them from the effects of magnetism on board ship.[52]

Criticism of Fisher's work also came from the Arctic expert William Scoresby, the same man who in 1817 had encouraged John Barrow to commission the expedition on which Fisher sailed. Scoresby argued, incorrectly, that the Earth's magnetic field was likely to have a much greater effect on the rate of chronometers than local magnetism.[53] So although Scoresby felt that Fisher's observations were the result of both local and terrestrial magnetism, he ignored the effects of local magnetism and proposed three ways of eliminating the effects of the Earth's field: (1) use a non-ferrous metal to make the balance (he recommended platinum), (2) free the balances from any magnetism, and (3) give the chronometer a fixed position in relation to the magnetic meridian.[54] Scoresby felt that his third solution was most likely to succeed completely.[55] Yet it was also the most impractical, since it required mounting a chronometer in such a way that it could be rotated to keep it aligned in a constant orientation relative to the Earth's magnetic field.

The strongest challenge to Fisher's work came, however, from the American chronometer-maker William Cranch Bond.[56] Bond felt that Fisher was wrong to claim that a ship's magnetism was fixed, arguing instead from the 'well known' fact that 'a bar of iron … will affect the magnetic needle very differently when placed in different positions as it regards the magnetic equator'. In Bond's opinion, therefore, different headings of the ship would affect a chronometer's rate differently, some accelerating it more than others.[57] Bond's conclusion bears a striking similarity to Flinders's work on magnetism in compasses. Having recorded 225 ratings (rates before and after a voyage and rate on board) from 133 chronometers, Bond concluded that there was little, if any, change between the mean rates before and after being placed on ships, and that chronometers did 'not gain in their rates in consequence of being removed to the vessel'.[58] As Brooks has argued, Bond was somewhat overstating his results since his tests on board ship were not regulated, with little control over the lengths of voyages and cargoes carried. All Bond proved, therefore, was that 'given a large number of chronometers, there is no systematic difference either gaining or losing in the sea–land rates.'[59]

Brooks has viewed the publication of Bond's article as marking the end of serious interest in the debate over chronometers and magnetism, since he found no mention of

52 Barlow, op. cit. (51), 381.

53 W. Scoresby, 'Observations on the errors in the sea-rates of chronometers arising from the magnetism of their balances; with suggestions for removing this source of error', *Transactions of the Royal Society of Edinburgh* (1823), **9**, 353–64, 353–4.

54 Scoresby, op. cit. (53), 358–9.

55 Scoresby, op. cit. (53), 361.

56 W. Cranch Bond, 'Observations on the comparative rates of marine chronometers', *Memoirs of the American Academy; Arts and Sciences* (1833), **1**, 84–90.

57 Bond, op. cit. (56), 85.

58 Bond, op. cit. (56), 86.

59 Brooks, op. cit. (3), 256.

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the topic in Brewster's 1837 publication, *Terrestrial Magnetism*, and no new articles in Barlow's entry for the *Encyclopaedia Metropolitana* (1848).[60] Fisher's own research seems initially to confirm this, since his scientific findings from Parry's second voyage (1821) made little reference to chronometers beyond the mandatory rate observations. The report in the appendix to Parry's journal concentrated instead on terrestrial refraction and magnetic dip.[61] Nevertheless, a large amount of material in Fisher's surviving personal papers relate to later investigations into the effects of magnetism on chronometers. Moreover, some of this research was published, while some unpublished material reveals the subsequent involvement of Airy in Fisher's work.

Fisher's later chronometer research, 1832–40

Fisher's subsequent research can be divided into two parts, the first carried out at Portsmouth, the second at Greenwich. The Portsmouth research was published in the *Nautical Magazine* in 1833 and contained Fisher's observations on a new glass spring designed to eliminate the effects of magnetism.[62] The research followed experiments in the early 1830s by the well-known chronometer-makers Arnold and Dent, with glass balances and springs. They had hoped that by making these parts non-metallic they would reduce the effects of magnetism. But this proposal had encountered criticism from those who felt that glass was too brittle to be used in a chronometer and would shatter. Yet once their idea came to the attention of Admiral Sir Thomas Williams, he instructed Fisher, then chaplain of HMS *Victory* in Portsmouth harbour, to make further tests. Fisher's resulting article indicated that he had accidentally 'tested' the balance's durability by dropping the chronometer when he first received it. He returned the chronometer to Arnold and Dent to be repaired, but they reported that neither the balance nor the spring had been broken by the fall. Upon its return, Fisher further tested the chronometer's durability by placing it near a cannon and firing the gun. His final test was to fire an entire broadside nearby to see if this had any effect on the chronometer. Fisher's subsequent experiments showed that the glass balance was quite acceptable and had performed as well as any metal balance under the conditions, but without the additional problems caused by magnetism. Concerns that gunfire might affect the performance of navigational equipment increased as weapons became more powerful, and were still salient nearly fifty years later in 1879 when the Royal Navy began tests on Sir William Thomson's new design of compass on HMS *Northampton*, under the command of Captain J. A. Fisher (no relation to the Rev. George Fisher).[63]

Fisher soon returned his attention to the effects of magnetism on chronometers. His further work in the late 1830s was described in two notebooks in his personal papers in

60 Brooks, op. cit. (3), 263 – although Brooks does note that it seems likely that Barlow actually wrote the section as early as 1823.

