THE ENGLISH PATENT SYSTEM AND EARLY RAILWAY TECHNOLOGY 1800-1852

Stephen Edward Murfitt

PhD

University of York
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ABSTRACT

This thesis examines the relationship between the English patent system and early railway-related inventive activity, and it is proposed that the patent system influenced the rate and direction of early railway technology. Contrary to the current historiography of the patent system, it is argued that prior to the Patent Law Amendment Act (1852), in the absence of substantive Parliamentary intervention, the judiciary crafted and shaped the principles of patent law which provided certainty and security for patentees. Inventors involved in railway-related technology found great utility in a unique patent system which they used, relied upon, and promoted to their peers.

The requirement post-1733 for a specification to be filed with a patent application, contributed to the origins of what today might be termed knowledge management. The patent system engendered a developing database of technical knowledge that was codified, controlled, circulated and commercially exploited. Profit was a key motive for those who patented railway-related inventions, which often involved high expenditure, of both time and money, and the patent system secured vital monopoly profits. The pecuniary advantage offered by an effective patent system served to incentivise the development and diffusion of early railway technology.

This thesis demonstrates the value of industry-specific analysis of the workings of the patent system. The early railways are recognised as a fully cultural artefact, an approach that provides insights into the technological processes and economic development of the early railways, and since nascent railway technology was but one of several emerging, interwoven technologies, the investigation extends beyond the railway proper.

These proposals are tested by reference to contemporary evidence relating to the professional engineering enterprises of George and Robert Stephenson, Marc and Isambard Kingdom Brunel and a number of individuals of less renown, whose patented inventive activity met the demands of the emerging railways.

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In the course of my research I have visited the various libraries and archives listed in my bibliography and have always received courteous and helpful advice.

Finally, to my wife Susan, who has at all times been a critical friend of my work and whose constant encouragement throughout has meant that I have remained on task to complete this thesis.

DECLARATION

I declare that this thesis is a presentation of original work and I am the sole author. Elements of this work have been presented as conference papers, but not published. This work has not previously been presented for an award at this, or any other University. All sources are acknowledged as references.

CHAPTER 1

INTRODUCTION

> The railway was invented, if that term may be used, in Britain - and more specifically in England. In its first few decades it was spread most thickly and developed most rapidly within Britain, and until about 1870, when the pace of the industrial expansion at home began to slacken, Britain was at the heart and centre of railway activity throughout the world.
>
> Robbins[1]

> Britain in particular is noted for the establishment of a patent system which has been in continuous operation for a longer period than any other in the world.
>
> Khan[2]

This thesis challenges the current historiography of the English patent system prior to the legislative reforms of 1852, and the consensus that it was a largely ineffective means of protecting the interests of inventors and did not serve to incentivise inventive activities. A re-evaluation of the effectiveness of the patent system is pivotal to the central examination undertaken here of the influence of the patent system on the development and diffusion of early railway technology. It is key to this reassessment that the patent application process provided for partial adjudication as to novelty and prior to 1852, in the absence of substantial legislation, the judiciary contributed to the crafting and shaping of patent principles during the early period of industrialisation. Furthermore, it is argued here, that the obligation from 1733 for patentees to file a specification outlining the details of the patent, constituted a growing database of technical information. In today's terms, this contributed to the management of knowledge. The patent system allowed early railway technological knowledge to be codified, controlled, circulated and commercially exploited some 80 years earlier than is generally accepted.

The contemporary evidence of the pioneers of railway-related inventive activity, and their funders, demonstrates that they found great utility in a unique patent system which they used, relied upon and promoted to their peers. Many inventors depended on the period of protection afforded by a patent to develop the potential of an invention and, eventually, to secure monopoly profit. It is argued here that

[1]Michael Robbins, *The Railway Age* (London: Manchester University Press, 1998), 91. Jack Simmons in a previously unpublished article suggested the Victorians invented the railways: Jack Simmons, "The Victorian Railway in retrospect," *Journal of the Railway and Canal Historical Society* 38, (2015): 291-295.

[2]B. Zorina Khan, "An Economic History of Patent Institutions," in Economic History Association (EH.net, March 16, 2008), http://eh.net/encyclopedia/an-economic-history-of-patent-institutions/ [accessed July 20, 2012].

patented inventive activity was the preferred choice for many inventors involved with early railway technology. The alternative settings of collective invention and or working an invention in secret, were generally unattractive for the protection of railway-related inventive knowledge. Furthermore, the evidence presented in this thesis demonstrates that the pecuniary advantage offered by the patent system incentivised the development and diffusion of early railway technology.

The operation of the patent system did not attract detailed academic analysis until the 1980s when Dutton and MacLeod produced seminal monographs.[3] As to the correlation between patents and early railway-related inventive activity, little historical investigation has been completed to date. This is a matter of surprise since by the middle of the nineteenth century, patents totalled in excess of fourteen thousand, of which railway-related patents formed a significant number. This gives rise to some pertinent questions. Why did the number of railway-related patents rise so substantially in the early nineteenth century? Why did investors and railway entrepreneurs make application for patents in such numbers? What, if any, was the effect of the granting of railway-related patents upon early railway technology? In addressing these questions, this thesis contributes to a better understanding of the patent system as one of the significant influences on the development of early railway technology.

In reassessing the current historiography of the patent system it is demonstrated here that within the context of early railway technology, patent fees were not a major deterrent and application for a patent involved far more than mere registration.[4] Contrary to the conclusions of Dutton and MacLeod,[5] the evidence considered here suggests that the arbitrariness of the courts did not constitute a serious weakness in the patent system and that any judicial hostility towards patentees prior to 1830 has been overstated. By the beginning of the nineteenth century the pioneers of railway innovation had available to them a system that whilst not perfect, was fit for purpose, facilitated patent protection and provided an opportunity for monopoly profits.

The cultural dimensions of the early railways are often overshadowed by the mechanical and physical elements.[6] This thesis moves beyond the railway proper and considers early railway technology in the broad context of time and place. As advocated by Divall, it is a fundamental error to regard the sheer physical reality of the railways as the only essence.[7] It is incumbent on the railway historian to examine the social structures and processes of which railways are part and to take into account a range of

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[3] Harold I. Dutton, *The Patent System and Inventive Activity during the Industrial Revolution* 1750-1852 (Manchester: Manchester University Press, 1984). Christine MacLeod, *Inventing the Industrial Revolution: The English Patent System1660-1800* (Cambridge: Cambridge University Press, 1988).
[4] MacLeod, *Inventing the Industrial Revolution*, 76 and 41.
[5] MacLeod, *Inventing the Industrial Revolution*, 61. Dutton, *The Patent System and Inventive Activity,* 77-8.
[6] Michael J. Freeman, *Railways and the Victorian Imagination*, (New Haven and London: Yale University Press, 1999).
[7] Colin Divall, "Beyond the History of Early Railways," in *Early Railways 2*, ed. M.J.T Lewis (The Newcomen Society, 2003) 1-9, 6.

financial, speculative and economic factors.[8] Understanding the early railways as a fully cultural artefact assists in identifying what Lewis has characterised as the conceptual and technical foundations of the Railway Age, when railways were central to Britain's extraordinary contribution to technological and industrial development during the early part of the nineteenth century.[9] Increasingly, history of transport scholarship borrows other disciplines' novel theories, techniques and approaches to the subject.[10] Such an interdisciplinary approach is adopted in this thesis where the English judicial framework of the early nineteenth century is fundamental to the arguments. This thesis moves away from the approach of many railway historians who concentrate on 'blinkered'[11] company history, a historiographical emphasis that fails to appreciate the evolutionary framework of the early railways.

The re-evaluation undertaken here of the operation of the patent system prior to 1852 identifies two significant themes. Firstly, the commencement of the codification of technical knowledge in 1733 contributed to what today might be described as knowledge management. Knowledge management is understood as the promotion of an integrated approach for the identification, capture, retrieval, distribution, sharing, use and re-use of information and knowledge assets.[12] Prior to the period of early industrialisation, much tacit knowledge held in the minds of practitioners would have been transferred by teaching and practical demonstration, but the resultant dissemination of technological knowledge would have been both localised and slow. It is demonstrated here that the combined effect of the requirement after 1733 for the filing of detailed specifications, and the associated availability of respected technical publications, provided access to technical knowledge for those involved in early railway-related inventive activity. This is an area of study to have received little academic interest to date.[13] It seems likely, therefore, that codification of technical information by way of an effective patent system had a significant influence on the accessibility and diffusion of early railway-related technological knowledge.

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[8] Colin Divall and George Revill, "Cultures of transport, representation, practice and technology," *Journal of Transport History* 26 (2005, 3rd series): 99-111, 109. A revised article appears at http://www.york.ac.uk/media/workingwiththeuniversity/documents/cpd/sectorscourses/Cultures.pdf [accessed December 20, 2014].

[9] Michael. J. T. Lewis, "The railway in industry," in *The History and Practice of Britain's Railways,* eds. Rod W. Ambler, Howard Newby and David Dilks, (Aldershot: Ashgate Publishing Ltd., 1999), 77-95, 80.

[10] John Armstrong, "Transport History, 1945-95: the rise of a topic to maturity," *Journal of Transport History* 19, (1998): 103-121.

[11] Michael Robbins, *Points and Signals* (London: Allen and Unwin, 1967), 15-16. See also Michael Robbins, "What kind of railway history do we want?" *Journal of Railway History* 3, (1957): 65-75.

[12] There are many definitions of 'knowledge management'. The definition adopted here is that of the World Intellectual Property Organisation (WIPO). "The Knowledge Management Strategy of the World Intellectual Property Organization", *WIPO Information Document,* August 4, 2015, 4. http://www.wipo.int/edocs/mdocs/govbody/en/a_55/a_55_inf_5.pdf [accessed June 24, 2016].

[13] Arapostathis and Dutfield have investigated changing patterns of knowledge management practices and intellectual property regimes across a number of different techno-scientific disciplines, but for a later period. Stathis Arapostathis and Graham Dutfield, eds., *Knowledge Management and Intellectual Property*, (Cheltenham: Edward Elgar, 2013).

A patent system that is effective will influence the inclination to patent. A second theme to emerge, therefore, from this re-appraisal of the patent system is the effect of the institutional parameters on railway-related inventive activity. The reassessment offered here establishes that from the late eighteenth century, which is much earlier than many academics give credit, the English patent system provided accessible, enforceable patent rights. That is not to say that the patent system in and of itself engendered a propensity to patent. The many and varied motives for the patenting of railway-related inventive activity, including reputational status and the protection of a competitive edge, are explored in this thesis. Nevertheless, the contemporary evidence considered here demonstrates that pecuniary advantage was a significant motive for the pioneering patentees of railway-related inventions, particularly in circumstances where a period of monopoly was essential to recover the often substantial costs involved in both initial experimentation and further development of the patented invention. Many of the important inventions of the early nineteenth century were subject to patents, and railway technology was no exception. This thesis examines and challenges the view that inventive genius was poorly rewarded.[14] It considers the fragmented, but persuasive evidence that pecuniary gain was a substantive motive of patentees. Furthermore, that the financial advantage offered by an effective patent system served to encourage the inventive efforts that helped shape the pace and direction of railway-related innovation during the late eighteenth and early nineteenth centuries.

This thesis seeks to respond to Mokyr's observation that the relationship between patenting and technological progress is still obscure.[15] Furthermore, and significantly, it is contended here that it is vital to consider the patent system and its effect on inventive activity within the context of individual industries since each has specific technological characteristics. By focusing on the development of the early railways, this thesis draws upon the benefits of particular yet contextualised evaluation, rather than general analysis. In recent decades the emergence and development of patent systems has become an area of historical inquiry embracing economic, social, technological, industrial and intellectual history.[16] Despite this renewed research effort, much remains to be done.

[14] For example, Clark does not accept that inventors made money from their inventions: 'the empirical difficulty with the appropriability argument is the appallingly weak evidence that there was any great gain in the returns to innovators in England in the 1760s and later ... the Industrial Revolution economy was spectacularly bad at rewarding innovation'.[14] Gregory Clark, "The Industrial Revolution," in *Handbook of Economic Growth,* Vol.2A eds. Philippe Aghion and Steven Durlauf (Oxford: Elsevier Press, 2014): 217-262.

[15] Joel Mokyr, *The Gifts of Athena: Historical Origins of the Knowledge Economy* (Princeton: Princeton University Press, 2005), 295.

[16] For a recent example of industry-specific analysis see, Jonathan P. Hopwood-Lewis, "Intellectual Property and Secrecy in Early British Aeronautics, 1897-1914," (Ph.D thesis, University of Bristol, 2014). See also, Roger Barton, "Construction of the Network Society: Evolution of the Electric Telegraph 1837-1869," (Ph.D thesis, University of London, 2007). Sandro Mendoça, "The evolution of new combinations: Drivers of British marine engineering competitiveness during the nineteenth century," (D. Phil thesis, University of Sussex, 2012), http://sro.sussex.ac.uk/39708/1/Mendon%C3%A7a,_Sandro.pdf [accessed January 15, 2016].

1.1 The patent system: reappraisal of the historiography

> [I]nvention in its modern sense emerged in the course of the eighteenth century when lawyers and administrators began systematically to make the distinction between ... the invention and the material artefact in which it was expressed.
>
> Sherman and Pottage[17]

The patent system in England originated with the issuing of letters patent by the Crown, a royal prerogative intended primarily to promote new trades for public benefit, especially from and to overseas. The origins of the term patent are concealed by more recent definitions. Today, patent has the precise and technical meaning of a document issued by a government office which describes an invention and creates a legal situation in which the patented invention can normally only be exploited (manufactured, used, sold, imported) with the authorisation of the owner of the patent. The protection conferred by the patent is limited in time.[18] Patents confer intellectual property rights that influence how, where, by whom, and at what cost new technologies are used. As observed by Kranakis, patents are tools of power and control over technology and people.[19]

The definition of invention adopted for this work is that provided by Schmookler for whom invention is a new way of producing something old (a process invention), or an old way of producing something new (a product invention), and every invention is a new combination of pre-existing knowledge which satisfies some want.[20] On this understanding, inventive activity relies on existing knowledge, or the recombining of aspects of existing knowledge. It encompasses processes of discovery, both inventive and innovative. Inventive activity is inherently uncertain, involving trial and error, and often, particularly in relation to the early railways, considerable investment of time and money.

According to Schmookler, innovation is the *first* use of invention, whilst diffusion refers to the rate at which the innovation is imitated by other users. There is no consensus over whether invention and innovation is one and the same thing. Usher, for example, in advancing his cumulative synthesis approach divides the act of invention into four stages, but does not accept the distinction between invention and innovation.[21]

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[17] Brad Sherman and Alain Pottage. *Figures of Invention. A History of Modern Law* (Oxford: Oxford University Press, 2010), 1.
[18] WIPO, *Intellectual Property Handbook: Policy, Law and Use* (Geneva: World Intellectual Property Organization, 2008), 17.
[19] Eda Kranakis, "Patents and Power: European Patent-System Integration in the context of Globalization," *Technology and Culture* 48, no.4 (October 2007): 689-728, 689.
[20] Jacob Schmookler, *Invention and Economic Growth* (Cambridge Mass.: Harvard University Press, 1966), 6.
[21] Abbott Payson Usher, *A History of Mechanical Inventions* (Cambridge: Cambridge University Press, 1954), 65. The four stages defined by Usher are: (1) perception of the problem; (2) preparation and setting; (3) the primary act of insight; (4) critical revision and development.

The broad historiography of the early patent system generally encompasses the processes prior to the Patent Law Amendment Act (1852), by which patents were formally awarded and recorded, and the role of the judiciary in the adjudication of patent disputes in an evolving industrial society. Many of the early histories of the patent system were written by lawyers and economists. Gordon (1897) detailed the remedies available to the public as a consequence of monopolies created by patents.[22] Hulme and Davies (commencing in 1896) wrote a series of articles in the *Law Quarterly Review* on the history of the patent system and the patent specification,[23] and Fox (1947) produced a study of the history and features of patent monopoly.[24]

It was not until 1984 that Dutton went beyond administrative and legal history with his analysis of the determinants of inventive activity and evaluated the importance of patents both for inventors and those who worked them.[25] His historical narrative of the patent system is pertinent to the arguments presented in this thesis in that he considered the effect of patents on inventive activity from 1750 to 1852. Furthermore, Dutton was one of the first academics to consider the importance of patent agents and their role in the application for patents and the preparation of specifications.

Nevertheless, the evidence considered in this thesis challenges several of Dutton's inferences, in particular his overarching conclusion that prior to 1830 there was a marked judicial hostility towards patentees. According to Dutton, the small number of reported cases indicates that patentees were rarely willing to embark upon litigation. He concluded that prior to 1830, success at law was something of a lottery.[26] Somewhat ironically, Dutton observed that what he regarded as the many imperfections of the patent system prior to 1852 may have tended to accelerate the rate of innovation and technological change. According to Dutton, a system that efficiently protects inventors will slow down the rate of innovation. He proposed that where a system is imperfect in practice, this could serve *either* to reduce the supply of inventive output and slow down the rate of technological change, *or* leave the supply of inventive output unchanged, and quicken the speed of innovation.[27] He concluded that if inventors were under the misapprehension that the patent system was more perfect than it was, then relatively high

[22] J.W. Gordon, *Monopolies by Patents and the Suitable Remedies Available to the Public* (London: Stevens and Sons, 1897).
[23] Edward Wyndham Hulme, "The history of the patent system under the prerogative and at common law," *Law Quarterly Review* (LQR) 12, (1896): 141-154. Edward Wyndham Hulme, "On the consideration of the patent grant past and present," *LQR* 13, (1897): 313-318. Edward Wyndham Hulme, " The history of the patent system under the prerogative and at common law - a sequel," *LQR* 16, (1900): 44-56. Edward Wyndham Hulme, "On the history of patent law in seventeenth and eighteenth centuries," *LQR* 18, (1902): 280-288. Edward Wyndham Hulme, "Privy Council law and practice of letters patent for invention from the restoration to 1794," *LQR* 33, (1917): 63-75, 181-195. David R Seaborne Davies, "The early history of the patent specification," *LQR* 50, (1934): 86-109, 260-274.
[24] Harold George Fox, *Monopolies and Patents: A Study of the History and Future of the Patent Monopoly* (Toronto: University of Toronto Press, 1947).
[25] Dutton, *The Patent System and Inventive Activity,*10.
[26] Dutton, *The Patent System and Inventive Activity*, 72.
[27] Dutton, *The Patent System and Inventive Activity*, 204.

rates of inventive activity and diffusion would result. Dutton recognised that patents are not synonymous with economic growth. Furthermore, that patent statistics do not reflect the *quantity* of inventive output. Significantly, he opined that since standards of assessment of patent applications were 'low' between 1750 and 1833, it is quite possible that the number of patents *overstates* the level of activity.[28]

The arguments advanced in this thesis challenge Dutton's findings in several important respects. Firstly, the re-evaluation undertaken here of the historiography of the patent system prior to 1852 establishes that adjudication took place as to the merit of a patent by one of the Law Officers, the Attorney General or the Solicitor General, and that standards were far from low. In the specific case of railway technology, it is established here that patentees held the patent system in some regard. Had the system proved ineffective in practice, then inventors would have abandoned it. The evidence demonstrates quite the reverse. Secondly, it is argued here that in relation to the early railways there is no evidence to support Dutton's hypothesis that an efficient patent system would have slowed the rate of innovation. For instance, this thesis challenges arguments for the so-called blocking effect of Watt's patented separate condenser. Thirdly, Dutton's notion that patenting numbers for the early nineteenth century may have been less than the patent record suggests, is not substantiated by the data considered in this thesis. It is demonstrated here that prior to 1852 many, if not most patents covered multiple inventions and patented inventive activity was more prevalent than is suggested by patent data *per se*. Significantly, it is demonstrated here that patented inventive activity was a substantial characteristic of early railway technology where the patent system was a central safeguard to the realisation of eventual profits. It is difficult to avoid surmising that Dutton's conclusions were prejudiced by misconceptions about both the patent record and the operation of the patent system. His conclusion that it was the very imperfections of the patent system that most likely encouraged inventive activity, suggests an effort to accommodate the facts of burgeoning inventive activity with misconceptions about patent numbers, and a perceived ineffectiveness of the patent system.

The evidence considered here in relation to early railway technology endorses Dutton's recognition that pecuniary advantage was a significant motive for many patentees, but demonstrates that his analysis is deficient in several respects. Dutton's statistical work, and that of much subsequent scholarship, relied on the number of *decided* patent dispute court cases to assess the efficacy of the patent system, whereas there is good evidence that many patent disputes were settled before they reached court with defendants agreeing to pay a licence fee for use of a patent. A much clearer understanding of the effectiveness of the patent system emerges if, as in this thesis, the *processes* of litigation, rather than *decided* cases, are factored into the assessment.

[28] Dutton, *The Patent System and Inventive Activity*, 6.

MacLeod added to the literature, in 1988, with a study of the institutional context of inventive activity and innovation from 1660 to 1800.[29] Her approach differed from that of Dutton's in that her starting point was a detailed chronological analysis of the workings of the patent system, followed by a consideration of the role of patents, and the social characteristics of patentees. MacLeod was sceptical of the value of patents as a gross measure of successful invention and / or innovation, or in generating significant technological change. She challenged Dutton's view that prior to 1830 the judges held anti-patent prejudice. She proffered it was not an issue of judicial bias, but that confusion and inconsistency were rife.[30] MacLeod has continued to write extensively on the subject of patents and has made a substantial contribution to the literature, including a cautious evaluation of the effect of the patent system, at least in the early phases of the Industrial Revolution.[31] In 2010, in a report prepared for the Strategic Advisory Board on Intellectual Property Policy reviewing patents and industrialisation for the period 1624 to 1907, MacLeod and Nuvolari concluded there is no scholarly consensus on the impact of the patent system on inventive activity, that at best its influence was 'second order'.[32]

The contemporary evidence considered in this thesis, relating to the individuals involved in early railway technology, demonstrates that the patent system's effect was more first order, than second. MacLeod and Nuvolari recognised that patents had close links with industrialisation, but argued that the patent system should be considered as a technology in its own right, shaped by its invention and development They concluded that North's long-standing causal link[33] between intellectual property rights and the commencement of the Industrial Revolution was incorrect. They proposed a reversal of the causal arrow, that industrialisation promoted the patent system.[34] A theme developed further by MacLeod in 2012 in a public, unpublished lecture.[35] Nevertheless, MacLeod and Nuvolari's recognition that a patent was an instrument of competition growing in value within an increasingly

[29] MacLeod, *Inventing the Industrial Revolution* (1988).
[30] MacLeod, *Inventing the Industrial Revolution*, 58.
[31] See also, Christine MacLeod, "The paradoxes of patenting: invention and its diffusion in 18th and19th century Britain, France, and North America," *Technology and Culture* 32, no.4 (1991): 885-910. Christine MacLeod "Concepts of invention and the patent controversy in Victorian Britain," in Robert Fox (ed.) *Technological Change; Methods and Themes in the History of Technology* (Amsterdam, Harwood Academic Publishers, 1996), 137-154. Christine MacLeod, *Heroes of Invention: Technology, Liberalism and British Identity, 1750-1914* (Cambridge, Cambridge University Press, 2007).
[32] Christine MacLeod and Alessandro Nuvolari, "Patents and Industrialisation; An Historical Overview of the British Case, 1624-1907," *Report to Strategic Advisory Board for Intellectual Property*, (LEM Working Paper Series, 2010), 30. http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2019844 [accessed December 30, 2012]. The Strategic Advisory Board for Intellectual Property Policy (SABIP), established in June 2008 and dissolved in July 2010, was set up as an advisory non-departmental body to give Ministers strategic advice on intellectual property issues. The first, and only Chair was Dame Lynne Bradley, Chief Executive of the British Library.
[33] According to North, 'By 1700 ... England had begun to protect private property in knowledge with its patent law. The stage was now set for the industrial revolution'. Douglass C. North and Robert P. Thomas, *The Rise of the Western World: A New Economic History* (Cambridge: Cambridge University Press, 1973), 155-156. North's more recent work is considered later in this chapter.
[34] MacLeod and Nuvolari, "Patents and Industrialisation," 28.
[35] Christine MacLeod, "No Patent System, No Industrial Revolution?" Public Lecture, University of Leeds, November 27, 2012, unpublished electronic copy subsequently provided by the facilitator in December 2012.

capitalistic manufacturing economy, is identified here to be entirely accurate in relation to the technologies associated with the early railways. Furthermore, MacLeod and Nuvolari identified that inventing is a risky activity and that capitalists may not have invested in invention without the protection of a patent. They correctly acknowledge that without a patent system, investment capital would have been harder to find. MacLeod and Nuvolari's observations in relation to risk and capital investment are of critical importance to the exploration undertaken in this thesis.

This thesis builds on the work of Bottomley who has reassessed the patent system and concluded that with a proper appreciation of the workings of the patent system, patents can be understood to have incentivised the development of new technology.[36] According to Bottomley, the patent system made a signal contribution to technological development during the Industrial Revolution. He proposes that the potential profits secured by the protection it provided, were integral to encouraging inventive activity. Significantly, Bottomley highlights the propensity to patent in sectors such as manufacturing machinery and engines where there were no alternative means of protecting commercial technological knowledge.[37]

Bottomley has undertaken an examination of selected inventors' probate valuations to argue that profit was a significant motive for inventors and that in many cases invention paid.[38] He identified that the family backgrounds of many of those who acquired wealth as a result of their inventions were atypical. They were not the inheritors of financial capital, but of social capital in the form of technical training and ready access to professional networks of male relatives.[39] Bottomley has identified the historical trends that were fundamental to establishing the institutional parameters of the patent system. His study has demonstrated that the rise of professional networks, the stabilisation of certain bureaucratic requirements and the circulation of codified knowledge facilitated the emergence of modern English patent law. Bottomley has also explored the emergence of joint-stock companies between 1845 and 1852, the formation of which facilitated the securing of capital thus supporting the incentive to engage in inventive activities.[40]

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[36] Sean Bottomley, "Patents and the first industrial revolution in the US, France and Britain, 1700-1850," Working paper 14-14 Institute for Advanced Study in Toulouse (2014), http://idei.fr/sites/default/files/medias/doc/wp/2014/wp_iast_1414.pdf [accessed July 14, 2015].
Sean Bottomley, "Patenting in England, Scotland and Ireland during the Industrial Revolution, 1700-1852," *Explorations in Economic History* 54, (2014): 48-63. Sean Bottomley, "Patent Cases in the Court of Chancery 1714-58," *Journal of Legal History* 35, (2014): 27-43. Sean Bottomley, "The Returns to Invention during the British Industrial Revolution". Unpublished, electronic copy provided by the author on July 22, 2015.
[37] Bottomley, *The British Patent* System, 293-4
[38] Bottomley, "The Returns to Invention". Bottomley builds on and adapts a database compiled by Meisenzahl and Mokyr. Ralf Meisenzahl and Joel Mokyr, "The Rate and Direction of Invention in the British Isles in the British Industrial Revolution. Incentives and Institutions" in *The Rate and Direction of Inventive Activity Revisited*, eds. Josh Lerner and Scott Stern (Chicago: University of Chicago Press, 2012), 443-482.
[39] Bottomley, "The Returns to Invention," (unpublished).
[40] Bottomley, *The British Patent* System, 279.

The securing of capital in relation to the early railways generally involved patentees, co-promoters, patent agents and lawyers, and the role of these various players in the development of patent law is a focus of this thesis. It is an important premise of this thesis that the early railways were socio-technical systems dependent upon political, economic and cultural parameters. The particular circumstances of the developing railways included a requirement to draw upon evolving technology beyond that traditionally categorised as the railway proper.[41] Echoing Landes' proposition that optative history (history not as it was, but as we would have it) is untrue and misleading,[42] Divall warns that history was a messy business in the living and care must be taken not to impose an order or structure that it did not possess at the time.[43] Any examination of the development of the early railways must be rooted in the circumstances of time and place and it is for this reason that Arapostathis and Gooday's recent cultural-history approach to the diverse contributors of patent-based knowledge, is relevant to the arguments proposed in this thesis.

Arapostathis and Gooday have examined the surge in patent centred disputes during the late nineteenth century in the new technologies of electrical power, lighting, telephone and radio.[44] They considered several disputes and analysed how Britain's patent laws changed from the 1870s to the 1920s. Although their study relates to a different industry at a later period of industrialisation, their approach is relevant to the arguments presented in this thesis because it highlights the significant influence of the adversarial legal system in the making of patent law and its practices. Interestingly, the authors comment that the proprietary character of knowledge was long-established in the ethos of certain technological sectors.[45]

Of particular significance to this thesis, Arapostathis and Gooday demonstrate the contribution of numerous actors in the shared social network who substantially shaped the cultures of litigation, the creation of patent rights and the establishment of patent practices.[46] However, there is an important distinction to be made between the period under focus in Arapostathis and Gooday's study, 1870 to 1920, and the era of the early railways. Railway technology developed at a time when there was little or no statutory guidance as to the formulation of patent law. Arapostathis and Gooday consider that the Patent Law Amendment Act (1852),[47] which arguably for the first time introduced a statutory code for

[41] Donald Mackenzie and Judy Wajcman, eds., *The Social Shaping of Technology* (2nd ed. Buckingham, 1999), 11-27, quoted in Colin Divall, "Beyond the History of Early Railways," *Early Railways 2,* ed. M.J.T. Lewis (London: The Newcomen Society, 2003):1-9, 4.
[42] David S. Landes, "East is East and West is West," in Maxine Berg and Kristine Bruland, *Technological Revolutions in Europe. Historical Perspectives* (Cheltenham: Edward Elgar, 1998), 19-38, 19.
[43] Colin Divall, "Beyond the History of Early Railways," in *Early Railways 2,* ed. M.J.T. Lewis (London: The Newcomen Society, 2003):1-9, 3.
[44] Stathis Arapostathis and Graeme Gooday, *Patently Contestable. Electrical Technologies and Inventor Identities on Trial in Britain* (Cambridge: MIT Press, 2013).
[45] Arapostathis and Gooday, *Patently Contestable*,18
[46] Arapostathis and Gooday, *Patently Contestable*, 84-85.
[47] Patent Law Amendment Act (1852), 15 & 16 Vict. c. 83.

patents, was the turning point in the culture of invention.[48] They also acknowledge that the Patents, Designs, and Trade Marks Act (1883) introduced a regime that encouraged patented inventive activity by ordinary inventors who did not have access to capital.[49] Nevertheless, and as argued in this thesis, pre-1852 was a period with minimal statutory guidance and a time when the adversarial court system made a significant contribution to the creation of patent law.

It is of significance to the arguments advanced in this thesis that Arapostathis and Gooday, in seeking to contextualize the issues of knowledge management implicated in patent disputes in the electrical industry, adopt a focus that differs from the majority of historians of technology who concentrate on the merits of the invention itself. Arapostathis and Gooday claim to make three major contributions to the scholarship of law and technosciences. Firstly, they acknowledge the significant contribution of the adversarial system in the making of patent law and its practices. Secondly, they emphasise the extent to which intellectual property rights are industry-specific rather than applying universally to all technologies. Thirdly, they identify that the historiography of patents in electrical knowledge technologies consists of more complex phenomena than the self-evident growth of intellectual property rights for patentees. Drawing upon Biagioli's suggestion of integrating legal processes with stories of invention ('law as technology'),[50] they argue that the collective contribution of patent agents, lawyers, expert witnesses and judges to the making (and unmaking) of patent rights, substantially shaped the cultures of litigation and of patent practices.[51]

Beauchamp, in similar vein, in a recent consideration of Alexander Graham Bell's invention of the telephone, has proposed that patents were ultimately the tools of business, that regardless of who conceived the invention, it was the pioneering companies and their lawyers who truly *made* the fundamental patent. Beauchamp emphasised that the history of patents and patent law is fundamental to any understanding of industrial development. Although his analysis relates to a specific industry at a period beyond the remit of this thesis, his study highlights that the scope of patent grants was shaped by the processes of litigation.[52]

Beauchamp's recognition of the role of the judiciary is pertinent to this thesis. He has demonstrated that Bell's lawyers took advantage of the strong American judicial regard for pioneer patents and successfully fought off the claims of obscure prior inventors: 'If Bell's lawyers made history it was

[48] Arapostathis and Gooday, *Patently Contestable*, 60.
[49] Patents, Designs, and Trade Marks Act, 1883, 46 & 47 Vict. C. 57. Arapostathis and Gooday, *Patently Contestable*, x.
[50] Arapostathis and Gooday, *Patently Contestable*, 216, n.18.
[51] Arapostathis and Gooday, *Patently Contestable*, 84-85.
[52] Christopher Beauchamp, *Invented by Law: Alexander Graham Bell and the Patent That Changed America* (Cambridge, Mass.: Harvard University Press, 2015), 206.

because they made monopoly first'.[53] Furthermore, Beauchamp draws comparisons between the American and English patent systems suggesting that by the late nineteenth century, the former was 'democratic, bureaucratic, powerfully entrenched, and prominent in the business of the federal courts',[54] while the English system was 'weaker in administration, thinner in judicial support and for a time threatened with outright abolition'.[55] Beauchamp is fundamentally incorrect as to the English system. The reassessment of the English patent system undertaken in chapter 2 of this thesis, establishes that it was in far better shape than is often reflected in scholarly opinion.

This thesis builds on the approaches of Arapostathis, Gooday and Beauchamp and contributes to the literature. Distinctively, this industry-specific analysis of the utility of the patent system identifies three significant characteristics of the early railways. Firstly, it is a principal characteristic of the early railways that they were litigated into existence before parliamentary select committees. Kostal, who examined the interaction of industrial development and law in the context of the railway industry, has observed that it took fifty years of powerful dialectical exchange between the world's first steam railway companies and an 'ancient and largely unreformed system of law and lawyering'.[56] According to Kostal, lawyers were indispensable in the complex process of obtaining parliamentary approval to run railway lines and then to build them, as well as in the subsequent need to facilitate mergers and takeovers and represent railway companies in law suits. Furthermore, he has claimed that lawyers engaged in fraudulent dealings and capitalised on the needs and problems of the railway industry. The evidence considered in this thesis demonstrates that Kostal was substantially incorrect both as to his description of an unreformed system of law, and his accusation that lawyers 'served to disorganise' English railway capitalism. It is demonstrated in this thesis that those individuals, including lawyers, who were involved in applications for patents, and negotiated numerous licence agreements, played an important and positive role in the sector of the developing railways.

It is argued in this thesis that a system emerging primarily as a result of litigation gives rise to important consequences. Kostal drew attention to the cost of obtaining statutory powers and Bentham, writing in 1839, described legal costs as the grand instrument of mischief in English practice.[57] The process and cost of litigation which can often result in bankruptcy or liquidation (it is often said that a judgement of a court not only identifies the successful arguments, but also decides which of the litigating parties goes into liquidation or faces bankruptcy), creates great awareness of the need to preserve assets. An early railway company having secured running powers at great cost would have understood the need to

[53] Christopher Beauchamp, "Who Invented the Telephone? Lawyers, Patents, and the Judgments of History," *Technology and Culture* 51, no.4 (October 2010): 854-878, 878.
[54] Beauchamp, *Invented by Law*, 131.
[55] Beauchamp, *Invented by Law*, 132.
[56] R.W. Kostal, *Law and English Railway Capitalism 1825-1875* (Oxford: Clarendon Press,1994), 52.
[57] Jeremy Bentham, "Principles of Judicial Procedure, with the outlines of a Procedure Code," in *The Works of Jeremy Bentham*, vol.7, ed. John Bowring, (Edinburgh: William Tait, 1839), 111-112.

preserve all forms of assets, including acquired railway-related technical knowledge. As explored in later chapters, funders of commercial enterprises such as Lord Ravenscroft, Edward Pease and Matthew Boulton were particularly keen to secure patents as a means of preserving the economic value of inventive knowledge.

A second significant characteristic of the early railways was the entrepreneurialism which involved innovation, risk-taking and alertness to opportunity. Financiers organised and assumed the risk of a business in return for profits, and it would have been necessary to assimilate a great deal of technical information. In explaining the function of the entrepreneurial purpose, Casson has rejected the neoclassical view that everyone had access to the same information. He has argued that the entrepreneur has better or at least more relevant information than other individuals.[58] The evidence considered in this thesis supports Casson's proposal that entrepreneurship involves judgement and decision-making in uncertain times, and that an entrepreneur is incentivised to exploit the commercial information upon which his judgement is based. As identified by Casson and Godley, it was the pioneering engineers who were the strategic thinkers behind the creation of the early railways,[59] but it is demonstrated here that, for example, the father and son dynasties of the Stephensons and Brunels were dependent on the support and funding of their entrepreneurial sponsors.

The entirely private funding of the initiation and development of the early railways constitutes a third characteristic which distinguished the English network from its European equivalents. Acquired railway knowledge became important as the early railway companies faced up to what Jeans, the contemporary author and journalist, described as the two compelling forces of public demand and competition.[60] In England, it was the railway companies, not the State, who bore the risk of the enterprise and there was a significant requirement to provide returns to investors. The contemporary evidence considered in this thesis demonstrates that uniquely the patent system offered entrepreneurs, whether inventor or investor, a means to achieve profits, and encouraged diffusion of technological knowledge. Baumol and Strom have recently proposed that the patent system was a critical element of the 'explosion' of productivity that paved the way for the Industrial Revolution and its sequel.[61] They propose that the patent system promoted innovative entrepreneurship both by the reward of a temporary legal monopoly and by providing opportunities for the licensing and sale of patented rights. Baumol and Strom identify the

[58] Mark Casson, *The Entrepreneur. An Economic Theory* (Cheltenham: Edward Elgar, 2003), 79, 119.
[59] Mark Casson and Andrew Godley, "Entrepreneurship in Britain 1830-1900," in *The Invention of Enterprise*, eds., David S. Landes, Joel Mokyr and William J. Baumol, (Oxford: Princeton University Press, 2010), 211-242, 235.
[60] J. Stephen Jeans, *Railway Problems: an inquiry into the economic conditions of railway working in different countries* (London: Longman, 1887).
[61] William J. Baumol and Robert J. Strom, "'Useful knowledge" of Entrepreneurship: Some Implications of the History," in *The Invention of Enterprise*, eds., David S. Landes, Joel Mokyr and William J. Baumol, (Oxford: Princeton University Press, 2010), 527-542, 535.

pivotal role of the patent system which made it possible to transform intellectual property into a saleable commodity.

1.2 The patent system: economic theory

> There seems to be only three motives that can excite a man to make improvements in the arts, the desire to doing good to society, the desire of fame and the hope of increasing his private fortune.
>
> Watt [62]

The evidence presented in this thesis supports Arrow's classic exposition that awarding patents to inventors encourages inventive activity.[63] In a seminal article, which has had a powerful and continuing effect on thinking, and endorsed as recently as 2012,[64] Arrow (1962) set out the conflict between the high cost of producing knowledge and the low social cost of using it. He identified that the initial costs of inventions are much greater than subsequent competitors' costs of imitation.[65] In a free market those who invent cannot obtain a return above the market price and therefore cannot recover the cost of invention. He argued that by excluding other parties from using inventive knowledge, the patent system allowed inventors to recover monopoly profits.

The literature in relation to patents and economic theory is extensive. North's evaluation of the importance of patents in relation to industrialisation is particularly relevant to this thesis. In analysing economic growth, North proposed that institutional settings are central, including how and why those settings change over time, and what kinds of economic behaviour they induce. He was in no doubt as to the importance of patents for economic development and concluded that by 1700, England had begun to protect inventive knowledge with its patent law and it was this that set the stage for the Industrial Revolution.[66] In later work, whilst recognising that no framework exists to allow a full understanding of how property rights and patent systems evolved, North continued to emphasise the immense importance in history of property rights as providing incentives for innovation and enrichment. He argued that the patent system established a systematic set of incentives that encouraged technological change and raised the private rate of return.[67] His conclusions are supported by the evidence considered in this thesis.

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[62] James Watt, letter to Lord Loughborough, July 8, 1785, Boulton and Watt Papers, MS 3147/3/85, Birmingham City Reference Library.
[63] Kenneth Arrow, "Economic Welfare and the Allocation of Resources for Invention" in *The Rate and Direction of Inventive Activity: Economic and Social Factors*, ed. R.R. Nelson (Chicago: University of Chicago Press, 1962), 609-626.
[64] Lerner and Stern, *The Rate and Direction of Inventive Activity Revisited* (2012).
[65] Arrow, "Economic Welfare," (1962).
[66] North and Thomas, *The Rise of the Western World*, 155-156.
[67] Douglass North, *Structure and Change in Economic History* (New York: Norton Publishing, 1981), 164-165. Douglass North, "A Recommendation on How to Intelligently Approach Emerging Problems in Intellectual Property Systems," *Review of Law and Economics* 5, (2009): 1131-1133, 1132.

The evaluation undertaken here of the effectiveness of the patent system in relation to early railway technology, necessarily encompasses a consideration of the diverse reasons for inventors deciding to take out a patent. It is demonstrated in this thesis that whilst patentees' reasons included ambition and reputation, the overriding consideration was financial return. There is an established literature analysing the many and various incentives for patenting. Biagioli, for example, challenges the traditional dichotomy between 'credit as credibility' and 'credit as rewards. His proposition extends Latour and Woolgar's distinction between those who invented in order to enhance their reputation, and those whose primary motive was financial.[68] Biagioli seeks to demonstrate that in science and scientific studies, seemingly divergent rights have existed in the form of financial credit (a capitalist economy) and status (regulated by the economy of sociocultural rewards). As established in chapter 7, this distinction between patents conceived as rights to control the market (financial reward) and as rights over credit for creativity (reputation), is borne out by the partnership of Cooke and Wheatstone. A considerable tension existed between the two partners' polarised positions regarding the value (credit) of their jointly held patents, which resulted, ultimately, in arbitration. However, Lord Kelvin and Robert Stephenson are good examples of individuals who accomplished both. They achieved significant reputations as well as wealth.

In 1992, Rosenberg *et al* published a collection of papers examining the factors influencing the commercialisation of technology.[69] Rosenberg's approach has been adopted in much of the literature concerned to ascertain the crucial primary agents for economic advance during the nineteenth century, and two stand-out inventions have been identified. The development of the steam engine as a source of motive power, and Cort's Puddling Process which made available a cheap and satisfactory malleable iron.[70] Von Tunzelmann's study, for example, on the relationship between steam power and industrialisation, and the dissemination of technological knowledge, emphasised the crucial role of the developing steam engine during the Industrial Revolution. He identified that steam power represented a significant reduction in the energy costs that would have been incurred had resort had to be made to successively undesirable sites for water power.[71] There have been contrary proposals such as that of

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[68] Mario Biagioli, *Galileo's Instruments of Credit: Telescopes, Images, Secrecy* (Chicago: University of Chicago Press, 2006), 8. For a current exposition on 'credit as credibility' and 'credit as rewards' see, Bruno Latour and Steve Woolgar in Laboratory Life: The Construction of Scientific Facts (Princeton: Princeton University Press, 2013).

[69] *The Commercialisation of New Technologies*, Conference, University of Stanford, 1989. See Nathan Rosenberg, Ralph Landu and David C. Mowery, *Technology and the Wealth of Nations* (Stanford: Stanford University Press, 1992).

[70] Nick von Tunzelmann, *Technology and Industrial Progress: The Foundations of Economic Growth,* (Cheltenham: Edward Elgar Publishing, 1995)

[71] Nick von Tunzelmann, *Steam Power and British Industrialisation to 1860* (Oxford: Clarendon Press, 1978), 286.

Szostak, who considered that the importance of steam power has been exaggerated and that it was England's roads and waterways that drove technological invention, rather than steam locomotion.[72]

Von Tunzelmann's links between steam power and industrialisation were endorsed if somewhat tempered, in 2004 by Crafts who identified steam technology as a General Purpose Technology (GPT), defined as a technology that initially has much scope for improvement and eventually comes to be widely used.[73] According to Crafts, the growth process of steam technology was subject to episodes of sharp acceleration and deceleration. Steam technology contributed little to economic growth before 1830 and had its peak only with the advent of high pressure steam post-1850. Notwithstanding the debate about precisely when steam technology came to dominate macroeconomic outcomes, von Tunzelmann's contention that steam power ensured a continuing process of industrialisation and technological change, and hence substantial economic growth, has proved long standing.

Bruland has acknowledged the value of the contribution of von Tunzelmann to the history of steam power generally, and to an understanding of the long term dynamics of the Industrial Revolution.[74] Nevertheless, in an overview of the effect of technological change on industrialisation, she cautions that the critical technologies approach of von Tunzelmann tends to see technological change as something that explains the industrialisation process, but is rarely itself seen in need of explanation.[75] In particular, and of relevance to this thesis, Bruland highlights the paucity of systematic studies on the impact of specific technologies on industrialisation.[76]

The historiography of the patent system as reassessed here in the context of the specific technologies associated with the early railway industry, highlights two significant themes. The management, accessibility and dissemination of railway-related technological knowledge, and the incentivisation of further inventive activity.

1.3 The patent system: management of knowledge

> The key to the Industrial Revolution was technology, and technology is knowledge.
>
> Mokyr[77]

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[72] Rick Szostak, *The Role of Transportation in the Industrial Revolution; A Comparison of England and France* (Montreal: McGill-Queen's University Press, 1991), 6.

[73] Nicholas Crafts, "Steam as a general purpose technology. A growth accounting perspective," *The Economic Journal* 114, (2004): 338-351.

[74] Kristine Bruland and Keith Smith, "Industrialisation, steam power and economic historiography; the contribution of Nick von Tunzelmann" (Preliminary draft January 2, 2010, for conference held on March 29-30, 2010, at The Freeman Centre, University of Sussex, http://nickfest.freeman-centre.ac.uk/conference program/K-Bruland-Smith, [accessed February 18, 2012].

[75] Kristine Bruland "Industrialisation and Technology", in *The Cambridge Economic History of Modern Britain*, eds. Roderick Floud and Paul Johnson (Cambridge University Press, 2004), 117-146, 122.

[76] Bruland "Industrialisation and Technology," 143.

[77] Mokyr, *The Gifts of Athena*, 29.

The management and accessibility of codified knowledge is a key theme of this thesis. It is foundational to the arguments presented here that, as identified by Biagioli, it was the requirement for the written specification that initiated the fundamental conversion of patents from a system of early modern privileges granted by the Crown to what is now regarded as intellectual property rights.[78] The situation is neatly summarized by Sherman and Bently's observation that with the advent of a written specification, patents began to evolve from being a product of the Royal Prerogative, to an accessible codified system, and that by 1852 the patent system was a creature of the administration.[79]

According to Trajtenberg, it is knowledge, rather than labour, machines, land or natural resources that is the key economic asset.[80] In acknowledging that the patent system encouraged technological innovation, Mokyr has concluded that commercial viability required both inventors and manufacturers to protect knowledge, and the patent system provided that security. He draws attention to the importance of industry-specific analysis.[81] This thesis endorses Mokyr's recommendation, but with a gloss. It is argued here that the patent specification performed the critical task of improving access to knowledge. It is demonstrated here that in relation to the specific industry of the early railways, much of the creative thinking of the leading inventive engineers of the day was captured by the conversion of their ideas into a patent specification which was subsequently published in official records and contemporary technical journals.

According to Mokyr, few scholars would argue with Kuznets' view that useful knowledge lies at the core of modern economic growth.[82] Nevertheless, Kuznets' proposition that economic growth is based on an increase in useful or tested knowledge,[83] contrasts with a number of seminal contributors, most notably Adam Smith and Karl Marx.[84] The expansion of knowledge continues to be a focus of academic debate concerned with economic change and development, a discussion that must remain largely beyond the remit of this thesis which is concerned primarily with the management and diffusion of knowledge rather than epistemological considerations.

[78] Biagioli, Mario. "Patent republic: representing inventions, constructing rights and authors," *Social Research,* 73 (2006): 1129–1172, 1130.
[79] Brad Sherman and Lionel Bently, *The Making of Modern Intellectual Property Law. The British Experience 1760-1911* (Cambridge: Cambridge University Press, 1999), 134.
[80] Jaffe. A. Trajtenberg, *Patents Citations and Innovation; a window on the knowledge economy* (Massachusetts: Massachusetts Institute of Technology, 2002), 1.
[81] Joel Mokyr, *The Enlightened Economy. Britain and the Industrial Revolution 1700-1850* (London: Penguin Books, 2009), 409.
[82] Joel Mokyr, "Innovation in an Historical Perspective: Tales of Technology and Evolution" in *Technological Innovation and Economic Performance,* eds. Benn Steil, David Victor and Richard Nelson, (Princeton: Princeton University Press, 2002), 23-48, 25.
[83] Simon J. Kuznets, *Economic Growth and Structures* (New York: W.W. Norton Book Co., 1965), 84-87.
[84] Adam Smith, *An Inquiry into the Nature and Causes of the Wealth of Nations,* eds. R.H. Campbell, A.S. Skinner and W.B.Todd, (Oxford: Oxford University Press), 1976.

This thesis contributes to the literature in that it undertakes a sector-specific analysis of the effect of the patent system on early railway-related inventive activity and the resultant dissemination of technological knowledge. The approach adopted in this thesis is influenced by Rosenberg's acknowledgement of the importance of interdisciplinary research in the pursuit of understanding technological change.[85] He considered the legal environment to be an important influence on technology commercialisation, but a subject little studied.[86] In this thesis, Rosenberg's proposition is adopted and extended in two important respects. Firstly, this study crosses interdisciplinary lines and considers the role of the adversarial legal system and the part played by the judiciary in shaping and framing the principles of patent law. Secondly, in order properly to examine the conceptual and technical foundations of early railway technology, this analysis explores the wider context of some associated technologies of the early nineteenth century. Nascent railway technology was but one of a number of emergent technologies and cannot be considered in isolation.

It is demonstrated here that prior to, and during the first half of the nineteenth century an effective patent system facilitated the management of technical knowledge. Hitherto, the contribution of the patent system to the origins of knowledge management has received little academic attention,[87] but it is argued here that the codification that commenced in 1733 had the effect of converting tacit knowledge into explicit knowledge, in a usable form. From 1733 explicit knowledge was organized, categorized, indexed and accessible. The Industrial Revolution created a fertile ground for knowledge to become collective, and safeguarding knowledge through patents (and trade secrets) became customary.

The evidence considered in this thesis challenges both Casson's suggestion that a knowledge based economy, in contrast to an economy based on natural resources, physical capital and low skill labour, did not develop until the late Victorian era,[88] and Drucker's opinion that every industry prior to 1850 was based on experience rather than knowledge.[89] According to Drucker, the Industrial Revolution changed the meaning of knowledge. It converted experience into knowledge, apprenticeship into textbooks, secrecy into methodology, doing into applied knowledge.[90] However, for Drucker, knowledge understood as systematic, purposeful, organised information, had practically nothing to do with any technologies or industries before 1850.[91] Drucker highlights a vital process, but this thesis

[85] Nathan Rosenberg, *Perspectives in Technology* (Cambridge: Cambridge University Press, 1976), 83.
[86] Rosenberg, Landu and Mowery, *Technology and the Wealth of Nations*, 7.
[87] Whilst Drucker was the first to coin the term 'knowledge worker', in the early 1960s, the term 'knowledge management' did not formally enter popular usage until the late 1980s. See Kimiz Dalkir, *Knowledge Management in Theory and Practice,* (Massachusetts: MIT Press, 2011), 16, 5. An informal survey conducted by Dalkir identified over a hundred published definitions of knowledge management and of these, 'at least seventy-two [he] considered to be very good!'
[88] Casson, *The World's First Railway System*, 57.
[89] Drucker, *The Age of Discontinuity*, 58.
[90] Peter F. Drucker, *Post Capitalist Society* (New York: Harper Business, 1993), 29.
[91] Peter F. Drucker, *The Age of Discontinuity* (London: Pan Books, 1971), 58.

challenges his timeframe. It is argued here that systematic, and purposeful organisation of technical information commenced in 1733, and it is demonstrated in this thesis that the pioneers of emerging railway technology, several decades before the 1850s, found great utility in the patent system. Some tacit knowledge continued to be protected and strenuously policed by craft guilds, by the drawing up of policies and apprenticeship regulations.[92] The creation of industrial or craft communities undoubtedly led to the sharing of knowledge between the competing individuals of those communities (such as the Cornish miners), and the sharing in some cases led to collective invention. These alternative settings for the management and control of inventive knowledge are considered in this thesis, but found not to have been a substantial aspect of railway-related inventive activity.

Much railway-related inventive activity was achieved by those who worked on the shop floor using their experience and observation, and this created a tension between capital and labour. Both MacLeod and Inkster have drawn attention to the conflicts that arose in patenting as between employer and employee.[93] Knowledge, as Daunton has observed, is a complicated term and has a multiplicity of meanings with troublesome relationships. He prefers the plural 'knowledges'.[94] According to Daunton, tacit knowledge was often held in low esteem, lacking authentication, status or authority. He has observed that employers anticipated that the knowledge accumulated by employees gave them undue influence over production. This led employers to systematise practical knowledge in the hands of engineers.[95] Nevertheless, it is demonstrated in this thesis that in relation to the early railway companies, the impetus for control and management of knowledge derived from an assortment of sources. In particular, those who funded railway innovation insisted on the management and preservation of inventive knowledge. In the absence of formal research (or any public funding) for the early railways, the individuals and companies concerned depended entirely upon private backing, and those financiers were looking for a return on their investment.[96]

This thesis identifies a number of significant investors who may not have been prepared to fund strategic inventions unless the relevant inventive knowledge was made the subject of a patent. Edward Pease, the major subscriber for the bulk of the capital in Robert Stephenson and Co., is a vivid example of a funder who recognised the crucial need to control and manage knowledge, and that this was best

[92] Daunton, *The Organisation of Knowledge*, 8.
[93] Christine MacLeod, "Negotiating the Rewards of Invention: The Shop Floor Inventor in Victorian Britain", *Business History* 41, no. 2 (April 1999): 17-36. Ian Inkster, "Manufacture and Technical Change: The Patent Evidence" in *The Golden Age. Essays in British Social and Economic History 1850-1870,* eds. Ian Inkster *et al,* (Aldershot: Ashgate Publishing Ltd. 2000), 121-139.
[94] Daunton, *The Organisation of Knowledge*, 1.
[95] Daunton, *The Organisation of Knowledge,* 9.
[96] In contrast with today where current debate is concerned with how basic research be funded in view of maximizing the efficiency of the innovation system as a whole: Galli Silvia, "Innovation-Specific Patent Protection and Growth" (Ph.D. diss., University of Durham, 2012), http://etheses.dur.ac.uk/3525/ [accessed October 20, 2012].

achieved through the patent system. His role is examined in detail in chapter 5 along with that of Edward Starbuck who managed the Company's increasing number of patents, and who took a forceful line with competitors in the event of infringement of patent rights. It is demonstrated in this thesis that the control and management of knowledge was crucial for the stakeholders of early railway technology who relied upon the patent system to protect their investment and secure monopoly profits.

In a series of papers relating to the American patent system (but equally applicable to the English system), Khan and Sokoloff have shown that the patent system exhibited many characteristics of the market place.[97] Many inventors responded to demand by patenting their ideas and then sought to secure a profit by licensing the knowledge that related to the invention. It is central to this thesis that the assignment and licensing of knowledge can only effectively take place when that knowledge is codified in some way. Mokyr questions whether a patent system is truly essential for the growth of useful knowledge.[98] However, it is argued here that in the context of early railway technology, the accessibility of codified knowledge in the form of published specifications, whether in official registers or contemporary journals, constituted a form of knowledge management that informed subsequent inventive activity.

1.4 The patent system: encouragement of inventive activity

> I am of the opinion that many great inventions would never have been brought to bear, as they have been, but for the encouragement offered by a patent.
> .
> Farey [99]

It is argued in this thesis that the patent system had an identifiable effect on early railway-related inventive activity. The reappraisal undertaken here of the operation of the patent system prior to 1852, identifies the motives and practices of the patentees and entrepreneurs of the early railways and in particular that the effectiveness of the patent system encouraged inventive activity.

The patent system was not of itself a cause for industrialisation in Britain. It did not affect the prevailing economic conditions that determine whether an invention may be commercially viable. Ireland possessed a patent system based upon the English system, but saw very little inventive activity, or industrialisation, during the early nineteenth century because the necessary economic conditions were

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[97] B. Zorina Khan and Kenneth L. Sokoloff, "Patent Institutions, Industrial Organization and Early Technological Change: Britain and the United States, 1790-1850," in Maxine Berg and Kristine Bruland, eds., *Technological Revolutions in Europe. Historical Perspectives* (Cheltenham: Edward Elgar Publishing Ltd, 1998), 292-313, 306.

[98] Mokyr, *The Gifts of Athena*, 295.

[99] John Farey, June 8, 1829, *Select Committee on the Law Relative to Patent Inventions* (1829), 141. Marc Isambard Brunel in giving evidence to the same committee and in answer to the question as to whether a period of 14 years was long enough for a patent replied, 'It is a great deal for some and not enough for some others; I shall lose probably six years before I come to make anything of my present patent', 39. Samuel Clegg, giving evidence on 29 May 1829, informed the committee that he thought there should be a power to extent the period of the patent 'upon a proper application; saying that such a sum of money has been expended; and that the time it has to run will not be sufficient to remunerate the expenses and to make a profit', 95.

not in place. In France during the relevant period patents were of marginal importance due to the lack of enforcement of patent rights.[100] This thesis demonstrates that the unique availability of the English patent system to those involved in the early railways reduced the threshold at which it became commercially viable to develop new technology. Unlike any other patent system in existence at the time, the English system uniquely allowed applications for patents to be decided by reference to consistent legal criteria and those that were granted were secure and well defined. The evidence considered in this thesis supports Khan's observation, made in relation to the United States, that once systematic examination and other improvements had been introduced, there was considerable growth in the American market for technology.[101]

The sector-specific study undertaken in this thesis argues that the characteristics of early railway technology were such that the patent system had an identifiable and positive effect on railway-related inventive activity. The contemporary evidence establishes confidence in, and reliance upon the patent system. Many of the strategic inventions of early railways (such as the 'travelling engine', that contributed in establishing Britain's epithet, 'workshop of the world') would not have been developed but for the encouragement offered by the patent system. The board minutes of many of the early railway companies demonstrate they were receptive to approaches from patentees, often allowing their premises to be used for the testing of, and development of inventions. The evidence demonstrates that many of the early railway companies relied on, and were enthusiastic purchasers of patented products. The period 1820 to 1850, in particular, proved to be an unparalleled market opportunity for entrepreneurial inventors who sought to capitalise on the opportunities offered by early railway technology

It is demonstrated in this thesis that the inauguration of Robert Stephenson and Co. (which developed to become the world's largest locomotive manufacturer) was influenced by the principal funders' insistence that patents be taken out to protect the engineering genius of George and Robert Stephenson. An insistence that realised eventual and substantial profits for the shareholders. The business practice of securing, and extending significant patents led to competitors being faced with a stark choice if they wished to avoid infringing existing patents and or costly litigious proceedings. Choices between either manufacturing under licence, or developing and patenting novel locomotive designs. The evidence considered in this thesis demonstrates that both scenarios contributed to increasing patented innovative output.

Evolving railway technology was characterised by numerous patented improvements to existing patented inventions. As standardisation gathered pace, patented designs were 'tweaked' and subsequent,

[100]Bottomley, "Patents and the first industrial revolution" (2014).
[101]B. Zorina Khan, "Selling ideas: An International Perspective on Patenting and Markets for Technological Innovations 1790-1930," *Business History Review* 87, (2013): 39-68.

innovative improvements were made the subject of patents. Furthermore, the singularity of many of the railway companies' engineering works resulted in a proliferation of patented designs. It is argued in this thesis that the patent system was used extensively for incremental improvements and novel inventions within early railway technology, and that financial considerations were paramount for the pioneers of much railway-related inventive activity. Increasingly, the influence of market forces reached beyond individual inventors and investors' needs to secure adequate remuneration. The evidence considered in this thesis demonstrates that the sale and licensing of patent rights was a progressively significant contribution to the commercial success of railway companies and their suppliers. In short, the patent system encouraged inventive activity.

1.5 Methodology and Resources

Recognition that technological change is an extremely complex process is foundational to the arguments constructed in this thesis. Technology involves both inventive and innovative activity, a distinction sometimes overlooked in the literature on technological change.[102] In this thesis, in the context of early railway technology, innovation is understood to serve as a specific tool of entrepreneurship to exploit the commercial opportunities of novelty. It is central to the scope of this thesis that invention, innovation and the subsequent diffusion of technological knowledge was often as a consequence of the actions of individuals other than the inventor, or the inventor was only able to realise those commercial opportunities with the help of other stakeholders. For instance, the methodology adopted here includes a consideration of the roles of Edward Starbuck and Stanton and Co., solicitors, and their involvement in the business interests of Robert Stephenson and Co., an involvement which, hitherto, has received little attention.

Primary sources consulted during this research include personal correspondence, diaries and contemporary biographies of a number of significant pioneers of the early railways, including George and Robert Stephenson, Marc and Isambard Kingdom Brunel, Edward Pease, John Ramsbottom, William Cooke and Charles Wheatstone. The primary and secondary sources provide valuable contemporary evidence of these individuals' views, motives and utilisation of the patent system.

The technical press of the day and the law reports of disputed patent cases provide detailed information as to the role of patents in contemporary society. Similarly, extensive board minutes of many of the early railway companies are available and provide contemporaneous evidence of the attitude of those companies to patenting. Two important evidential documents, *Report and Minutes of Evidence taken before Select Committee on the Law Relative to Patent Inventions* (1829) and *Report and Minutes of Evidence taken before a Select Committee on the Signet and Privy Seal Offices* (1849), capture the

[102] For example, Usher eschews any distinction between invention and innovation preferring instead a 'cumulative synthesis approach.' Usher, *A History of Mechanical Inventions*, 60.

views and advice of those who operated and participated in the patent system at the time. In addition, many of the important inventors produced papers that were discussed, and reported, most notably in the *Proceedings of the Institution of Mechanical Engineers* and the *Proceedings of the Institution of Civil Engineers*. These papers provide valuable insight as to inventors' perceptions of the workings of the patent system.

A further line of inquiry undertaken in this thesis is a consideration of the emerging service sector during the late eighteenth and early nineteenth centuries. Limited academic research has been completed to date with regard to the work of patent agents, but it is clear from the sources consulted in the course of this study, that they did more than just apply for patents. They used business skills to put technology to work. Well before the end of the nineteenth century it was an established practice for the work of individual inventors to be channelled into the technology market by a network of patent agents, engineers and lawyers whose role it was to translate an invention into a commercial commodity.[103] The reference works of the early patent agents Carpmael, Farey and Woodcroft, constitute a substantial component of the contemporary sources available for consultation.

Railway technology is recognised here as an amalgam of technologies making up a single complex socio-technical system. It has not been possible within the remit of this thesis, or necessary, to cover a great number of components. Nevertheless, the evidence reveals that certain constituents dominated railway-related inventive activity during the relevant period. Motive power is the obvious principal component, but to undertake meaningful analysis, this thesis offers a wider consideration of associated technologies beyond the railway proper. Relevant technologies associated with water and timber treatments and rubber products are examined in the context of patented processes applicable to railway technology, as well as some examples of specific railway equipment, namely, rails and safety valves, both of which engendered a substantial number of inventions and innovations, many of which were patented.

This thesis considers the contemporary evidence in the light of current literature on the historiography of the patent system, inventive activity in general and the early management of technical knowledge. Examination of primary and secondary sources identifies the substantial extent to which entrepreneurial inventors involved with the early railways, and their investors, engaged with the patent system in the development and conduct of their commercial interests.

It is argued here that pre-1852 the English patent system was in much better shape than is currently represented in mainstream academic literature. The arguments of this thesis are developed as follows. Chapter 2 traces the historiography of the patent system prior to 1852. Current academic opinion is

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[103] Kristine Bruland, "The Management of Intellectual Property at home and Abroad: Babcock and Wilcox 1880-1901," *History of Technology* 24, (2002): 151-170.

challenged, in particular assessments that the patent system was largely ineffective prior to 1852. It is argued that from the late eighteenth century the railway pioneers and inventors had available to them a system that was effective, facilitated patent protection and had the support of the judiciary.

Chapter 3 considers the value of patent data. Consideration is given to contemporary publications, as well as subsequent collations. The evidence demonstrates extensive recourse to patent data by inventors and their investors, but also lawyers and patent agents, and reveals that patented knowledge provided an accessible database of technological information. The chapter establishes the utility of patented knowledge in the context of the early railways. In particular, the extent to which regular consultation of published specifications, whether in official records or technical journals of the day, influenced the direction, if not the pace of inventive activity and commercial relationships. The chapter also assesses the value of patent data for subsequent, current scholarship.

Chapter 4 challenges scholarly opinion that during the late eighteenth and early nineteenth centuries, rather than relying on the patent system to protect and capitalise on inventive knowledge, inventors preferred instead voluntary sharing of knowledge among competing individuals (collective invention) and or working an invention in secret. It is argued in this chapter that there is little evidence these alternative settings found wide applicability within the early railways, but rather the individuals involved with railway technology generally chose to rely on the patent system to control and manage their technical knowledge. By reference to the contemporary evidence, it is also demonstrated that expectation of profit was a significant influence in the making of that choice.

Chapters 5 and 6 test the findings reached in preceding chapters by means of a detailed examination of the professional lives of the dynamic railway engineers George and Robert Stephenson, and Marc and Isambard Kingdom Brunel, who incontrovertibly made a significant and substantial contribution to railway-related inventive activity in the early part of the nineteenth century. These chapters scrutinise primary and secondary sources to ascertain the extent of their respective engagements with the patenting system, and their motives for so doing. Significantly, the evidence considered in these chapters identifies consequences in relation both to inventive activity and the management of knowledge. In chapter 5, for instance, it is suggested there is good evidence to suppose Robert Stephenson was a secret purchaser of shares in the Electric Telegraph Co. with an explicit aim of market dominance. An investigation that has received little academic attention to date. Similarly, chapter 6 challenges scholarly consensus regarding Isambard Kingdom Brunel's professed anti-patent stance. It is argued here that his correspondence reveals a markedly different attitude to patents in practice. In sum, these chapters argue that the pioneering engineers of the early railway industry, found great utility in the patent system.

Chapter 7 builds on the investigations of chapters 5 and 6 and extends the focus from engineers who enjoyed substantial reputational status, to the many individuals of less renown who sought to meet the demands of the emerging railways. This chapter examines the professional working practices of three inventors who contributed to the developing technology of the early railways, namely, John Ramsbottom, William Cooke and Charles Wheatstone. The Cooke and Wheatstone partnership, formed to promote electric telegraphy, provides a particularly apposite example of the tension that existed between reputational and financial motives for patenting. It is argued in this chapter that many of the strategic thinkers involved with the early railways relied on the patent system both for marketing purposes and to secure a period of monopoly profits.

Finally, chapter 8 contributes to the findings and arguments established in previous chapters by moving beyond the railway proper to consider the wider context of associated technologies. Many of the materials and items of equipment key to other industrial settings were fundamental to the emerging railways. In this chapter it is argued that the commercial success of the early railway companies depended in no small part on associated technologies, and that patented inventions represented lucrative commercial opportunities. This chapter establishes the pivotal role of the patent system in the entrepreneurial pursuits of individuals involved in technological developments with wider application to the early railways. The evidence considered in this chapter consolidates the arguments developed in preceding chapters that the patent system was effective and served to encourage railway-related inventive activity.

CHAPTER 2

THE PATENT SYSTEM: A DISPUTED HISTORIOGRAPHY

> The tools of legal history have rarely been brought to bear on the history of technology ... the fate of patents in the courts remains a black box.
>
> Beauchamp[1]

Introduction

This chapter challenges much of the current historiography of the patent system prior to 1852. In particular, the arguments presented here contest the assessments by Dutton and MacLeod that expense was a major deterrent,[2] that it was a system merely of simple registration[3] and that prior to 1830 judges were hostile to patents.[4] According to Dutton, during the late eighteenth and early nineteenth centuries inventors considered the judicial system to be more a matter of 'chance than calculation',[5] that success at law was very uncertain, a lottery. If such assessments are accurate, then the patent system would have proved unattractive to the inventors and funders of the period. However, it is argued here that the pioneers of the early railways had available to them an effective patent system that facilitated patent protection and provided an opportunity for monopoly profits, and a judicial system supportive rather than hostile towards patentees. It is a premise of this thesis that a combination of these factors encouraged the development and diffusion of early railway technology, and contributed to the commencement of the management of railway-related technical knowledge.

The sector-specific analysis offered here has implications for a wider understanding of the dynamics of the patent system of the early nineteenth century, a time when there were few alternative means for the promotion and protection of commercially viable innovative technological advances. The expediency of the patent system would have differed across individual technologies and, although beyond the remit of this thesis, the effectiveness of the system as reassessed here may have been a significant influence in the development of other technologies.

[1] Christopher Beauchamp, "Who invented the Telephone? Lawyers, Patents and the Judgements of History," *Technology and Culture* 4, (2010): 854-878, 854.
[2] MacLeod, *Inventing the Industrial Revolution,* 76.
[3] MacLeod, *Inventing the Industrial Revolution,* 41.
[4] Dutton, *The Patent System and Inventive Activity,* 77-78.
[5] Dutton, *The Patent System and Inventive Activity*, 72.

MacLeod and Dutton are agreed on perceived shortcomings of the patent system, but differ as to the implications for inventive activity. According to Dutton, the administrative and legal flaws of the system may have had a positive effect on technical development, and weak legal security may have led to the diffusion of technology. MacLeod has dismissed these arguments as excessively optimistic. She has suggested that it was not until 1830 when there was a change of judicial attitude from hostility to an appreciation of the role of patents, that a coherent body of law was developed removing inventors' insecurity which had, hitherto, inhibited diffusion.[6] Scholarly opinion persists as to the ineffectiveness of the early patent system. Inkster, writing in 2012, agrees with Dutton and MacLeod as to the failings of the patent system prior to 1852, which he regards as insubstantial, costly and badly monitored or regulated.[7] Similarly, in 2015, Beauchamp opined that the English patent system of the eighteenth century was not fit for purpose and was threatened with abolition.[8]

The broad definition of the English patent system adopted here is the process by which patents prior to 1852 were formally awarded and recorded, together with the role of the judiciary in the adjudication process of patent disputes in an evolving industrial society. The vital role of the judiciary is often assigned to the histories of other knowledge systems and neglected by the historians of technology. Arapostathis and Gooday suggest that the adversarial legal system provided the context for the 'ultimate configuration of meanings, identities and roles in inventive patenting'.[9] Their analysis relates to electrical technologies at a later period. Nevertheless, Arapostathis and Gooday's approach is informative and supports the arguments presented here. Their understanding of the role of the legal system at the relevant time is complemented by the arguments constructed here for a reassessment of the workings of the patent system. Between 1624 (The Statute of Monopolies) and 1852 (The Patent Law Amendment Act), in the absence of substantial parliamentary intervention in relation to patent law, the judiciary developed a coherent set of patent law precedents and principles. Additionally, perhaps in response to the pressures of rapid industrialisation, judges developed novel remedies for the enforcement of alleged patent infringements. This is contrary to Macleod's opinion that difficulties in enforcement meant that patents were rarely of value to the inventor.[10]

In this thesis the challenge to the scholarly consensus is undertaken by reference to three significant dates. Firstly, the timing of the transfer of patent disputes from the Privy Council (senior members of the judiciary who formally advise the sovereign on the exercise of the Royal Prerogative) to the courts of equity and common law. Secondly, the date from which it became common practice for the Law Officers, the Attorney General or the Solicitor General, to require an application for a patent to include

[6] MacLeod, "The Paradoxes of Patenting," 906.
[7] Inkster, "Highly Fraught with Good to Man," 116.
[8] Beauchamp, *Invented by Law,* 132.
[9] Arapostathis and Gooday, *Patently Contestable,* 85. The authors' notion of social activity is dependent upon patent protection and is distinct from 'collective invention' which is discussed in Chapter 3.
[10] MacLeod, *Inventing the Industrial Revolution,* 69.

a specification, a written description of the invention. Thirdly, the date from which the courts insisted upon an accurate specification as part of the adjudication when considering alleged infringement. Having established the importance of these three dates, it is possible to argue for a reassessment of the historiography of the patent system prior to 1852.

2.1 Three significant dates

The first significant date is concerned with the transfer of patent disputes to the jurisdiction of equity and common law courts. Originally, where patents were defined as privileges granted by the monarch, disputes were decided by the Privy Council, the monarch's own court.[11] It is a matter of importance that the basis of the jurisdiction of the Privy Council was a consideration of the public good. This would have taken precedence over the rights of inventors and patentees.[12] The Privy Council ultimately relinquished its jurisdiction in relation to patent disputes to the equity and common law courts. In 1785, in *Arkwright v Nightingale*, Lord Loughborough stated,

> … we must never decide private rights upon the idea of public benefit. I must tell the jury that they must shut out that part of the argument. I cannot let a cause between A and B be determined upon consequential reasons that it is beneficial to the public that B should prevail.[13]

As will be examined later, Hulme, an early historian of the judicial system, identified the date of transfer as 1753.[14] However, the timing of that transfer, and the reasons for it are the subject of much academic debate. MacLeod has suggested that it was not until 1766 that the Privy Council surrendered its authority and the common law courts commenced the development of a coherent system of patent case law and patent rights.[15] According to Bottomley, the Privy Council had become an irrelevancy much earlier. He argues for 1688, the year of the Glorious Revolution.[16]

Notwithstanding the lack of consensus, there is good evidence that jurisdiction in relation to patent rights was passing to the equity and common law courts from as early as 1714. Patent disputes that were begun in the court of Chancery, commenced with the issuing of a bill of complaint and those issued for the period 1714 to 1758 demonstrate that of the 339 patents granted, at least 18 were the subject of a bill of complaint.[17] For the later period 1758 to 1800, numerous bills of complaint were issued in relation to patents.[18] It is argued here that the judiciary was formulating principles of patent law far earlier than is generally acknowledged, and providing patentees with a means of protecting and enforcing their rights.

[11] Biagioli, "Patent republic," 1130.
[12] Bottomley "Patent Cases," 30.
[13] *Arkwright v Nightingale* (1785) 1 CPC 38. William Carpmael, Law Reports of Patent Cases, vol.1 (London: A. Macintosh, 1843), 41.
[14] Hulme, "Privy Council Law," 194.
[15] MacLeod, *Inventing the Industrial Revolution*, 61.
[16] Bottomley, *The British Patent System,* 111.
[17] Court of Chancery: Six Clerks Office: Pleadings 1714 to 1758, C11, National Archives, Kew.
[18] Court of Chancery: Six Clerks Office: Pleadings 1758 to 1800, C12, National Archives, Kew.

The Chancery courts offered remedies to patentees that were unavailable elsewhere. For example, injunctions could be imposed with immediate effect, an attractive sanction for patentee litigants.

The second significant date pertinent to this reassessment is 1733 and the commencement of the Law Officers' practice of requiring a written specification to be filed within three months of a patent application. The specification submitted by John Naismith for his patent in 1711 is regarded as the first true written specification, but by 1733 the specification was generally required of all potential patentees.[19]

The third significant date is 1778 when it was decided by the judge in *Liardet v Johnson,* that the *consideration*[20] for a patent must be the disclosure of the invention in the specification. From 1778 a legal obligation was placed on an inventor to support an argument as to patent infringement with a written specification, an obligation that led to two important consequences. Firstly, as Biagioli argues, it represented the beginning of the conversion of patents from privileges granted by the monarch, to modern intellectual property rights.[21] Secondly, the filing of a written specification can be understood to signify a form of commencement of the management of technical knowledge.

It is recognition of the significance of these three dates, 1714, 1733 and 1778, that justifies reappraisal of the current historiography of the patent system. From the early eighteenth century, far earlier than is generally acknowledged, the common law and equity judges were establishing enforceable principles of patent law.

2.2 Two common misconceptions

Having established three significant dates relevant to this reassessment of the patent system, two common, and persistent misconceptions remain to be addressed. Firstly, the evidence of the Law Officers' caveat hearings does not support MacLeod's assertion that prior to the Industrial Revolution the English patent system was one of simple registration with little consideration either as to merit or whether the application infringed an existing patent.[22] Similarly, in a recent consideration of early electrical technologies from the 1870s to the 1920s, Arapostathis and Gooday propose that a system of 'simple' registration existed until 1905[23] and that the court room was the only formal forum for the

[19] MacLeod, *Inventing the Industrial Revolution,* 49. Bottomley, *The British Patent System,* 46-47.
[20] Consideration is a legal term defining a benefit/value, which must be bargained for between the parties, and is the essential reason for a party entering into a contract. Consideration must be identified for the contract to be binding between the parties.
[21]Modern intellectual property rights are generally understood in terms of the assets of intangibles that can consist of patents, trade secrets, copyrights and trademarks, or ideas. Biagioli argues that it is the specification requirement that 'makes the patent system defensible in political terms'. Biagioli, "Patent republic," 1130.
[22] MacLeod, *Inventing the Industrial Revolution*, 41.
[23] Arapostathis has argued for 1907. Stathis Arapostathis, "Contested inventors: British patent disputes and the culture of invention in the late nineteenth century," in Arapostathis and Dutfield, eds., *Knowledge Management and Intellectual Property*, 145-161, 145

resolution of patent disputes.[24] However, at caveat hearings the Attorney General or Solicitor General adjudicated on the novelty of a proposed patent, and a parliamentary return for 1849 records 1,687 such hearings between 1838 and 1847.[25] Furthermore, the high number of hearings suggests an established practice stretching back into the previous century. In 1849, Francis Campin, patent agent and member of staff at the law offices, who for some ten years had 'been in the practice of passing patents', confirmed to a parliamentary select committee, 'one third of all patents are opposed'. He went on to describe the various steps that allowed caveat hearings and suggested that the matter of importance to patentees was to 'get their rights insured to them in a perfect manner and at no small cost'.[26] In giving evidence to the same committee, William Carpmael, patent agent for 27 years, was very supportive of the caveat system because, 'I have seen wrongs prevented by the opportunity being afforded for a second opposition'.[27] He was equally supportive of the role of the Law Officers as the 'proper [men] to decide these issues' and he confirmed in his answers that both Sir Michael Faraday and Isambard Kingdom Brunel had been called upon to assist with caveat hearings. The process of caveat hearings is detailed later in this chapter, but the evidence is clear. The system enabled the claims of the petitioner to be investigated and was thus far more rigorous than one of mere registration. A robust system would have been attractive to potential railway inventors and investors looking to secure a return.

The second, persistent misconception is MacLeod's assertion that expense was a major deterrent to the obtaining of a patent. Macleod's opinion was not shared by Dutton who suggested that many patentees could share the cost of patenting with their employers, business partners and other inventors.[28] MacLeod's argument is not borne out by analysis of the views of many of those involved with early railway technology who were using the system at the time. As demonstrated in chapter 5, George Stephenson, an illiterate and likely impecunious colliery enginewright and brakesman, was able to fund his joint, first patent application in 1815. Furthermore, in 1829, several of the witnesses giving evidence before a parliamentary select committee argued that patent fees should be increased. Marc Brunel maintained that the expense of patents should be 'high', and Samuel Clegg argued that the fees should be 'higher'.[29] In 1849, Frederick Campin told another parliamentary select committee that although he would like to see a reduction in the fee, there was a danger it would lead to a profusion of applications for petty modifications. He argued for the same policy as in France namely, that of annual instalments.[30]

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[24] Arapostathis and Gooday, *Patently Contestable*, 7, 34.
[25] *Patents for inventions. A return of the number of letters patent sealed at Westminster Hall for each of the last ten years, ending 31 December 1847, together with the fees paid; &c.* (House of Commons, February 12, 1849), 7-8.
[26] Francis Campin, August 19, 1848, *Report and Minutes of Evidence taken before a Select Committee on the Signet and Privy Seal Offices* (London: Clowes and Son, 1849) 15, 18.
[27] William Carpmael, August 25, 1848, *Select Committee on the Signet and Privy Seal Offices* (1849), 32.
[28] Dutton, *The Patent System and Inventive Activity*, 110.
[29] Marc Brunel, May 11, 1828, and Frederick Campin, August 19, 1848, *Report and Minutes of Evidence taken before a Select Committee on the Law Relative to Patent Inventions. Select Committee on the Law Relative to Patent Inventions* (House of Commons, June 12, 1829), 39, 45.
[30] Frederick Campin, August 19, 1848, *Select Committee on the Signet and Privy Seal Offices* (1849), 21.

In this chapter, it is argued that prior to the emergence of early railway technology, the judiciary contributed to the establishment of enforceable patent principles. In order to develop this argument, it is necessary to provide a brief history of the development of the English Patent system and the status of the Statute of Monopolies 1624.

2.3 Historiography of the English patent system

The historiography of the patent system dates back well over a century, and the starting point for analysis is a series of pioneering articles in the *Law Quarterly Review* between 1896 and 1934 by E. Wyndham Hulme (the then Librarian of the Patent Office) and D. Seaborne Davies, which made an important contribution to the administrative and judicial history of the patent system.

There is debate as to when the first patents were granted. May has suggested the patent system originated in Venice in the fifteenth century.[31] He advocates that a few patents had been granted in Venice prior to 1474, but that in that year Venice promulgated its first patent statute, which Adams suggests may be the first modern patent law.[32] As to the granting of patents in England, Hulme writing in 1896 attributed the first grant of a patent as a reward for inventors to one Jacob Acontius who petitioned Elizabeth 1 for the grant of a monopoly.[33] Acontius, an Italian engineer, had taken out letters of naturalization and was in receipt of a small Crown pension. In 1559 he suggested to the Crown that a monopoly was the most effective method of rewarding an inventor. His recommendation appears to have borne fruit by the adoption of a monopoly policy in 1561, but Acontius did not receive his patent until 1565. Hulme records as follows, from the Patent Rolls and Calendars: 'No. XVL.1565 Sept 7. Licence to James Acontius for the manufacture of machines for grinding, & Co [for twenty years] (Latin)'.[34]

During the Middle Ages the industrial attainments of England were below the level of their continental rivals France, Germany, Italy, Spain, and the Low Countries. The slow infiltration of improved processes was traceable to the more advanced civilization of the East. In 1331, the Flemish weaver,

[31] Christopher May, "Antecedents to Intellectual Property. The European Pre-history of the Ownership of Knowledge," *History of Technology* 24, (2002): 1-20, 2. May comments that prior to the Venetian Statute there was little that could be regarded as intellectual property, but ideas about owning knowledge were not novel in the fifteenth century.

[32] The Act provided: … every person who shall build any new and ingenious device in this city, not previously made in our Commonwealth, shall give notice of it to the office of General Welfare Board when it has been reduced to perfection so that it can be used and operated. It being forbidden to every other person in any of our territories and towns to make any further device conforming with and similar to said one, without the consent and license of the author for the term of ten years. John Adams, "History of the Patent System," in *Patent law and theory: a handbook of contemporary research,* ed. Toshiko Takenaka (Cheltenham: Edward Elgar, 2008), 101-131, 101.

[33] Acontius was born in Trent in northern Italy. He qualified as a lawyer, but was also a talented engineer undertaking the fortification of the town of Berwick on Tweed and the drainage of the Plumstead Marshes. "Aconcio, Jacopo (*c*.1520–1566/7?)," in *Oxford Dictionary of National Biography,* ed. H. C. G. Matthew and Brian Harrison (Oxford: OUP, 2004); online ed., ed. David Cannadine, January 2014, http://www.oxforddnb.com/view/article/69 [accessed19 Sept 2015].

[34] Hulme, "The History of the Patent System," 148.