61 Parry, op. cit. (5), 165–88.

62 G. Fisher, 'Experiments on chronometers; glass balance springs', *Nautical Magazine* (1833), **II**, 737–8.

63 Fanning, op. cit. (38), 107.

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the NMM.[64] The first concerns tests performed on fifteen chronometers in 1835 for the chronometer-maker Edward Dent, in which the change in their rates was measured during a journey between Hartwell Observatory in Buckinghamshire and Greenwich.[65] The observatory at Hartwell had been built on the estate of John Lee, like Fisher a Fellow of the Royal Society, as well as a member of the Royal Astronomical Society. Lee was justly proud of his observatory, renowned as one of the best in Britain, well stocked with modern equipment.[66] The surviving notebooks contain little analysis and are predominantly a set of results giving the serial number of each chronometer and an account of its rate during the journey, showing how it changed over time. The findings were presumably sent to Dent to help with his work.

The second notebook contains the results of experiments to monitor the rates of chronometers in three separate trials. The first involved suspending the chronometers, in the second the chronometers' gimbals were clamped, while in the third Fisher placed the chronometers on pads of wool.[67] The results were published in the *Nautical Magazine* in 1837, where Fisher claimed that a solution to the problem of the acceleration of chronometer rates would be 'one of the most important contributions ever made to nautical astronomy'.[68] The paper supported a previous article in the *Nautical Magazine* by Arnold and Dent that had in turn endorsed Fisher's theory of the effects of magnetism. Fisher then revisited his earlier research into the effect on a chronometer's rate of its position relative to the magnetic azimuth, claiming that his results showed that these added up 'to a very serious amount'. The article concluded by promising more research on the problem, which Fisher hoped to publish in the near future.

However, this research was never published, largely due to the intervention of George Biddell Airy, the newly appointed Astronomer Royal. In 1836 Fisher had sent the results of the experiments described a year later in the *Nautical Magazine* to Airy for his inspection, but had received no response to his letter.[69] Having carried out further tests, Fisher noticed some anomalies in his results that he was unable to explain and wrote to Airy for his advice on the matter.[70] Four days later Airy wrote back with his conclusions, which would have been unwelcome to Fisher, since Airy concluded that the 'inequalities of these chronometers are more likely to be caused by something mechanical than by magnetism'.[71] Airy was not dismissing the idea that magnetism could affect chronometers: he published an article on the subject only a year later.[72] But the Astronomer Royal felt in this case that the evidence did not support Fisher's

64 G. Fisher, Notes on Chronometers, Hartwell Observatory, National Maritime Museum (NMM), Mss. ref, FIS/21; George Fisher, Workings on Chronometers, NMM, Mss. ref. FIS/22.

65 G. Fisher, Rates of Chronometers, NMM, Mss. ref. FIS/21.

66 J. Lee, 'An account of the observatory at Hartwell House', *Monthly Notices of the Royal Astronomical Society* (1854), **14**, 215–17. For more on Lee himself see A. McConnell, 'Lee, John (1783–1866)', *ODNB*, Oxford, 2004 (online edition: http://www.oxforddnb.com/view/article/16297, accessed 23 June 2007).

67 G. Fisher, Chronometer Research, NMM, Mss. ref. FIS/22.

68 G. Fisher, 'Effects of magnetism on the rates of chronometers', *Nautical Magazine* (1837), **V**, 160–5, 160.

69 Fisher to Airy, 6 April 1836, CUL, RGO 6/585.

70 Fisher to Airy, 11 November 1839, CUL, RGO 6/585.

71 Airy to Fisher, 15 November 1839, CUL, RGO 6/585.

72 G. B. Airy, 'Magnetism of chronometers', *Nautical Magazine* (1840) **VIII**, 231–7.

conclusions. It seems that Fisher and Airy nevertheless became friendly and corresponded regularly. The Astronomer Royal asked for advice on topics as wide-ranging as magnetism in compasses,[73] terrestrial longitude[74] and the need for a Spanish-speaker to translate a book he wished to read.[75]