John Kempe and Co. was granted letters of protection with the intention of introducing to England skills relevant to the textile industry, but extended to contain a general promise of like privileges to all foreign weavers, dyers and fullers on condition of their settling in England and teaching their arts to those willing to be instructed.[35] The early grants did not exclude others from practising a particular craft or technology. The first to do so was that awarded to John Utynam in 1449 for the art of making all colours of glass. There arose the practice of the granting of two distinct kinds of patents: those for the granting of monopolies over things already invented; and those granting monopolies for novel inventions. The former being generally resented by both Parliament and the public, whereas the latter were viewed favourably.[36]

Patents were but one type of royal letters patent described in 1768 by William Blackstone, the jurist, in the following terms,

> … [t]he King's grants are ... a matter of public record ... These grants, whether of lands, honours, liberties, franchises or ought besides are contained in charters or letters patent ...'[37]

Inventions were, therefore, one part of this class and described as 'ought besides'. They were thus originally the document by which the Crown conferred special privileges.[38] In the time of Elizabeth 1 it was a major policy of her Chief Minister, later Lord Burghley, to award patents to foreign artisans who imported new manufacturing processes or invented new products previously unknown in England, including textiles, mining, metallurgy and ordnance. The guilds of the day were consulted in an attempt to avoid disputes, but Burghley's policy did not provide the desired results.[39] With mounting tension between Parliament and the Crown as to what was considered a misuse of the Royal Prerogative, Parliament enacted the Statute of Monopolies (1624).[40] This had the effect of excluding various grants, but section VI of the Act was concerned with patents for invention and is dealt with in more detail below.

Before considering the influence of the common law, it is necessary to consider the process of obtaining a patent.[41] Prior to 1852 there was no dedicated Patent Office, and an application for 'letters patent' had to be referred in accordance with the Clerks Act (1535) to one of the Crown's Law Officers, namely the

[35] Hulme, "The history of the patent system," 142.
[36] Adams, "History of the Patent System," 102.
[37] William Blackstone, *Commentaries on the Laws of England in four volumes, vol. 2* (Oxford: Clarendon Press 1765-1769), 346.
[38] John Farey produced for the Select Committee on Patents in 1829 a 'list of the various Acts of Parliament by which the operation of exclusive Privileges and other Acts by which the granting of Royal Letters Patent is authorised and regulated; also, Acts for promoting and encouraging improvements in Arts and Manufacturers by granting Rewards to Inventors; and by prolonging the Terms of their Patent Rights'. The list numbered 116 for the period 1225 to 1829. *Law Relative to Patent Inventions* (1829), 163.
[39] MacLeod, *Inventing the Industrial Revolution,* 14.
[40] Kyle argues that the 1624 Act was not a case of conflict between the Monarch and The Commons, who both united against the powerful interests of the Lords. The enactment illustrates a close co-operation between the King and the Commons: Christopher Kyle, "But a New Button to an Old Coat: The Enactment of the Statute of Monopolies, 21 James1 cap. 3," *The Journal of Legal History* 19, (1998): 202-223.
[41] For a detailed explanation of the process see: *Signet and Privy Seal Offices* (1849), viii-ix.

Attorney General and Solicitor General,[42] who checked that the patent would not contravene the Statute of Monopolies. As discussed above, it is clear from a parliamentary return for 1849 that the system also involved caveat hearings concerned with adjudication as to novelty. For the period 1838 to 1847, of the 5993 patent applications made to the Law Officers, 2,064 were subject to opposition and 1,687 proceeded to a caveat hearing.[43]

A caveat hearing could be general or special. A general caveat hearing was a first stage opposition before one of the Law Officers who heard each party separately in order to preserve secrecy.[44] Special caveat hearings dealt with a final challenge from a party seeking to stop a patent from receiving the Great Seal.[45] By their nature special caveat hearings were considered at a last stage of the process and came before the Lord Chancellor, although he usually delegated them to the Law Officers. According to Fredrick Campin, about a 'fiftieth part' of applications were subject to a special caveat hearing.[46] William Carpmael was very supportive of the Law Officers in their adjudication of caveats, and approved of their eventual promotion to the judiciary,

> … unquestionably, and for these reasons, the [Law Officers] very quickly became masters of the subject of the patent law; they are soon at the very head of their profession as advisers in patents and ultimately are made Lord Chancellor or chiefs of the different courts. And by that means we have the very best men that possibly can be conceived as judges to try patent cases. All the broad lines of patent decisions have been laid down by men who have been [Law Officers].[47]

The patentee could choose to enrol in one of three Chancery offices, the Enrolment Office (or Close Rolls), the Rolls Office (or Chapel), or the Petty Bag Office.[48] Between 1617 and 1852, some 14,359 patents were granted, and the cost of an English patent depended on its nature. By 1849, it could be between £100 and £120,[49] a significant sum when a skilled worker earned between £1 and £2 a week. Marc Brunel giving evidence in 1829, stated, 'I think the expense of patents should be pretty high in this country, or else if it is low you will have hundreds of more patents yearly, and you would obstruct very much the valuable pursuits'.[50] Samuel Clegg also argued, before the same committee, for the expense to be increased.[51] In 1849, a number of those giving evidence before the parliamentary select committee argued that the high cost was an advantage because it prevented frivolous patent applications and meant that only applications of merit were considered. Frederick Campin stated,

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[42] The Clerks of the Signet and Privy Seal Act 1535, 27 Hen.VIII c 11.
[43] *Patents for inventions* (Parliamentary Return, 1849), 7-8.
[44] 'The Attorney or Solicitor General always hears each party separately, they are never confronted', Gravenor Henson, *The civil, political and mechanical history of the framework knitters* (Nottingham: 1831, reprinted A. M. Kelley, 1978), 269.
[45] The Great Seal was granted by the Lord Chancellor and delivered, together with the patent, to the patentee. There was a public seal day every Friday.
[46] Fredrick Campin, August 19, 1848, *Select Committee on the Signet and Privy Seal Offices* (1849), 17.
[47] William Carpmael, August 25, 1848, *Select Committee on the Signet and Privy Seal Offices* (1849), 25.
[48] From 1849, only the Enrolment Office was used.
[49] Fredrick Campin, August 19, 1848, *Select Committee on the Signet and Privy Seal Offices* (1849), 17.
[50] Marc Brunel, May 11, 1829, *Select Committee on the Law Relative to Patent Inventions* (1829), 38.
[51] Samuel Clegg, engineer and patentee, stated, 'I think [patent fee] would be better if it were more'. Samuel Clegg, May 29, 1829, *Select Committee on the Law Relative to Patent Inventions* (1829), 95.

> I do not think it would be a good policy to give a patent a very small expense because we should be inundated with trifling modifications in such a manner that there would not be a manufacturer in the Kingdom able to turn his hands in his manufactory to make the slightest improvement without interfering with some person's patent right.[52]

It is of interest that when the Patent Law Amendment Act (1852) reduced considerably patent application fees, the number of applications rose appreciably.[53]

It has been argued here that the significant developments in the English patent system prior to 1852 took place within the jurisdiction of the common law, which is further considered below. However, prior to that consideration it is necessary to examine in greater detail the Statute of Monopolies (1624), considered by many to be the foundation of the English patent system.

2.4 Statute of Monopolies 1624

In order to advance the argument that the judiciary created and developed the principles of patent law, it is necessary to consider the Statute of Monopolies of 1624, the first English statute to include patents in its subject matter. The 1624 Statute essentially enacted existing common law principles shaped by judges, and the evidence considered in this chapter establishes that in the absence of further substantial statutory guidance until the passing of the Patent Law Amendment Act in 1852, a period of some two hundred years, the judiciary was called upon to create the precedents of patent case law. In particular, the developing industrial economy of the late eighteenth century, including nascent railway technology, made increasing demands on judicial interpretation of patent law.

The Statute of 1624 outlined the circumstances of exception to the existing general prohibition on monopolies that could be made for an invention. A number of early writers gave undue importance to the Act, and considered that it formed the foundation of the English patent system. Turner writing in 1847 stated that the Act provided the 'first germ of the Patent Law, springing forth from the destruction of despotic privilege, like the young tree from the ruined castle'.[54] More recently, Kyle, writing in 1998, suggested,

> The Statute of Monopolies of 1624 is the founding statute of copyright and patent law in the English speaking western world ... the historiography of the Act has been based on the notion that an increasingly self-confident Commons managed to gain the upper hand over a reluctant King and force him to forego his prerogative right to grant monopoly patents ... the first statutory invasion of the [royal] prerogative.[55]

Kyle's interpretation of the founding of patent law can be challenged. For example, the first legal treatise on patents in 1803, written by John Collier, declared that 'the Statute of the 21st of James cannot be correctly said to impose any new restraints, but to prevent licence being substituted by law, by avoiding

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[52] Fredrick Campin, August 19, 1848, *Select Committee on the Signet and Privy Seal Offices* (1849), 21.
[53] Bottomley, *The British Patent System*, 64.
[54] T. Turner, *Remarks on the Rights of Property in Mechanical Invention with reference to Registered Designs* (London: W. J. White, 1847), 8.
[55] Kyle, "But a New Button to an Old Coat," 203.

any doubts and difficulties attending the legitimate exercise of the prerogative'.[56] Hulme, writing at the end of the nineteenth century, rightly argued that a number of the Statute's sections were declaratory of the common law,[57] and Boehm has advanced the view that the Statute relied heavily on King James 1's *Book of Bounty*, where he declared monopolies to be illegal.[58]

Sherman and Bently trace the prominence given to the Statute to the latter part of the nineteenth century, and argue that prior to this the Statute was not regarded as marking the beginnings of patent law. They point to the *Report of the Select Committee on the Law Relative to Patent Inventions* (1829), which lists and treats in a similar manner a number of statutes,[59] and insofar as the Statute of Monopolies was concerned, it was said to be chiefly declaratory of what had been said by the judges.[60] Sherman and Bently argue that the prominence given to the 1624 Statute as the foundation of patent law is the product of a nineteenth century re-writing of history. They suggest that the foundations of patent law are to be found instead in Royal Charters and Royal Letters Patent of the Crown dating from 1335. They urge that the temptation to rewrite history in our own image should be resisted.[61]

Sherman and Bentley also suggest that the process of drafting patent bills and legislation in the nineteenth century, even if not always successful, concentrated ideas and forced those involved to focus in more detail on the nature of the law. However, they propose that patent law did not exist in any recognisable form at the time, that the legislative processes were 'creating' rather than finding the law.[62] They cite as an example the Bill drafted by Godson in 1831,[63] where the word 'manufacture' is defined.[64] Nevertheless, Sherman and Bentley's analysis gives insufficient weight to the role of the judiciary in 'creating' the precedent based system of patent case law.

More recently, Gubby has argued that whether or not declaratory of the common law, the Act was of fundamental importance. She argues that the Statute of Monopolies formed the basis of the development of common law of the eighteenth and early nineteenth centuries.[65] She draws attention to the many patent case judgements of the period that make reference to the Act,[66] including *Hornblower v Boulton and*

[56] John Dyer Collier, *An Essay on the Law of Patents for New Inventions* (London: A. Wilson, 1803), 119-120.
[57] Hulme, "The History of the Patent System," (1896).
[58] Klaus Boehm, *The British Patent System* (Cambridge: Cambridge University Press, 1967), 16.
[59] Sherman and Bently, *The Making of Modern Intellectual Property Law*, 208-209.
[60] *Select Committee on the Law Relative to Patent Inventions* (1829). The appendix reads 'British Law of Patents for Inventions. A list of the various Acts of Parliament, by which the operations of exclusive privileges granted by Royal Charters and Royal Letters Patent, is limited and restrained, and other Acts by which the granting of Royal Letters patent is authorised and regulated.
[61] Sherman and Bently, *The Making of Modern Intellectual Property Law*, 208.
[62] Sherman and Bently, *The Making of Modern Intellectual Property Law*, 106.
[63] Richard Godson (1797-1849) MP for St. Albans and Kidderminster, 1831-1849, wrote one of the first treatise on patent law. Richard Godson, *Practical Treatise on the Law of Patents for Inventions and of Copyright with an Introductory Book of Monopolies* (London: Joseph Butterworth, 1823).
[64] Sherman and Bently, *The Making of Modern Intellectual Property Law*, 105-106.
[65] Helen Gubby, *Developing a Legal Paradigm for Patents* (The Hague: Eleven International Publishing, 2012), 92.
[66] Gubby, *Developing a Legal Paradigm*, 89.

Watt (1799)[67] where Mr Justice Gross cited the 1624 Statute in some detail. Gubby is incorrect in her analysis. She places undue importance on the citation of the Act, and fails to take into account the significance of judicial interpretation.

In reaching decisions, the judiciary was obliged to refer to any relevant statutory or case law authority. A failure to do so could have led to a judgement being challenged under the principle *per incuriam* ('through lack of care'), a judgement given without reference to a statutory provision of some relevance. Additionally, under circumstances where the Statute lacked detail, judicial interpretation was paramount. Blackstone, in his famous *Commentaries*, provided a list of interpretative criteria where he said that the courts had to consider the intention of the legislature, the effects and consequences, and the spirit and reasons of the law.[68]

This line of reasoning was articulated by Lord Denning, one of the most influential judges of the second half of the twentieth century and a substantial contributor to the growth of English common law, when he stated, in 1977,

> The judges do not go by the literal meaning of the words or by the grammatical structure of the sentence. They go by the design or purpose which lies behind it. When they come upon a situation which is to their minds within the spirit - but not the letter - of the legislation they solve the question by looking at the design and purpose of the legislation - at the effect it was sought to achieve ... this means that they fill in the gaps, quite unashamedly, without hesitation.[69]

Denning was of course referring to the situation as he saw it at the time of his judgement, but it is likely that the judges of the eighteenth and nineteenth century would have adopted a similar approach.

It is of significance for the arguments constructed in this thesis that innovation in early railway technology would have created a substantial 'gap' for the judges concerned with railway-related patent dispute cases. The Statute of Monopolies 1624, some 200 years before the emergence of railway technology, could not contain any detail of Parliament's intent in relation to the railways. The Act set out the barest of principles which the courts had to consider in their judgements, but the subject matter of emerging railway technology was unique, and required judges to create a new set of patent precedents. Sherman and Bently identify another factor which increases the 'gap', namely the absence of intellectual property law.[70] However, as argued above, judges were of necessity called upon to adjudicate patent dispute cases and by the beginning of the nineteenth century there was increasing certainty as to the principles of patent law.

The creative element of any judgement concerned with technical innovation becomes more apparent when one considers the competences required of judges who were unlikely to have received any training

[67] *Hornblower v Boulton and Watt* (1799), 1 HPC 397, 101 ER 1285.
[68] Blackstone, *Commentaries vol.3,* 430.
[69] *James Buchanan and Co. Ltd v Babco Forwarding and Shipping (UK) Ltd* (1977) QB 213-214,
[70] Sherman and Bently, *The Making of Modern Intellectual Property Law*, 3.

in engineering. Hence, Hutcheson writing in 1928 on the difficulty of legal judgement in patent disputes, stated that a judge hearing a patent case must have,

> … something of that same flash of genius that there is in an inventor, which all great patent judges have had, that intuitive brilliance of the imagination, that luminous quality of mind, that can give back, where there is an invention an answering flash for flash.[71]

Hutcheson rightly emphasises the important role of the speculation, intuition and insight of judges, and it is argued later that judges such as Lord Mansfield and others brought these qualities to the determination of patent disputes, and the shaping of English common law.

Section VI of the Statute of Monopolies 1624 sets out the important exception that all monopolies were against the law of the realm:

> Provided also and be it declared and enacted that any declaration before mentioned shall not extend to any letters patent and grants of privilege for the term of fourteen years or under, hereafter to be made, of the sole working or making of any manner of new manufactures within this realm, to the true and first inventor and inventors of such manufactures, which others at the time of making such letters patent and grants shall not use, so as also they be not contrary to law, nor mischievous to the State, by raising prices of commodities at home, or hurt of trade, or generally inconvenient.

The Act introduced the period of 14 years of protection for inventors, and established a dispute process by instituting a quorum of six Privy Councillors who could rescind a patent for an invention that was harmful, or already in use. As outlined earlier, the Privy Council retained these powers, arguably, until 1688 when jurisdiction was transferred to the common law and equity courts, and patents began to be adjudicated in terms similar to those of modern intellectual property rights.

Sir Edward Coke served as a Law Officer and appeared for the plaintiff in *Darcy v Allen* (1602) concerning a monopoly for importing playing cards. A monopoly which was set aside by the court following argument about the common law of patents. Coke was a Member of Parliament and served on the committee that considered the Bill of 1624. He was regarded as an expert on the Act and in his publication *Institutes*, he set out his view that the Act permitted letters patent for the sole working of new manufacturers, provided seven conditions were fulfilled. MacLeod provides a helpful summary and explanation, reproduced at Table 1. The Act introduced a number of concepts that had been the subject of decisions in the common law courts, for example, the concept of 'true and first inventor'. Hulme argued that the Statute did not introduce a new definition.[72] A view endorsed by Davies who suggested the term was used by the Tudors and Stuarts to encourage trade and commerce.[73] The pre-1624 reading of the word 'inventor', according to Hulme, meant one who had either invented, or introduced the invention into the realm.

[71] Joseph C. Hutcheson, "The Judgement Intuitive: The Function of the 'Hunch' in Judicial Decision," *Cornell Law Quarterly* 14, (1929): 274-288, 284.
[72] Hulme, "The History of the Patent System," 55.
[73] Davies, "The Early History of the Patent Specification," 96.

Table 1: Conditions for permitted letters patent for sole working of new manufacturers

i. Patent term limited to 14 years, being twice the statutory prescribed seven-year period of trade apprenticeship
ii. Patent must be granted for the 'first and true inventor'
iii. Patent must be 'of such manufacture, which any other at the making of such letters patent did not use'
iv. Patent must not 'be contrary to law', which meant newly invented[74]
v. Patent must not lead 'to a rise in prices of commodities at home'.
vi. Patent must not be 'to the hurt of the trade'
vii. Patent should not be 'generally inconvenient'. (Coke's rather surprising example of this principle was that a patent should not 'turn labouring men to idleness')

Source: MacLeod, *Inventing the Industrial Revolution*, 18.

Until the passing of the Patent Law Amendment Act in 1852, the legislative basis of the English patent system was provided substantially by the Statute of Monopolies.[75] However, undue emphasis has been placed on the influence of the 1624 Statute which was largely declaratory of existing common law principles and provided limited guidance for the subsequent development of patent law. Significant patent case law was developed over the course of the following two centuries and it is an important premise of this thesis that the principles of patent law created and developed by the judiciary provided the legal route by which patent disputes concerning the early railways were played out. Legislation may be, as suggested by de Pablos, an indication of realities which form a part of political, economic and cultural interests.[76] However, Parliament did not address the political, economic and cultural interests of the patent system until 1852. Such matters were left to the judiciary.

2.5 The courts' structure

The central importance of the judiciary has deep roots. In 1154, Henry II institutionalised the common law by creating a unified system that was common to the country, and which elevated local custom to

[74] In cases where a new addition was invented which made the former more profitable, then Coke did not consider this to be newly invented. He relied upon the decided case of *Bircot's case* decided in 1573 which remained good authority until the late eighteenth century when it was overturned as an authority. *Bircot's case* (1573) 3 Co. Ins. 184 Exch. 382.
[75] An Act to Amend the Law Touching Letters Patent for Inventions 1835, 5 & 6 Wm. IV C.83. Known as Lord Brougham's Act (1835), it was the first change in patent law following the Statute of Monopolies. The Act allowed a patentee to amend the specification and to apply to extend a patent period beyond fourteen years, but did not permit any other substantive changes.
[76] Ana Romero de Pablos, "Temporalities and Localities of Industrial Property Rights: The Spanish Patent System from 1929 to 1986," *International Diversity in Patent Cultures - a historical perspective. Rethinking Patent Cultures Workshop.* University of Leeds, May 15, 2014.

the national level.[77] Judges went on circuit around the realm and in time the formal reporting of their decisions greatly aided the creation of precedents upon which the common law relied heavily. It is a distinctive feature of the common law that it represents the law as expressed in judicial decisions. Prior to 1873 when they were merged, there were three senior common law courts in England with four judges sitting in each, namely, the Court of Kings Bench, the Court of Common Pleas and the Court of Exchequer. It was the judges, regarded by the eighteenth century commentator, William Blackstone, as the 'depository of the laws, the living oracles',[78] who established the principles of common law.

The common law courts structure of the eighteenth century was not coherent, due to overlapping jurisdiction between courts. A decision on a patent dispute by one senior court could be brought again, by the same parties, before a different senior court. The same court could hear the same case on more than one occasion. A case was generally heard before a single judge and jury, a process known as *nisi prius.* A verdict reached at *nisi prius* had to be returned to a full court before the judgement could be finalised. This meant that applications (motions) for a new trial were routine. If the new trial was concerned with a challenge as to facts, then the case would be re-heard by a jury, but if there was a challenge as to the law, the case would go from the Court of Common Pleas and Exchequer, by a Writ of Error, to the Court of Kings Bench. The House of Lords was the highest court of review.

The equity courts did not hear cases with a jury. If a patentee wanted to apply for an equitable remedy such as an injunction to prevent the use of a patent, or for an account of profits wrongfully obtained by an alleged infringer, then it was the equity courts that possessed the necessary jurisdiction. These equitable remedies would have been attractive to patentees, but their role has been given insufficient weight in the literature. In 1829, giving evidence to a parliamentary select committee, John Farey emphasised the role of injunctions, 'the Chancellor will grant an injunction *ex parte* leaving it to be maintained, or removed according to the evidence'.[79] In the common law courts, patent disputes were heard before juries who, in the eighteenth century, did not represent a cross section of the community. A juror was expected to hold an interest in land because it was thought men of estate were less likely to succumb to bribes.[80] The parties could apply for a special jury which was introduced to deal with cases that were 'of too great nicety for the discussion of ordinary freeholders'.[81] Special juries were attractive to patentees. In 1796, in a letter to Thomas Wilson, James Watt declared,

[77] In January 1176, Henry II held a meeting of his Great Council at Northampton where a decision was made to divide England into six judicial circuits, with three judges sitting on each circuit. Brand and Getzler, *Judges and Judging,* 3.

[78] William Blackstone, *Commentaries on the Laws of England* vol. 1, (Oxford: Clarendon Press 1765-1769), 69.

[79] John Farey, May 11, 1829, *Select Committee on the Law Relative to Patent Inventions* (1829), 33. The courts also directed inspection of premises to validate patent applications.

[80] Giles Duncombe, *Trials per pais or, the laws of England concerning juries by nisi prius* (London: Woodfall and Strahan, 1766), 109.

[81] James Oldham, *English Common Law in the Age of Mansfield* (Chapel Hill: University of Carolina Press, 2004), 25.

> Captain Morcom should not sell the bear's skin until he has killed the beast, to be certain of setting our patent aside is rather too bold, we have good reason to hope to the contrary. The cause is in Common Pleas, we are plaintiffs and shall have a Special Jury, with as we hope the Chief Justice to preside ... their talk of some other person having invented it is a mere bugbear.[82]

The litigant applying for a special jury had to pay the fees, unless the judge certified a special jury was required. Prior to 1825, there were no particular requirements for special jurors although the members were still expected to be of a certain social standing and hold an interest in land. The special jury called together in the case of *R v Arkwright* (1785) included a broker, a bell manufacturer, a chinaman and a gentleman.[83] The County Juries Act of 1825 imposed conditions for members of special juries in that they needed to comprise merchants, bankers, or esquires.[84]

Matters of law were for the judge, and matters of fact for the jury. In patent cases the questions of fact for the jury were usually concerned with whether the invention was new, the inventor was the true inventor and or the specification was clear. Lemley, in his examination of eighteenth century English juries, concluded that the role of the jury was circumscribed. In patent disputes judges gave their opinions as to the facts even though the adjudication of facts was for the jury, and gave instructions such as 'if you believe X you must find for the plaintiff'.[85] For example, in the case of *Arkwright v Nightingale* (1785), Lord Loughborough's direction to the jury rested upon 'simply whether you believe five witnesses who have sworn to a positive fact'.[86] Similarly, in *Cochrane v Braithwaite* (1832) Judge Denman directed the jury as follows,

> … several of the defendant's witnesses have given it as their opinion that an apparatus constructed in the manner set forth in the plaintiff's specification would not work, but I do not think that any mere opinion of this sort is to be put in competition with the positive testimony of such men as Brunel, Bramah, Birkbeck, Turrell and Partington, who all swore that they had actually seen the plaintiff's apparatus at work.[87]

Oldham researched law reporting in the London newspapers between 1756 and 1786, and concluded that the London press contained a surprising amount of information about court proceedings.[88] In support of Lemley, Oldham cited several reported examples where judges (including Lord Mansfield) gave very clear instructions to the juries as to their verdicts. Oldham concluded that the juries considered they had

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82 James Watt, letter to Thomas Wilson regarding causes in Common Pleas, June 30, 1796, *Matthew Boulton and James Watt Correspondence*, AD1583/9/35, Cornish Record Office, Truro.
83 Richard Arkwright, *The trial of cause instituted by Richard Pepper Arden Esq, his Majesty's Attorney General, by writ of Scire Facias, to repeal a patent granted on the sixteenth of December 1775 to Mr Richard Arkwright* (London: Hughes and Walsh, 1785) 11.
84 County Juries Act 1825, 6 Geo 4 c 50.
85 Mark Lemley, "Why do Juries decide if Patents are Valid?" *Virginia Law Review* 99, (2013): 1673-1736, 1690.
86 *Arkwright v Nightingale* (1785), 1 WPC 60.
87 *Cochrane v Braithwaite* (1832) 1 CPC 493, 501
88 James Oldham, "Law Reporting in the London Newspapers, 1756-1786," *The American Journal of Legal History* 31, (1987): 177-206, 177.

a moral obligation to follow the direction of the judge. Judges frequently directed juries to find for one party or the other, and juries ordinarily complied.[89]

Judges also had the power to dismiss a case before the jury had been invited to return a verdict. This was called ‘nonsuit'. A case could be nonsuited by the judge on a number of grounds: delay on the part of the plaintiff; a decision by the judge that the plaintiff had failed to show a sufficient case to put to the jury; or some error or defect in the plaintiff’s case. A deficiency in the specification was a common cause of nonsuit. Deficiencies such as a failure to distinguish between the new and old invention,[90] the specification was misleading,[91] or the invention was not considered to be new.[92] An examination of the reported cases, (and Lord Mansfield’s court note books)[93] demonstrates that a nonsuit judgement was a common decision in patent cases. It is clear, therefore, that a combination of the judicial power to nonsuit, the practice of juries to follow the direction of the judge and the absence of juries in the equity courts, meant that it was the judges of the time who played a substantial role in the development of patent law prior to 1852.

The process generated by Arkwright's second patent is illustrative of the multiplicity of proceedings generated by essentially the same issue in dispute. Two cases were brought by Arkwright, and one by the Attorney General. In *Arkwright v Mordaunt* (1781)[94] the case came before Lord Mansfield sitting in the Court of Kings Bench when the court found against Arkwright. Four years later, in *Arkwright v Nightingale* (1785)[95] the case came before Lord Loughborough sitting in the Court of Common Pleas, and Arkwright was successful. The Attorney General (Richard Pepper Arden) then sought to repeal the patent by writ of *scire facias* (at the request of a consortium of cotton manufacturers) and the case came before Mr Justice Buller sitting in the Court of Kings Bench with a jury. The jury 'without a minute's hesitation'[96] found for the Crown, and Arkwright's patent was revoked. Arkwright applied for a new trial but Lord Mansfield refused the request. 'It is very clear to me, upon your own shewing there is no colour for the rule ... a verdict has been found which is satisfactory to the judge'.[97] Had he allowed the application, the whole process would have started again.

Recent improvements in the cataloguing of cases initiated in the court of Chancery have established much greater recourse to the courts by patentees than previously supposed.[98] One of the reasons for this

[89] Oldham, *English Common Law*, 68.
[90] *Macfarlane v Price* (1816), 171 ER 446.
[91] *Savory v Price* (1823), 1 CPC 432.
[92] *Hill v Thompson* (1818), 1 WPC 249.
[93] John Adams, "Intellectual property cases in Lord Mansfield’s court notebooks," *The Journal of Legal History 8*, (1987): 18-24.
[94] *Arkwright v Mordaunt* (1781), 1 WPC 59.
[95] *Arkwright v Nightingale* (1785).
[96] Arkwright, *The trial of a cause*, 187.
[97] Arkwright, *The trial of a cause*, 191.
[98] Court of Chancery Pleadings 1714-1800, C11 and C12, National Archives.

preference for the court of Chancery would have been the remedies unavailable elsewhere. As discussed above, requests for an account to be taken (the assessment by the court of the financial loss caused by the act of infringement) were popular. Also, remedies of discovery, where each party was ordered to disclose to the other relevant documents, and remedies of injunction restraining an alleged infringer by way of threat of a money claim, or imprisonment. Injunctive relief was comparatively straightforward and allowed patentees to enforce their rights relatively quickly, without difficulty.

The advent of accurate law reporting in the mid-eighteenth century, together with newspaper reporting and the availability of contemporary pamphlets, enabled a system of precedent to be adopted. The formal reporting of cases, by such persons as James Burrows and Henry Cowper, captured the pleadings in a case, the arguments of counsel and the judgement of the court.[99] Lord Mansfield, in particular in his judgements on patent cases, referred to his reliance on the reports drawing a distinction between accurately and poorly reported cases.[100] However, some commentators have argued that Lord Mansfield's reputation was unfairly enhanced by high quality reporting of his judgements.[101] In certain cases, the only reports were those that appeared in newspapers. For example, the important case of *Liardet v Johnson* (1778) was only substantially reported in *The Morning Post* (February 23, 1778), *The Public Advertiser* (February 23, 1778), *The St James Chronicle* (February 21-24, 1778) and in pamphlets published by the parties after the hearing.[102]

This chapter has emphasised the prominent role of the judiciary in the creation of patent law. The authority of the judges in the court of Chancery, where there were no juries, the judiciary's ability to nonsuit, and the evidence presented here that juries in the common law courts were likely to follow the direction of judges, even on matters of fact, demonstrate the significant role of the judiciary in the development of patent law principles. It is pertinent and crucial, therefore, to examine the attitude and approach of the judiciary to patent disputes.

2.6 The role and attitude of the judiciary

[99] Sir James Burrow, *Reports of Cases Argued and Adjudicated in the Court of the King's Bench: during the time Lord Mansfield presided in the court, 1756-1772*, 5 volumes, (London: Brooke, 1777). Henry Cowper, *Report of Cases Adjudged in the Court of King's Bench from 1774-1778*, 2 volumes, (London: Brooke and Rider, 1809).

[100] John Wallace, writing in 1882, describes Burrow's Reports as 'works of art', and quotes Mansfield's view that Burrow's Reports were not always accurate. John W. Wallace, *The Reporters* (Boston: Soule & Bugbee, 4th ed.1882), 449, 451.

[101] 'Mansfield, as his contemporaries fully recognised, was singularly blessed in the private reporters he attracted, and it is easy to mistake the novelty and distinctiveness of his judicial leadership simply on account of his unmatched quality of the law reports covering his tenure at Kings' Bench'. David Lieberman, *The Province of Legislation Determined: Legal Theory in Eighteenth-Century Britain* (Cambridge: Cambridge University Press, 2002), 8.

[102] John Adams and Gwen Averley, "The Patent Specification; The role in Liardet v Johnson," *Journal of Legal History* 7, (1986):156-177, 165.

This chapter challenges the consensus that prior to 1830 there was judicial hostility towards patents, and that it was not until 1852 that patent law began to develop thus improving the security of patent rights. It is argued here that too much weight has been given to populist views, rather than to a detailed understanding of the work of the judiciary and the processes of litigation. In 1830, Charles Babbage expressed a populist view when he stated that the system was likely to 'stab the inventor through the folds of an Act of Parliament and rifle him in the presence of the Lord Chief Justice of England'.[103] If correct, then this would have been a serious impediment for potential patentees of early railway technology.

Dutton, in an analysis of judicial approach, claimed that judges were operating at a time when the quantity and quality of inventive activity was changing rapidly and the Statute of Monopolies (1624) provided little guidance as to the nature of an invention that could be subject to a patent.[104] Much is made of Lord Kenyon's statement in *Hornblower v Boulton and Watt* (1799), that he was not one who greatly favoured patents, and yet many commentators fail to record that he found for the patentee.[105] Dutton's assessment that prior to 1830 there was a hostility towards patents on the part of some judges, is challenged by MacLeod who suggests there is no evidence prior to the mid-eighteenth century of any anti-patent prejudice, but rather there was inconsistency and confusion.[106] However, Dutton and MacLeod agree that whatever may have been the previous position, by 1830 a more favourable approach towards patentees was adopted by judges. Dutton claims to have established that between 1750 and 1799 only 39 per cent of reported patent cases were decided in favour of the patentee, and by 1840 the success rate had increased to 76 per cent.[107]

Bottomley challenges Dutton's assumption that a case lost by a patentee is evidence of an anti-patent attitude. He cites examples where fraud was established on the part of the patentee who, therefore, deserved to lose their case.[108] Bottomley supplements Dutton's statistics by including cases from Hayward's *English Patent Cases*,[109] published subsequent to Dutton's work and containing all patent cases reported between 1660 and 1883, and further cases identified from Woodcroft's *Reference Indices*.[110] Bottomley demonstrates that Dutton undercounted both the number of litigated patent cases,

[103] Charles Babbage, "Reflexions on the Decline of Science in England, and on some of its Causes," *The Quarterly Review*, 43 (1830): 305-342, 333.
[104] Dutton, *The Patent System and Inventive Activity*, 72.
[105] *Hornblower v Boulton and Watt* (1799).
[106] MacLeod, *Inventing the Industrial Revolution*, 58.
[107] Dutton, *The Patent System and Inventive Activity*, 79.
[108] *Smith v Dickenson* (1804), 1 HPC 527. The patentee had stolen and patented an invention. The court awarded that the patent be awarded to the plaintiff and together with £300 damages. Bottomley, *The British Patent System*, 80.
[109] Peter Hayward, barrister, former editor of the official Reports of Patent Cases and of the Fleet Street Patent Reports. His most notable publication is the eleven volumes of patent cases for the period 1600-1883. Peter A. Hayward, *Hayward's Patent Cases, 1600-1883: A Compilation of the English Patent Cases for Those Years* (Abingdon: Professional Books, 1987-1988).
[110] The *Reference Indices* are considered in detail in chapter 3.

and the proportion of those won by patentees before 1830. Bottomley concludes that there is little evidence of judicial hostility or prejudice, and that by 1770 the judiciary had created a rationale of a patent being a contract between the inventor and the public.[111]

Bottomley's analysis is relevant to the arguments made here, but does not go far enough. Scrutiny of patent cases decided at a final hearing and that reached the law reports, is of only limited value for establishing the extent of patent litigation, for two important reasons. Firstly, law reporting was still in its infancy. An examination of pleadings in equity cases initiated in the court of Chancery, filed in all divisions of the Six Clerks Office for the period 1714 to 1800, reveals many unreported patent dispute cases.[112] By way of example there are two reported cases, in 1795 and 1798, involving Boulton and Watt's patented separate condenser for a steam boiler.[113] However, at least fifteen injunctions were obtained by Boulton and Watt between 1794 and 1798 to enforce their patent rights and most of these patent dispute cases did not reach the law reports of the day.[114]

Secondly, the modern day position is that a mere three per cent of all civil claims commenced in the courts reaches a final hearing and judgement,[115] and the position may not have been so different during the eighteenth and nineteenth centuries.[116] The reasoning being that the litigation *process* itself (the many procedural steps, taken by each party, between the issuing of proceedings and the judge's final decision) identifies the strengths and weaknesses of the dispute parties' cases as each step of the process is completed. The disclosure of relevant documents, and perhaps expert evidence, enables both parties to a patent dispute to reassess their chances of success at a final substantive hearing. This encourages

[111] Bottomley, *The British Patent System,* 79-85.
[112] Court of Chancery: Six Clerks Office: Pleadings 1714 to 1758, and Court of Chancery: Six Clerks Office: Pleadings 1758 to 1800; C11 and C12 respectively, National Archives, Kew.
[113] Boulton and Watt v Bull (1795), 1 HPC 369; Hornblower and Maberly v Boulton and Watt (1799). 1 HPC 397.
[114] *Boulton v Bull* (1794) C12/1730/17; *Boulton v Hawkins* (1794) C12/1552/24; *Boulton v Pasmore* (1794) C12/463/32; *Boulton v Reed* (1794) C12/1546/8; *Boulton v Rosewarne* (1794) C12/1986/15; *Boulton v Vivian* (1794) C12/1730/16; *Boulton v Daniell* (1795) C12/213/31; *Boulton v Paley* (1795) C12/956/13; *Boulton v Oxnam* (1795) C12/213/16; *Boulton v Bateman* (1796) C13//477/73; *Boulton v Fenner* (1796) C12/966/3; *Boulton v Hornblower* (1796) C12/213/11; *Boulton v Thackeray* (1796) C12/1552/25; *Boulton v Carpenter* (1798) C12/232/27; *Boulton v Reed* (1798) C12/233/11. The archive of pleadings for this period is incomplete and it is possible that Boulton and Watt may have sought and been granted in excess of 15 injunctions. For example, the 1785 bill book records a total of 1,544 bills, but only 1,110 survive. See Henry Horwitz and Patrick Polden, "Continuity or change in the Court of Chancery in the seventeenth and eighteenth centuries?" *Journal of British Studies* 35, (1996): 24-57, 30, n.18.
[115] 3.4% (2009), 3.3% (2010), 3.2% (2011), 3% (2012), 3% (2013), 2.8% (2014), 2.9% (2015). Civil Justice Statistics provided via email dated April 12, 2017, by Analytical Services, Ministry of Justice. Available at https://www.gov.uk/government/statistics/civil-justice-statistics-quarterly-october-to-december-2016 [accessed April 12, 2017].
[116] Kesan and Ball, in an empirical evaluation of (US) patent cases at the end of the twentieth century, found approximately 80% were settled prior to trial. Kesan, Jay, P. and Gwendolyn G. Ball, "How are Patent Cases Resolved? An Empirical Examination of the Adjudication and Settlement of Patent Disputes," *Washington University Law Review* 84, (2006): 237-312, 259.

settlement of disputes.[117] The litigation process is continually evolving, but opportunities for the disputing parties to evaluate their cases at different stages of the process has always been present. If the evaluation by one party to a patent dispute is that they will lose at the final hearing, then they will seek to settle on the best terms available to avoid unnecessary cost. For these reasons, the reliance by much of the patent literature on *decided* cases (particularly by Dutton) is flawed.

A much clearer view as to patentees' reliance and recourse to the common law and equity courts emerges when consideration is given to the number of pleadings that were *issued*. Notwithstanding that the contemporary records as to the issuing and settling of cases are difficult to trace, there is evidence that the majority of patent disputes were settled before they came to court often with the patentee, in return for dropping the case, agreeing to licence the use of the patent to the defendant. Matthew Hill, barrister specialising in patent disputes, in giving evidence to a parliamentary select committee in 1851 stated,

> … matters [are] often arranged between the parties, the defendant taking a license, which is a very common termination of patent disputes, it not being to the interest of either party to throw the invention open to all the world, but, if they can, to agree among themselves.[118]

Bottomley has established that between 1770 and 1845, some 30 per cent of English patents were assigned in full, and a further 25 per cent were assigned in part or licensed.[119] He acknowledges that since at the time many assignments and licences were unregistered, the true figures are likely to be higher.

Holdsworth, in his seminal work on the history of English law, concluded that in the eighteenth century the courts recognised the commercial advantages of encouraging inventors by the granting of patent rights. Referring to the case of *Boulton and Watt v Bull* (1799), Holdsworth stated that by 1799 the judiciary had 'quite got over their prejudices against patents, which had been due to the early association of patent rights with pernicious monopolies'.[120] Clegg, giving evidence to a parliamentary select committee in 1829, opined that the Chief Justice 'considers patent property more sacred and that a slight alteration or a little technical difference should not set aside the patent'.[121] Similarly, Carpmael in giving evidence to a parliamentary select committee in 1849 praised the ability of judges some of whom had adjudicated caveat hearings as Law Officers. He referred to them as the 'very best men' and 'we may

[117] Uff and Higgins identify the significance of the litigation process in reaching settlement in modern-day construction law disputes. John Uff and Joanna Higgins, "The structured avoidance of disputes," *Arbitration and Dispute Resolution Law Journal* 4, (1995), 170.
[118] Matthew Hill, May 26, 1851, *Report and Minutes of Evidence taken before the Select Committee of the House of Lords appointed to consider of the Bill, intituled, "An ACT Further to Amend the Law Touching Letters Patent for Inventions. Appendix C,* (House of Lords, July 4, 1851): 280.
[119] Bottomley, *The British Patent System,* 225. For the later period 1870 to 1883, Khan estimates that approximately 35% of British patents were assigned and or licensed. B Zorina Khan, *The Democratization of Invention; Patents and Copyrights in American Economic Development 1790-1900* (Cambridge: Cambridge University Press, 2005), 62.
[120] William Holdsworth, *A History of English Law Volume XI* (London: Methuen and Co., 1938), 430-431.
[121] Samuel Clegg, May 29, 1829, *Select Committee on the Law Relative to Patent Inventions* (1829), 96.

now largely refer the admirable decisions we have in the books upon patent cases, and which are cited in all parts of the world.'[122]

The supportive attitude of the judiciary can be established by reference to a number of reported cases. In *Arkwright v Nightingale* (1785), Lord Loughborough stated, 'the law has established the right of patents for new inventions; that law is extremely wise and just'.[123] Mr Justice Buller, in *Boulton and Watt v Bull* (1795), opined,

> … few men possess more ingenuity or have greater merit with the public than the plaintiffs on this record, and if their patent can be sustained as a matter of law no man ought to envy them the profits and advantages arising from it ... because the world has undoubtedly derived great advantage from their ingenuity.[124]

Similarly, in *Hornblower v Boulton and Watt* (1799) Mr Justice Ashurst stated,

> … the encouragement of new invention is of infinite importance to the Kingdom; and where it appears incontestable that the invention does possess all the useful properties that this ... [steam engine] ... professes to do, it would be hard if the inventor should be robbed of his reward by a frivolous criticism, when the public are actually enjoying the fruits of his labour.[125]

It is argued here, therefore, that by the late eighteenth century the common law had resolved any perceived tension between justice for individuals and the need to provide protection to patentees in an expanding industrial economy. For Dutton, in balancing the needs of inventors with those of society, judges were satisfied that patents were important for economic growth.[126] This accords with Ashton's observation that the need for funding was crucial and 'made it possible for Britain to reap the harvest of her ingenuity'.[127] There is good evidence that key inventors of the day would not have utilised a patent system perceived to be hostile to inventors. Bessemer stated that it was 'sheer madness'[128] for men to waste their energy and money without the protection of a patent, and Watt stated he feared 'an engineer's life without patent was not worthwhile'.[129] There can be little doubt that Boulton would not have advanced capital to finance Watt's steam engine without the security of a patent granted by an Act of Parliament. Writing to Lord Dartmouth, in 1775, Boulton stated,

> … as a great part of the time of his patent is elapsed and [Watt's] own life very precarious, and as a large sum of money must yet to be expended before any advantage can be gained from it, I think that his abilities and my money may be otherwise better employed, unless Parliament be pleased to grant a prolongation of the term of the executive privilege.[130]

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[122] William Carpmael, August 25, 1848, *Select Committee on the Signet and Privy Seal Offices* (1849), 26.
[123] Carpmael, *Law Reports*, 49.
[124] *Boulton and Watt v Bull* (1795). 1 HPC 369.
[125] *Arguments of the Judges in Mr Watt's Patent Trial 1799,* Boulton and Watt Papers, MS 3147 2/50, Birmingham City Library.
[126] Dutton, *The Patent System and Inventive* Activity, 81.
[127] T.S. Ashton, *The Industrial Revolution 1760-1830* (Oxford: Oxford University Press, 1968), 76.
[128] Bessemer, *Autobiography*, 82.
[129] Albert E. Musson and Eric Robinson, *Science and Technology in the Industrial Revolution* (Manchester: Curtis and Brown, 1969), 207.
[130] Matthew Boulton, letter to Lord Dartmouth, February 22, 1775, *Historical Manuscripts Commission, Fourteenth Report, Appendix, Part 1, The Manuscripts of the Earl of Dartmouth vol.3*, (London: Eyre and Spottiswoode, 1896), 213-214.

Similarly, as demonstrated in chapter 5, Edward Pease may have been reluctant to finance Robert Stephenson and Co. without the protection of patents.

From the eighteenth century onwards, the judges of the equity and common law courts substantially shaped patent law and its remedies. Until 1852, in the absence of legislature reform, the English patent system at the behest of the judges continually evolved and responded to the needs of an industrial economy. The opinion of Sherman and Bently is particularly relevant, that 'the legal process is *itself* creative ... that [judges] played an important role in shaping the (essence of) intangible property'.[131] As expounded by May, the law does not exist in a vacuum, but reflects social norms. The law is affected by shifts in social understandings of legitimate interests or justices.[132] This is a continuing process and modern day examples would be the common law approach seen in decided cases in relation to computer software and human embryonic research.[133]

The contribution of the judges during the eighteenth century placed England in an exceptional position. No other country (with the exception of the Venetian Republic) enacted patent laws earlier than the 1790s[134] or had an equivalent common law system that had been developing since 1176.[135] Only in England were inventors able to make substantial returns from what we might now call intellectual property rights thus encouraging them to develop the new technology required by industrialisation. It is beyond the remit of this thesis but further research may demonstrate that the influence of the patent system was a contributing cause for the Industrial Revolution taking place in England, a cause rarely discussed in the current literature.[136] Uniquely, until the 1790s when the French and American patent systems were developed, no other country had a patent system used so frequently by inventors. If, as is argued in this thesis, patents encouraged inventive activity in England (and eventually the USA),[137] this was an exceptional relationship when compared with other countries in the world at the time. As Beatty points out in his comparative study of the effect of patents in nineteenth century Mexico, most

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[131] Sherman and Bently, *The Making of Modern Intellectual Property Law,* 57.
[132] May, "Antecedents to Intellectual Property," 1.
[133] For example, The Patents Act (1977). The use of human embryos for industrial or commercial purposes are not patentable inventions but there is extensive case law as to what might constitute a human embryo.
[134]In the US the first Patent Act was passed in 1790; in France, 1791; in Germany, 1877.
[135] Paul Brand and Joshua Getzler, eds., *Judges and Judging in the History of the Common Law and Civil Law* (Cambridge: Cambridge University Press, 2012), 3.
[136] For example, Robert. C. Allen, "Why was the Industrial Revolution British?" (*The Simon Kuznets Lecture,* Yale University, October 7, 2010). https://www.researchgate.net/publication/228040506_Why_was_the_Industrial_Revolution_British [accessed December 15, 2012]. Robert Allen argues the 'path to the Industrial Revolution began with the Black Death': Robert Allen, *The British Industrial Revolution in Global Perspective* (Cambridge: Cambridge University Press, 2009), 21. MacLeod argues 'England started at least 50 years earlier than the classic 1760 -1830 Industrial Revolution'; *"No Patent System, No Industrial Revolution?"* Public Lecture, University of Leeds, November 27, 2012.
[137] Khan and Sokoloff, *Patent Institutions*, 292-313.

of the world patent systems were crafted, administered and reformed in economies largely dependent on the importation of foreign machines, processes and products.[138]

This chapter seeks to make a further contribution to Beauchamp's concern that 'the tools of legal history have rarely been brought to bear on the history of technology ... the fate of patents in the courts remains a black box'.[139] The merits of the system for granting patents prior to 1852 can now be reviewed in a more credible light and this is important when considering the adjudication of patents by the courts at the relevant time. It is possible to build on Bottomley's research and insight into the early patent system to show that the fate of patents in the courts had many positive outcomes that would have reassured the early railway inventors that the judiciary was supportive of the protection of the exclusivity of patented invention rights.

It is argued here that the legal system created by precedent a coherent system of patent law principles which would have provided encouragement to the early railway pioneers to use the patent system to protect their inventions. Landes has written about 'reciprocal adjustment of law and industrial capitalism' where he referred to the relative dearth of studies in this area. Specifically, he suggested that any study as to the connection between common law and economic development would have to recognise that law is built upon an autonomous rationale, 'a conservatism built on precedent and the niggling complexity of institutionalised justice ... [in which] questions of morality and social prejudices intervene'.[140]

By the time the common law was called upon to determine patent disputes arising as a consequence of the emergence of the early railways, the judiciary was making a valuable contribution to a modern system of intellectual property rights. Furthermore, by the end of the eighteenth century the availability of knowledge in the form of law reports, and technical journals was a considerable aid to judges in the creation of precedent, and the development of a coherent patent law. It is now necessary to consider the development and enforcement of the principles of that patent law.

2.7 The shaping, development and enforcement of patent law principles by the judiciary

There is historiographical consensus that prior to 1830, possibly prior to 1842,[141] there were no significant developments in legal precedent and the principles of patent law. According to Khan and Sokoloff, the absence of major patent statutes between 1624 and 1852 resulted in a situation where patent policies were unpredictable and 'effected on an *ad hoc* basis by the courts, Law Officers and the

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[138] Edward Beatty, "Patents and Technology Change in Late Industrialization: Nineteenth-Century Mexico in Comparative Context," *History of Technology* 24, (2002): 121-150, 143.
[139] Christopher Beauchamp, "Who invented the Telephone? Lawyers, Patents and the Judgements of History," *Technology and Culture* 4, (2010): 854-878, 854.
[140] David Landes, *The Unbound Prometheus: Technological Change and Industrial Development in Western Europe from 1750 to the Present* (Cambridge: Cambridge University Press, 1969), 199.
[141] Dutton, *The Patent System*, 75.

Lord Chancellor'.[142] MacLeod describes the legal situation prior to 1830 as highly uncertain and the equity courts as 'rarely guided by precedent'.[143] However, any such uncertainty would have proved a serious impediment to inventors and funders associated with early railway technology and, as demonstrated later, is contrary to the evidence.

It is argued here that the historiographical consensus must be challenged and reassessed in a number of important respects. Firstly, it was the very absence of statutory intervention that necessitated the judiciary to develop patent principles. This identifies with Sherman and Bently's emphasis on the positive role the law plays in creating its own subject matter.[144] Secondly, common law was developed by reference to the doctrine of precedent,[145] whereas equitable principles developed by the court of Chancery were based on natural law[146] resulting in the witty aphorism that equity varied with the length of the Chancellor's foot.[147] However by, and as early as 1818 the court of Chancery had established a system of precedent rules, procedures and novel remedies reflecting the precedent basis of the common law. A number of judicial pronouncements underlined this approach. In *Gee v Pritchard* (1818) the Lord Chancellor, Lord Eldon, stated,

> … the doctrines of this court ought to be as well settled and made as uniform almost as those of the common law … nothing will inflict on me, on quitting this place, greater pain than the recollection that I had done anything to justify the reproach that the equity of this court varies like the chancellor's foot.[148]

In 1829, with the purpose of assisting a parliamentary select committee, John Farey provided evidence of settled principles of patent law by reference to 75 judgements, stretching back to 1624. His list included,

> … the most important cases of Trials at Law, respecting patent rights which have been reported in books of cases, or cited by judges, as containing the principal decisions of the Courts of Justice thereon, since the Statute of Monopolies [1624]: with extracts and quotations of the principal decisions of judges as reported in the books of cases which are received as authentic reports, by the Courts.[149]

One of the striking features of industrial growth during the nineteenth century was the rapid introduction of railway technological innovations where much of the subject matter either had not pre-existed, or needed to be adapted for the evolution of the early railways. In this context, the common law played a vital role in shaping and developing patent law generally, but in particular the shaping of patent law

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142 Zorina Khan and Kenneth Sokoloff, "Patent Institutions, Industrial Organization and Early Technological Change: Britain and the United States, 1790-1850," in Maxine Berg and Kristine Bruland, eds. 292-313. *Technological Revolutions in Europe: Historical Perspectives*. Cheltenham: Edward Elgar Publishing Ltd, 1998, 296, n.16.
143 MacLeod, *Inventing the Industrial Revolution,* 61.
144 Sherman and Bently, *Making of Modern Intellectual Property Law*, 57.
145 A principle or rule established in a previous legal case that is either binding on or persuasive when deciding subsequent cases with similar issues or facts.
146 The unchanging moral principles regarded as a universal basis for all human conduct.
147 Attributed to the eminent seventeenth century jurist John Selden. Robert Waters, *John Selden and his Table Talk*, (New York: Eaton and Mains, 1899), 102.
148 *Gee v Pritchard* (1818), 36 ER 670.
149 John Farey, June 8, 1829, *Select Committee on the Law Relative to Patent Inventions* (1829), 182.

relevant to the emerging early railways. By reference to some of the significant cases that established the general principles of patent law, the following sections consider evidence that emphasises the significant role and influence of the judiciary.

2.7.1. Jurisdiction: *Darcy v Allen* (1602)[150]

> ... with [*Darcy v Allen*] commenced the history of the English common law patent system.[151]

Any detailed consideration of the role and significance of the judiciary in the process of shaping patent law principles must commence with the case of *Darcy v Allen* (1602).[152] Although at this time the Privy Council retained jurisdiction for hearing patent validity cases and those for prolongation of the monopoly period, *Darcy v Allen* established the right of the common law judges to determine patent disputes. As articulated by Fisher, the case is 'one of the elder statesmen, if not the elder statesman of intellectual property law ... an account of a bold and uncompromising pronouncement by the courts of the common law that serves as a defining moment within constitutional history.'[153]

The case concerned a patent for the sole making and selling of playing cards which the court determined to be void because it was a monopoly and against the common law. The reports of the case do not disclose the judicial reasoning and therefore reliance has to be placed on the arguments of counsel set out in the contemporary case reports of Coke, Moore and Noy, which Fisher, the most recent commentator on the case, considers record the vested interests of the reporters and which coloured their writings. Both Noy and Coke were ardent anti-monopolists, and Fisher argues that their reports present an extreme, if not inaccurate view of the case.[154]

Notwithstanding the debate, the significance of the case for the arguments presented in this thesis, is that it signifies the commencement of the development of patent principles by the judges and a change of approach from one of consideration of 'public benefit' to one of 'novelty'. Previously, Elizabeth I had been adamant that since it was the Crown's prerogative to grant privileges then it followed that she, rather than the judiciary, had absolute jurisdiction over patent disputes. In 1601, in her Golden Speech to Parliament, Elizabeth I conceded that her grants could be adjudicated by the law.[155] *Darcy v Allen* (1602) is, therefore, a historical marker in the treatment of the royal prerogative. Significantly, this case

[150] Darcy v Allen 1602, 11 Co. Rep. 84.
[151] E. Wyndham Hulme, "The history of the Patent System under the Prerogative and at Common Law," *Law Quarterly Review* 12, (1896): 141-154, 151.
[152] Darcy v Allen (1602), 11 Co. Rep. 84. KB.
[153] Mathew Fisher, "The case that launched a thousand writs or all that is dross? Re-conceiving Darcy v Allen: the case of Monopolies," *Intellectual Property Quarterly*, no. 4 (2010): 356-372, 356.
[154] Fisher, "The case that launched a thousand writs," 368. Coke appeared for the plaintiff, Darcy, (but lost) before he rose to be Chief Justice of the Court of Common Pleas and, later, Chief Justice of the Kings Bench. Noy was the co-sponsor, in 1622, of the Bill that was a predecessor of the Statute of Monopolies 1624.
[155] Terence Hartley, *Proceedings in the Parliaments of Elizabeth I:1593-1601*, vol.3 (Leicester: Leicester University Press, 1981), 292-3.

demonstrates the common law at work some twenty-two years before Parliament's intervention in 1624 with the passing of the Statute of Monopolies.

2.7.2. First and true inventor: Dollond v Champneys (1766) [156]

> … the first major patent case at common law since the early seventeenth century.[157]

The issue of 'first and true inventor', a core patent principle encapsulated in the Statute of Monopolies, became a key question for judges who were called upon to interpret the concept as they responded to the needs of a rapidly developing industrial economy. MacLeod describes *Dollond v Champneys* (1766) as the first major patent case in which the judiciary began to address the thorny problem of the proper consideration of a patent. A view challenged by Sorrenson who demonstrates that the 1766 case was not the first.[158] Notwithstanding the academic debate, *Dollond v Champneys*, which centred on Dollond's patent for the making of achromatic lenses, emphasises the developing significance of judicial interpretation. A Dr Hall had made the same discovery as Dollond, but at an earlier time and had 'confined it to his closet'.[159] The judge found for Dollond who was to be considered the first inventor because, although not the *original* inventor, he had been the first to make the invention *public*.

This case established the principle that creativity was secondary to disclosure, the impetus to trade being the governing factor. As industrialisation advanced, a number of different scenarios arose that required further determination by the judges of 'first and true inventor'. An example would be the import trade where it was not necessarily the original inventor who was granted the patent, but the individual who had introduced the *benefit* of the invention to English society. In the case of *Lewis v Marling* (1829), Lord Tenterden stated,

> It is no doubt incumbent on the plaintiff to show that their machine is new, but it is not necessary that they should have invented it from their own heads; it is sufficient that it should be new as to the general use and public exercise in this kingdom.[160]

2.7.3. Addition to patent: Morris v Braunson (1776)[161]

> … an authority for the introduction of more lenient rules on the validity of patents.[162]

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[156] *Dollond v Champneys* (1766), 1 HPC 165. Although subsequent rulings made reference to this case, the action in 1766 by Peter Dollond against Champneys (alias Champness) does not appear in Law Reports. See A.C. Ranyard, "Note with respect to the Invention of the Achromatic Telescope," *Monthly Notices of the Royal Astronomical Society* 46, (June 1886): 460-461.
[157] MacLeod, *Inventing the Industrial Revolution*, 61.
[158] Richard Sorrenson, "Dolland and Son's Pursuit of Achromaticity 1758-1789," *History of Science* 39, (2001): 31-55.
[159] *Boulton and Watt v Bull* (1795). 1 HPC 369.
[160] *Lewis v Marling* (1829), 1 WPC 492.
[161] *Morris v Braunson* (1776), Bull. N.P. 77.
[162] Frank D. Prager, "Standards of Patentable Invention from 1474 to 1952," *University of Chicago Law Review* 20, (1952), 69-95, 72.

Another of the pressing issues requiring to be addressed during the eighteenth century was whether an improvement to an existing process could be the subject of a patent. The case of *Morris v Braunson* (1776) concerned a patent for making eyelet holes in silk and an objection that it was not novel, but an addition to an existing process. The case came before Lord Mansfield who declared the patent to be good and stated,

> After one of the former trials on this patent, I received a very sensible letter from one of the gentlemen who was upon the Jury, on the subject whether, on principles of public policy there could be a patent for an addition only. I paid great attention to it, and mentioned it to all the judges ... that objection would go to repeal almost every patent that ever was granted.[163]

Lord Mansfield's reputation was international, 'one of the greatest men who ever sat on any bench'[164] and, according to Oldham, many of the principles of patent law which were applied during the Industrial Revolution and beyond, were crafted by Mansfield.[165] He was a substantial contributor to the development of the common law in relation to patents recognising the need to adapt the law to more sophisticated technological times.[166] Mansfield's approach to patentable improvements to existing processes would have been particularly important where there was a need to adapt existing technology to meet the demands of the developing railways.

2.7.4. Specification: *Liardet v Johnson* (1778)[167]

> ... [*Liardet v Johnson*] a landmark in the history of English patent law.[168]

According to Adams and Averley, many patentees were anxious to prepare a specification that provided enough detail to maintain registration, but insufficient information to allow others to pirate the invention. When James Watt secured his first patent in 1769, he took great pains to prepare his specification for the separate condenser but he was advised by his friend Dr Small, 'as to your principles we think they should be enunciated (to use a hard word) as generally as possible, to secure you as effectually against piracy as the nature of your invention will allow'.[169] In the event, Watt omitted to submit his drawings. An omission that may have contributed to his many subsequent, and protracted litigious actions. It is perhaps significant that his later applications for patents were always well documented.

It is against this background that the case of *Liardet v Johnson* has to be considered, and although a landmark case on any basis, the degree of its importance depends on scholarly views as to practice that preceded its determination. In 1711 John Naismith was required by the Law Officers to detail his methods of distilling spirits with his patent application, and from 1733 it became standard practice to

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[163] *Morris v Braunson*, quoted in Oldham, *English Common Law*, 200.
[164] An opinion offered by Chief John Marshall in the case of *Livingston v Jefferson* (1811), 15 Federal Cases 660, 664; quoted in Oldham, English Common Law, 370
[165] Oldham, *English Common Law*, 364.
[166] Oldham, *English Common Law*, 205.
[167] *Liardet v Johnson* 1778, 62 ER 1001.
[168] Hulme, "On the consideration of the Patent Grant," 317.
[169] Adams and Averley, "The patent specification," 170.

require such a specification. There is much academic discussion as to what was behind the instigation of a specification. For example, Hulme opined that it was at the suggestion of and for the benefit of the patentee.[170] MacLeod prefers that it was an initiative on the part of the Law Officers to assist them to discriminate between superficially similar inventions.[171]

Adams and Averley argue that the requirement to file a specification was imposed on patentees far earlier, that the purpose of the specification had always been to instruct the public and, therefore, *Liardet v Johnson* was not a landmark case. In his seminal work, *A History of English Law*, Holdsworth stated,

> Perhaps the greatest change in patent law which the transfer from the [Privy] Council to the courts made, was the new view taken by the courts as to the consideration for the grant of a patent. Under the old practice the consideration for the grant was the introduction into, and working, of a manufacture which was new in Great Britain. Under the new practice the consideration is the written disclosure of the invention contained in the specification.[172]

Holdsworth maintained it was Lord Mansfield in *Liardet v Johnson* who determined that the consideration of the patent was the disclosure of the invention in the specification. The *Morning Post* which reported on the case in 1778, quoted Lord Mansfield as follows,

> [The] point is whether the specification is such as instructs others to make it. For the giving of encouragement is this: that you must specify upon record your invention in such a way as shall teach an artist, when your term is out, to make it – and to make it as well as you by your direction for then at the end of the term, the public have the benefit of it.[173]

It is significant that following *Liardet v Johnson* (and despite the case having not been officially reported), Lord Mansfield’s judgement was followed in other patent cases during the period when railway technology was emerging and developing. In *Harmer v Playne* (1809) Lord Ellenborough cited Lord Mansfield as follows,

> … and when Lord Mansfield said (in the case of Liardet v Johnson) that the meaning of specification was, that others might be taught to do the thing for which the patent was granted, it must be understood to enable persons of reasonably competent skill in such matters to make it.[174]

The Law Officers introduced the need for a specification, probably as early as 1733 and, therefore, the contract conceptualisation had jurisprudential antecedents some time before the case of *Liardet v Johnson*. However, a matter of greater importance, which is not prominent in the current literature, is that regardless of whether the requirement for a specification was created by the Law Officers or the judiciary, the practice of filing a specification signifies a contribution to the commencement of the codification of technical knowledge. Knowledge which would have existed previously as tacit knowledge, either retained 'under the workman’s cap'[175] or passed by word of mouth.

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[170] Hulme "On the history of patent law,” 285.
[171] MacLeod, *Inventing the Industrial Revolution*, 49 -51.
[172] Holdsworth, *A History of English Law* vol. XI, 427
[173] Hulme, "On the history of patent law,” 285.
[174] *Harmar v Playne* (1809), DPC 318–319.
[175] Daunton, *The Organisation of Knowledge in Victorian Britain*, 9.

Once the precedent for a detailed specification had been established, judges moved on to decide how they should approach the interpretation of the specification. By the 1820s any suggestion of a strict literal interpretation of the specification was on the wane. The test applied was whether the patentee had made a fair and effective communication, and as a result specifications were rarely set aside on the basis of minor defects. The challenge for the judiciary, particularly in relation to emerging railway technology, was to understand the fundamental principles of the specification, and for this reason the role of the expert witness became significant.[176]

2.7.5. Manufacture: *Crane v Price* (1842)[177]

> … perhaps the most important judicial intervention of the period.[178]

Hindmarch, writing in 1848, stated that it was not until the judgement in *Crane v Price* that the definition of 'new manufacture' was finally clarified.[179] James Watt had described his invention of a separate condenser as 'a *method* of lessening the consumption of steam and consequently fuel in fire engines'. The judiciary spent much time in the case of *Boulton and Watt v Bull* (1795) considering whether a 'method' could be a 'manufacture', and these arguments were further developed in the case of *Hornblower v Boulton and Watt* (1799). The reporter in *Wood v Zimmer* (1815) stated that from these two cases 'may be deducted almost all of the learning and law on the subject of patent for new invention'.[180]

Crane v Price (1842) concerned a patent for the application of a hot air blast to anthracite in the smelting or manufacture of iron ore. Sherman and Bently are clear that the case settled the question as to whether a method or process as distinct from the thing produced could be the subject of a valid patent.[181] Bottomley challenges the understanding that *Crane v Price* defined 'new manufacture' for the first time. He is concerned that if such was the position then inventive activity would have been discouraged in areas where inventive output could not be presented as a straightforward 'manufacture'. Although Bottomley concedes that the position is open to argument, he refers to a number of earlier cases and treatises where the issue appeared to be settled prior to 1842. For example, *Roebuck v Stirling* (1774)[182] established that chemical processes could be patented. Similarly, Bottomley points out that in *Boulton and Watt v Bull* (1795) counsel for Mr Bull took no issue as to the admissibility of methods as patents.[183] By reference to reported decisions, Bottomley puts forward a convincing argument that patentability of

[176] Graeme Gooday, "Liars, Experts, and Authorities," *History of Science* 46, (2008): 431–456. Helen Gubby, *Developing a Legal Paradigm for Patents* (The Hague: Eleven International Publishing, 2012), 205.
[177] *Crane v Price* (1842), 134 ER 239.
[178] Sherman and Bently, *The Making of Modern Intellectual Property Law,* 108.
[179] W. Hindmarch, *Law and Practice of Letters Patent for Invention* (London: Stevens and sons, 1848), 84.
[180] *Wood v Zimmer* (1815), 171 ER 162.
[181] Sherman and Bently, *The Making of Modern Intellectual Property Law,* 108.
[182] *Roebuck v Stirling* (1774), 1HPC 174-177
[183] Bottomley, *The British Patent System*, 151.

methods was of some importance in the encouragement of further inventive activity from as early as 1774.

The cases considered in this section establish some of the more important principles relating to patents that were settled by the judiciary. There were of course many other instances where judges sought to shape patent law as they responded to emerging technology. Having established that the judiciary developed early patent law and its structures, it is now necessary to examine the role of the judges in cases concerning core technology of the early railways.

2.8 Early railway patent cases

It is important to emphasise that the obtaining of a patent *combined* with the threat of litigation represented an important resource for the leading, early railway engineers as they sought to safeguard the financial viability of their inventions.[184] A sample of reported railway patent cases falling within the period under consideration here, appears in Table 2. However, mindful of the point made earlier that many patent cases would have commenced as a formal dispute process and subsequently settled prior to hearing, the role of patents in early railway technology cannot be considered solely by reference to reported railway patent cases.

Table 2: A sample of reported cases prior to, and including 1852

Subject matter	**Case reference**
Axle boxes	Newton v Grand Junction Railway Co. (1845) 5 HPC 301
Axle boxes	Newton v Vaucher (1851) 5 HPC 321
Carriage axle boxes	Hardy's Patent (1849) 5 HPC 923
Carriage wheels	Losh v Hague (1837-9) 3 HPC 125
Carriage wheels	Smiths Patent (1847) 7 HPC 195
Carriages and wheels	Haddon v Smith (1847) 5 HPC 445
Railway turntables	Holmes v London NWRly Co. (1852) 6 HPC 501
Railways	Adams and Richardson Patent (1852) 6 HPC 379
Atmospheric system	Griffith and Samunda Patent (1846) 5HPC 289
Atmospheric system	Pinkus' Patent (1848) 5 HPC 831

Source: Hayward's Patent Cases, vol.1.

Law reporting was in its infancy and, as established above, a number of patent dispute cases were reported in the technical journals, but remained unreported in the formal law reports of the day. For example, on February 20, 1847, The *Patents Journal and Inventors Magazine* reported the case *Ellis v Ormerod et al* concerning the alleged infringement of a patent for railway weighing machines and turntables. Notwithstanding the fact that the decision in this case did not reach the formal law reports of the day, the subject matter was clearly of sufficient significance to be reported on in the technical press. Robert Stephenson (together with George Parker Bidder and William Cubitt) was called by the plaintiff

[184] These arguments are developed more fully in chapters 5, 7 and 8.

to give evidence that the plaintiff's invention was new and original, and that the defendant's machines were identical with those of the plaintiff.[185] Intriguingly, the outcome of the action is not reported.

One of the regular challenges faced by the judiciary was the application of existing technology to the early railways. In the case of *Losh v Hague* (1837),[186] Losh had taken out a patent for 'improvements in the construction of wheels for carriages *to be used on railways*'.[187] It was common ground that one Paton had taken out a patent for a carriage wheel, but for use on roads. Lord Abinger put the question in the following manner,

> The learned counsel has stated that Mr Losh has taken out his patent to use on railways. He says that wheels used by Mr Paton, or by any other workman, who were called as witnesses, were never applied to railways. That opens the question whether a man who finds a wheel readymade shall get a patent for applying it to a railway. There is some nicety in considering that subject. [188]

The judge accepted that Losh was not the first inventor, but nevertheless was entitled to his patent in the circumstances. The case established an important principle in that it enabled the adoption and adaptation of existing technology, in this instance for early railway technology, to be the subject of a patent application.

2.9 Conclusion

This chapter has challenged the current historiography of the English patent system prior to 1852. The operation of the patent system was more effective than is currently acknowledged in the literature. The conversion and codification of experience into technical knowledge commenced in 1733 with the requirement for the filing of a specification shortly after making an application for the grant of a patent. The evidence establishes that the cost of an application for a patent grant was not a major deterrent to potential applicants, and the practice of holding caveat hearings, as opposed to a system of mere registration, introduced a rigour of adjudication as to merit which found favour with inventors and funders alike. The contemporary evidence of the early users of the patent system demonstrates that they found great utility in a unique patent system which they relied upon and promoted to their peers.

The historiography of the development of legal precedents and principles of patent law prior to 1830 has also been reassessed in this chapter. In the absence of any significant parliamentary intervention between 1624 and 1852, the judiciary of the day developed patent principles often necessitated by the rapid, technological advances of the late eighteenth and early nineteenth century. By the beginning of the nineteenth century the judges of the common law and equity courts had developed a precedent based approach to judicial decision making in the formulation of patent principles. The evidence presented

[185] *The Patents Journal and Inventors Magazine,* February 20, 1847, 645.
[186] *Losh v Hague* (1837), 3 HPC 125.
[187] The patent was granted to George Stephenson and William Losh.
[188] *Losh v Hague* (1837). 1 WPC 197. Thomas Webster, *Reports and Notes of Cases on Letters Patent for Inventions* (London: T. Blenkarn, 1844), 207.

here has established that patentees utilised the legal system to a much greater extent than has hitherto been identified in the literature which generally overlooks the equitable jurisdiction of the court of Chancery. A more accurate picture of the utilisation of the patent system emerges if the *process* of litigation, rather than the *number* of reported patent cases is considered and examined. The analysis undertaken here of reported patent cases prior to 1830 has established a supportive attitude of the judges towards patentees and the enforcement of their patent rights, including novel judicial means of enforcement particularly suited to patent dispute cases.

The patent system provided the early industrialists, including the railway pioneers, with a reliable, accessible, repository of technical information. In the following chapter the developing database of publicly available technical knowledge that was created as a result of patented inventive activity between 1733 and 1852 is considered and, in particular, what statistical analysis of patent data may reveal about inventive activity and the diffusion of technological knowledge.

CHAPTER 3

THE VALUE OF PATENT DATA

> We have a choice of using patent statistics cautiously and learning what we can from them, or not using them and learning nothing about what they can teach us.
>
> Schmookler[1]

> Anyone who had the ambition to become the historian of inventions, could do no better then take such a work on patents, because he would there not only find the true course of inventions, but he would also find every futile effort made in that direction ... it would be the most valuable encyclopaedia of invention ever published.
>
> Woodcroft[2]

Introduction

In this chapter, it is argued that insufficient consideration has been given, hitherto, to the quality and quantity of patented technical information that was available to the pioneers of the railways and the implications of that accessibility for the rate of innovation and diffusion within early railway technology. It has been shown in the preceding chapter that the codification of what had previously been tacit knowledge took place from as early as 1733 when, increasingly, patentees were obliged to outline the details of an invention in a specification. The specifications were filed in one of three offices of Chancery and were available for inspection. This chapter considers the utility of the filing of patent specifications, and the subsequent availability of patented information in technical publications. The evidence presented here, of recourse to the patent system by inventors and their investors, as well as lawyers and patent agents, reveals that patented knowledge provided an accessible and valuable database of technological information. Furthermore, this chapter offers an assessment of the value of patent data for subsequent, current scholarship.

The statistical interpretation of patent data and what they may or may not reveal about the processes of innovation and technological change during the period of the Industrial Revolution, is the subject of extensive academic debate. Much scholarly analysis is concerned with the emerging industrial sector as a whole, an approach that neglects to take into account the characteristics and peculiarities of individual industries. By focusing on the early railways, the sector-specific analysis undertaken here

[1] Jacob Schmookler, *Invention and Economic Growth* (Cambridge, Mass., Harvard University Press: 1966), 56.
[2] Bennet Woodcroft, May 20, 1851, *Reports and Minutes of Evidence taken before the Select Committee of the House of Lords appointed to consider the Bill[s] ... An Act further to amend* [*and for the further Amendment of* ...] *the Law touching Letters Patent for Invention* (House of Lords, July 4, 1851), 227-8, paras.1585-6.

seeks to contribute to an understanding of the relationship between patents and the development of railway technology during the Industrial Revolution.

3.1 The collation of patent data

By the middle of the nineteenth century the acceleration in the number of patented inventions was such that when the first head of England's Patent Office, Bennet Woodcroft, prepared an index of the patents filed in each of the three offices of Chancery, the number of patents granted between 1617 and 1852 totalled some 14,354.[3] Woodcroft is important to this thesis because his work provides a comprehensive record of patented inventions and highlights the rapid increase in patents granted after 1760, the period when railway technology was developing. The number of patents registered per annum, as collated by Woodcroft, is tabulated in Appendix A, and represented in Figure 1. According to Woodcroft's chronological collation, the number of patents registered in the 1760s numbered over 200, nearly 500 in the 1780s and continued to double every two decades to the mid-nineteenth century.

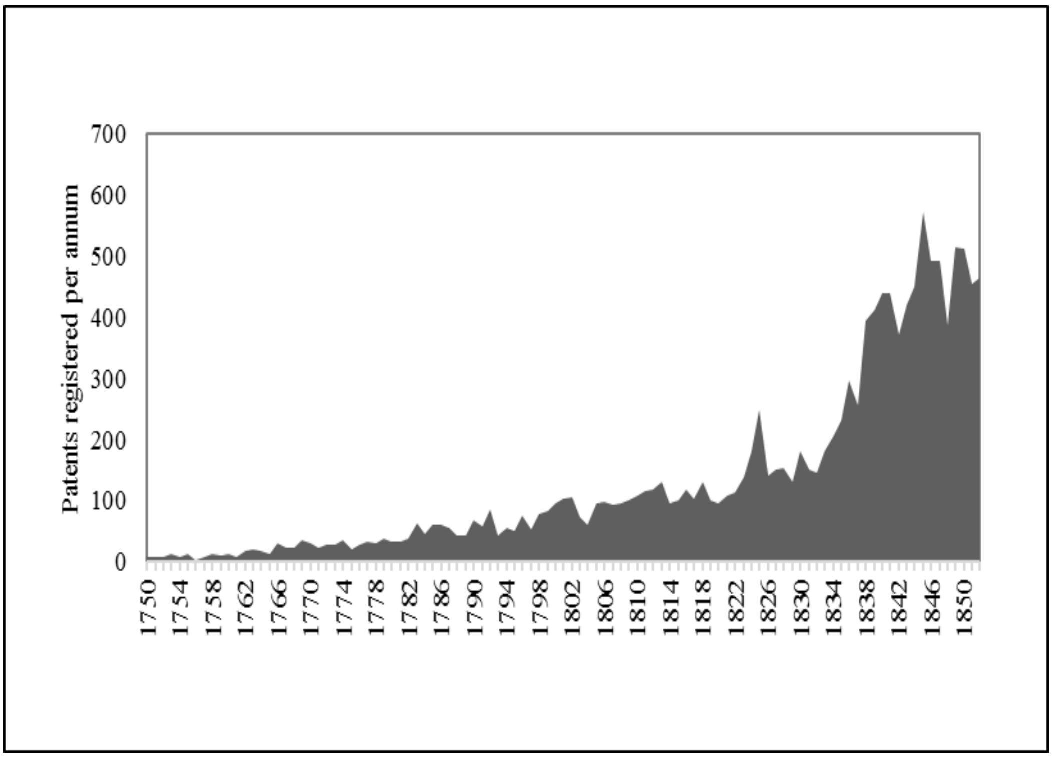

Figure 1: Patents granted per annum, 1750-1852. (see Appendix A).

Source: Woodcroft, *Patents of Invention Chronologically Arranged* (1854), 122-1518.

It is argued here that a detailed examination of the acceleration in patented inventive activity within the early railway sector leads to a greater understanding of the relationship between the patent system and

[3] Bennet Woodcroft, *Titles of Patents of Invention Chronologically Arranged, 1617-1852* (London: Eyre and Spottiswoode, 1854).

early railway technology. Furthermore, any consideration of patented railway-related inventive activity prior to 1852 must involve examination of Woodcroft's collation which establishes that patent numbers increased substantially in the early nineteenth century, and that the number of railway-related patents was significant. Woodcroft published a chronological index of patents in 1854 and the following year inaugurated the *Reference Index*, a guide to the particular Chancery office of enrolment of a patent, and the journals where abstracts of specifications could be found.[4] The indices were published in blue covered folders, known as the blue books, it being the practice of the day for Government publications to appear in blue. From 1854 to the present day, researchers have been assisted by Woodcroft's herculean task.[5]

As will be discussed in subsequent sections of this chapter, patent numbers *per se* do not necessarily assist with meaningful assessment of the impact of the patent system on advancing railway technology, and there is need for wider, detailed analysis. Nevertheless, the high number of railway-related patents, as collated by Woodcroft, does suggest a willingness on the part of pioneering railway inventors to turn to the patent system. In advancing the argument that Woodcroft's undertaking provides significant information on the enterprise of inventors, and to assess the value of his efforts, it is pertinent to provide brief details of his background. He was the first technical expert in the newly established Patent Office: engineer, patentee, patent agent, university professor, librarian, museum collector and historian of technology. Woodcroft is often referred to as the 'father' of the Patent Office, if not the only parent.[6] In 1853, writing in the preface of one of his subject surveys, Woodcroft made exaggerated reference to the records of invention as 'the accumulated knowledge of mankind.'[7] Hewish offers a more nuanced approach suggesting that Woodcroft was aware of the value of patent data, that they provide immediate evidence of priority (the establishment of novelty) in the legal process, as well as stimulus to further inventive activity.[8]

In 1847, Woodcroft was appointed to a Chair of Machinery at University College, London, and in 1857 was successfully proposed as a Fellow of the Royal Society, when Isambard Kingdom Brunel was one of his supporters for nomination.[9] In 1852, with the passing of the Patent Law Amendment Act, Woodcroft was appointed Superintendent of Specifications in the new Patent Office, and set about the collation and publication of patents granted since 1617. In the peak year of 1856, over three million

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[4] Bennet Woodcroft, *Titles of Patents of Invention Chronologically Arranged, 1617-1852.* (London: Eyre and Spottiswoode, 1854).
[5] John Hewish, *The Indefatigable Mr Woodcroft*. *The legacy of invention* (London: The British Library, 1979), 23.
[6] Hewish, *The Indefatigable Mr Woodcroft,* 7.
[7] Bennet Woodcroft, *Appendix to the Specification of English Patents for Reaping Machines* (London: Queens Printers, 1853) ix.
[8] Hewish, *The Indefatigable Mr Woodcroft,* 7-8.
[9] R.B.Prosser, "Bennet Woodcroft FRS," *The Engineer: Obituary*, February 14, 1879, 1-8, 6.

words and 1,500 drawings were copied from the Rolls in preparation for their printing.[10] He published a series of pamphlets descriptive of early patented inventions including the Marquis of Worcester's account of his steam engine.[11] These formed part of the Patent Office Library, opened in 1852, which by 1860 was reputedly the greatest technical library in the country, and probably in Europe,[12] and was later incorporated into the British Library. A further Woodcroft innovation was the publication of the *Commissioners of Patents Journal* which first appeared in 1854 and is still being published today, containing news of applications, as well as English and foreign patent information. In 1857, Woodcroft was responsible for the opening of the Patent Office Museum in South Kensington, London (the future Victoria and Albert Museum). He gathered portraits of inventors (inspired by collections in the USA) and rescued the Symington marine steam engine 'the parent engine of steam navigation' used in the first trial in 1788 by Patrick Miller of Dalswinton in Dumfriesshire.[13] Woodcroft was responsible for securing and preserving the world’s oldest steam engine, *Puffing Billy* (1814), and Stephenson’s *Rocket* (1829).[14] Woodcroft’s importance lies in his substantial and sustained contribution to the history of technology. Without his efforts, it is doubtful whether some of the most important artefacts of the Industrial Revolution would have been preserved. His work provided the cornerstone of patent and library institutions which survive today.

Woodcroft is widely recognised to have been a remarkable man,[15] and it is perhaps the creation of his *Reference Indices* for which he will be most remembered. MacLeod and others agree that his work and the ensuing blue books, copies of which can be found in numerous libraries worldwide, must be the starting point for all subsequent statistical research in relation to patents.[16] However, the evidence does not support MacLeod’s observation that Woodcroft's perspective on invention was entirely biographical, that he sought merely to preserve historical records, physical objects and the memory of the individuals responsible for them.[17] The significance of Woodcroft’s undertaking in producing accessible, published patent information cannot be overstated. In relation to the arguments advanced in this thesis, his work

[10] John Hewish, *Rooms near Chancery Lane. The Patent office under the Commissioners, 1852-1883* (The British Library, 2000), 37-41.
[11] Christine MacLeod, *Heroes of Invention. Technology, Liberalism and British Identity 1750-1914* (Cambridge: Cambridge University Press, 2007), 253.
[12] Hewish, *Rooms near Chancery Lane,* 44, 147-159. Hewish, *The Indefatigable,* p.7.
[13] Hewish, *The Indefatigable Mr Woodcroft*, 32.
[14] Prosser, "Bennet Woodcroft”, 118-119. Woodcroft was particularly keen to construct a replica of the contents of James Watt's Heathfield workshop but his Treasury masters would not support the endeavour to build a room which he wished to be the very 'counterfeit presentment' of the 'classic garret'. Editorial comment, *The Engineer*, June 8, 1877, 397-8, 398
[15] Brian Spear, "Bennet Woodcroft - Patent information pioneer," *World Patent Information* 34, (2012):159-162. http://www.deepdyve.com/lp/elsevier/bennet-woodcroft-patent-information-pioneer-BXC7pWi8mW [accessed July 30, 2013]
[16] MacLeod, *Inventing the Industrial Revolution,* 2.
[17] MacLeod, *Heroes of Invention*, 253.

is highly significant. As observed by Hewitt, Woodcroft put the bibliography of invention on a sound basis in daily practice.[18]

In 1868, Woodcroft published a volume devoted entirely to railway-related patents, *Abridgements of Specifications relating to Railways*.[19] Patents are listed in chronological order and for the period 1770 to 1852, some 239 patents are recorded (See Appendix B and Figure 2). This figure is surprisingly low and warrants consideration in two important respects.