Yet the correspondence with Airy apparently terminated Fisher's writings on the effects of magnetism on chronometers, although others continued to publish in this area. Gould suggests that the last contribution to the debate was made in 1856 by E. D. Johnson, who patented a magnetic disperser. This invention incorporated a separate one-day movement independent of the chronometer, which rotated the chronometer using a rubber-covered roller, thus averaging out the effects of magnetism.[76] After Johnson's patent, however, work moved away from the effects of terrestrial magnetism and began to concentrate on the construction of the instruments themselves. The problems of magnetism, however, subsequently became an issue with more portable chronometer watches and precision pocket watches, since these were more likely to be moved into areas of magnetic influence. Following the increasing use of powerful electric motors on board ship and in industry as a whole, a new kind of anti-magnetic watch with non-ferrous balance and spring made its appearance at the end of the nineteenth century. Although no conclusive explanation for the acceleration of chronometers was ever made, it is now generally accepted that the most likely cause has nothing to do with magnetism. A more plausible explanation appears to be the presence of stresses in the hardened steel balance springs introduced during manufacture. These would gradually migrate, changing the spring's elastic characteristics during the first few years of its use.

After these experiments, Fisher's work with chronometers ended. He concentrated on his career at the Royal Hospital School, Greenwich.[77] His obituary in the *Monthly Notices of the Royal Astronomical Society* claimed that Lord Auckland, then First Lord of the Admiralty, offered him either the living of Falstone in Northumberland or the chaplaincy and headmastership of the Royal Hospital School. Apparently Fisher accepted the latter offer and became the principal of the school in 1860.[78] The minutes of the school's Board of Commissioners reveal that Fisher was appointed as headmaster

73 Airy to Fisher, 12 April 1859, CUL, RGO 6/689. On this particular matter the two men quite strongly disagreed on the results, with Airy eventually telling Fisher that he was completely wrong in his view that there was no merit in using magnets to correct compasses. Their disagreement is seen in two further letters: Fisher to Airy, 15 April 1859, and Airy to Fisher, 16 April 1859, both in CUL, RGO 6/689.

74 Airy to Fisher, 24 June 1841, CUL, RGO 6/585.

75 Airy to Fisher, 17 October 1861, CUL, RGO 6/1824.

76 Gould, op. cit. (7), 343.

77 The school had been founded by William and Mary under the 1694 charter for the Greenwich Hospital, with premises finally built in about 1716. Boys at the school were taught writing, arithmetic and navigation. See N. Macleod, 'History of the Royal Hospital School', *Mariner's Mirror* (1949), 35, 182–202; H. D. Turner, *The Cradle of the Navy: The Story of the Royal Hospital School at Greenwich and at Holbrook, 1694–1988*, York, 1990.

78 Anon., op. cit. (2), 143. However, Turner's account of the school's history makes no reference to Fisher as headmaster in the list it provides, although there is a gap between 1856 and 1862; see Turner, op. cit. (77), 182.

in February 1857 with a salary of £500 per annum.[79] Fisher had been under consideration for the post for at least one year prior to his appointment, since the Admiralty had asked the board to recommend his salary increase if he were so appointed in February 1856.[80] By the time of his appointment as headmaster, Fisher had already overseen the building of an observatory for the school and had been able to exploit his close connections with Airy, asking the Astronomer Royal's advice on layout and the equipment to purchase.[81] In response Airy went so far as to offer new equipment free of charge.[82] The observatory was opened in 1859[83] and Fisher observed the solar eclipse of 18 July 1860 from the new building.[84] Upon his retirement in 1863 Fisher moved to Rugby in Warwickshire, where he died ten years later on 14 May 1873 at the age of 78.

Conclusion

Despite an apparently haphazard career George Fisher made a number of significant contributions to the science of his day. From his early Arctic voyages with Buchan and Parry, through to his time as chaplain on HMS *Victory*, Fisher contributed in particular to the understanding and design of chronometers. He was the first to test the effect of magnetic influences on chronometers, as well suggesting methods to solve the problem. This paper has also shown that there was more to Fisher's chronometer research than has previously been acknowledged. Whereas it had been assumed that his interest in chronometers ended after his 1820 article, a study of his personal papers shows that he continued his research into the 1830s, still looking for a solution to the problem of magnetism through the use of glass balances and springs. As a result of his published work, several other researchers looked into the possible problems that chronometers might have been experiencing from magnetism. This led to a period of experimentation and interest in the subject that helped to refine and improve the design of one of the most important pieces of maritime equipment of the nineteenth century. Yet because of an obituary that ignored his research in this area, the leading instigator of this movement was not given the credit that he deserved.

79 Greenwich Hospital School, Board of Commissioners Minute Book, 5 February 1857, NA ADM 67/108.
80 Greenwich Hospital School, Board of Commissioners Minute Book, 7 February 1856, NA ADM 67/107.
81 Fisher to Airy, 25 January 1849, CUL, GRO 6/142.
82 Airy to Fisher, 25 January 1849, CUL, GRO 6/142.
83 Turner, op. cit. (77), 66–8.
84 Anon., op. cit. (2), 143.