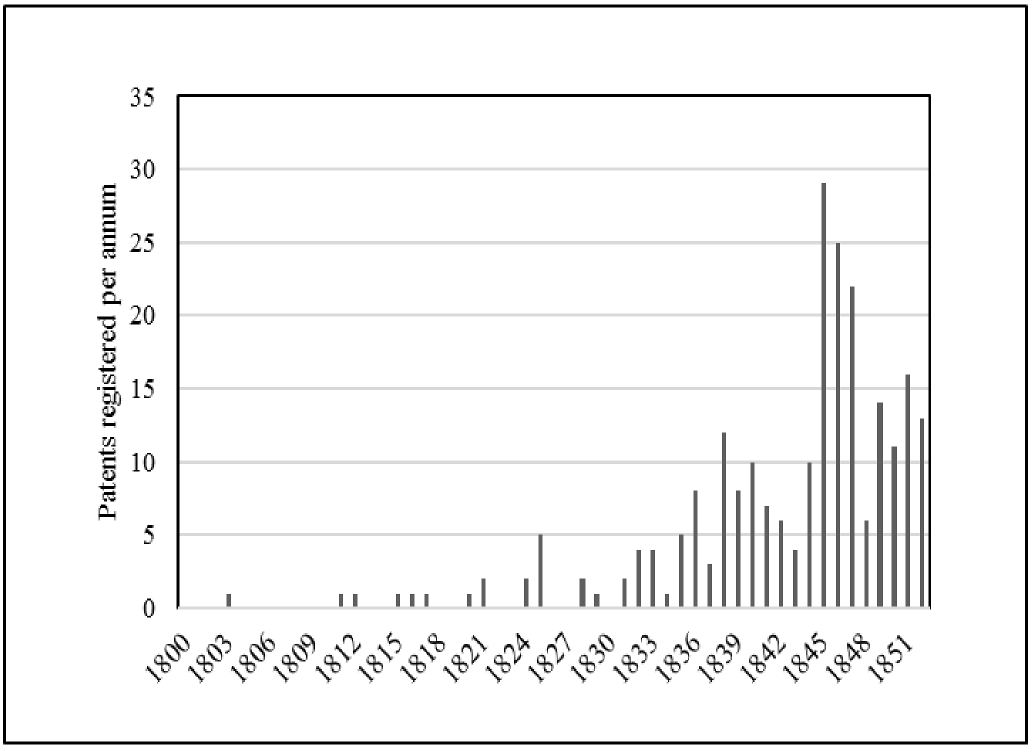

Figure 2: Patents relating to railways, ranked chronologically.

Source: Woodcroft, *Abridgements relating to Railways*, 1-136.

Firstly, in the preface to the 1868 collation, Woodcroft observes,

> The number of Specifications at this time printed and published amounts to nearly 61,000. A large proportion of the Specifications enrolled under the old law, previous to 1852, embrace several distinct Inventions, … it cannot be doubted that several properly belonging to the group which forms the subject of this volume [railway-related] have been overlooked.[20]

The significance of Woodcroft's caveat for the arguments presented in this thesis cannot be overstated. Prior to 1852 it was the practice for a patent to cover multiple inventions. For example, John Gray's patent of 1838, for valve gear, the so-called 'horseleg' motion, the first manifestation of an expansion

[18] Hewish, *The Indefatigable Mr Woodcroft*, 7-8.
[19] Bennet Woodcroft, *Patents for Inventions. Abridgements of Specifications relating to Railways,1770-1863* (London: Eyre and Spottiswoode, 1868).
[20] Woodcroft, *Specifications relating to Railways*, Preface.

gear for locomotives, included 4 inventions.[21] Similarly, the Adams Richardson patent of 1847 for a 'fish plate' securing one rail to the next, encompassed no fewer than thirty railway-related inventions.[22] Secondly, scrutiny reveals that Woodcroft's categorisation 'relating to railways' is not a collation of railway-related patents as understood in this thesis. For example, it does not include any inventions relating to steam locomotives. For these two reasons, namely multiple inventions included within a single patent and the nature of Woodcroft's classification, the total number of railway-related patents is likely to have been considerably understated.

A different assessment of total patent numbers in the field of early railway technology can be made by examining Woodcroft's *Subject-matter Index* (1854).[23] The assessment is unavoidably crude, but totalling up the relevant patents across a series of related categories, as tabulated in Appendix C and represented in Figure 3, including steam locomotives and associated apparatus such as boilers, springs and buffers, etc. reveals railway-related patents of the order of 890, as compared with 239 listed in the *Abridgements of Specifications relating to Railways* for the same period.

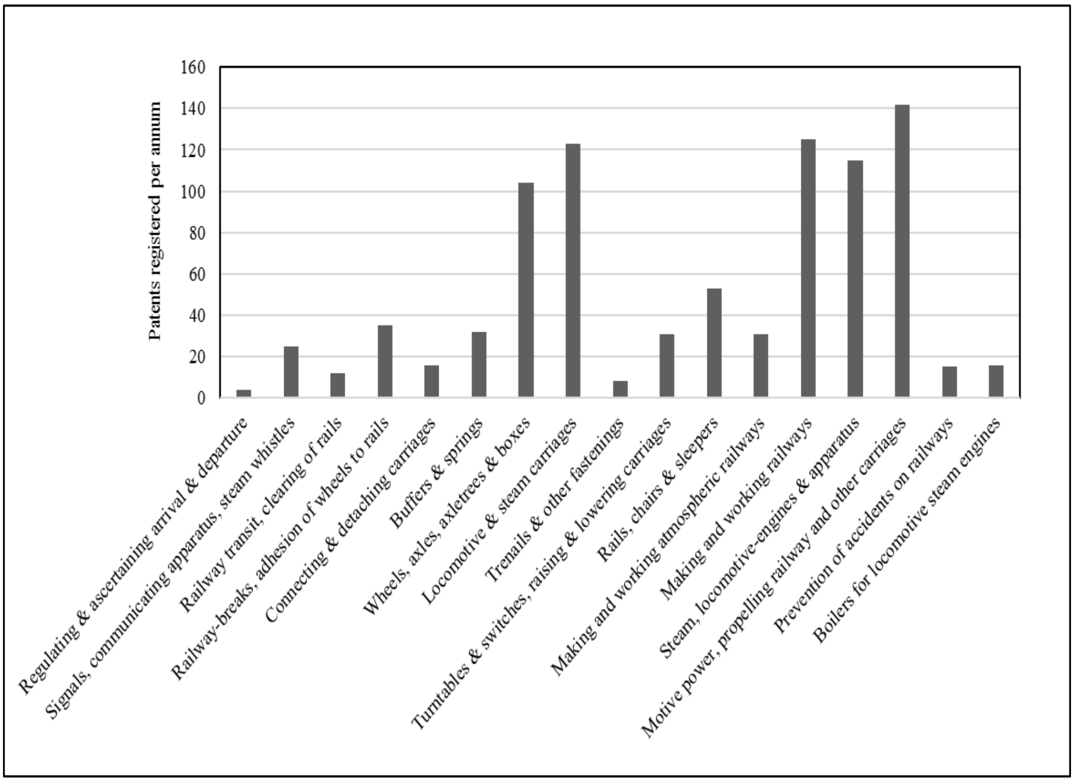

Figure 3: Patents relating to railways ranked according to process, for the period 1800-1852.

Source: Woodcroft, *Subject-matter Index* (1854), 523-536.

[21] John Gray, *Steam engines and apparatus connected therewith …*, Patent No 7745, July 26, 1838.
[22] William Bridges Adams and Robert Richardson, *Construction of Railways …*, Patent No. 11715, May 24, 1847.
[23] Bennet Woodcroft, *Subject-matter Index (made from titles only) of Patents of Invention 1617-1852*, (London: Eyre and Spottiswoode, 1854).

The data presented in Figures 2 and 3 underscore the quantity of, and marked acceleration in railway-related patents during the first half of the nineteenth century. Furthermore, the statistics emphasise the value of sector-specific analysis in any assessment of the processes of innovation and technological change. This approach is at variance with much scholarly analysis which is generally focused on the emerging industrial sector as a whole. Sullivan, for example, who relies heavily on Woodcroft's work, has written extensively in relation to patent statistics and their value in determining the timing and nature of innovation.[24] Many of his conclusions, based on an overall analysis of patent numbers, are relevant to this thesis, not least his opinion that the patent system had a central role in encouraging invention and innovation.[25] According to Sullivan, from the mid eighteenth century a number of elements came together to trigger an acceleration of invention. However, the evidence considered in this thesis challenges his observation that railway technology was a 'relative latecomer', experiencing its inventive acceleration in the decade 1811 to 1820.[26] The seemingly arbitrary choice of the period 1811 to 1820 is not explained by Sullivan, and it is not supported either by the evidence considered in later chapters of this thesis, or by analysis of Woodcroft's collation, *Abridgements relating to Railways*. As shown in Figure 2, and notwithstanding that the number of patented inventions is almost certainly understated, a more appropriate estimate of the period of acceleration in railway-related patenting rates would be 1820 to 1850.

The arguments constructed in the previous chapter support Sullivan's conclusion that there is no evidence that rules or regulations altered the costs and benefits of obtaining a patent around the mid eighteenth century.[27] The evidence considered here also supports Sullivan's proposal that the propensity to patent lies in the distinction between patentable and nonpatentable inventions, that many inventions of the period, such as biological and organisational changes in farming, were not patentable. Sullivan identifies the acceleration of patent grants to be evidence of the rapid and widespread economic changes associated with the Industrial Revolution, that the acceleration in *patentable* invention is evidence that England had entered her Age of Invention.[28] Sullivan's distinction between patentable and nonpatentable inventive activity is an important one, and the evidence considered in later chapters of this thesis endorses his conclusion that patenting rates had an identifiable impact on the growth of certain macro-technologies, including the early railways. However, he is surprisingly dismissive of the value of

[24] Richard Sullivan, "England's Age of Invention: The Acceleration of Patents and Patentable Invention During the Industrial Revolution," *Explorations in Economic History* 26, (1989): 424-452; Richard Sullivan, "The Revolution of Ideas: Widespread Patenting and Invention During the English Industrial Revolution," *The Journal of Economic History 2*, (1990): 349-362; Richard Sullivan, "Estimates of the Value of Patent Rights in Great Britain and Ireland 1852-1876", *Economica* 61, (1994): 37-58; Richard Sullivan, "Patent Counts and Textile Invention; A Comment on Griffiths, Hunt and O'Brien," *Journal of Economic History* 55, (1995): 666-670.
[25] Sullivan, "Estimates of the Value of Patent Rights," 37.
[26] Sullivan, "England's Age of Invention," 355.
[27] Sullivan, "The Revolution of Ideas," 351.
[28] Sullivan, "England's Age of Invention," 424.

industry-specific analysis. An opinion that is challenged by the findings of the investigation undertaken here.

It is pertinent to the arguments made in this thesis that Sullivan identified the acceleration in patented inventions in the latter part of the eighteenth century as having caused a significant change in England's ‘knowledge process'.[29] He proposed that technical development is a three-part progression of creation, dissemination and application of inventions. Whilst Sullivan is correct in his assessment, this thesis seeks to emphasise the significant contribution of patented technological knowledge that was available to inventors, accessible from official Chancery records and technical journals of the day. The contemporary evidence considered in this thesis suggests that the availability of patented technological data may have had an important role, hitherto largely unrecognised, in facilitating the step-change in the management and control of the knowledge process of the late eighteenth and early nineteenth centuries.

Sullivan made his initial observations in 1989, and in 1992 Crafts and Harley published a seminal paper arguing that the Industrial Revolution was a more gradual economic change, initially restricted to only a handful of modernized sectors.[30] Nevertheless, Sullivan has continued to argue that the sharp acceleration of patent numbers took place across a broad industrial front. It is of relevance to this thesis that Sullivan identifies developments in the inventions of machinery as having raised the overall propensity to patent. He identifies approximately 46.6 per cent of total patents taken out between 1801 and 1850 were for machines, the era when steam engines were perfected for the textile and railway industries. According to Sullivan, the widespread increase in patenting indicates that perceived profits from invention increased over the entire spectrum of industries and this led to a macroeconomic 'trigger' mechanism.[31] This theme, the link between propensity to patent and perceived profits, is considered in more detail in the following chapter.

The analysis undertaken here supports Sullivan’s conclusion that assessing patent data in relation to overall inventive activity is unreliable, particularly since not all inventions were patentable. However, he has also suggested that evaluation of data relating to the *renewal* of patents could provide an indicator of the ratio of patents to patentable inventions, the propensity to patent. Sullivan makes a connection between a patentee’s decision to renew a patent and the value of patent rights. He seeks to establish a correlation between the two distinct concepts of the value of a patent right (the ability to secure a monopoly, financial return) and the economic value of an invention (which, according to Sullivan, may be measured by the discounted value of resources saved as a result of the invention).[32] This proposal merits examination in relation to early railway technology. During the period under consideration here,

[29] Sullivan, "England's Age of Invention,” 447.
[30] Nicholas F.R. Crafts and C. Knick Harley, "Output Growth and the British Industrial Revolution: A restatement of the Crafts-Harley view," *Economic History Review* 45, (1992): 703-730.
[31] Sullivan, "The Revolution of Ideas,” 359.
[32] Sullivan, "Estimates of the Value of Patent Rights,” 37.

the process of prolongation of a patent, the ability to extend the term of the patent, rested either with Parliament or the Privy Council and the evidence demonstrates that both the initial period of patents and the renewed terms varied widely. Prior to 1835, prolongation was obtained by a private Act of Parliament and some twenty-five applications were considered by various parliamentary select committees.[33] According to Woodcroft's evidence before a parliamentary select committee in 1851, the initial periods of the earliest patents varied between twelve, twenty-one and thirty-one years.[34] Following Lord Brougham's Act in 1835, applications for extensions were made to the Privy Council, and between 1835 and 1852 some seventy-seven[35] applications were considered, when it was the practice of the Privy Council to prolong for a further seven years in appropriate cases.[36] The test applied by both Parliament and the Privy Council in considering applications for prolongation was one of benefit to the public and, significantly, whether the patent had demonstrably failed to reward the patentee, an issue that is explored more fully in the following chapter. By way of example, James Watt's patent for a separate condenser was granted in 1769 and subsequently extended by an Act of Parliament in 1775 for a further term of twenty-five years.[37]

Notwithstanding the preceding discussion about the variable monopoly periods for patents when originally granted, and the non-standard periods of prolongation, a number of studies have evaluated inventive activity by reference to renewal data. The scholarship in this area is generally concerned with the period post-1852, which was something of a watershed following the imposition of a renewal regime by the Patent Law Amendment Act. The 1852 Act sought to ensure a full period of fourteen years for the life of a patent with an initial fee payable at the time of application, followed by further instalments at three and seven years. Nevertheless, during the second half of the nineteenth century, post the 1852 reforms, it was still possible to extend a patent for a significant period. In 1864, Robert Fairlie patented a locomotive characterised by having two boilers, and in 1878 he persuaded the Privy Council to prolong his patent for an additional term of seven years on the ground of insufficiency of remuneration.[38]

Schankerman pioneered the approach of evaluating inventive activity by reference to renewal data, and in a study with Pakes, for the period 1950 to 1976, assumed that it was an indicator of the value of a patented invention if the patentee was prepared to expend on renewal fees to prolong the period of

[33] Dutton, *The Patent System and Inventive Activity*, 155.
[34] Evidence of Bennet Woodcroft, May 22, 1851, *Report and Minutes of Evidence taken before the Select Committee of the House of Lords appointed to consider of the Bill, intituled, "An ACT Further to Amend the Law Touching Letters Patent for Inventions* (House of Lords, July 4, 1851), 243
[35] Dutton, *The Patent System and Inventive Activity*, 155.
[36] Richard Godson, *A Practical Treatise on the Law of Patents for Inventions and of Copyright,* (London: Saunders and Benning, 1840) Appendix, 12.
[37] An Act vesting in James Watt, engineer, the sole use and property of certain steam engines … of his invention … for a limited time. 1775. 15 G. III. c.61
[38] "Judicial Committee of the Privy Council, April 12", *The Times*, April 13, 1878, 11.

protection.[39] Offering a comparative historical context, Sullivan applied the Schankerman and Pakes model to the period 1852 to 1876.[40] Similarly, in 2003, MacLeod, Tann, Andrew and Stein evaluated steam engine patents in the nineteenth century with a focus on the fallibility of renewal data.[41] The authors took issue with Sullivan on the basis that his application of the Schankerman model was based on mistaken assumptions about the behaviour of patentees, that patentees had freedom of choice. MacLeod *et al* argued that in relation to the period under consideration by Sullivan, inventors' choices were limited in that, in many cases, they had neither sufficient information about the technical viability of their invention, nor the financial resources to reach a decision in favour of renewal.

As has been argued in the previous chapter, and notwithstanding the earlier period under consideration here, any suggestion that the cost of patent fees was a deterrent, is too sweeping a claim. The sector-specific analysis undertaken here has found evidence that a number of the pioneers of early railway technology were not distracted by the cost, some even argued for increased fees. Furthermore, it is extraordinary to suggest that, across-the-board, many nineteenth century patentees failed to understand the technical viability of their patented inventions.[42] In relation to early railway technology, the evidence is clear that inventors of the calibre of George and Robert Stephenson had a very good understanding of the viability of their patented inventions. It was precisely this understanding that attracted funders of the quality of Edward Pease. For example, in a letter dated 10 October 1821, Edward Pease wrote to a co-investor describing George Stephenson in the following terms, 'a self-taught genius, a man thou would be remarkably pleased with, there is such a scale of sound ability'.[43]

The evaluation of data relating to the renewal of patents has been the subject of much scholarship. However, it has been argued here that renewal data is inherently unreliable for the pre-1852 period. In relation to early railway technology, therefore, rather than relying on patent data and statistics to assess the influence of patented inventive activity on the processes of innovation and technological change, a clearer picture emerges when due consideration is given to the *accessibility* of patented technical information, both in the offices of Chancery and contemporary technical publications. Significantly, and

[39] Mark Schankerman and Ariel Pakes, "Estimates of the value of patents rights in European countries during the post-1950 period," *Economic Journal* 96, (1986): 1052-1076. See also, Mark Schankerman, "How valuable is patent protection? Estimates by technology field using patent renewal data," *National Bureau of Economic Research Working Paper no 3780*, London School of Economics and Political Science; Centre for Economic Policy Research (CEPR) (July 1991).
[40] Sullivan, "Estimates of the Value of Patent Rights," (1994), and "Patent Counts and Textile Invention," (1995).
[41] Christine MacLeod, Jennifer Tann, James Andrew and Jeremy Stein, "Evaluating inventive activity: the cost of nineteenth century UK patents and the fallibility of renewal data," *Economic History Review* 56, no.3 (2003): 537-562.
[42] MacLeod, Tann, Andrew and Stein, " Evaluating inventive activity," 561.
[43] Edward Pease, letter to Thomas Richardson, October 10, 1821, Hodgkin Papers, D/Ho C/63/2, Durham County Record Office, Durham.

notwithstanding the risk of espionage,[44] the diffusion of novel ideas was facilitated by the publication of detailed patent specifications in numerous technical journals. Kronick's study of the origins and development of the scientific and technical press between 1665 and 1790, concluded there were two identifiable trends post-1665. Firstly, a rapid increase in the number of new journals being published, and secondly, many of those periodicals were dedicated to technology.[45] Significantly, these publications would have been widely available to the pioneers of the early railways.

3.2 The publication of patent specifications

Detailed accounts of patent specifications began to appear in technical journals from the late 1700s, and it is argued here that patent specifications provided an early form of codified technological knowledge. It is relevant to the arguments presented here that any curb on the publication of patent specifications would have impacted on the usefulness of the patent system to the pioneers of the early railways and would have weakened the resultant diffusion of patented railway-related technological knowledge. As identified in chapter two, between 1624 and 1852 there was an absence of substantive parliamentary intervention as to patent regulation.[46] Nevertheless, on two occasions Parliament considered Bills seeking to place restrictions on the publication of patent specifications. Significantly, for the arguments presented in this thesis, neither of the Bills were successful.

In 1793, a Bill was introduced to the Commons proposing the filing of 'secret' specifications because 'copies thereof may be obtained by foreign agents and emissaries and transmitted to foreign countries'.[47] In 1820, a further Bill proposed that access to specifications should only be possible following application to the High Court for permission.[48] Had either of these Bills been enacted, they would have undermined one of the purposes of the patent system, to allow access to specifications even if that increased the risk of espionage.[49] In 1824 a civil engineer, Bryan Donkin, observed to a parliamentary select committee,

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[44]French industrial espionage was overwhelmingly concentrated on Britain: 'Following their usual practice, the royal government sent abroad experts [*hommes de l'art*] to study the secrets and filch them as needed'. C. Ballot, *L'Introduction du Machinisme dans L'Industrie Francaise* (Lille-Paris, 1923), 437, quoted in John R. Harris, *Industrial Espionage and Technology Transfer* (Aldershot: Ashgate, 1998), 2.

[45] David A. Kronick, *A History of Scientific and Technical Periodicals. The origins and development of the scientific and technical press between 1665 and 1790* (Metuchen, N.J.: Scarecrow Press, 1976).

[46] An Act to Amend the Law Touching Letters Patent for Inventions 1835, 5 & 6 Wm. IV C.83. Known as Lord Brougham's Act (1835), was the first change in patent law following the Statute of Monopolies and allowed a patentee to amend the specification, but did not permit any other substantive changes.

[47] *A Bill Intituled an Act for securing the rights of Patentees in Certain Cases from the Encroachments of Foreigners* (House of Lords, 1793), 2.

[48] *A Bill to prevent the inconvenience arising from the facility of procuring copies of specifications inrolled by grantees of letters patent for the sole working and vending of new manufactures within this realm* (House of Commons, 1820).

[49] *Select Committee on the Signet and Privy Seal Offices* (1849), 36.

> [A] foreigner, or any person, for a few shillings, can go to our record offices, and examine a specification, containing a description of the best machines we have, because for all the most valuable machine patents are obtained; specifications are by law registered there, and the offices are open to any man, and copies can be obtained at a small expense.[50]

In 1829, giving evidence to a parliamentary select committee appointed 'to inquire into the present state of the law and practice relative to the granting of patents for inventions', John Farey stated, 'I think it is always improper, that there should be anything like a secret specification, under any circumstances whatever'.[51] His view was endorsed by Charles Few, 'I think there would be more mischief done by closed specifications than by open specifications'.[52] Giving evidence at a later date to the same select committee John Farey considered the 'excessive rapidity and extensive spread of new ideas by our periodical publications' to be one of the most important advantages British manufacturing enjoyed over its American and continental rivals.[53] In 1849, William Carpmael giving evidence before another parliamentary select committee stated,

> [T]here is no official index, no Government Index; but there are indexes of number published in works that retain them. The 'Repertory of Arts,' The 'London Journal of Arts' and 'The Mechanics' Magazine,' all contain lists of them; and there are the Blue Books published. with all the specifications at the Rolls Chapel up to a certain date, with subject matter more or less appended to them ... but a person can have no difficulty in searching at the present time.[54]

Khan proposes that technical diffusion was constrained by lack of information. She argues that lower diffusion would tend to increase the value of intellectual property rights belonging to those able to obtain a patent, and reduce the likelihood of further developments in the sector.[55] These arguments are not supported by the evidence. Specifications of patented railway-related inventions frequently appeared in contemporary periodicals, including the new, cheap publications arising out of a radical context which enjoyed large circulations.[56] In 1824, Thomas Dibdin reported upwards of 100,000 'twopenny' publications in circulation per week, and a distribution of 15,000 copies of the *Mechanics' Magazine*.[57] This low priced scientific weekly, was the first publication of its kind and William Bridges Adams was a regular contributor.

Mechanics' Magazine was founded in 1823 by Joseph Clinton Robertson, pseudonym Sholto Percy, a Scottish patent agent, writer and periodical editor, whose methods included soliciting letters to the editor

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[50] *Six Reports from the Select Committee on Artizans and Machinery* (House of Commons, 23 February - 21 May 1824), 35.
[51] John Farey, 11 May 1829, *Select Committee on the Law Relative to Patent Inventions* (1829), 36
[52] Charles Few, May 15, 1829, *Select Committee on the Law Relative to Patent Inventions* (1829), 47.
[53] John Farey, June 9, 1829, *Select Committee on the Law Relative to Patent Inventions* (1829), 132.
[54] William Carpmael, August 25, 1848, *Select Committee on the Signet and Privy Seal Offices* (1849), 33.
[55] B. Zorina Khan, *The Democratization of Invention: Patents and Copyrights in American Economic Development, 1790-1920* (Cambridge, Mass.: Cambridge University Press, 2005), 59.
[56] The rise in cheap publications was made possible by new developments in printing technology which included stereotype plates on steam powered presses. This fast, cheap production facilitated mass circulation.
[57] Jonathan R. Topham, "John Limbird, Thomas Byerley, and the Production of Cheap Periodicals in the 1820s," *Book History* 8, (2005): 75-106, 97 n.107.

on an extensive scale, and publishing them without payment.[58] Robertson, a political radical, was prominent in the early days of the working class press in London, and in debates within the Mechanics' Institute movement. During the 1820s, benevolent groups and individuals created Mechanics' Institutes containing inspirational and vocational reading matter, available for a small fee, principally for 'mechanics' (civil and mechanical engineers), an emerging class of reader who could not afford subscription libraries. Increasingly, during the 1820s, the *Mechanics' Magazine* covered railway inventions, and by the end of the decade had become a partisan of the railroad lobby's argument against the steam carriage, which ran on the road and was promoted by the mainstream press, including the *Times*. Robertson's talent for promoting inventions was such that by the 1840s the *Mechanics' Magazine* had become entirely subordinate to his patent agency enterprise.[59]

The first monthly magazine devoted entirely to railways, the *Railway Magazine*,[60] appeared in May 1835, and in November of the same year the weekly *Railway Gazette* commenced publication. In August 1839, physicist John Herepath converted the monthly *Railway Magazine* into a weekly newspaper, changing the title to *Herepath's Railway Magazine, Commercial Journal and Scientific Review*, which by 1844 had a weekly circulation of 1,800 copies. Most of the material carried by these low-priced scientific periodicals was derived from patent data, and by publishing patent specifications, these publications offered a significantly cheaper way of obtaining the latest technical information than had it remained in tacit form or worked in secret, the alternative in the absence of patent protection.[61] In 1835, Luke Herbert set out his chief aim in publishing *Engineer's and Mechanic's Encyclopaedia* in the following terms,

> … to publish a work to embrace a judicious selection of all those machines, engines, manipulations, processes, and discoveries, that now lie scattered throughout several hundred volumes of scientific journals, or are inscribed in obsolete characters upon the rolls of the Court of Chancery, in the form of specifications of patent inventions ... to accomplish an undertaking of such great advantage to operative men in a form *adapted to instant reference and ready application* [Herbert's emphasis].[62]

Commencing in 1832, the *London Journal of Arts and Science*, edited by the successful patent agent and instrument maker William Newton, not only published information relating to patents, but included information on the associated administrative procedures. Increasingly, the emergence of professional

[58] John E. C. Palmer, "Authority, idiosyncracy, and corruption in the early railway press, 1823–1844," *Journal of the Railway and Canal Historical Society* 31, (1995): 442–457, 443.
[59] Drawn into the railway world, in 1830 Robertson conducted the defence for John Braithwaite and John Ericsson in a patent case, on boilers, brought by Lord Cochrane and Alexander Galloway. The case centered on a boiler utilised in the locomotive *Novelty* which ran in the Rainhill Trials in October 1829. Palmer, "Authority, idiosyncracy and corruption," 445.
[60] Not to be confused with the current *Railway Magazine* which commenced publication in 1897.
[61] Sean Bottomley, "Patents and the first industrial revolution in the US, France and Britain, 1700-1850," Working paper 14-14 Institute for Advanced Study in Toulouse (2014), http://idei.fr/sites/default/files/medias/doc/wp/2014/wp_iast_1414.pdf, 16, [accessed July 14, 2015].
[62] Luke Herbert, *The Engineer's and Mechanic's Encyclopædia, comprehending practical illustrations of the machinery and processes employed in every description of manufacuture of the British Empire ... with nearly two thousand engravings*, Vol. I (Thomas Kelly: London, 1835), p.iv.

societies from the middle of the nineteenth century engendered publications dedicated to chronicling the technical advances of the day. In 1856, Edward Healey whose friends included Robert Stephenson and Isambard Kingdom Brunel, founded *The Engineer* thought to be one of the world's oldest journals of a professional society. Healey and his successors recorded rapid advances in engineering and technology throughout the Victorian age.[63]

Many of the early technical journals (the most relevant periodicals of the day are listed in Table 3) published considerable information about new patents, together with details of the specifications, and informed comment as to the patent in question.

Table 3: Scientific and technical periodicals

Repertory of Arts	monthly	1794-1885
London Journal of Arts and Sciences	monthly	1820-1867
Mechanics' Magazine	weekly	1823-1893
Register of Arts and Sciences	weekly	1824-1832
Engineers' and Architects' Journal	monthly	1837-1866
Inventors' Advocate	weekly	1839-1841
Record of Patents Inventions	weekly	1842-1843
Artizan	monthly	1843-1873
Patent Journal	monthly	1846-1851
Practical Mechanics' Journal	monthly	1848-1873

Source: Bottomley, *The British Patent* System, 189 n.48. The publication years are from Henry Carrington Bolton, *A Catalogue of Scientific and Technical Periodicals 1665-1895*, (Washington DC: The Smithsonian Institution, 2nd edition 1897).

Two examples from one of the oldest journals, the *Repertory of Arts* (later *The Repertory of Patent Inventions and other Discoveries and Improvements in Arts Manufacturers and Agriculture*) serve to illustrate the point. In November 1825, under the heading 'New Patents', details were provided of a patent granted to Henry Palmer on 22 November 1821. In addition to providing a copy of the specification, the following comment appeared,

> Mr Palmer's railway differs from those in common use in consisting of one rail only elevated on posts some height above the ground … [a detailed explanation follows]. We consider Mr Palmer's railway to be a very ingenious invention and think his publication on the subject contains much useful information on railways in general.[64]

The same edition of the *Repertory* gave details of a patent granted to John Vallance on 19 February 1824 for producing locomotion to stationary engines.[65] An informed discussion as to the merits of the invention extended to some seven pages, prefaced by the following editorial comment,

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[63] *The Engineer – Centenary Edition, 1856-1956,* (1956): 146.
[64] *The Repertory of Patent Inventions and other Discoveries and Improvements in Arts Manufacturers and Agriculture* vol. 1 (London: T and G Underwood, 1825), 131.
[65] John Vallance, *Means of intercourse by which persons may be conveyed, goods transported, …,* Patent No. 4905, February 19, 1824.

> The number of patents having greatly increased since the commencement of the Repertory in the year 1794 it has become impossible to publish specifications within any moderate period … therefore it has been decided to give an account in an abridged form, accompanied by remarks of every new patent as soon as the specification shall be enrolled … and afterwards to print the specification of such patents.[66]

Detailed knowledge relevant to early railway technology appeared regularly in contemporary technical journals. In 1830, Timothy Hackworth, an early locomotive engineer, was called upon to design a number of locomotives for coal traffic on the Stockton and Darlington Railway. He designed a class of locomotive known as Wilberforce, and Robert Stephenson and Co. was instructed to build three of these engines. On 8 November 1831, the Company wrote to Hackworth in the following terms,

> Dear Sir, - We are sorry to inform you that we fear that your new locomotive boiler which we are making is a patent of Napiers of Glasgow. We have discovered it in the *Repertory of Arts* for this month … we cannot proceed with the tubes till we hear from you.[67]

This letter illustrates recourse made to published patent details by the leading locomotive manufacturer of the day, and is evidence that the contemporary press was consulted by those involved in early railway technology. The patent in question, for a 'return multi-tubular fire tube', had been granted in March 1831.[68] Hackworth contacted Napiers and managed to persuade them that he had made extensive use of the return-tube prior to the date of their patent. Subsequently, by mutual agreement, both companies continued to use the tubes without further complaint.[69]

In 1846 the *Patent Journal* was founded with the explicit aim of providing details of all patents granted, a period when, according to Palmer and Paar, more than half of all patents were associated with railways. The monthly periodical was of small format until 1848 and contained diagrams, many folding.[70] The availability and legitimacy of technical publications is underlined by Woodcroft who captured the details of patents in his indices, but also included detailed references to technical and legal literature where patents were referenced. For example, in relation to James Watt's entry for his patented separate condenser, Woodcroft lists some 13 publications where the patent was referenced (reproduced in Table 4). The listing indicates that the patent was lodged in the Rolls Chapel, but also directs the reader to relevant law reports, journals and parliamentary reports. Such wide reporting of Watt's patented invention doubtless reflects the significance of the technological innovation. By contrast, John Blenkinsop's patent for the railway rack and pinion principle whilst a significant invention, was only referenced in three publications (reproduced in Table 5). The low number of references for Blenkinsop's

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[66] *Repertory of Patent Inventions and other Discoveries*, 52-59, 52.
[67] Robert Stephenson and Co., letter to Timothy Hackworth, November 8, 1831, Hackworth Papers, HACK 3/3/1/2, National Railway Museum, York.
[68] David and William Napier, March 4, 1831. Patent 6090
[69] Robert Young, *Timothy Hackworth and the Locomotive* (Ilkley: The Scholar Press,1975), 254.
[70] Palmer and Paar have listed 12 publications founded during the formative years of the railway press. They have also identified some 22 short-lived periodicals that played a significant role in fomenting the railway 'mania' of 1845-1846. John E.C. Palmer and Harold W. Paar, "Transport" in *Victorian Periodicals and Victorian Society*, eds. J. Don Vann and Rosemary T. VanArsdel (Aldershot: Scolar Press, 1994) 186-191.

patent is surprising given the success of the invention and suggests that at the time it was perceived to have less commercial application.[71] This salient point is developed further in chapter 4.

Table 4: Entry in *Reference Index* for Watt's Patent No. 913[72]

Patent Number	Reference
	Repertory of Arts, vol.1, page 217
	Mechanics' Magazine, vol.1, page 4
	Register of Arts and Sciences, vol.4, pages 24 and 346.
	Engineers' and Mechanics' Encyclopaedia, vol.2, page 725
	Webster's Reports, vol.1, p.56, note; also pages 230, 282 and 285,
	Webster's Patent Law, page 46 (also page 127 cases 30, 31 and 32),
	Blackstone's Reports, vol.2, page 463
913	Carpmael's Report on Patent Cases, vol.1, pages 117 and 156
	Davies on Patents, pages 155, 162 and 221
	Parliamentary Report, 1829 (Patent Law), pages 187, 189 and 190
	Vesey, jun[r] Reports, vol.3, page 140
	Term Reports by Durnford and East, vol.8, page 95
	Rolls Chapel Reports, 6th Report, page 160
	Rolls Chapel

Table 5: Entry in *Reference Index* for Blenkinsop's Patent No. 3431[73]

Patent Number	Reference
	Repertory of Arts, vol.21 (second series), page 138.
	Register of Arts and Sciences, vol.4 page 441.
3431	Engineers' and Mechanics' Encyclopaedia, vol.2, page 395.
	Petty Bag

Source: Bennet Woodcroft, *Patents for Invention: Reference Index:1617- 1853* (London: G.E. Eyre and Spottiswoode, 1855), 14, 100.

There is good evidence that these technical publications were in great demand abroad and played an important role in the international diffusion of technology. In 1825, the eminent engineer Henry Maudslay was asked by a Select Committee whether it was within his knowledge that 'the French are in possession of drawings and plans of almost every patent as soon as they are published in England?' Maudslay replied,

> Yes, I know from circumstances that have come to my own knowledge. On the first of every month, books are packed off to Hamburgh, and sent through Holland and all parts of the Continent … This is a copy of the French *Repertory of Arts* [alluding to a book produced by the witness], and this is a drawing of a machine, and is a good a plan as a man need to work from, and I know this machine was not at work in our mint when this book was published in France.[74]

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[71] John Blenkinsop's Patent No.3431 was for the principle of rack and pinion, and not the steam engine *per se*.
[72] Reproduced from Bennet Woodcroft, *Patents for Invention: Reference Index:1617- 1853* (London: G.E. Eyre and Spottiswoode, 1855), 14.
[73] Reproduced from Woodcroft, *Patents for Invention, Reference Index:1617- 1853,* 100.
[74] Henry Maudslay, June 30, 1825, "Report from the Select Committee on the Export of Tools and Machinery," *Parliamentary Abstracts: containing the substance of all important papers laid before the two Houses of Parliament during the session of 1825(-1826),* (London: Longman, Rees, Orme, Brown and Green, 1826), 385-395, 394-395.

It is a foundational premise of this thesis that recognition of the availability of published patent specifications for the pioneers of the early railways contributes to an understanding of the role and influence of the workings of the patent system on the development of early railway technology. The arguments constructed in this thesis support the conclusion of MacLeod *et al* who have evaluated patent data in relation to innovative activity in a number of areas of steam power development, and determined that patent records and specifications have a 'tremendous' contribution to make to the study of engineering and technology.[75]

This thesis also seeks to rely on aspects of the work of Nuvolari and Tartari who have made a substantial contribution to the field of patent analysis. In 2009 they suggested a new indicator based on the 'relative visibility' of individual patents in the contemporary technical and legal literature as summarised in Woodcroft's *Reference Index of English Patents of Inventions 1617-1852*.[76] They considered each patent summarised by Woodcroft and made the basic assumption that the comparative visibility of each patent provides a reasonable proxy for its relative technical and economic significance. The authors assigned a quality score (WR1*) to each patent equal to the number of references listed by Woodcroft. For example, as illustrated in Table 4 above, Woodcroft's entry for Watt's patent No.913 lists numerous references in contemporary journals. This occasioned the assignment of a high quality score by Nuvolari and Tartari. The authors argue that their new indicator assists in the debates relating to the nature and dynamics of innovation during the Industrial Revolution. They suggest that their indicator seeks to reconcile the traditionalist approach advanced by Sullivan (rapid and widespread change) with the revisionist view (a more gradual dynamic) proposed by Crafts and Harley. The authors maintain that Sullivan is too optimistic in his views, and in terms of scope of change they suggest that although patents were relatively widespread, patents of comparatively high quality emerged only from a few sectors.

Significant to the study undertaken here, Nuvolari and Tartari acknowledge that steam technology generated high quality patents, but their conclusion that the critical phase of top quality patents occurred during the second half of the nineteenth century, is not supported by the evidence in relation to early railway technology. It is demonstrated here that technical breakthroughs were a feature of the early railway industry throughout the first half of the nineteenth century. Furthermore, no evidence has been found in relation to early railway technology to support Nuvolari and Tartari's proposal that the impact

[75] James Andrew, Jennifer Tann, Christine Macleod and Jeremy Stein. "Steam Power Patents in the Nineteenth Century. Innovations and Ineptitudes," *Transactions of the Newcomen Society* 72, (2000-2001): 17-38, 34.

[76] Alessandro Nuvolari and Valentina Tartari, "Bennet Woodcroft and the Value of English Patents, 1617-1841," *Explorations in Economic History* 48, (2011): 97-115. See also: Alessandro Nuvolari, Bart Verspagen and Nick von Tunzelmann, "The early diffusion of the steam engine in Britain, 1700-1800: a reappraisal," *Cliometrica* 5, (2011) 291-321, http://link.springer.com/article/10.1007%2Fs11698-011-0063-6 [accessed March 20, 2012]; Roberto Fontana, Alessandro Nuvolari, Hiroshi Shimizu and Andea Vezzulli, "Reassing patent propensity: evidence from a data-set of R&D awards 1977-2004," *University of Lisbon School of Economics and Management working paper* (March 2013); http://pascal.iseg.utl.pt/~depeco/wp/wp092013.pdf [accessed 31 August 2013].

of certain macro prototype inventions on productivity growth became visible only following a period of adaptation, improvement and refinement by a stream of micro inventions.[77] The work of Nuvolari and Tartari, and their recognition that steam technology generated high quality patents, described as technological blockbusters, validates further study of the impact of the patent system on the development of early railway technology. However, as will be demonstrated in chapter 4, their contention that much inventive activity took place in a localised setting, outside of the patent system does not withstand scrutiny in relation to early railway technology.

In addition to the proliferation in technical journals, and as identified in the previous chapter, the developing genre of law reporting included decisions in patent dispute cases. The reporting of patent disputes assisted early railway inventors and their advisers in two important respects. Firstly, details of the invention specification were often fully explored in the law report. Secondly, the judges created patent principles that were certain and could be relied upon as part of a precedent system. William Carpmael writing in 1842 was able to state, 'the extensive publication of the modern decisions in courts of law in patent cases has … removed all doubts as to patent property being secure'.[78] William Carpmael was a leading patent attorney of the day and the contribution of patent agency to the effectiveness of the patent system is now considered, including the significant role of many patent agents in the contemporary publication of patented data.

3.3 The role of patent agents

It is argued here that patent agents had an active and constructive role in the workings of patent system far earlier than is generally recognised. There is good evidence that by the 1770s, much of the administration for the process of applying for a patent was undertaken by individuals who understood the process and who could receive written instructions from anywhere in the country. The evidence considered here demonstrates that the agency of these individuals may have been a contributing factor to the overall effectiveness of the patent system. In addition, many of the early patent agents edited or contributed to technical publications, and it is a central argument of this thesis that the publication of patent specifications in contemporary journals contributed to the dissemination of technological knowledge.

The extent to which patent agents assisted inventors during the early part of the nineteenth century is difficult to ascertain, but they appear to have had three main functions. Firstly, to prepare the specification, and many of the early patent agents, individuals such as William Carpmael, John Farey and Moses Poole, were consulting engineers who would have possessed the necessary technical know-how. Secondly, to act as brokers in the financing of patents and the selling of assignments. In 1835,

[77] Nuvolari and Tartari, "Bennet Woodcroft and the Value of English Patents,"113.
[78] William Carpmael, *The Law of Patents for Inventions Familiarly Explained, for the use of inventors and patentees* (London: Simpkin, Marshall and Co., 5th edn. 1842), 6.

when asked about patents, Farey told a parliamentary select committee that he was 'chiefly employed by capitalists who have consulted me whether they should lay out their money in them'.[79] Thirdly, to provide guidance both as to the advisability of making a patent application and potential infringements. In 1851, Carpmael informed a parliamentary select committee that in 'six out of every seven cases before us we advise them not to take out patents'.[80]

According to Dutton, patent agency was a nineteenth century phenomenon.[81] However, James Watt writing to Matthew Boulton, in 1782, urged Boulton to spur on 'Mr Handley with the patent and at the same time cause to enquire what new patents are now going through the office.'[82] Thomas Handley was a patent attorney, based in Rolls Building, Fetter Lane, London. He advised on and processed all of Watt's patents, including the copying machine (1780), the rotative patent (1781), the expansive working and double acting patent (1782), the parallel motion and steam carriage (1784) and the smoke consuming furnace (1785). He also informed Boulton and Watt of the progress of other engine patents, and found and sent them rival specifications including Robert Cameron's 1784 patent for a helical rotative engine.[83] Handley is a good example of a patent attorney assisting an early railway inventor. He was involved not only with the preparation of patent applications, but was also tasked with the interrogation of patent records held in the offices of Chancery to ascertain new patent applications. His research would have identified potential infringements of Watt's patents, and would also have served to identify prospective inventive opportunities.

There is good evidence that during the eighteenth century many of the first agents were officials in patent administration, who used their skills for private clients. Moses Poole, in giving evidence to a parliamentary select committee in 1849, stated he had inherited his position as Clerk of Inventors in the Patent Office from his father, who had held the post since 1776. He was asked whether his father practised as a patent agent, to which he replied, 'My father always did.'[84] There is some debate about whether Poole senior inherited the patent agency from a Mr Lamb, which would suggest that there had been two generations of patent agents prior to Poole junior taking up the position.[85] If this is found to be the case, it would establish a role for patent agents far earlier than is generally recognised.

[79] *Select Committee on Patents Amendment Bill*, 1835, (House of Lords), quoted in Dutton, *The Patent System and Inventive Activity*, 93, n.48.
[80]William Carpmael, March 12, 1851, *Minutes of Evidence taken before the Select Committee of the House of Lord appointed to consider the Bill to extend the provisions of the Design Act, 1850, and to give protection from Piracy to persons exhibiting inventions in the Exhibition of 1851* (House of Lords, 1851), 10.
[81] Dutton, *The Patent System and Inventive Activity*, 86
[82] James Watt, letter to Matthew Boulton, February, 13-16, 1782, quoted by Dutton, *The Patent System and Inventive* Activity, 182.
[83] Boulton and Watt Papers, Thomas Handley Correspondence 1777-1788, MS 3147/3/501, Birmingham City Library. Cameron's patent is discussed in John Farey, *A Treatise on the Steam Engine: historical, practical and descriptive* (London: Longman, Rees, Orme, Brown and Green, 1827), 656.
[84] Moses Poole, August 31, 1848. *Select Committee on the Signet and Privy Seal Offices* (1849), 54.
[85] Lamb was patent clerk to the Attorney General, See Bottomley, *The British Patent System*, 67, n.152.

In 1821, Moses Poole formed a partnership with William Carpmael and by 1829 their business was flourishing.[86] According to Dutton, by 1850 there were some 20 patent agencies in London alone, dominated by three firms. Poole and Carpmael who handled 43 per cent of patent applications, Newton and Co. who handled 24 per cent, and Robertson and Co. who handled 13 per cent.[87] Inkster's recent analysis of patent agency concentrates on the late nineteenth century by which time, he observes, patent agents were the 'legal beavers and engineers of Southampton Row and Chancery Lane'. Of over 1000 patentees recorded for the Holborn district in London, for the period 1855-1870, some 80 per cent were patent agents or engineer-agents, almost all of whom depended for their livelihood on re-writing, advising and managing the patent communications for foreign applicants.[88]

It is commonly opined that between 1617 and 1853, patents were awarded predominantly to individuals with addresses in London, that patenting was London-centric leading inventors to eschew the patent system, choosing instead alternative settings for the protection of inventive knowledge. This proposition is not supported by the evidence presented in this thesis. For example, contrary to MacLeod's opinion, the siting in London of the offices of Chancery and latterly the Patent Office, seems not to have proved problematic for potential patentees.[89] In 1829, Farey informed a parliamentary select committee,

> … the only acts the inventor is allowed to perform for himself are the making of an affidavit of his having invented the object for which he applies for the patent … all the rest may be done by his attorney or patent agent.[90]

Many of the pioneering patentees of the early railway industry were located in the north east of England, and in the case of James Watt in Edinburgh. There is good evidence that although these individuals travelled widely, they employed the services of patent agents and lawyers to attend to patent documentation, and to monitor the official patent registers for novel developments and or potential infringements. It is beyond the remit of this thesis, but a wider consideration of the influential role of patent agents prior to 1852, would likely challenge scholarly consensus by establishing that it was the patent agents, rather than patentees who were predominantly based in London. Furthermore, patent agents assisted inventors who sought to acquire patents abroad. This would have been important to the early railway companies, particularly the manufacturers who endeavoured to sell locomotive overseas. Carpmael informed a parliamentary select committee in 1851 that one half of patent applications with which he was concerned were taken out abroad.[91]

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[86] John Farey, May 11, 1829, *Committee on the Law Relative to Patent Inventions* (1829), 16. The firm continues to the present day as Carpmaels and Ransford.
[87] Dutton, *The Patent System and Inventive Activity*, 87
[88] Ian Inkster, "An historical analysis of patent data," *Transactions of the Newcomen Society* 73, (2004): 179-208, 192.
[89] MacLeod, *Inventing the Industrial Revolution*, 118-124.
[90] John Farey, May 11, 1829. *Select Committee on the Law Relative to Patent Inventions* (1829), 16.
[91] William Carpmael, March 12, 1851, *Select Committee … to extend the provisions of the Design Act* (1851), 13.

Guagnini suggests that the market for inventors was sector-specific and that the attitudes of patent agents varied according to the state of the development of a particular technology.[92] Hitherto there has been little academic interest in the role of patent agents within early railway technology and further investigation is warranted. Nevertheless, since railway-related patent numbers were significant during the early nineteenth century, it is likely, following the reasoning of Guagnini, that patent agents played an important role in promoting the utility of the patent system to those involved in railway-related inventive activity. It is of relevance to the themes being developed in this thesis that patent agents, and others, would have contributed to the effectiveness of the patent system not only as to their valuable administrative skills but also their strategic advice to potential patentees. During the first half of the nineteenth century patent agents were assimilating the outcome of court decisions and making available a substantial body of knowledge on patent literature and practice, including the publication of reference works, and their professional interests and agenda deserves more systematic empirical research.[93]

3.4 The value of patent statistics

Woodcroft's collations of early patents and his subsequent reference volumes have motivated much academic interest in the value of patent data, but scholarly debate centres almost entirely on general analysis. It is argued here that in relation to railway technology, four identifiable, interrelated drivers may explain the acceleration in railway-related patents during the late eighteenth and early nineteenth centuries. Firstly, Britain's burgeoning railway inventive talent. The engineering dynasties of the Stephensons and the Brunels, as well as the 'diligent, intelligent, dutiful, sober and conscientious' personnel who were able to meet the demands of the emerging railways,[94] constituted a pool of talented individuals unparalleled elsewhere in the world. Secondly, a rapidly evolving railway network demanded either the development of new technology or the adaptation of existing technologies for railway use. Thirdly, the opportunities available for inventors and their funders who sought to control and manage inventive knowledge, namely, whether to work an invention in secret, engage in collective invention or make recourse to the patent system. Fourthly, the extensive investment that was often required in order to develop railway-related inventions. These latter themes are developed further in following chapters. For example, in chapter 4, contemporary evidence is considered that demonstrates profit to have been a significant motive for many of those involved in early railway technology. Similarly, in circumstances where initial investment was significant and profit was a necessary

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[92] Anna Guagnini, "Patent Agents in Britain at the Turn of the Twentieth Century. Themes and Perspectives," in *Technology and Culture* 31, (2012):158.
[93] Guagnini, "patent agents,"159.
[94] Michael Duffy, *Electric Railways1880-1890* (London: Institution of Engineering and Technology, 2003), 1. Cunningham, in an appraisal of David Joy's valve gear, also makes important reference to a later generation of engineers who were talented, but largely overlooked. James Cunningham, "David Joy and his Radical Valve Gear," (MA. Diss., University of York, 2001).

concomitant motive, secret working and collective invention are shown not to have been approaches of choice.

The many and various drivers of patented inventive activity are addressed in the literature. For example, MacLeod acknowledges that rising patent numbers reflected the blossoming of inventive talent.[95] Also, North, referencing the importance of the Statute of Monopolies (1624), has opined that the granting of patent rights was an important contributing factor for the Industrial Revolution.[96] North's observation supports the arguments made here, that inventors of railway technology found great utility in the patent system, but this thesis seeks to place a gloss on North's contribution in that whilst the patent system may have encouraged technological change, it was not as a consequence of the 1624 Act. Building on the work of Arapostathis and Gooday, it is argued here that the patent system should be understood as a material consequence of the work of the judiciary and the adversarial court system, which by the beginning of the nineteenth century was contributing to and shaping patent law.[97]

Dutton was the first academic to look at inventive activity for its own sake, and to consider what effect patents had on those who used the system. His analysis of the English patent system during the Industrial Revolution, whilst identifying that it was not perfect, recognised that it did provide a degree of protection for an inventor. Paradoxically, Dutton concluded that the inefficiencies of the patent system may have accelerated the process of innovation and technological change.[98] It is likely that both North and Dutton were influenced by a consideration of the statistics concerned with the acceleration of patenting rates and the classification of the patent tables. Dutton was interested in the direction of patent activity ranked by process and published a table showing 97 classifications between 1750 and 1851. Steam was the first classification with 984 patents, being some 5.75 per cent of patents granted. Railway carriages were fifteenth in his list (325) being 1.9 per cent, and railways were twenty-seventh (227) with 1.32 per cent.[99] Some caution must be exercised with regard to Dutton's classifications and what he included therein. Nevertheless, Dutton was clear that the imperfect nature of the patent system 'created something close to the ideal'.[100] So long as patents provided a degree of protection, and were better than any other alternative, it paid inventors to take out patents in order to protect their inventions.

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[95] MacLeod, *Inventing the Industrial Revolution*, 5.
[96] Douglass North, *Structure and Change in Economic History* (New York: Norton, 1981), 164-166. Douglass North was the co-recipient (with Roger Fogel) of the 1993 Nobel Memorial Prize in Economic Sciences when the Committee described his contribution as 'having renewed research in economic history by applying economic theory and quantitative methods in order to explain economic and institutional change'. The Sveriges Riksbank Prize in Economic Sciences in Memory of Alfred Nobel 1993. *Nobelprize.org.* Nobel Media AB 2014. Web. 1 Mar 2016, http://www.nobelprize.org/nobel_prizes/economic-sciences/laureates/1993/ [accessed September 2, 2015].
[97] Arapostathis and Gooday, *Patently Contestable*, 85.
[98] Dutton, *The patent system and Inventive Activity*, 204.
[99] Dutton, *The patent system and Inventive Activity*, 206.
[100] Dutton, *The patent system and Inventive Activity*, 205.

It is recognised here that there are inherent difficulties in using patent numbers as output indicators of inventive activity, that there is a need to move beyond mere patent counting. MacLeod who has been at the forefront of academic writing on the value of patent analysis,[101] advocates evaluation not only of the volume of inventive activity, but also of the technological significance of potential inventions. She does not define technological significance, but implies an equivalence with Nuvolari and Tartari's designation of 'breakthrough' inventions.[102]

It is demonstrated in later chapters of this thesis that early railway technology was characterised by many patented incremental improvements, as well as so-called breakthrough inventions, and that patented inventive activity often clustered around critical problems. The availability of published patented technical data would have informed inventors of problem areas, and highlighted the potential commercial value of innovative solutions. The evidence considered in later chapters is persuasive that technical achievement and economic potential were intrinsically linked within the early railway industry.

The arguments constructed in this thesis recognise that the growth of a technological system should be assessed by reference to the contribution of non-heroic inventors, as well as the pioneering engineering giants of early industrialisation. According to MacLeod and Nuvolari, economic and social historians have been preoccupied with the social and economic *effects* of technological change (for example the impact of new technologies) rather than its *sources*.[103] They carried out a prosopographical investigation of the major British inventors as selected by the Victorian edition of the *Dictionary of National Biography*, and established that of the 383 individuals born between 1650 and 1900, who were credited with at least one invention, 40 per cent did not apply for a patent. The authors concluded that there should be a careful reassessment of technological dynamism so as not to concentrate on the 'glamorous' technologies, but to consider the ingenious and less well known inventors who have found no place in the heroic tales of the Victorian age.[104] In chapters 7 and 8 of this thesis, it is established that the many patented incremental improvements to inventions, by relatively inconspicuous individuals including

[101] See for example: MacLeod, *Inventing the Industrial Revolution* (2002); Christine MacLeod, "The paradoxes of patenting: invention and its diffusion in 18th-and19th century Britain, France, and North America," *Technology and Culture* 32, no.4 (October, 1991) 885-910; Christine MacLeod "Concepts of invention and the patent controversy in Victorian Britain," in Robert Fox (ed) *Technological Change; Methods and Themes in the History of Technology* (Amsterdam, Harwood Academic Publishers, 1996), 137-154; MacLeod, *Heroes of Invention* (2007); Christine MacLeod and Alessandro Nuvolari, "Patents and Industrialisation; An Historical Overview of the British Case, 1624-1907," Report to Strategic Advisory Board for Intellectual Property, LEM Working Paper Series, 2010, http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2019844 [accessed July 23, 2013].
[102] Nuvolari and Tartari, "Bennet Woodcroft and the Value of English Patents,"113.
[103] MacLeod and Nuvolari, "The Ingenious Crowd: A Critical Prosopography of British Inventors 1650-1850," *The Netherlands Working Paper 05.04*, (Eindhoven Centre for Innovation Studies, Department of Technology Management, Technische Universiteit Eindhoven, The Netherlands, April 2005), 4, http://cms.tm.tue.nl/Ecis/Files/papers/wp2005/eciswp126.pdf [accessed April 27, 2011]
[104] MacLeod and Nuvolari, "The Ingenious Crowd," 19.

those from associated technologies beyond the railway proper, played a central role in the development of early railway technology. Furthermore, as is discussed in later chapters, the evidence suggests that the significant economic potential of some patented incremental improvements, often deemed critical to the momentum of railway technology, served to incentivise further inventive activity.

The evidence considered in this industry-specific evaluation of the patent system, does not support a proposition by MacLeod and Nuvolari that the effect of the patent system on industrial development was at best 'second order'.[105] There is good evidence that in relation to early railway technology, the economic benefits and protection provided by the patent system were crucial for many of the individuals involved in inventive activity. MacLeod does acknowledge that whilst difficulties have to be recognised in their assessment, the rise in the number of patents which commenced in the third quarter of the eighteenth century, requires explanation, that patent numbers have to be reinterpreted, not recalculated.[106] However, the arguments constructed in this chapter challenge the premise of MacLeod and Nuvolari, who in their recent historical overview for the period 1624 to 1907 as to patents and industrialisation, suggested that no consensus has been reached as to whether the emergence of the patent system had a favourable impact on inventive activity during the period.[107] According to MacLeod, many inventors found it too expensive or inconvenient to patent, and many would have seen no benefit from patenting their invention in the particular circumstances in which they intended to use it. Furthermore, the authors advocate it is unlikely that many inventors would have considered a patent to have been a worthwhile commercial investment. These generalisations are not borne out by either the evidence considered in this thesis, or the analysis of patent collations in respect of early railway technology as discussed in this chapter.

Whilst MacLeod and Nuvolari acknowledge that Britain was a world technological leader, the first industrial nation, and notwithstanding their suggestion that even without the patent system, inventors would have continued to invent, their misconceptions about the workings of the patent system, have led MacLeod and Nuvolari to place emphasis on the prevalence of inventive activity that occurred *outside* the patent system. The contemporary evidence of individuals such as James Watt, Robert Stephenson, Henry Bessemer and William Cooke confirms that they would have been unlikely to invest in invention without the protection provided by the patent system. In 1829, giving evidence to a parliamentary select committee, John Farey stated,

> I am of the opinion that many great inventions would never have been brought to bear, as they have been, but for the encouragement offered by a patent.[108]

[105] MacLeod and Nuvolari, "Patents and Industrialization," 30.
[106] Christine MacLeod and Alessandro Nuvolari, "Inventive Activities, Patents and Early Industrialization. A Synthesis of Research Issues." *Danish Research Unit for Industrial Dynamics*, Druid Working Paper 28 (2006), http://www3.druid.dk/wp/20060028.pdf, 7, [accessed October 25, 2010].
[107] MacLeod and Nuvolari, "Patents and Industrialization," 28.
[108] John Farey, June 8, 1829, *Select Committee on the Law Relative to Patent Inventions* (1829), 141.

According to MacLeod and Nuvolari, a reassessment of the socio-economic contours of the Industrial Revolution by such writers as Crafts and Harley (dynamics of productivity growth)[109] and Mokyr (the key to the Industrial Revolution was technology and technology is knowledge)[110] should be taken into account in assessing the role of patents in relation to industrialisation. However, the evidence in relation to early railway technology does not support MacLeod and Nuvolari's suggestion that the patent system should be considered as a technology in its own right, developed by commercially minded men in order to promote it, that an oligarchic society produced an oligarchic patent system.[111] Rather it was the case that during the late eighteenth and early nineteenth centuries, many artisans and engineers made recourse to the patent system. Notwithstanding that the figures are likely to be understated due to the practice of the day where a single application for a patent covered multiple inventions, a database of 759 inventors[112] compiled by Meisenzahl and Mokyr has identified that of 72 'superstar' inventors born between 1660 and 1830, 81 per cent obtained at least one patent, and 21 per cent ten or more.[113] Furthermore, the database includes the inventive activity of less well-known individuals, 'tweakers' and 'implementers', of which some 60 per cent took out at least one patent. The work of Meisenzahl and Mokyr supports many of the foundational arguments of this thesis, that in the context of the development of the early railways, the effect of the patent system was more likely first order, than second.

3.5 Conclusion

It has been argued in this chapter that if there is genuine intention to evaluate railway-related inventive activity, then patent data provide an extensive and original record. In relation to the work of Woodcroft, who claimed he had produced the most valuable encyclopaedia of invention ever published, there can be few original records containing such a wealth of unique information relating to the technical and social data of inventions across a range of evolving technology during the eighteenth and nineteenth centuries. Nevertheless, it has been argued in this chapter that patent numbers *per se* are unreliable indicators of patented inventive activity within early railway technology. Many patents granted during the period under consideration covered multiple inventions and, prior to 1852, there was no consistency either in the original monopoly period of a patent, or any subsequent prolongation.

This chapter has considered the extent to which technical information was available to be drawn upon by the early railway pioneers, from a number of sources, and whether an effective patent system encouraged the diffusion of railway-related technology. By the late eighteenth century, the availability of patent records in the offices of Chancery, technical publications and law reports constituted a growing database of technological information, accessible to the inventors and funders of the early railways.

[109] Crafts and Harley, "Output growth and the British Industrial Revolution," (1992).
[110] Mokyr, *The Gifts of Athena*, 29.
[111] MacLeod and Nuvolari, "Patents and Industrialisation," 28.
[112] Unpublished, electronic copy of database provided by the authors on August 14, 2015.
[113] Meisenzahl and Mokyr, "The Rate and Direction of Invention," 443-482.

Daunton, Casson and Drucker in their respective assessments of the history of knowledge management, place little weight on the database of patent specifications that was created by the patent system, but in this thesis it is argued that a wide variety of actors, including inventors, investors, lawyers and patent agents, found great utility in the patent system, that the patent system offered practitioners an effective means of controlling and managing technical knowledge. It was an established practice for patent agents to channel patented inventive activity into the technology market, to translate an invention into a commercial commodity. Many of the early patent agents published reference works and contributed to, or edited technical journals of the day which constituted a substantial component of the contemporary sources available for consultation.

Traditionally, academic approaches to the effectiveness of the patent system have been concerned with overall statistical analysis of patent data, rather than a consideration of specific industries at particular periods of time. The approach adopted in this thesis has been influenced by that of Arapostathis and Gooday, who have examined patent centred disputes during the late nineteenth century in the emerging technologies of electrical power, lighting, telephone and radio. Their recognition that the adversarial legal system made a significant contribution to the development of patent law is both germane and crucial. So too is their recognition of the multiplicity of individuals, including patent agents and lawyers, who provided considerable administrative and strategic skills for inventors and their funders, all of whom contributed to the overall effectiveness of the patent system.

It is argued here that patent data can be used with sensitivity by the railway historian to examine consolidated sources of information about the activities of inventors, funders and their various associates and their contribution to evolving railway technology during the relevant period. Having considered the value of patent data in relation to early railway technology, the following chapter examines alternative settings for the management and protection of unpatented technological knowledge, and considers the likely motives for early railway pioneers' perceived propensity to patent.

CHAPTER 4

INVENTIVE ACTIVITY OUTSIDE THE PATENT SYSTEM

> Under the conditions prevailing during the nineteenth century [collective invention] was probably the most important source of invention.
>
> Allen[1]

Introduction

This chapter examines the prevalence of railway-related inventive activity outside the patent system. In particular, the settings of collective invention and secret working are considered and it is demonstrated that neither was utilised to any great extent by the early railway pioneers. Several academics argue that collective invention was the most important setting for invention during the nineteenth century. If such a position were correct in relation to early railway technology, then it would displace one of the core arguments of this thesis, that the early railway inventors and their funders found great utility in the patent system. The arguments constructed in this chapter propose that the pioneers of early railway technology generally chose to rely on the patent system to protect their knowledge. Furthermore, it is argued that the expectation of profit was a significant influence in the making of that choice.

Historians and economists interested in innovation differ in the significance they place on the settings within which technological change occurs. Business historians tend to focus on the relevance of institutional location. For example, the organisational synthesis, led by Chandler's study of four American conglomerates post-1920, views the large firm as the central force in technological development, linking investment and corporate change.[2] Another approach, the momentum school, suggests that systems technologies do not rely on a corporate champion, or even on an active commercial pursuit, but on a collective momentum.[3] According to Hughes, systems technologies have developed as a result of the collective momentum of the interest in a systems pursuit from a variety of participants.[4] His momentum school took the two models of technological determinates and social determinates and

[1] Robert C. Allen, "Collective Invention," *Journal of Economic Behaviour and Organisations* 4, (1983):1-24, 21.
[2] Alfred Chandler and Takashi Hikino, *Scale and Scope. The Dynamics of Industrial Capitalism* (London: Belknap Press, 1994).
[3] Thomas P. Hughes, *American Genesis: A Century of Invention and Technological Enthusiasm 1870-1890* (New York: Viking, 1989).
[4] Walter. W. Powell and Eric Giannella, "Collective Invention and Inventor Networks," in *Handbook of the Economics of Innovation* vol.1, eds., Bronwen Hall and Nathan Rosenberg (Amsterdam, London: Elsevier, 2010), 575-605.

added time as the unifying factor. Hughes argued that when a technology is young, the state can take deliberate control, but he was concerned with the period post-1870. Duffy identifies a systems technology in the context of British railways, namely twentieth century electric traction.[5] Neither the organisational nor the momentum approach assists to any great extent with an analysis of the setting of invention and innovation in the context of early railway technology which, during the late eighteenth and early nineteenth centuries, was not a centrally controlled entity, but rather control rested with the individual, disparate and highly competitive railway companies.

In a seminal paper, addressing who invents and why, Allen (1983) proposed a third school, institutions, and identified three categories, namely, non-profit institutions such as universities and government agencies, firms that undertake research and development, and, individual inventors. [6] He also suggested that a fourth setting should be recognised, namely collective invention.

4.1 Collective Invention

Allen defined collective invention as the essential precondition for free exchange of information about new techniques and designs among firms in a specific industry. According to Allen, collective invention is different from know-how trading where information is exchanged on a bilateral basis and non-participants are excluded. Collective invention has attracted academic comment as to its applicability during the eighteenth and nineteenth centuries. The arguments range from collective invention being probably the most important source of invention, to being no more than a marginal phenomenon.

With one notable exception there is no evidence produced by Allen, or any other study, to suggest that collective invention played a significant role in the development of early railway technology. The one relevant example that Allen identifies is the application of the principle of 'compounding' to rotary engines.[7] Benjamin Hick who led much of the innovation in this field collaborated with Charles Beyer, a designer of textile machinery. Hick was able to share knowledge of Woolf's principle of compounding, thus enabling Hick to equip mills with an improved rotary engine.[8] It is pertinent to the analysis presented here that, notwithstanding this evidence of knowledge sharing, Allen acknowledges that many of the engineers making steam engines chose to patent their innovative improvements.

Allen's 1983 study drew heavily on his research into the iron and steel industry in Cleveland, England, during the period 1870 to 1875. He traced the history of technical advances and concluded that the increases in furnace height, and blast temperature from 600F to 1000F, were accomplished by collective

[5] Duffy, *Electric Railways*, 80.
[6] Allen, "Collective Invention," 1.
[7] Allen, *The British Industrial Revolution*, 176.
[8] Compounding involves double expansion of steam, in two stages. A pistonless rotary engine replaces the cylinders and valve gear of a conventional reciprocating steam engine.

invention.[9] Nevertheless, Allen acknowledged that certain design aspects of the hot blast stoves were patented. Cowper (an independent inventor) and Cochrane (owner of Ormesby Ironworks) patented a hot blast stove, and Whitwell (owner of Thornaby Ironworks) patented a competing design, but in general, technological developments were achieved incrementally. Significantly, Allen identified that the operating results were made available to new entrants to the sector.

More recently, Allen has sought to develop his argument by emphasising the distinction between macro and micro inventions (anticipated by Rosenberg).[10] He suggests the former gave rise to the modern trilogy of research and development, venture capital and patent protection, whereas the latter were often local and cheaper thereby reducing the need for external finance or patent protection. This sharing of information meant that inventors could learn from each other and become more efficient.[11] Allen's conjecture rests on the idea that before the establishment of corporate research and development departments, inventive activities were a by-product of firms' investment processes and there was no need to resort to patent protection.

Allen does concede that the inventors of macro inventions tended to seek patent protection, and there can be little doubt that some of the most important inventions in early railway technology fall into this category. However, in the specific industry of the early railways, Allen’s proposal that micro-inventions were less commonly the subject of patents is not borne out by the evidence. In chapter 8 it is demonstrated that technology associated with the development of rails and safety valves progressed incrementally and, significantly, these micro inventions were often made the subject of patents.

In a stark rebuttal of Allen's conclusions, Mokyr argues that collective invention should be considered a marginal phenomenon. He suggests there are three reasonably well documented cases of successful collective invention,

> … the case documented by Allen (1983) of the Cleveland (UK) iron industry between 1850 and 1875, the case documented by MacLeod (1988)[12] of the English clock and instrument makers; and the case documented by Nuvolari (2004)[13] of the Cornish steam-engine after 1880. Examples of such cases are not many, and they require rather special circumstances that were not common, and collective invention in its more extreme form, to judge from its short lifespan was vulnerable and ephemeral.[14]

MacLeod has countered Mokyr's observation that there are only three well documented cases of collective invention. In a public lecture in 2012, she identified nine examples, in England and abroad,

[9] Allen, "Collective Invention," 4.
[10] Nathan Rosenberg, *Inside the Black Box* (Cambridge, Cambridge University Press, 1982).
[11] Robert C Allen, *The British Industrial Revolution in Global Perspective* (Cambridge: Cambridge University Press, 2009), 150.
[12] MacLeod, *Inventing the Industrial Revolution*, 188.
[13] Alessandro Nuvolari, "Collective invention during the Industrial Revolution: the case of the Cornish pumping engine," Cambridge Journal of Economics 28, (2004): 347-363.
[14] Joel Mokyr, "The institutional origins of the Industrial Revolution," quoted in Elhanan Helpman ed., *Institutions and Economic Performance* (Cambridge Mass.: Harvard University Press, 2008), 81.

and concluded that collective invention is unlikely to have been as marginal a phenomenon as Mokyr suggests, and in the event they prove to be exceptional, they should not be dismissed as curious exceptions.[15]

In a recent analysis of patenting rates (the ratio between patented inventions and total inventions) for research carried out in relation to inventions exhibited at Crystal Palace in 1851, Moser concluded that the different technological characteristics found across industries, were major factors in the patenting decisions of inventors. That inventors were most likely to use patents in industries where innovations were susceptible to reverse engineering, and secrecy would have been ineffective.[16] She also established that none of the patenting rates for British and American industries was higher than 50 per cent.[17] In considering railway technology it is important to employ a wider focus than that suggested by Moser. The early railways were an amalgam of complex technologies. Any detailed analysis of patenting rates within the specific industry of early railway technology must move beyond the railway proper and include consideration of some of the associated technologies upon which the developing railways relied.

4.1.1 The Industrial Revolution and collective invention

Collective invention may have been a setting for inventive activity within certain industries during the Industrial Revolution. However, the evidence considered in this chapter suggests that Allen's proposal as to the general applicability of collective invention, has little relevance to early railway technology. It is argued in this chapter that the early railway companies, operating in a highly competitive environment, were reluctant to share technical information. Furthermore, the contemporary evidence considered in this thesis demonstrates that the early railway pioneers made extensive use of the patent system to secure financial reward. The evidence does not support Allen's hypothesis that collective invention was probably the most important source of invention.

Prior to countering Allen's argument, it is necessary to summarise his explanation for industrialisation first occurring in Britain because, as he admits, it is different to most others.[18] Allen argued that during the eighteenth century, labour was remarkably expensive whilst energy (coal and water) was cheap. The steam engine, the water frame, the spinning jenny and the coke blast furnace increased the use of coal and capital relative to labour and were adopted, in England, to reduce overheads. In his Kuznets lecture, 2010, Allen argued that local learning led to the saving of costs and the resulting micro inventions facilitated the spread of the Industrial Revolution overseas. Other countries failed to take up these new

[15] Christine MacLeod, "No patent System, No Industrial Revolution?" (Public Lecture University of Leeds, November 27, 2012).
[16] Petra Moser, "Innovation without patents. Evidence from nineteenth-century world fairs", (Stanford University Department of Economics; National Bureau of Economic Research NBER) April 15, 2011 http://ssrn.com/abstract=930241 [accessed December 31, 2012], 1.
[17] The highest value she reported was 36.4% for the US machinery industry Moser, "Innovation without patents," 19.
[18] Allen, *The British Industrial Revolution*, 3.

methods because, according to Allen, the new techniques were too expensive to use in low wage countries. New techniques were only adopted once they became profitable, usually when the technique in question reached its most advanced form.[19] Allen argued that the Industrial Revolution was invented in Britain in the eighteenth century because it paid to invent it here, while it would not have been profitable in other times and places.[20]

Building on his study of the Cleveland steel industries, Allen identified three underlying reasons for the predominance of collective invention all of which, as argued here, have little relevance to developing railway technology. Firstly, that by releasing information and knowledge the owners and managers of firms might advance their professional ambitions, an argument developed by Arapostathis and Gooday in their analysis of late nineteenth century electrical industries.[21] Secondly, the close-knit community and the number of operatives involved in the process of designing and building a blast furnace meant it was difficult to keep information secret. Thirdly, inventors could be better compensated if their efforts were associated with assets that appreciated in value more rapidly owing to the collective enterprise. Allen argued that collective invention should be recognised as a significant setting for inventive activity. He contended that the principles he found applicable to the iron and steel industries in Cleveland during the late nineteenth century, have considerably broader application to the Industrial Revolution in general.[22] This is a surprising leap of logic. Allen provides no evidence in support of the application of his particular analysis to a general statement of principle.

Allen’s first substantive reason for the sharing of knowledge between managers and firms in the Cleveland industries, was the potential for advancement of individual professional ambition. However, in relation to the operation of early railway companies, a number of studies provide evidence of early railway engineers’ reluctance to share technical information.[23] The attainment of speed was central to early railway competition, both inter-company and in relation to the alternatives of water and road travel. Therefore, the continuing development of the steam locomotive was an important, highly competitive issue.[24] The early railway company superintendents created private empires resulting in a proliferation

[19] Robert C. Allen, "Why was the Industrial Revolution British?" (Kuznets lecture, Yale University, 2010)
[20] Allen, *The British Industrial Revolution*, 2. Allen argues that at the end of the eighteenth century, the economies with high wages were England, the USA, and the Low Countries, that those were the places in the world where it paid to invent labour saving technology. Robert Allen, "Technology and the Great Divergence," University of Oxford Department of Economics Discussion Paper Series, No. 548, (April, 2011). http://www.economics.ox.ac.uk/Research/wp/pdf/paper548.pdf [accessed September 20, 2012], 11.
[21] Arapostathis and Gooday, *Patently Contestable*, (2013).
[22] Allen, "Collective Invention,"1.
[23] For example, M.W. Kirby, "Product Proliferation in the Building Locomotive Industry,1850-1914: An Engineers Paradise?" *Business History* 30, (1988): 287-305.
[24] Divall and Shin identify that railway speed has never held one meaning even in the period known as modernity and that the determinants of the railways' historical cultures of speed were multiple, including wider cultural trends politics and business. Colin Divall and Hiroki Shin "Cultures of speed and conservative modernity: representations of speed in Britain's marketing," in *Trains, Modernity and Cultural Production: Riding the Rails*, eds. Benjamin Fraser and Steven Spalding (Lanham: Lexington Books, 2011), 3-26, 21.

of locomotive designs with little consideration to standardisation. Idiosyncrasies of design and the continuing expansion of locomotive types flourished.[25] Kirby has examined the proliferation of engine types, and although his research applies to the late nineteenth century, it is likely that the diversity he identified was characteristic of the earlier period.[26] Furthermore, the design of railway wagons, many of which were in private ownership, has been described as a riot of individuality.[27] The organisational structures and characteristics of the early railways suggest a deep rooted opposition to the sharing of technical information. This extended even to basic design knowledge and included, as is demonstrated in chapters 7 and 8, items of common equipment such as valve gears and safety valves which were generally made the subject of patent applications.

The second reason advanced by Allen for the predominance of collective invention was the difficulty of maintaining secrecy within a close-knit, localised community, but this does not translate to the circumstances of early railway-related inventive activity in two important respects. Firstly, the early railways were not characterised by close-knit communities. In 1836, railway lines in England were short and unconnected, but within seven years a survey by Francis Whishaw, civil engineer, of operating lines across England, Scotland and Ireland, demonstrated that railways had extended over 2,023 miles.[28] Whishaw's survey also established a number of through lines that connected, for example, London, Bristol, Edinburgh and Glasgow. However, although the rail systems were linked, the railway companies failed to co-operate. Some would not accept the carriages of other companies, there was no common signalling system, no common classification of goods, through booking over a number of lines was not possible and there were many disputes over the division of receipts.[29] This lack of co-ordination between the various railway companies reflects a failure to appreciate the advantages of easy through communications which, increasingly, were being demanded for the passage of freight and the conveyance of passengers. This short-sightedness enabled long distance road hauliers such as Pickfords to maintain good business during the period 1840 to 1850.[30]

Some early railway companies did recognise the need to tackle obstacles to through traffic and, led by George Carr Glynn, a banker with interests in railways, an inaugural meeting of the Railway Clearing

[25] The first, abortive attempt to evolve a standard range of locomotive designs was in 1917 when the Government asked the Association of Railway Locomotive Engineers to design a range of standard locomotives. Jack Simmons and Gordon Biddle, *The Oxford Companion to British Railway History* (Oxford: Oxford University Press, 1997), 470.
[26] Kirby, "Product Proliferation," 288.
[27] Simmons and Biddle, *The Oxford Companion to British Railway History*, 413.
[28] Francis Whishaw, "On means of extending the railway system into every portion of the United Kingdom," *Transactions of the Society, Instituted at London, for the Encouragement of Arts, Manufactures, and Commerce*, 55 (1843-1844): 183-196, 191.
[29] Jack Simmons and Gordon Biddle, *The Oxford Companion to British Railway History* (Oxford: Oxford University Press, 2003), 412.
[30] Simmons and Biddle, *The Oxford Companion to British Railway History*, 412.

House was held on 2 January 1842.[31] It was a voluntary organisation initially with a membership of just five railway companies.[32] By 1870, a large majority of railway companies had joined. The five principal objectives of the Clearing House were to organise the through booking of passengers, the through booking of personally owned carriages and horses, to divide passenger receipts on a mileage basis, to encourage through transport of goods on a rate per mile basis and to provide for all inter-company debts to be settled at the Clearing House.[33]

The continuing reluctance on the part of railway managers to share knowledge resulted in very slow progress towards the standardization of operating practices. In 1847 the member companies adopted Greenwich Mean Time, it being the former practice to check time by reference to local station time. Some progress was made with regard to the classification of goods and although a code of telegraphic signals was published in 1884, it was not fully adopted until 1904.[34] The practice of allowing private ownership of railway wagons created a motley assortment, which resulted in British freight trains being the slowest moving and costliest to operate in Europe. As a consequence, as late as 1910 coastal shipping was able to compete with the railways and carried an equivalent freight tonnage.[35] This contemporary evidence demonstrates a marked lack of co-operation on the part of railway managers for the period under consideration. It is argued here that collective invention had little influence on evolving early railway technology. The Railway Clearing House continued its work until it was disbanded in 1963, which perhaps confirms the magnitude of the task of achieving co-operation between the individual railway companies.

The second aspect of Allen's emphasis on the significance of localised communities and the sharing of information with competitors, is based on the notion that it would have been costly to keep an invention secret. This was an issue faced by many of the early railway pioneers. As will be discussed in the following chapter, Robert Stephenson experienced considerable difficulties in keeping the designs of his locomotive engines secret. The early railway companies operated within an extremely competitive environment at odds with the ethos of collective invention. Prior to 1844, when amalgamation of the railway companies commenced in earnest, competition for trunk routes between important towns was substantial and although this did not prevent some sharing of technical information, competition characterised many of the early inter-railway company relationships.

[31] George Carr Glynn was a partner in the family firm of Glyn Mills and Company, reputed at the time to be the largest private bank in London. Simmons and Biddle, *The Oxford Companion*, 182.
[32] Until the passing of the Railway Clearing House Act 1850.
[33] Simmons and Biddle, *The Oxford Companion*, 412.
[34] Philip S. Bagwell, *The Railway Clearing House in the British Economy 1842-1922* (London: Allen and Unwin, 1968). See also, Colin A. Divall, "Technological networks and industrial research in Britain: The London, Midland & Scottish Railway, 1926-47," *Business History* 48, no.1 (January, 2006): 37-57, 52.
[35] Simmons and Biddle, *The Oxford Companion*, 413.

The highly competitive nature of early railway technology cannot be overstated. The Clarence Railway Co., the first to be authorised in England for the sole purpose of competition, was sanctioned by Parliament in 1828. The aim of the Clarence Railway Co. was to undercut the Stockton and Darlington Railway Co. by accepting a much lower toll for freight traffic.[36] In 1836, six schemes for a 50 mile railway from London to Brighton were laid before Parliament and by 1852, there were competing services from London to Birmingham, Nottingham, Leeds, and Edinburgh, and from Liverpool to Leeds and Hull. By 1867, there were also competing routes between London and Dover, Portsmouth, Exeter, Manchester and Sheffield. As observed by Simmons and Biddle, by 1867 Britain had opted for a railway system much more competitive than any other except in the USA.[37] Such an environment did not prevent co-operation, but it is argued here that such competition was more likely to lead to the protection, rather than the sharing of inventive knowledge. Later, when the railway companies faced competition from the motor car there was co-operation as to marketing,[38] but there were few such opportunities during the first half of the nineteenth century.

To underscore the inadequacy of Allen's generalisations about the significance of knowledge sharing during the years of early industrialisation, it is important to note that there was no careful planning of a national railway network in England, as in France and Belgium, rather it was a system where each proposal was litigated into existence at great cost.[39] As Kostal has observed, the railway system emerged following lengthy and robust dialectical exchange between those promoting the first steam railway companies and Parliament.[40] In 1845, the directors of the embryonic Caledonian Railway Co. recorded that expenses incurred up to the time of the passing of the Caledonian Railway Act (1845) were of the order of £75,000.[41] In the words of McKean, it was money spent to win 'the long and arduous contest ... just to persuade Parliament to permit its very birth'.[42] Kostal draws attention to the cost of obtaining statutory powers citing the London and North Western Railway Co. (LNWR) which by June 1857 had spent £869,771 on parliamentary litigation alone.[43]A system litigated into existence gives rise to important consequences, not least, litigation creates a greater awareness of the need to preserve all forms of assets, including acquired railway knowledge and it is argued here that the sharing of technical knowledge by the early railway pioneers was limited. As is demonstrated in later chapters, the principal funders of early railway technology such as Edward Pease, Lord Ravenscroft and Matthew Boulton

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[36] Simmons and Biddle, *The Oxford Companion*, 84.
[37] Simmons and Biddle, *The Oxford Companion*, 101.
[38] Divall and Shin, "Cultures of speed," 21.
[39] McKean suggests that the early railway system 'owed its existence less to an efficient strategy than to can only be called *adhocary-pokery'*: Charles McKean, *Battle for the North* (London: Granta Books, 2006), 11.
[40] Kostal, *Law and English Railway Capitalism*, 2.
[41] Caledonian Railway Company Minutes, August 27, 1845, BR/CAL/1/7/00208, National Archives of Scotland, Edinburgh.
[42] McKean, *Battle for the North*, 10.
[43] Kostal, *Law and English Railway Capitalism*, 126-127.

were particularly keen to secure patents and urged their respective inventors, whether business partners or employees, not to share technical knowledge.

The third and final reason advanced by Allen for the prevalence of collective invention within the Cleveland steel industries is that it allowed inventors to be better compensated for their efforts. However, the contemporary evidence establishes that within the developing railway industry many inventors regarded the patent system as the preferred means to achieve financial reward. Further evidence is set out below in section 4.3, and chapters 5, 7 and 8 consider evidence of the determination of many funders and inventors of railway-related technology both to re-coup the cost of experimentation and to secure monopoly profits.

4.1.2 The 18th century Cornish pumping engines and collective invention

The arguments advanced above to counter Allen are equally relevant to Nuvolari's study of the Cornish pumping engines, and his surprising and largely unsubstantiated conclusion that collective invention settings were a crucial source of innovation during the early stages of industrialisation.[44] Nuvolari did not concur with Allen that collective invention settings were probably the most important source of invention, but he did conclude that collective invention was a significant setting for innovation.

Nuvolari's arguments do not establish that collective invention settings would have been attractive to the pioneers of early railway technology or utilised by them to any great extent. However, Nuvolari does concede that the rate of innovation may be sector-specific. In relation to intellectual property rights, he suggests that their impact on the rate of innovation is likely to have depended very much on the nature of the technology in question.[45] Nuvolari's recognition of the significance of sector-specific analysis is borne out by the evidence considered in this thesis, but the evidence does not support his conclusion regarding the significance of collective invention settings.

Nuvolari challenged the writings of Dutton, Sokoloff and Khan all of whom stressed the stimulating impact on the rate of technological innovation exerted both by the patent system, and the development of a market for patented technologies. As discussed in the previous chapter, Dutton concluded that few funders were willing to invest in an invention unless it was protected by a patent.[46] Nuvolari emphasised the significance of anonymous incremental advances that occurred within collective invention settings. He examined the continuous and sustained flow of improvements to the stationary steam engines in Cornwall, which contributed to the raising of their thermodynamic efficiency. In concluding his case

[44] Nuvolari, "Collective invention," (2004).
[45] Nuvolari, "Collective Invention," 361.
[46] Dutton, *The Patent System and Inventive Activity*, 169.

study, he opined that economic historians should not rely on the patent system to explain the dynamics of technological advance during the early phases of industrialisation.[47]

Nuvolari's summary of the organisation of the copper and mining industry in Cornwall in the seventeenth and eighteenth centuries, identifies that mining was hampered by flooding, and that stationary pumping engines which consumed coal were expensive owing to the coal having to be imported by sea from Wales. Between 1777 and 1801, Boulton and Watt erected in the mines of Cornwall some 49 pumping engines incorporating Watt's patented separate condenser. The contractual agreement was usually with the 'adventurers' (the mine entrepreneurs), who would be charged an annual royalty equal to one third of the savings of the fuel costs attained by the Boulton and Watt engine in comparison with the competing Newcomen engine.

Watt considered this a very favourable arrangement and writing to Jonathan Hornblower in October 1776 stated,

> … our profits arise not from making the engines, but from a certain proportion of the savings in fuel which we make over any common engine that raises the same quantity of water to the same height. The proportion of savings we ask for is one third to be paid to us annually for 25 years, or if the employer chooses it, they may purchase part at ten years' price for real money.[48]

As discussed earlier, when he applied for his first patent, Watt followed the advice of his friend Dr Small and did not provide a detailed specification.[49] Nuvorali argues that because the patent was broad in scope covering all engines making use of the separate condenser *and* all engines using steam as a working substance, the patent had a 'very large blocking power'.[50] It was intrinsic to Boulton and Watt's business strategy, argues Nuvorali, to enforce the patent by extensive litigation thus using the blocking power of the patent to gain absolute control of the evolution of steam technology.

Nuvorali's conclusion that Watt's patent of 1769 had a detrimental effect on the rate of innovation in steam technology is not supported by the evidence. Nuvolari is one of a number of academics who argue that Watt used the patent system as a 'legal cudgel' with which to smash the competition,[51] that the patent arrested the development of steam engine technology and delayed the industrial revolution by a couple of decades.[52] According to Selgin and Turner, the problem with the argument that Watt's patent had a blocking effect is that high pressure steam engines (sometimes known as 'modern steam' or 'strong steam') did not require a separate condenser.[53] They conclude that Watt's patent posed no barrier to the emergence of the high pressure steam technology which would subsequently form the backbone of early

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[47] Nuvolari, "Collective invention," 349.
[48] James Watt, letter to Jonathan Hornblower, October 17, 1776, Boulton and Watt Papers, MS 3147/3/80, Birmingham City Reference library.
[49] Adams and Averley, "The patent specification," 170.
[50] Nuvolari, "Collective Invention," 353.
[51] Michele Boldrin and David Levine, *Against Intellectual Monopoly* (Cambridge, Cambridge University, 2008) 2.
[52] Boldrin and Levine, *Against Intellectual Monopoly*, 3.
[53] Selgin and Turner, "Watt, Again?" 1113.

railway development.[54] Furthermore, the contemporary Samuel Smiles opined that the presence of the Watt patent 'stimulated the ingenuity of the [Cornish] engineers to contrive an engine that should answer the same purpose', and enabled them to evade making any further payment to Boulton and Watt.[55]

Jonathan Hornblower commenced developing a compound engine in 1781 that worked on relatively high pressure steam. This prompted Watt to obtain an injunction against Hornblower in 1799, the last year of Watt's patent term. Whilst it is generally accepted that team Watt comprised prodigious lobbyists,[56] since high pressure steam did not necessarily require a separate condenser it is probable that Watt was not entitled to his injunction. Hornblower and others could have developed steam technology without infringing Watt's patent. Richard Trevithick, recognising that high pressure steam was the route forward, took out his first patent in 1802 for the construction of a more powerful steam engine.

Watt's patent expired in 1800 and Nuvolari tracks the emergence of the collective invention setting from 1811 onwards. The captains of the mines (the managers) produced a publication, *Lean's Engine Reporter*, named after a highly respected mine captain.[57] This monthly journal reported on technological improvements, and in particular the emergence of Trevithick's high pressure engine which became the basic design for Cornish mines. According to Nuvolari, *Lean's Engine Reporter* facilitated the effective exploration and communication of the merits and use of high pressure steam engines, and as a result the efficiency of Cornish engines improved steadily.

Nuvorali advances three reasons for the emergence of the disclosure regime.[58] Firstly, scientific understanding lagged behind steam technology and it was safer in a number of respects to extrapolate from existing and tried designs. Secondly, the Cornish mining industry operated a cost book system where mine entrepreneurs paid rent to the landowner and this *peculiarity* permitted 'internalisation' and generated disclosure of innovations.[59] Thirdly, the growing practice of a professional ethos among engineers of the time, who shared their experiences and improved their career prospects. Although Nuvolari's arguments are based on the Cornish mine setting, he argues that his study has broader implications and that collective inventive processes were probably a common feature of many local production systems in the nineteenth century. Nuvolari states that the Cornish miners were not a 'curious exception'. He points to the French silk industry and the American railway companies' experience of

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[54] Richard Trevithick took out a further patent in 1808 for machinery for discharging vessels of their cargo. Philip Payton, "Trevithick, Richard (1771–1833)," in *Oxford Dictionary of National Biography*, ed. H. C. G. Matthew and Brian Harrison (Oxford: OUP, 2004); online ed., ed. David Cannadine, October 2007, http://www.oxforddnb.com/view/article/27723 [accessed 21 Nov 2015].
[55] Samuel Smiles, "The Early History of the Locomotive," *The Engineer* 23, (February 1867): 91-92, 91.
[56] Eric Robinson, "Matthew Boulton and the Art of Parliamentary Lobbying," *The Historical Journal* 7, (1964): 209-229. A list of Watt's influential supporters appears in the appendix, 224-229.
[57] Nuvolari, "Collective Invention," 354.
[58] Nuvolari, "Collective Invention," 356-357.
[59] Nuvolari, "Collective Invention," 357.

patent blockage that led to the creation of patent pools or semi-automatic cross licences and knowledge sharing.[60]

It is argued here that Nuvolari's explanations for the emergence of the disclosure regime in the Cornish mining industry have little or no relevance to early railway technology. Firstly, his emphasis on the tendency to extrapolate from existing designs, was not characteristic of the early railways. As discussed above, a variety in design of locomotives and wagons burgeoned within the idiosyncratic empires of individual locomotive superintendents.

Nuvolari's second reason, that the economic structures of the Cornish mining industry were 'peculiar' and encouraged the disclosure of innovations, is to exaggerate the significance of the cost book system, or renting contract of the Cornish setting. This financial arrangement was not sufficiently unusual to justify a claim that it would have facilitated collective invention settings. Advancing industrialisation engendered a variety of commercial contractual arrangements.

Thirdly, Nuvolari suggests the information disclosure regime was a result of the developing professional ethos amongst mining engineers. However, early nineteenth century mining engineers were not professional as the term is understood today. As Abbott points out, one of the characteristics of an evolving profession is the control of abstract knowledge and the management of the knowledge that generates the practical techniques.[61] The mining engineers were merely acquiring valuable technical knowledge, and at that stage did not exercise control.

The issue of control of knowledge is central to academic debate concerned with the prevalence of collective inventive settings. However, it is of particular relevance to the arguments presented in this thesis, that MacLeod has identified circumstances where the control of knowledge was gradually transferred from collective invention settings where it resided initially, to the protection provided by the patent system.

4.1.3 The 17th century guilds and collective invention

The early railways were not subject to regimes or structures in anyway similar to the guilds of the seventeenth century. However, as the guilds lost control of knowledge they became increasingly entrepreneurial and resorted substantially to the patent system for the protection of inventive knowledge. It is in this latter regard that comparisons can be made with early railway technology.

[60] Steven Usselman *Regulating Railroad Innovation* (Cambridge: Cambridge University Press, 2002), 105-107. Steven Usselman, "Patents purloined: railroads, inventors and the diffusion of innovation in 19th Century America", Technology and Culture 32, no.4 (Oct, 1991): 1047-1075.
[61] Andrew Abbott, *The System of Professions* (Chicago: University of Chicago Press, 1988), 9. See also, L.T.C. Rolt, *The Mechanicals. Progress of a Profession*, (London: Heinemann, 1967).

MacLeod identifies characteristics of the clockmaking and instrument trades of the seventeenth and eighteenth centuries in relation to the control of knowledge. For example, the London guilds arranged their resources in such a way as to object to any patent that related to their trade. The clockmakers' guild was one of the most vigilant, and between 1688 and 1718 spent over £500 to defeat three patents and two Acts of Parliament.[62] A control that they exercised until the second quarter of the eighteenth century. The power of the guilds in England diminished during the eighteenth century and was eventually extinguished with the repeal of the apprenticeship laws in 1814.[63] Macleod identifies that as the guilds' control diminished in the middle of the eighteenth century, the makers of clocks, watches and instruments made extensive use of the patent system.

The building of the railways was an entrepreneurial activity involving innovation and alertness to opportunity, but also risk taking.[64] Many of the early entrepreneurs were *individuals*, without the benefit of limited liability. Furthermore, although limited liability was generally contained in the Special Act whereby a railway *company* obtained its powers of construction and operation, it did not become generally available to all companies until 1855.[65] Individual entrepreneurs, and most non-railway companies, in the absence of limited liability bore the financial risk themselves. Casson identifies that an entrepreneur has more relevant knowledge than others[66] and, as is argued in subsequent chapters of this thesis, in order to preserve those assets and reduce risk, the early railway entrepreneurs were more likely to turn to the patent system than be willing to share inventive knowledge.

MacLeod's study does not provide any evidence that collective invention would have been relevant for early railway technology, but is significant for the arguments presented here because it highlights that in certain entrepreneurial activities of the eighteenth century, it was the patent system rather than collective intention, that was the prevailing influence on choices for the protection of knowledge. Notwithstanding these conclusions, in later studies MacLeod has challenged Mokyr's assertion that collective invention was a marginal phenomenon, an assessment she considers to be premature.

4.1.4 The prevalence of collective invention

In a report to the Strategic Advisory Board for Intellectual Property Policy, MacLeod and Nuvolari considered further examples of successful collective invention.[67] Suggesting it was not merely a British

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[62] MacLeod, *Inventing the Industrial Revolution*, 113.
[63] Peter H. Wilson, *A Companion to Eighteenth-Century Europe* (London, John Wiley & Sons, 2009), 67. The Statute of Artificers 1563 set out terms and conditions for training (including a duration of seven years and for the master–apprentice relationship). The Act was repealed in 1814.
[64] Casson suggests that the British rail network was over capitalised due to excessive duplication of lines. His counter-factual network demonstrates inefficiencies due to excessive competition between towns. Mark Casson, "Railway Promotion in Victorian Britain: engineering triumph or waste of capital?" in *Early Main Line Railways*, ed., Peter Cross-Rudkin (Clare: Six Martletts Publishing, 2016), 1-16.
[65] Limited Liability Act, 1855, 18 & 19 Vict. c 133.
[66] Casson, *The Entrepreneur*, 79.
[67] MacLeod and Nuvolari, "Patents and Industrialisation," (2010).

phenomenon and that there is need to consider the evidence outside Britain, the authors described all examples of successful collective invention as oligopolistic in nature, comprising a small number of companies with a large market share. If that was an underlying characteristic of collective invention settings, then they would have had little or no relevance or application to the early railways for which the reverse was true.

MacLeod and Nuvolari concluded that where industries were characterised by oligopolistic structures, processes of collective invention could be achieved by means of patent pools or research associations where knowledge was only shared by the members of the pool or association. The authors cite the example of the American producers of Bessemer Steel, who decided that the patent system produced an unsatisfactory innovative performance and that by sharing information through the Bessemer Association (a patent pool holding control of the essential patents in the production of Bessemer steel), innovative performance was stimulated.[68] MacLeod and Nuvolari presented these cases of collective invention as evidence that it is unlikely collective invention was as marginal a phenomenon as Mokyr has suggested. They argued that even if these settings prove to be exceptional cases, they should not be dismissed as curious exceptions.[69] According to MacLeod and Nuvolari, citing contemporary parallels such as open source software, inventive activities can be organised very effectively without resort to patent protection.

The evidence presented in this thesis establishes the organisation of the early railway sector was far from oligopolistic, and that the examples of collective invention settings relied upon by MacLeod and Nuvolari have little significance for the arguments made here. The early railway sector was an amalgam of several technologies comprising a single complex socio-technological system. Some technologies were core to the developing early railways, examples would include motive power, carriages, signalling and permanent way, each with many sub-cores of their own. If these relevant technologies are confined and defined only by reference to individual, distinct inventive settings, it fails fully to take into account what Lewis described as the conceptual and technical foundations on which the railways were built.[70] Simmons argued that by the 1840s the railways were beginning to establish themselves as a national institution.[71] By 1850 there were approximately 6,000 miles of railway open to traffic and the total

[68] Patent pools (common in America) are a form of collective invention retaining the means to make a profit. They can be defined as an agreement between two or more patent owners to licence one or more of their patents to one another or to third parties, and are usually associated with complicated technologies which require complementary patents in order to provide efficient technical solutions. Nevertheless, and strictly beyond the remit of this thesis, Moser and Lampe's study of the first patent pool in America, the Sewing Machine Combination (1856-1877) concluded quite the opposite, that patent pools discouraged innovation. Lampe and Moser's study of the first patent pool in the United States, the Sewing Machine Combination (1856-1877). Ryan Lampe and Petra Moser, "Do Patent Pools Encourage Innovation? Evidence from the Nineteenth Century Sewing Machine Industry." *The Journal of Economic History* 70, (2010): 898-920.
[69] MacLeod and Nuvolari, "Patents and Industrialisation," 20.
[70] Michael. J. T. Lewis, "The railway in industry," quoted in Rod W. Ambler, Howard Newby and David Dilks, eds. *The History and Practice of Britain's Railways* (Aldershot: Ashgate Publishing Ltd, 1999), 77-95, 80.
[71] Jack Simmons, *The Railways of Britain* (London: Macmillan London Limited, 1986),15.

receipts in that year amounted to a sum in excess of £13,000,000.[72] The following year the railways were responsible for the considerable movement of people, of all social classes, to the Great Exhibition. It was a social revolution that could not have been achieved without the railways.[73] By 1841, nearly 12,000,000 passenger journeys had been completed, and by 1851 the number had increased tenfold, to 120,000,000.[74]

Whilst it is accepted that patents were not the only drivers of innovation during the period of early industrialisation, it is argued here that sector-specific analysis is vital to an understanding of the settings that encouraged innovation. It is argued in this chapter that whilst there may be evidence of collective invention within some industries, there is little evidence that it was a significant driver in early railway technology. Many of the characteristics of early railway technology were not consistent with those of the collective invention settings considered in the literature thus far.

It is an important distinguishing feature of the early railways that their development remained wholly within private hands. A situation rarely adopted elsewhere in Europe. Writing in 1887, Jeans stated, in reference to the 'great bulk of the traffic, there is so much competition between the principal railway [companies] that if they did not each provide the best facilities within their power in the way of rapid delivery, they would be left behind in the race'.[75] It is argued here that in such circumstances there would have been little opportunity for either collective invention settings, or working inventions in secret.

4.2 Secret working

Secret working is inherently difficult to research but it is possible to identify characteristics which, whilst not amounting to evidence, provide indicators that secret working would not have been a significant setting for inventive activity during the development of early railway technology. The available literature suggests that the practicability of secret working was a valid consideration under certain circumstances with inventors on occasions deciding to patent one invention, and yet working another in secret. For example, Berg's work on commerce and creativity in eighteenth century Birmingham has identified that the institutional set-up underpinning innovative activities was based on patents as well as trade secrets.[76]

There is evidence that during the early stages of industrialisation, there were circumstances where secrecy was a viable option for inventors. In 1796 James Watt, renowned for his use of the patent system and his patented separate condenser, invented an indicator to measure the pressure in a steam engine's

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[72] Michael Robbins, *The Railway Age,* (Manchester, Manchester University Press, 1998), 25.
[73] Robbins, *The Railway Age,* 25.
[74] Simmons, *The Railways of Britain,* 224.
[75] Jeans, *Railway Problems,* 359.
[76] Maxine Berg, "Commerce and Creativity in Eighteenth-Century Birmingham," in *Markets and Manufactures in Early Industrial Europe*, edited by Maxine Berg, 180-203. (London, Routledge, 1991).

cylinder based on the position of the piston. Only a small pencil diagram of the indicator appeared in marketing endeavours and details of the invention were kept secret for some thirty years. The invention was never made the subject of a patent and did not become public until about 1826.[77] Similarly, Bessemer's bronze powder (colouring agent for gold paint) was one of the most systematically well-kept industrial secrets of the nineteenth century. The secret was preserved for thirty-five years because, Bessemer stated, 'it would be impossible for us to maintain this price if the details of my system were shared and described in a patent blue-book, which anyone could buy for sixpence'.[78] Other examples of successful secret working are Sir Titus Salt's process of utilising alpaca wool, and John Braithwaite's underwater gunpowder charges.[79]

The first indicator as to circumstances where inventors may not have chosen to rely on secrecy is related to the size of the invention in question. Bessemer chose to keep his bronze powder invention secret, and yet in 1885 decided to patent his eponymous convertor because at twenty-five feet tall there would have been a number of practical difficulties in keeping the details of the construction secret. The point was well made by Hindmarch QC in 1863 whilst hearing evidence as a Commissioner. In questioning one Richard Roberts as to secret trade, he asked, 'with regard to the manufacture of machinery, I believe it is very difficult to keep that secret.' Roberts replied, 'Yes, especially when the objects are large … I do not think there is much secret trade, but I do know this, no trade can be kept secret long, a quart of ale will do wonders in that way.'[80] Richard Roberts, himself the inventor of the self-acting spinning mule, added that he had been offered access to a new power loom without the inventor's consent.

Benjamin Huntsman the inventor of crucible steel, or cast-steel, is a good example of a successful inventor of a sizeable invention who despite a reputation for being secretive, failed to preserve the details of his invention. He declared that he would not reveal his method even if he were offered £50.[81] For many years Hunstman exported his entire output to France, but he seems to have fallen victim to industrial espionage. Numerous Europeans with an interest in technology, visited Britain during the seventeenth and eighteenth centuries knowing that the country was ahead of the rest of Europe in its manufacturing techniques and organization. During the 1760s Huntsman received visits from Ludwig Robsahm, Swedish engineer, and probably the Frenchman Gabriel Jars, and as a consequence of their visits aspects of Huntsman's process were discovered.[82] Growing competition of imported French

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[77] Alessandro Nuvolari, *The Making of Steam Power Technology* (Eindhoven: Eindhoven University Press,2004). Nuvolari suggests that it was John Southern, Watt's assistant, who invented the indicator.30, n47.
[78] Bessemer, *An Autobiography* (1905), 61.
[79] Meisenzahl and Mokyr, "The Rate and Direction of Invention," 462.
[80] Richard Roberts, February 18, 1863. *Report of the commissioners appointed to inquire into the workings of the law relating to letters patent for Invention* (London: Eyre and Spottiswoode,1864), 81-82.
[81] Alan Birch, *Economic History of the British Iron and Steel Industry*, (Abingdon: Routledge, 2005 reprint.), 306.
[82] David Hey, "Huntsman, Benjamin (1704–1776)," in *Oxford Dictionary of National Biography*, ed. H. C. G. Matthew and Brian Harrison (Oxford: OUP, 2004); online ed., ed. David Cannadine, October 2008, http://www.oxforddnb.com/view/article/14247 [accessed September 8, 2016]

cutlery made from Huntsman's cast-steel alarmed the Sheffield cutlers, who tried unsuccessfully to have the export of the steel prohibited.[83] The secret of Huntsman's process was ultimately pirated by a Sheffield iron-founder, Samuel Walker, who, according to Smiles, entered Huntsman's works disguised as a starving beggar asking to sleep by a fire for the night.[84] Huntsman chose to rely on secrecy and did not patent his process, as a consequence his process was revealed to his competitors.

There is some evidence that inventors changed their minds as to the effectiveness of secrecy when they had been subjected to foreign espionage. James Nasmyth, a prominent and successful engineer, stated in his autobiography,

> … we gave our foreign visitors every facility and opportunity for seeing our own tools at work, and they were often so much pleased that, when they came to order one special tool, they ended by ordering many, the machine tools in full activity thus acting as their most effective advertisements.[85]

However, in April 1842, when visiting a French dockyard, Nasmyth saw in action a steam hammer that he himself had invented. His host, Bourdon, explained that during a visit to Nasmyth's Bridgewater foundry, and whilst Nasmyth was absent, his partner had shared the details of the original design. Bourdon described how he had been struck by its simplicity and probable efficiency, that he had taken careful note and sketches on the spot and that the results had in all respects realised the high expectations. Nasmyth records,

> I now became alarmed, and feared lest I should lose the benefits of my invention … I may add that the patent was secured in June 1842, or less than two months after my return from France.[86]

In considering the prevalence of secrecy in early railway technology, the size of the invention was likely to have been an important factor in an inventor's choice of means for the control of knowledge. Much of early railway technology consisted of large objects the engineering details of which would have been difficult to keep secret. In 1832 Robert Stephenson wrote to his father about an employee, Kennedy, who had left the employment of Robert Stephenson and Co. to work for a competitor, Edward Bury, in Newcastle. Stephenson expressed the view that Bury would not have been in a position to make 'a single engine' had it not been for technical information provided by Kennedy.[87] Stephenson also recognised that apprentices posed a potential risk for the disclosure of inventive information to rivals. In a letter dated 1836, he observed,

> I regret having made any arrangements for allowing some of them to come into the office, to become acquainted in every detail with our plans etc. They have no sooner done so than they leave and carry away what has cost us a great deal of money and more thought.[88]

[83] Samuel Smiles, *Industrial Biography: Iron-makers and Tool-makers* (London: John Murray, 1884), 107
[84] Smiles, *Industrial Biography*, 108-109.
[85] James Nasmyth, *James Nasmyth. Engineer; an Autobiography* (Whitefish, Montana: Kessinger Publishing, facsimile edition 1885), 98.
[86] Nasmyth, *Autobiography*, 98-99.
[87] Robert Stephenson, letter to George Stephenson, December 18, 1832, Robert Stephenson and Co., GB 0756 1970-473, ROB 4/9/18/7.
[88] Quoted by James G. H. Warren, *A Century of Locomotive Building by Robert Stephenson and Co. 1823-1892* (Newton Abbot: David and Charles, 1970), 89.

Robert Stephenson and Co.'s stance on patents is considered in greater detail in chapter 5 and the evidence demonstrates a reluctance on the part of the inventors and their funders to rely on secrecy. From an early stage the directors identified that patenting was an essential means of controlling technical knowledge and ensuring the financial stability and unprecedented economic success of the Company.

Even under circumstances where inventors of large objects were able to keep their invention secret within the workplace (a difficult task for the reasons outlined above), it often became impracticable once the invention became available for public inspection. For example, when locomotives became operational it was relatively easy for the design to be copied. David Joy, a successful railway inventor with several railway patents to his name, held a number of railway company locomotive superintendent posts, including for the Oxford Worcester and Wolverhampton Railway Co. He kept a detailed diary and his entry for January 1845 records,

> Dutton, our manager, knew nothing of locomotives, so I had to take all particulars from the railway's engineer, Mr. Cawbey, and I made all the drawings of the engine, going to the station to copy details from Stephenson's engines chiefly.[89]

A second indicator of inventors of early railway technology demonstrating a preference for relying on patenting rather than secrecy, is in circumstances of large scale manufacturing industries. Moser is representative of those who recognise that patenting was more widely used in sectors such as steam engineering and manufacturing machinery (sectors central to the Industrial Revolution) where secrecy was ultimately incompatible with the commercial workings of large scale technologies. Her statistical survey of inventors represented at the Great Exhibition (1851) concluded that inventors in countries without patent laws concentrated on industries where secrecy was an effective alternative to patent grants, such as scientific industries, food processing and dye stuffs. Inventors in 'patentless countries' tended to avoid innovation in manufacturing and other machinery. Moser concluded, that as machinery and mechanisation became more important, countries where there was no patent protection lost any early lead in manufacturing industries.[90]

A third indicator of circumstances under which inventions would not have been suitable for secret working would be those where the invention in question was susceptible to reverse engineering. That is to say, circumstances where the end consumer could work out for themselves the secret of the manufacture. Starr suggests reverse engineering assists the historian of engineering technology to clarify how equipment developed, and can demonstrate that design choices were not arbitrary.[91] Bottomley argues that secret working prevented sequential development of technology. He cites the example of Bessemer's bronze powder and poses the question how could anyone else improve Bessemer's methods

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[89] David Joy, Extract from the "Diaries of the Late David Joy", ed. G.A. Sekon. *Railway Magazine* (1908), 22-23, http:www.steamindex.com/library/joydiary.htm [accessed March 13, 2012].

[90] Petra Moser, "How do patent laws influence innovation?" 1232.

[91] Fred Starr, "Design and Development of Exhaust Valves from the Perspective of Modern Thinking: Part 3: Reverse Engineering of American and British sodium cooled valves," *The International Journal for the History of Engineering & Technology* 86, no.1 (2016): 70-92, 89.

of production if they could not find out how it worked?[92] A considerable number of railway-related inventions were susceptible to reverse engineering. For example, Robert Stephenson and Co. designed a number of steam locomotives that were manufactured in large numbers and distributed and exported around the world. This was only feasible as a consequence of patent protection. Once a locomotive had entered operation, opportunities for reverse engineering were legion thus enabling customers and competitors alike to capitalise on Stephenson’s unique designs. Furthermore, inventors and funders often required an extended period of time to recover the cost of the outlay of an invention by way of monopoly profits. It is unlikely that secret working would have achieved those objectives.

The role of secrecy in relation to early railway technology is a difficult analysis. There is insufficient evidence to prove either way the extent to which the pioneers of the early railways resorted to secrecy and proposals can only be speculative. The best that can be said is that there are historical indicators, as considered above, to suggest that relying on secrecy to control inventive knowledge may not have been appropriate for the inventors of the early railways, particularly under circumstances where inventions were large objects, produced in large scale manufacturing processes or susceptible to reverse engineering.

In analysing whether collective invention or secrecy was exploited to any great extent by the inventors of railway-related technology, and to advance the argument that they found greater utility in the patent system, it is crucial to adopt an evidence-based approach. Examination of what inventors themselves said concerning the control of inventive knowledge provides a check balance to the arguments presented so far in this chapter. Their evidence is considered in the following section.

4.3 Propensity to patent

Powell and Giannella's study of collective invention and inventors' networks during the nineteenth and early twentieth centuries, suggests that collective invention has attracted academic attention because the concept defies conventional wisdom about appropriability, an inventor's ability to capture profits.[93] They pose the question, why would inventors have invested in expensive exploratory efforts when the odds of capturing the fruits of research were low. They propose that any definition of collective invention should be linked to intellectual property.[94]

According to Moser, as early as 1833, surveys of inventions suggested that inventive activity was motivated by expected profits.[95] In examining whether innovative activity is motivated by expected

[92] Bottomley, *The British Patent System*, 291.
[93] The environmental factors that govern an inventor's ability to capture profits generated by an innovation.
[94] Powell and Giannella, "Collective Invention," 578. They seek to argue for a social definition: 'collective invention is technological advance driven by knowledge sharing among a community of inventors who are often employed by organisations with competing intellectual property interests'.
[95] Joseph Rossman, "The Motives of Investors", *Quarterly Journal of Economics* 45, (1931): 522-528.

profit, Moser opined that a necessary condition for patent laws to influence innovation, or a significant share of it, is responsiveness to profit incentives, and that the relevant supportive literature goes back a long way.[96] Similarly, Mokyr suggests inventive activity was driven by a desire to make money, and technological change depended on the expected pay off of the costs of research and development.[97] Schmookler has also produced evidence of the importance of profit incentive. He has demonstrated that the number of American patents for railway equipment increased as sales climbed.[98]

A valuable, contemporary opinion from an inventor about inventors' motives and their need of patents, is provided by a letter dated 8 July 1785 from James Watt to Lord Loughborough, the judge who had recently set aside Arkwright's patent.[99] James Watt expressed his concern that if patent protection were not to be granted, then finance and energies would be directed to other areas where they could be safeguarded. Watt was dependent on Boulton as a funder, and Watt appears to be making the point to Lord Loughborough that unless patent protection were granted, funders such as Boulton would look for safer businesses within which to invest their money.

> There seems to be only three motives that can excite a man to make improvements in the arts, the desire to doing good to society, the desire of fame and the hope of increasing his private fortune ... but when the three motives are united they must provide the strongest stimulus that can act upon the human mind ... We are now bringing steam engines into use, ... which cannot fail of being a great advantage to the manufacturers of this country; but if our right to our patent should be taken away, or rendered elusive, we must drop any further pursuits of that scheme and apply ourselves to other businesses where our property can be more effectually guarded.[100]

Similarly, in 1824, Edward Pease, writing to Thomas Richardson his partner in Robert Stephenson and Co., provides compelling evidence as to the importance of the profit motive for inventors and their financial backers. He expressed concern about the patent of George Stephenson that was about to expire. He told Richardson that Stephenson needed to adopt some improvements to get a new patent, and that 'ought to leave us no small sum for either making or licences'.[101] Chapter 5 examines in more detail the role of Pease who 'had care' of the patents for Robert Stephenson and Co.

Further evidence is provided by the minutes of a parliamentary select committee, in 1829, when John Farey, whose views commanded considerable respect at the time and to whom Isambard Kingdom Brunel turned when he was contemplating taking out a patent, underlined the importance of the profit

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[96] Petra Moser, "How do patent laws influence innovation? Evidence from nineteenth century world fairs," *American Economic Review* 95, (2005): 1214-1236.
[97] Mokyr, *The Enlightened Economy*, 270.
[98] Jacob Schmookler, "Changes in Industry," in *The Rate and Direction of Inventive Activity: Economic and Social Factors*, ed., R.R. Nelson (Princeton: Princeton University Press, 1962), 195-232.
[99] Arkwright v Nightingale (1785). 1 WPC 60.
[100] James Watt, letter to Lord Loughborough, July 8, 1785, Boulton and Watt Papers, MS 3147/3/85, Birmingham City Reference Library.
[101] Edward Pease, letter to Thomas Richardson, October 23, 1824, Hodgkin Papers, D/Ho, C/63/5, Durham County Record Office.

motive.[102] (Farey's two volume work, *A Treatise on the Steam Engine* (1827)[103] has been described by von Tunzelmann as the finest work on technology published in the Industrial Revolution.)[104] In his evidence before the select committee, Farey described the need for a period of monopoly to recover the cost of producing an invention,

> … the question is when the profitable exercise will begin and how much previous loss and outlay is to be made up; in some instances, it begins from the first; in many cases it does not take place at all ... I have published a very full history of the origin and progress of the invention of the steam engine which shows these facts in a striking light; but it is not peculiar to the steam engine, for all the important inventions absolutely require the inducement of patent privileges.[105]

Many railway-related inventions, particularly the steam locomotive, required a number of years of design commitment, described by Robert Stephenson as 'expensive experiments'.[106] There was a need for a period of protection for the design in order to sell the finished product and reap eventual profit. Some twenty years later, in 1851, Thomas Webster, a barrister widely recognised as a leading authority on patent law, gave similar evidence to a select committee. He stated, 'hope of a pecuniary reward is a stimulus … I have no doubt that a great number of inventions would not be produced but for the hope of reward'.[107]

In 1830, Robert Stephenson writing to his father advised that he intended to take out a patent for a wagon axle, '… the patent cannot cost much and if it does get introduced upon railways … would produce a great deal of money'.[108] In a letter to Edward Pease, dated 27 October 1836, Robert Stephenson repeats his concerns, 'I am concerned about new rivals coming into the field of locomotive construction who have not had to begin with expensive experiments'.[109]

Similarly, in his autobiography, Henry Bessemer a prolific inventor who held at least 129 patents during the period, stated,

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[102] See chapter 6 at paragraph 6.6.
[103] John Farey, *A Treatise on the Steam Engine: historical, practical and descriptive* (London: Longman, Rees, Orme, Brown and Green, 1827). A second volume was published posthumously in 1843.
[104] Von Tunzelmann, *Steam Power*, 2.
[105] John Farey, June 8, 1829, *Select Committee on the Law Relative to Patent Inventions* (1829), 141. Marc Isambard Brunel in giving evidence to the same committee and in answer to the question as to whether a period of 14 years was long enough for a patent replied, 'It is a great deal for some and not enough for some others; I shall lose probably six years before I come to make anything of my present patent', 39. Samuel Clegg, giving evidence on 29 May 1829, informed the committee that he thought there should be a power to extent the period of the patent 'upon a proper application; saying that such a sum of money has been expended; and that the time it has to run will not be sufficient to remunerate the expenses and to make a profit', 95.
[106] Robert Stephenson, letter to Edward Pease, October 27, 1836, Robert Stephenson and Co. Papers, GB 0756, 1970-473, ROB 4/4/22, National Railway Museum, York.
[107] Thomas Webster, April 15, 1851, *Report and Minutes of Evidence taken before the Select Committee of the House of Lords appointed to consider of the Bill, intituled, "An ACT Further to Amend the Law Touching Letters Patent for Inventions.* House of Lords, July 4, 1851, 18.
[108] Robert Stephenson, letter to George Stephenson, November 8, 1830. Robert Stephenson and Co., GB 0756, 1970-473, ROB 4/9/18, National Rail Museum, York. Robert Stephenson had taken out his first patent in 1826 (Patent 5325), for axletrees.
[109] Robert Stephenson, letter to Edward Pease, October 27, 1836, Robert Stephenson and Co. Papers, GB 0756, 1970-473, ROB 4/4/22, National Railway Museum, York.

> There can be no doubt of the fact that the security offered by the patent law to the persons who expend large sums of money and valuable time in pursuing novel inventions, results in many new and important improvements in our manufactures, which otherwise it would be sheer madness for men to waste their energy and their money in attempting.[110]

Finally, as explored in chapter 7, in relation to the invention of the electric telegraph in 1837, Charles Wheatstone in commenting on his partner, stated he was impressed by William Cooke's 'single mindedness and determination' to make money from his patents.[111]

There is good evidence that the early railway companies were receptive to inventive suggestions many of which were the subject of patents, and they were prepared to pay licence fees. For example, the Liverpool and Manchester Railway Co.'s Board minutes provide evidence of the practice:

17 December 1838:	Laid on the table Mr Cole's plan and description of a patent locomotive engine and carriages.[112]
4 July 1839:	Read a letter from Mr G R Booth Hanley Staffordshire recommending an improved patent rail. Ordered that the Treasurer request a sketch and description of the same.[113]
8 July 1839:	Read a report from the Treasurer and Engineer on the subject of a steam power for hoisting at the Wapping Station and recommending Haques Patent Pneumatic and Vacuum Engine for the purpose, the cost of which according to estimates made would be about £2,000.[114]
9 December 1839:	Read a note from Mr John Gray offering the company the free use of his patented improvements in locomotive engineering at the rate of £20 per engine in reference to such engines as the Directors from time to time might think fit to apply the improvements to. Resolved Mr Gray's offer be accepted it being understood that the validity of the patent was taken for granted on which this mutual arrangement must be considered to depend.[115]

The period 1820 to 1850 proved to be one of unparalleled opportunity for entrepreneurs who sought to sell their patented inventions to the railway companies. The Liverpool and Manchester directors were willing to allow locomotive builders, and inventors of ancillary equipment, to undertake tests on their track in pursuance of the development of their inventions, and the Company sought to purchase those inventions (both patented and unpatented) which were of value.[116] For 24 June 1839, the minutes of a

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[110] Henry Bessemer, *Sir Henry Bessemer FRS. An Autobiography* (London: Offices of 'Engineering', 1905), 82,
[111] Jeffrey Kieve, *The Electric Telegraph: A Social and Economic History* (Newton Abbot: David and Charles, 1973), 22.
[112] Minutes of the Board of Directors of the Manchester and Liverpool Railway Company, RAIL 371/5/3, National Archives, Kew.
[113] Minutes, Manchester and Liverpool, RAIL 371/5/23.
[114] Minutes, Manchester and Liverpool, RAIL 371/5/66.
[115] Minutes, Manchester and Liverpool, RAIL 371/5/112.
[116] Ferneyhough, *Liverpool and Manchester Railway*, 113.

directors' Board meeting record, 'Mr E. B. Rowley asked for the loan of a locomotive boiler and wheels to fix his invention of a rotary engine. Agreed.'[117] In the particular example of the Liverpool and Manchester Railway Co., the staff and the officers of the Company were encouraged to develop inventions, and many of these were made the subject of a patent. For example, Henry Booth, the treasurer, patented screw couplings.[118] The Liverpool and Manchester Railway Co. was the first railway company to utilise the couplings which were subsequently used by other railways for a period of some 40 years.[119] Booth also invented methods of railway vehicle lubrication[120] and in a letter to Barnard of the Stockton and Darlington Railway Co., stated he had no intention to 'make it', but was 'happy to treat for a licence on the principle of receiving for my patent right one third of the saving you make'.[121] Melling, the Liverpool and Manchester Railway Co.'s Locomotive Superintendent, designed a 'patent link gearing' for locomotives.[122] In 1837 he patented an 'improved fireplace for a locomotive engine with hollow bars and ash pit constructed so as to form part of the boiler'.[123]

Thomas Crampton and Francis Webb provide further examples of enterprising engineers who patented their inventions and subsequently granted licences to manufacturers. Thomas Crampton took out several patents and subsequently licensed manufacturers in England, including the LNWR and in the USA.[124] Similarly, Francis Webb, LNWR Chief Mechanical Engineer, took out numerous patents which were utilised by his employers, and in recognition of their use, he was paid an additional sum by way of salary.[125] In 1902, a retrospective report in *The Engineer* stated, 'Although Mr Webb took out many patents, he never received any royalties from the Railway Company, who, however, in recognition of his services raised his salary from £5,000 to £7,000 a year'.[126]

A valuable insight as to the importance of profit motive in relation to patents can be tested by considering briefly the history of an important aspect of the development of the American locomotive. The roughly laid track of that country led to early realisation of a need for equalising beams to support the coupled driving wheels of the locomotive. Joseph Harrison invented such beams and took out US patents in 1838 and 1841. He reportedly received enormous royalty payments and beyond 1840 few, if any, American

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[117] Minutes, Manchester and Liverpool Railway Company, RAIL 371/5/63.
[118] Henry Booth, *Method of attaching railway-carriages together ….* Patent No. 6961. December 16, 1835.
[119] Ferneyhough, *Liverpool and Manchester Railway*, 88.
[120] Henry Booth, *Axle grease and lubricating fluid*. Patent No. 6814. April 14, 1835
[121] Henry Booth, letter to Paul Barnard, July 27, 1837, Stockton and Darlington Railway Company, correspondence and relevant letters: letters from Henry Booth *et al.*, RAIL 667/1085, National Archives, Kew. Booth adopted the same method for the calculation of his licence fee as James Watt when he licensed his stationary engine. James Watt, letter to Jonathan Hornblower, October 17, 1776, Boulton and Watt Papers, MS 3147/3/80, Birmingham City Reference library.
[122] John Melling, *Locomotive steam-engines to be used on railways or other roads …* Patent No. 7410. December 15, 1836.
[123] John Melling, *Locomotive steam-engines to be used on railways* .... Patent No. 7410. July, 26, 1837.
[124] C. Hamilton Ellis, "Famous Locomotive Engineers, XV, Thomas Russell Crampton," *The Locomotive* 46, no 571 (March 15, 1940): 67-70.
[125] John Spink, *F.W. Webb (1836-1906)* (Rothbury: LNRW Society, 2011), 20.
[126] *The Engineer* 94, (November, 1902): 523.

locomotives were built without equalising beams.[127] Harrison's idea can be traced back some eleven years prior to the date of his patent, to Timothy Hackworth in England, who used an identical arrangement on the locomotive *The Royal George.*[128]

A number of the early judgements in patent cases before the courts also assist with establishing that profit incentive was often central to the patentee, an aim that the judiciary came to support. In *Boulton and Watt v Bull* (1795) Mr Justice Buller stated that provided a patent was valid, then the patentee was fully entitled to the profits arising from the patent.[129] Similarly, as mentioned previously but worthy of repeat, in 1799, Mr Justice Ashurst stated,

> Encouragement of new invention is of infinite importance to the Kingdom; and where it appears incontestable that the invention possesses all the qualities that this [steam engine] professes to do, it will be hard if the inventor should be robbed of his reward.[130]

As discussed earlier, Meisenzahl and Mokyr have established that some 75 per cent of significant inventors born between 1660 and 1830, patented the majority of their important inventions.[131] A scenario that had not occurred at any previous point in time anywhere in the world.[132] Meisenzahl and Mokyr, and latterly Bottomley, have endeavoured to establish a causal connection between patented inventiveness and financial reward. Bottomley in particular has researched probate valuations.[133] However, interpretation requires a degree of care because, for the relevant period, probate valuations excluded the value of land holdings, and are therefore understated. Also, in some instances, the inventor's financial success would have been due to numerous associated factors, including the business expertise of others. James Watt's eventual, sizeable estate[134] was no doubt influenced by the business acumen of his partner Boulton, and Robert Stephenson benefited from the 'habits of business'[135] of both Longridge and Pease. As always it is important to consider established facts as an aid to interpretation. In chapter 7 of this thesis the inventions of William Fothergill Cooke and their effect on railway technology are discussed. Cooke sold his patents to the Electric Telegraph Co. for some £90,000 together

[127] John H. White, *A History of the American Locomotive. Its Development:1830-1880* (New York: Dover Publication, 1979), 153.
[128] Chapman F.D. Marshall, *A History of the Railway Locomotive Engine down to the end of the year 1831* (London: Locomotive Publishing Co., 1953), 173.
[129] William Carpmael, *Law Reports of Patent Cases, vol.1* (London: A Mackintosh, 1843), 132.
[130] *Arguments in Mr Watt's patent trial, 1799,* Boulton and Watt Papers, MS 3147/3/37, Birmingham City Reference library.
[131] Meisenzahl and Mokyr, "The Rate and Direction of Invention," 443-482.
[132] Bottomley, *The British Patent System,* 20. As discussed in chapter 3, since multiple inventions could be included in the same patent, then the figures understate the proportion of inventive output patented by these inventors.
[133] Bottomley, "The Returns to Invention". Unpublished.
[134] In excess of £60,000. Jennifer Tann, "Watt, James (1736–1819)," in *Oxford Dictionary of National Biography*, ed. H. C. G. Matthew and Brian Harrison (Oxford: OUP, 2004); online ed., ed. David Cannadine, September 2014, http://www.oxforddnb.com/view/article/28880 [accessed October 9, 2016].
[135] Michael Longridge, letter to Thomas Richardson, March 7, 1825, Stanton Croft and Co. (solicitors) Papers DT/SC/309, Tyne and Wear Record Office, Newcastle upon Tyne.

with the receipt of a substantial shareholding, but on his death in 1876 his estate amounted to £16.[136] In the intervening years he had lost everything in a slate mining venture in North Wales.[137]

With due regard to the caveats, Meisenzahl, Mokyr and Bottomley have argued convincingly that the significant patentees of the nineteenth century, across a spectrum of technologies, generally left sizeable estates. These scholars go some way towards establishing a causal link between successful patentees and financial reward. A hypothesis that has been tested here by a consideration of what inventors themselves said with regard to the issue, and by examining the actions of the railway companies in relation to patented inventive activity and the safeguarding of profit margins.

Clark is representative of those who do not accept that inventors made money from their inventions. He has argued that the Industrial Revolution economy was ‘spectacularly bad’ at rewarding innovation.[138] As has been argued above, in relation to the inventors of early railway technology there is strong evidence that Clark’s analysis is found wanting. Beauchamp’s observation, that patents are ‘attempts at appropriation', is the more apposite.[139] It is beyond the remit of this thesis, but there is scope for further scrutiny of this important aspect of the propensity to patent.

4.4 Conclusion

The early railways developed within a remarkably short period of time, and were subject to many incremental innovations. The bank of railway knowledge grew substantially during the eighteenth and early nineteenth centuries. This process of change took place at a time when the early railway sector was central to Britain’s extraordinary contribution to technology and business development. An examination of the literature in relation to collective invention and secret working has identified scant evidence that either was an important setting for invention in relation to railway technology.

There is no published literature in relation to railway technology to support Allen’s argument that collective invention was probably the most important source of invention during the Industrial Revolution. Mokyr's conclusion that collective invention cases were small in number and subject to special circumstances, may be a matter for continuing academic debate, but insofar as early railway technology is concerned, then Mokyr's analysis seems to be correct. This thesis seeks to contribute to the literature by responding to the clear need for further sector-specific research.

To date, the published examples of collective invention number thirteen, and none can be said to be supportive of an argument that collective invention, or the voluntary sharing of knowledge among

[136] Brian Bowers, *Sir Charles Wheatstone.* (London: Her Majesty's Station Office, 1975), 137
[137] James Burnley, “Cooke, Sir William Fothergill (1806–1879),” in *Oxford Dictionary of National Biography*, Oxford University Press, 2004; online edn, Jan 2011 http://www.oxforddnb.com/view/article/6192 [accessed Sept 19, 2015]
[138] Clark, "The Industrial Revolution," 229.
[139] Beauchamp, *Invented by Law*, 206.

competing individuals or companies, is likely to have played a significant role in the development of the early railways. Similarly, evidence considered in this chapter suggests that the nature of much of early railway technology was incompatible with secret working. Moser's observation that countries without patent protection lost any early lead in manufacturing is borne out by the example of Robert Stephenson and Co., one of the largest engineering enterprises in the world at the time. With such physically large products as steam locomotives, and numerous employees, secret working would rarely have been feasible.

Many early railway-related inventions were designed and produced in response to the increasing demands of railway companies and for many inventors financial reward would have been a primary motive. Many inventors sought proprietary rights over the products they developed and in most cases circumstances precluded either collective invention or working in secret from providing the required control of technical knowledge. Patents represented an enforceable property right enabling inventors either to licence their inventions for a royalty payment, or to sell their invention outright to secure an immediate return. Patents therefore, for the early railway pioneers, would have offered many advantages over collective invention or secret working.

As established by Meisenzahl and Mokyr, the majority of the most important inventors of the early Industrial Revolution took out patents and were prepared to use the legal system to enforce their patent rights. Furthermore, as demonstrated in the previous chapter, a significant number of patents granted during the period of the Industrial Revolution were railway-related. Bailey, in identifying the several and interactive issues that influenced technology in the developing railways, poses several questions including, to what extent were technological developments protected by their inventors through patenting? [140] The following chapter, in considering the business practices of Robert Stephenson and Co., seeks to address this line of enquiry.

[140] Michael R. Bailey, "Technology on the move: engineering development on early main line railways", in *Early Mainline Railways*, ed. Peter Cross-Rudkin (Clare, Suffolk: Six Martlets Publishing, 2016), 17-29, 25.

CHAPTER 5

GEORGE STEPHENSON AND ROBERT STEPHENSON

> ... and that Geo and Robert [Stephenson] would benefit from my habits of business in which they were both deficient. I offered to take part with them ...
>
> Longridge[1]

Introduction

The evidence presented in this chapter demonstrates that the effectiveness of the patent system during the first half of the nineteenth century, constituted a crucial element in the furtherance of the commercial enterprises of George and Robert Stephenson, enterprises that were reliant on business acumen. The expansion from craft industries to manufacturing initiatives gave rise to unprecedented considerations as to investment, and the patented inventive activities of George and Robert Stephenson provide important, supporting evidence for the reassessment being undertaken here of the current historiography of the patent system prior to 1852. It has been argued in the previous chapter that within the particular, and intensely competitive environment of early railway technology, pioneering engineers and entrepreneurs generally turned to the patent system in order to control and manage innovative knowledge and to realise adequate remuneration.

Few would disagree with Bailey's acknowledgement that the locomotive industry was central to Britain's extraordinary contribution to technology and business development during the early years of the Industrial Revolution. In particular his recognition that within the heavy manufacturing sector, partnership enterprise made possible the co-ordination of technical and business talent and entrepreneurial drive.[2] However, it is argued here that a consideration of the influence of the patent system has been a material omission by many historians in their understanding of the development of the early railways. For example, to date the entrepreneurial significance of the secret purchase of shares in the Electric Telegraph Co. by Robert Stephenson, the doyen of Victorian railway engineering, has attracted little academic interest. The examination undertaken in chapter 7 goes some way to address that lacuna, with a relatively detailed consideration of Stephenson's secret and substantial investment. A purchase of shares, by a nominee, that allowed him to acquire a stakeholding in the Electric Telegraph Co. Stephenson's recognition of the value of patents allowed him to exploit a commercial opportunity, and to capitalise on potential sales of patented telegraph systems to railway companies.

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[1] Michael Longridge, letter to Thomas Richardson, March 7, 1825, Pease/Stephenson family of Darlington, DP/S 2/61, Durham County Record Office.

[2] Bailey, "Decision making processes in the manufacturing sector. The independent Locomotive Industry in the 19th Century" (D.Phil thesis, University of York, 1999), 353.

The early development of the steam locomotive in the form we know today was rooted in the transport of coal, the early railway was a 'child of the English north east'[3] from the 'cradle of Gateshead in 1805 to its graduation with *Rocket* and *Planet'*.[4] Although the Great Northern coalfield was mined in a number of counties, the production of coal in the early 1800s was concentrated close to the waterways of the Tyne and Wear allowing access to London, and elsewhere. Between 1700 and 1830 national coal output grew tenfold from 3 million to 30 million tons per annum in response to the energy requirements of the expanding industrial sector.[5] Prior to the inauguration of the Stockton and Darlington Railway Co. in 1825, the important north eastern waggonways were within a radius of just 15 miles. In 1815, any person interested in new developments could have seen, on foot, in less than an hour, any one of the stationary engines at Coxlodge, Heaton, Wallsend or Killingworth collieries.[6] As steam engine design progressed, it is very likely that improvements became widely known within these adjacent communities. No doubt such information passed by word of mouth, and it may have been easy for any new advances to be observed and copied.

5.1 Edward Pease

Edward Pease was an individual who grasped the possibilities of the application of steam locomotives running on a railroad, and his substantial influence was largely responsible for the adoption of locomotives in place of horses on the Stockton to Darlington Railway. In a letter dated 10 October 1821, to his cousin and fellow Quaker and banker, Thomas Richardson, Edward Pease wrote,

> … do not be surprised if I should tell thee, there seems to us after careful examination no difficulty of laying a railroad from London to Edinr on which waggons would travel and take the mail at the rate of 20 miles an hour, when this is accomplished Steam vessels may be laid aside![7]

In 1821, an experienced enginewright and brakesman at Killingworth Colliery, one George Stephenson, was commissioned by Pease to survey the route of the proposed railway. Stephenson had impressed Pease who, in his letter to Richardson on 10 October 1821, stated, 'the more we see of Stephenson, the more we are pleased with him, he is altogether a self taught genius.'[8]

George Stephenson, his son Robert, and Edward Pease played key roles in early railway technology, and although it is the father and son who have received much of the credit, insufficient recognition has

[3] Michael Robbins, *The Railway Age* (Manchester: Manchester University Press, 1998), 10.
[4] Andy Guy, "North Eastern locomotive pioneers 1805-1827: a reassessment," in *Early Railways*, eds. Andy Guy and Jim Rees (London: The Newcomen Society, 2001), 117-144, 117.
[5] Michael Flinn, The History of the British Coal Industry Vol.II: 1700-1830 The Industrial Revolution, (Oxford: Oxford University Press, 1984), 240-1, quoted in Maurice W. Kirby, *The Origins of Railway Enterprise, The Stockton to Darlington Railway, 1821-1863* (Cambridge: Cambridge University Press, 2002), 9, n.1.
[6] Guy, "North Eastern locomotive pioneers," 138.
[7] Edward Pease, letter to Thomas Richardson, October 10, 1821, Hodgkin Papers, D/Ho C/63/2, Durham County Record Office.
[8] Edward Pease, letter to Thomas Richardson, October 10, 1821, Hodgkin Papers, D/Ho C/63/2. Andy Guy regarded the letter in the following terms: 'this must be one of the important railway letters'; providing a clear explanation as to why locomotives were adopted on the Stockton and Darlington Railway. Guy, " North Eastern locomotive pioneers," 131.

been assigned, hitherto, to those who provided business acumen to their developing enterprise. Rolt stated that it was not too much to say that the railway engineers, and in particular the two Stephensons, 'created the Victorian Age'.[9] Robbins argues, 'if responsibility for [the railway age] is to be assigned to one man, that man was George Stephenson. The age left its mark on the physical landscape, on social organisation, on political groupings, and on the map of the world'.[10] Writing in 1859, Samuel Smiles, in typical hero language, stated,

> … as tending to multiply and spread abroad the conveniences of life, opening up new fields of industry, bringing nations nearer to each other, and thus promoting the great ends of civilisation, the founding of the railway system by George Stephenson must be regarded as one of the most important events, if not the greatest, in the first half of this nineteenth century.[11]

However, these writers rarely give credit to the business acumen supplied by Pease and others, acumen that was essential to develop and capitalise the Stephensons' talents and skills. George and Robert Stephenson clearly possessed skills as mechanical engineers. In 1848, the *Railway Record* stated in 1848, 'Robert Stephenson's ... business as an engine-builder and engineer is of an extent that is literally incredible, and it still seems a progressive one'[12]. However, at the time of the commencement of the Newcastle enterprise both George and Robert Stephenson lacked business expertise.[13] They were not prepared for the harsh realities of the commercial world of the day.[14] Robert Stephenson as founding managing partner was 19 years of age and had just left university. The business acumen fundamental to supporting the Stephensons' engineering enterprise was provided by investors and funders such as Edward Pease, Thomas Richardson and Michael Longridge, amongst others.[15]

Edward Pease was a significant figure during the period of the early railways, not only in respect to his ability to realise finance from his Quaker networks, but also his participation in key business decisions.[16] As emphasised by Chandler, in the absence of institutional capital markets, regular meetings of the Society of Friends allowed the exploitation of geographically dispersed pools of capital.[17] Furthermore, Kirby suggests scholarly consensus that the Quaker businessmen of the time possessed a shrewd sense

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[9] L.T.C. Rolt, *George and Robert Stephenson, The Railway Revolution* (London: Penguin Books, 1960), viii.
[10] Robbins, *The Railway Age*, 2.
[11] Samuel Smiles, *The Story of the Life of George Stephenson, Railway Engineer* (London: John Murray, 1859), 350.
[12] *The Monthly Railway Record* vol.2, Railway Record Office, (August 19, 1848): 808.
[13] Bailey, "Robert Stephenson and Co.," 6.
[14] Bailey, *Robert Stephenson*, 174.
[15] Thomas Richardson, a major funder, was the owner of a local iron foundry. Michael Longridge, co-founder of Bedlington Ironworks was a partner. The original capital was £4,000 divided into ten shares of £400 each. The Stephensons and Longridge held two shares each, Pease held four. Edward Pease also held the shares of Thomas Richardson; Pease, Henry (1807–1881), Stockton and Darlington Railway, correspondence, GB 0756 2010-7055, National Railway Museum, York.
[16] Pease was a member of the Society of Friends whose distinctive structure and organisation had major consequences for business strategy and confidence at the time.
[17] Kirby, *Origins of Railway Enterprise*, 52-53. In three influential books, Alfred Chandler made a seminal contribution to the development of the theory of the firm: *Strategy and Structure: chapters in the history of economic enterprise* (1962), *The Visible Hand: the managerial revolution in American business* (1977) and *Scale and Scope: the dynamics of industrial capitalism* (1990)

of immediate possibility, but little sense of direction, changed rapidly as to the latter as the benefits of developing railway technology became evident.[18]

Pease enjoyed extensive family connections and personalised financial networks. He appointed Francis Mewburn, the Chief Bailiff of Darlington, as solicitor to the Stockton and Darlington Railway Co., the first railway solicitor,[19] and George Stephenson as Engineer. Pease, Richardson and Longridge corresponded on a regular basis, often confirming their faith in the engineering skills of both Stephensons. For instance, on 18 March 1823, Longridge writing to Pease stated,

> I am well satisfied that Geo has an extraordinary talent for the display of his peculiar interests and that managed well he may easily distance all his competition.[20]

In another letter to Richardson the following year, Pease recognised the talents of George Stephenson, but expressed concern that his administrative skills were lacking. He expressed a fear that Stephenson's poor business expertise could expose Pease, and other funders, to risk. Pease's letter, written on 10 May 1824, is highly significant to the themes developed in this thesis. It provides compelling evidence that as early as the 1820s, Pease regarded the patent system to be an effective, if not essential means of alleviating risk and achieving financial return,

> This concern has I think some promise in it if we succeed in getting managers. I sometimes fear whether his fame well laid for which his fame and ingenuity is great, his execution is torrid, defective and languid. The work in hand is the two Broughton engines toward which we have received £100 ... 2 for Lord Ravensworth, we must keep an eye on this last article [locomotives], the patent expires in 4 years, it will be that length of time before either the Liverpool, Birm or any Rail can want such engines, if it be possible we must have Geo to adapt some improvement for the engines to get a <u>new patent</u> [Pease's underlining]. I mean to write to him in a day or so to enter a caveat in the patent office for improvement for I cannot doubt such is the inquiry about railways that these engines will be an important thing and <u>ought</u> to leave us no small sum for either making or licenses. I am afraid of placing any more of my property at risque, thou know ... my family is large. I am almost afraid to do anything to get me deeper though my suffering by and any of those would not inconvenience me, yet I shall be sorry to add risque to risque imprudently.[21]

Pease, as an established businessman, was well placed to evaluate risk and he would have appreciated that in the tight knit community of the north east, knowledge of inventions and new developments, would quickly pass from one person to another. In his letter to Richardson, Pease made important connections between 'patents' and 'making no small sum.' He recognised that properly managed, inventive activity could be well remunerated. Pease would have possessed a detailed understanding of the investment needed to realise the commercial potential of George and Robert Stephenson's inventive prowess, and he would have appreciated the pressing need to protect investment during the period of

[18] Kirby, *Origins of Railway Enterprise*, 2.
[19] *Newcastle Daily Chronicle*, June 14, 1867, Pease-Stephenson Papers D/PS/5/9, Durham County Record Office.
[20] Michel Longridge, letter to Edward Pease, March 18, 1823, Pease-Stephenson Papers D/PS/2/33.
[21] Edward Pease, letter to Thomas Richardson, May 10, 1824, Hodgkin Papers, D/Ho C/63/5.

development and early sales.[22] In a letter written to Richardson and Longridge in December 1824, Pease recommended,

> We really ought some way or other, to engraft ourselves on to GS emoluments so far as to indemnify us from loss ... [Stephenson] should not place our property at risque ... self preservation, that first law, must I think ... be kept in view.[23]

Pease and his associates were, to quote Guy,[24] George Stephenson's spin doctors then, as much as Smiles would be later. They covered everything from his scale fees, to the essential need for fresh patents, from the advantages of new premises, to his style of dress. (It seems reasonable to suppose that George was probably most comfortable in his working clothes). Writing to Richardson on 10 October 1824, Pease stated,

> [George] is a clever man, but he must have leading straight; he should always be a gentleman in his dress, his clothes real and new, and of the best quality, all his personal linen clean every day his hat and upper coat conspicuously good, without dandyism.[25]

Without a framework of patent protection, it may not have been possible for the potential of George Stephenson, and later his son, to have been fully realised in what was to become one of the most substantial contributions to inventive activity in English railway technology. In this chapter it is demonstrated that patents were a method utilised by Edward Pease to ensure that the Stephensons' business remained financially sound. As demonstrated below, Pease clearly recognised patents as a means to financial advantage, an approach he urged upon his partners following the very successful inauguration of Robert Stephenson and Co. in 1823. His diary entry for 12 April 1847 records, in relation to the Company's premises, Forth Street works, 'this has been made a source of considerable income to me', and for 28 December 1848, 'during the course of the year I have received £7,000 from the concern at Forth Street'.[26]

5.2 George Stephenson

This chapter is not concerned with the Stephensons' engineering achievements *per se*, but examines the influence and role of those who provided business acumen, particularly Edward Pease, Michael Longridge and Edward Starbuck, and their resort to, and confidence in the patent system as a means of protecting technical knowledge and ensuring the financial stability of the Company. There have been substantial studies undertaken in respect of the achievements of both Stephensons,[27] and Rees finds it

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[22] The point was made by John Farey in giving evidence to the Select Committee on June 8, 1829. *Select Committee on the Law Relative to Patent Inventions* (1829), 141.
[23] Edward Pease, letter to Michael Longridge and Thomas Richardson, December 1824, Hodgkin Papers, D/Ho C/63/10.
[24] Guy, "North Eastern Locomotive Pioneers," 131.
[25] Edward Pease, letter to Thomas Richardson, May 10, 1824, Hodgkin Papers, D/Ho C/63/5.
[26] James G. H. Warren, *A Century of Locomotive Building by Robert Stephenson and Co. 1823-1892* (Newton Abbot: David and Charles, 1970), 103.
[27] Smiles, The *Story of the life of George Stephenson* (1960). Hunter Davies, *George Stephenson: The Remarkable Life of the Founder of the* Railways (Stroud: The History Press Ltd; revised reprint edition, 2004). Bailey, *Robert Stephenson* (2003), to mention a few.

surprising that George's locomotive work, especially for the settled period between 1816 and 1825, has received relatively little scholarly attention.[28]

On 27 July 1814, George Stephenson placed his first steam engine on the Killingworth colliery track. The engine was named *My Lord*, after his employer Lord Ravensworth, but soon acquired the new designation *Blucher* (often spelled *Blutcher*) in honour of Wellington's ally at the Battle of Waterloo.[29] Six months later, on 28 February 1815, George Stephenson was granted his first patent. It was taken out jointly with Ralph Dodds, the Colliery Viewer, and was concerned with basic aspects of the engine's design. Nicholas Wood, writing in 1838, commented on the noise caused by the gearing and the jerkiness of the propulsion of the engine,

> … [t]o obviate this became desirable, and Mr Stephenson, in conjunction with Mr Dodds took out a patent for a method of communicating the power of the engine directly to the wheels without the aid of these cog-wheels.[30]

It is hugely significant that George Stephenson and Ralph Dodds utilised the patent system in 1815, particularly since the current historiography suggests that prior to 1852 the system was largely unworkable, expensive, centred in London and involved convoluted application procedures. These two individuals, both with considerable practical skills and likely of limited financial means (it being six years before the funding influence of Pease *et al*), were prepared to access the offices of Chancery, in London, to protect their invention. Stephenson and Dodds clearly regarded the patent system to be accessible and effective. In the event, the owners of Killingworth Colliery, who presumably recognised the potential of the patent as well as Stephenson's talent, reimbursed both Dodds and Stephenson with the expenses they had incurred. The partnership minutes of William, Armstrong and Sons, for 18 March 1815 record,

> … resolved that the expense of the patent obtained by Geo Stephenson and Ralph Dodds for a travelling engine be defrayed by the partnership as a gratuity to those persons. Resolved that the said George Stephenson have his salary increased from 1.1.1815 to £100 per annum.[31]

The patent for George Stephenson's basic design, for his Killingworth and Hetton engine, is the first recorded application of cranked axles to locomotives. It is perhaps significant that Stephenson took such early steps to protect his design and to establish his reputation.[32] It has been suggested by Charlton, that Stephenson was not entitled to his patent. Nicholas Wood, a close collaborator of Stephenson's, recorded in his private diary that a locomotive of the same design as the patent had been run by Nowell and Co.

[28] Jim Rees. "The Stephenson Standard Locomotive (1814-1825); a Fresh Appraisal" in *Early Railways 2,* ed. Michael Lewis (London: The Newcomen Society, 2003), 177-201, 178.
[29] W.O. Skeat, *George Stephenson. The Engineer and His Letters* (London: IMechE, 1973), 32.
[30] Nicholas Wood, *A Practical Treatise on Rail Roads* (London: Longman, Orme, Brown, Green, & Longmans, 3rd ed. 1838), 289-290.
[31] Minute Book 1729 - 1844, William Armstrong and Sons, NRO 725/55/4, Northumberland Archives, Ashington.
[32] Stephenson's recourse to the patent system supports Biagioli's analysis of the traditional transcultural opposition between credit as credibility and credit as rewards, in that Stephenson achieved both. Mario Biagioli, *Galileo's Instruments of Credit: Telescopes, Images, Secrecy* (Chicago: University of Chicago Press, 2006), 8.

of Sunderland and by Grimshaw of Fatfield Colliery, on 24 February 1815, four days prior to the grant of Stephenson's patent.[33]

Nevertheless, George Stephenson impressed William Losh, senior partner in the firm of Walker Ironworks, who in 1815 invited Stephenson to devote two days a week to the Walker Ironworks for which he was to receive £100 a year.[34] In 1816 Losh and Stephenson were jointly granted a patent for a steam spring, described as being ‘kinder’ to the track.[35] In keeping with accepted practice of the period, the patent encompassed more than one invention. It included an improved wheel using malleable iron instead of cast iron and, more importantly, an improved type of cast iron rail and chair. George Stephenson had clearly not been deterred by his first experience of the patent system. Within one year, together with William Losh, he made this second patent application. A patent which subsequently proved to be lucrative. Nicholas Wood writing in 1831 commented,

> ... a more general benefit has been derived from the different contrivances established in this patent than any other on the subject of rail road conveyance.[36]

In 1821, when George Stephenson was appointed Engineer for the Stockton and Darlington Railway Co., he advised that the track should be built with edge rails, rather than plateways. Furthermore, even though he owned a share of the patent for cast iron rails, and to the disappointment of his co-patentee, Losh, Stephenson recommended using malleable iron rails. He had been very impressed by Birkinshaw’s patented wrought (malleable) iron rails which were being produced at Bedlington works in 15ft lengths. Similarly, when asked to recommend rails to the directors of the Liverpool and Manchester Railway Co., and despite the fact that he would have gained financially from the use of his own patented rails, Stephenson recommended the directors should use the best equipment and material available, and purchase Birkinshaw’s iron rails.[37] In his patent description, Birkinshaw stated he was dissatisfied with the brittleness of cast iron and he wanted a rail that would carry at least 'six times the weight intended to be carried along the road'.[38] It is not known how Stephenson came to learn of

[33] L.G. Charlton, *The First Locomotive Engineers* (Newcastle upon Tyne: Frank Graham, 1974), 46. Memorandum book of Nicholas Wood containing copies of notes, reports, calculations, strata, etc., relating to Killingworth and other collieries, NRO 602/21/23, Northumberland Archives, Ashington.
[34] John Cordy Jeaffreson and William Pole, *The Life of Robert Stephenson, FRS. With Descriptive Chapters on Some of his Most Important Professional Works,* vol.1, (London: Longmans, Green, Reader, and Dyer, 1864; Cambridge: Cambridge University Press, digitized edn. 2014), 33.
[35] George Stephenson and William Losh, *A Method of Methods of facilitating the Conveyance of Carriages and all manner of Goods and Materials along Railways and Tramways, by certain Inventions and Improvements in the construction of the Machine, Carriages, Carriage Wheels, Railways, and Tramways for that purpose*. Patent No. 4067. September 30, 1816. Steam springs were soon replaced by plate springs which became the preferred the method carrying the weight of the locomotive.
[36] Wood, *A Practical Treatise on Rail Roads*, 291.
[37] Henry Booth, the Treasurer of the London and Manchester Railway records ‘the directors determined to adopt the forged or iron rail in lengths of 5 yards each made after Mr Birkenshaw’s patent’. Henry Booth, *An Account of the Liverpool and Manchester Railway* (Liverpool: Wales and Bond Baines, 1830), 61.
[38] John Birkinshaw, *Manufacturing, and construction of, a wrought or malleable iron railroad or way*. Patent No. 4503. October 23, 1820.

Birkinshaw's rails, but there is contemporary evidence confirming that copies of Birkinshaw's patent specification were in circulation. On 28 June 1821, George Stephenson wrote to Robert Stevenson (no relation) who was connected with the Stockton and Darlington Railway Co. in an advisory capacity, and stated,

> … with this you will receive three copies of a specification of a patent malleable iron rail invented by John Birkinshaw of Bedlington, near Morpeth ... Your reference to Tindall Fell led the inventor to make some experiments on malleable iron bars, the result of which convinced him of the superiority of the malleable over the cast iron – so much so he took out a patent. Those rails are so much liked in this neighbourhood that I think in a short time they will do away with the cast iron railways.[39]

This letter is good evidence that the railway entrepreneurs of the day regarded the patent system not only as a means of protecting their own creative input, but also as an accessible repository of technological knowledge.

George Stephenson, who at the age of sixteen years taught himself to read and write, rapidly established himself with his contemporaries as to his undoubted engineering skills, both mechanical and civil. There is some debate as to the accuracy of George's claim that he was responsible for building sixteen locomotives, Rees argues it was probably thirteen.[40] Nevertheless, as wryly observed by Dunn, George Stephenson was the single, unqualified success of the locomotive pioneers.[41]

On 23 June 1823, George and his son Robert entered into partnership with Edward Pease and Michael Longridge to establish Robert Stephenson and Co., at Forth Street, Newcastle-upon-Tyne, the first railway locomotive manufacturing works in the world.[42] Pease was the major subscriber for the bulk of the capital of £4,000,[43] and the foundation, in 1824, of Robert Stephenson and Co. marked the inauguration of the modern locomotive industry. By the middle of the nineteenth century there were approximately twenty specialist builders of locomotives[44] with the Stephensons, Sharp Brothers (Manchester), E. B Wilson (Leeds), Edward Bury (Liverpool), and R and W Hawthorn (Newcastle on

[39] Quoted in Warren, *A Century of Locomotive Building,* 45.
[40] George Stephenson giving evidence to the House of Commons Select Committee on the Liverpool and Manchester Railway Bill, April 25, 1825; recalled in Smiles, *The Life of George Stephenson*, 232. Rees, "The Stephenson Standard Locomotive," 181. Bailey argues that George Stephenson was correct with his figure of 16. Michael Bailey, "'Blucher' and after: a reassessment of George Stephenson's first locomotives," paper delivered at the *Early Railways Conference*, Newcastle, June 16, 2016, (unpublished).
[41] Matthias Dunn, quoted in Guy, "North Eastern Locomotive Pioneers," 121.
[42] 'The importance of these works at the start of the early main line railway period cannot be overstated'; Ivor Lewis, "The development of the drawing office within UK mainline railway workshops," in *Early Main Line Railways*, ed. Peter Cross-Rudkin (Clare, Suffolk: Six Martlets Publishing, 2016), 148-163, 153.
[43] Maurice W. Kirby, *Men of Business and Politics. The Rise and Fall of the Quaker Pease Dynasty of North-East England, 1700-1943* (London: George Allen and Unwin, 1984), 17.
[44] 20 is the number calculated by M.W. Kirby, "Product Proliferation in the British Locomotive Building Industry, 1850-1914: An Engineers Paradise?" *Business History* 30, no.3 (1988): 287-305, 289; Bailey puts the figure at 33 locomotive manufacturers; Michael Bailey, ed., *Robert Stephenson - The Eminent Engineer* (Ashgate: Aldershot, 2003), 186. Jack Simmons puts the number at 40; Jack Simmons, *The Victorian Railway* (London: Thames and Hudson, 2009),70.

Tyne) being the principal manufacturers.[45] Robert Stephenson and Co., the market leader, achieved fame in 1829 with the building of the *Rocket* locomotive and went on to a 130-year career in the forefront of steam engine construction.[46] Warren, recording a century of locomotive building by the Company, has emphasised that the typical Stephenson locomotive was distinguished by its simplicity and fitness, which led to a level of production from the Company sufficient for the ordinary work of the world's railways.[47]

5.3 Robert Stephenson and Co.

Robert Stephenson and Co. was conceived as a means of developing and promoting the proven engineering skills of both George and Robert Stephenson and exploiting their financial potential in an expanding market beyond the north east. The partnership agreement of Robert Stephenson and Co. is set out at page one of the Company's minute books, and paragraph 6 of that agreement provided as follows,

> A compensation of three hundred pounds to be paid by the concern at the end of three years to the said George Stephenson upon condition of his assigning to the Partners the patents already by him obtained for locomotives and other engines or should the same George Stephenson make any other useful discovery for which the company may deem it worthwhile to take out a patent, the said company shall in common with said George Stephenson enjoy all the advantages of the said discovery the concern paying the expenses of the patent.[48]

There is evidence, as discussed below, that within the partnership it was Pease who had responsibility for capturing the value of the existing and, importantly, any future patents. Although speculative, it is likely that it was Pease who suggested the assignment of George Stephenson's patents to the Company. Nevertheless, it was perhaps an oversight to omit from the partnership agreement the benefits of any future patents taken out by Robert Stephenson, who subsequently received considerable fees from his later patents, and appears to have kept the proceeds for himself.[49]

In October 1824, Pease expressed concern that George Stephenson's 1815 joint patent with Ralph Dodds was coming to an end and that locomotive designs were being produced without the protection of patents. In a letter to Richardson, in very similar terms to a previous letter dated 10 May 1824 referenced above, he observed,

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[45] Kirby, "Product Proliferation," 289.
[46] Michael Bailey, "Robert Stephenson and Co and the Paper Drying Machine in the 1820s," *Bulletin of The International Association of Paper Historians* 23, (Velp, Netherlands, 1989): 6-11 and 51-66, 6.
[47] Warren, *A Century of Locomotive Building*, 407.
[48] Minute Book of Robert Stephenson and Co., June 23, 1823, GB 0756 1947-134, ROB 1/1, National Railway Museum, York.
[49] Bailey, "Decision making processes," 161.

> [W]e must keep our eye on this last article [locomotives] the patent expires in four years, it will be that length of time before either the Liverpool, Birm or any Rail can want such Engines, if it is possible we must have GS adopt some improvements for these Engines and get a new patent, I mean to write him in a day or two to enter a caveat in the patent office for improvements, for I cannot doubt such is the enquiry about Railway and any but these engines will be a most important thing and ought to leave us no small sum (Pease's underlining) for either making or Licences.[50]

Pease's repeated concerns, linking 'patents' and 'no small sum', were perhaps well founded because the failure on the part of George and Robert Stephenson to protect their inventions allowed emerging manufacturers to copy their designs. In particular, Edward Bury (1794-1858), the proprietor of the Clarence Foundry in Liverpool, started to produce and supply locomotives incorporating many of the Stephensons' novel features.[51]

Examination of the partnership minute book reveals that paragraph 6 of the partnership agreement was discussed on regular occasions, the matter of patents was kept under general review. For 3 December 1824, the minute book records, at paragraph 2,

> On considering the circumstances of the existing patent for locomotive engines and the short duration, say three years, and that patent expires that it is expedient to endeavour to have the same extended if it be practicable by petition to Parliament as Geo Stephenson has stated to this meeting that he does not at present see any additions can be made to his former invention of such moment as to entitle him to sue for a new patent; the care of this subject committed to EP.[52]

This is an interesting minute and one of considerable significance for the arguments being constructed in this chapter concerning both the management of early railway knowledge and the related role of patents. It is recorded that George Stephenson had no new ideas for the present (although they were soon to flow), but he was supportive of seeking an extension of his existing patents, which would have involved petition to Parliament.[53] Furthermore, the minute confirms that Edward Pease had 'care of the subject'. This evidence suggests that Pease was the driving force in the partnership with regard to patent protection, that it was Pease who advocated patents as a means to achieve protection of the Company's locomotive designs, as well as any subsequent incremental developments. Pease recognised the need to prevent innovations from being copied by competitors. He may have been aware of the experiences of Boulton and Watt who discovered that the German and Prussian barons had, in 1779, 'bribed a workman to dismantle part of an engine to show how it worked'.[54] Today much railway research and engineering

[50] Edward Pease, letter to Thomas Richardson, October 23, 1824, Hodgkin Papers, D/Ho C/63/5.
[51] Bailey, ed., *Robert Stephenson*, 172.
[52] Minute Book of Robert Stephenson and Co., December 3, 1824, GB 0756 1947-134, ROB 1/1.
[53] The two relevant patents, extended in 1824, were George Stephenson's first patent with Ralph Dodds, *Various Improvements in the Construction of Locomotive Engines*, Patent 3887, February 28,1815; and, his second patent with William Losh, *A Method of Methods of facilitating the Conveyance of Carriages and all manner of Goods and Materials along Railways and Tramways, by certain Inventions and Improvements in the construction of the Machine, Carriages, Carriage Wheels, Railways, and Tramways for that purpose*, Patent No. 4067, November, 26, 1816.
[54] Jennifer Tann and Anthony Burton, *Matthew Boulton: Industry's Great Innovator* (Stroud: The History Press, 2013), 113.

is underpinned by the taking out of patents,[55] and the evidence considered above demonstrates that the leaders of the emerging railway manufacturing industry of the early nineteenth century, in seeking protection for innovative designs and surety of financial reward, exploited the patent system to great advantage.

The establishment of Robert Stephenson and Co.'s Forth Street works created challenges for the partners in as much as there was need for new and improved locomotives in a vibrant, competitive market. On 7 March 1825, Longridge, replying to a letter from Richardson, stated,

> It was against my wish they commenced engine builders, but after they begun considering it beneficial to the Bedlington Iron Co and that Geo and Robert would benefit from my habits of business, in which they were both deficient, I offered to take part with them.[56]

This is important letter confirms the influence of both Pease and Longridge, and the benefit to the partnership of their respective business acumen, which extended to the obtaining and eventual enforcing of patents. Pease was an established man of business, and Longridge was the proprietor of the Bedlington Ironworks where the first malleable iron rails made under John Birkinshaw's patent were rolled.[57]

It was the success of the *Rocket* at the Rainhill trials in 1829 that established the works pre-eminence. Furthermore, given the emerging reputation of the Forth Street works, it would seem legitimate to speculate that even if one of the other contenders had won at Rainhill, lucrative follow-on orders would still have been placed.[58] On 3 September 1830, twelve days before the opening of the Liverpool and Manchester Railway, the first *Planet* locomotive was completed at the works. It was the first locomotive incorporating the design characteristics subsequently to be adopted by the world's railways over the next 150 years,[59] but the design was not patented. Perhaps George and Robert Stephenson were too pre-occupied to put time aside to instruct a patent agent and it remains a matter of speculation as to where responsibility lay, whether it was 'arrogance',[60] or lack of time or inaction on Pease's part when he had 'care of the subject' of patents. In any event, Bury and Hackworth took advantage of the Stephensons' omission and developed a number of similar designs, probably at some considerable financial loss to Robert Stephenson and Co. It would seem reasonable to suppose that the Company's bankers may have exerted influence on the Company to make application for patents. This could be a matter for further research, particularly since it is known that George Stephenson had close ties with George Alexander Brown of Brown Shipley and Co., Bankers. In 1830, Brown rode on the first engine to make a trial run

[55] By way of example, the patents taken out by Siemens continues to rise. In 2013, the number granted in continuing operations (including railway technology) increased by five percent year-over-year to 60,000; http://www.siemens.com/press/en/pressrelease/2013/corporate/axx20131213.htm [accessed January 8, 2014]
[56] Michael Longridge, letter to Thomas Richardson, March 7, 1825, Pease/Stephenson family of Darlington. D/PS 2/61, Durham Record Office.
[57] Warren, *A Century of Locomotive Building*, 65.
[58] Michael Bailey, "Robert Stephenson and Co. 1823-1829," *Transactions of the Newcomen Society* 50, (1978/79): 109-138, 127.
[59] Bailey, *Robert Stephenson*, 171.
[60] Bailey, "Decision making processes," 138.

on the Liverpool and Manchester Railway. He was also present, as an invited guest, on the opening day the following year.[61]

Four developments during the early 1830s demonstrate that as a probable consequence of advice from their partners and advisers, George and Robert Stephenson began to appreciate the need to make timely application for patents to protect both their designs and their income. Firstly, in 1830, Robert Stephenson developed a new type of wagon axle,[62] and the correspondence with his father demonstrates a keenness to apply for patents,

> On thinking its advantages carefully over they are of such a nature as to warrant a patent ... I hope you will think it well over, but as it is new and likely to answer, let us take out a patent for it, the patent cannot cost much and if it does get introduced upon railways a very small additional price on each carriage would produce a great deal of money.[63]

Later in the same letter, Robert urged his father to 'keep the matter quiet', indicating perhaps that Robert was developing an understanding of the need to protect his ideas. It is also clear from his comment 'would produce a great deal of money', that financial remuneration was very much a part of his thinking.

Secondly, in 1833, Robert Stephenson sent a clear message to his competitors when taking out his first significant patent for a three axle locomotive. The substantial rise in traffic on the Liverpool and Manchester Railway called for more powerful locomotives and Stephenson's *Planet* design was extended to incorporate a third axle. To emphasise his intention to his competitors he named the new locomotive *Patentee*. The *Patentee* design was utilised in locomotive fleets throughout the decade, it was either adopted by competitors under licence or produced in the Stephensons' Forth Street works.[64] The three axle locomotive enabled the Stephensons to regain their dominant position both as designers and manufacturers which had, hitherto, been allowed to slip. The design formed the basis of many engines put into service during the 1830s in France, Belgium, Germany, Italy and Russia.[65]

Thirdly, there is considerable evidence within the partners' correspondence of increasing awareness of the leakage of ideas to competitors, and the need both to manage and to protect developing railway knowledge. Robert Stephenson, writing to his father on 18 December 1832, expressed concern over Mathew Loam, a potential employee. He stated,

[61] Aytoun Ellis, *Heir of Adventure: The Story of Brown Shipley and Co, Merchant Bankers 1810 – 1960* (London: Brown Shipley & Co. Ltd., private issue, 1960), 56.
[62] Robert Stephenson took out his first patent in 1826. Robert Stephenson, *Axletrees to remedy the extra friction on curves to waggons, carts, cars, and carriages used on railroads, tramways, and other public roads.* Patent No. 5325, January 23, 1826. Bailey, seemingly mistakenly, refers to Patent No. 6092 (1831) as being the first to be taken out by Robert Stephenson. Bailey, *Robert Stephenson*, 173.
[63] Robert Stephenson, letter to George Stephenson, November 8, 1830. Robert Stephenson and Co. GB 0756 1970-473 ROB 4/9/18, National Railway Museum, York.
[64] Bailey, *Robert Stephenson*, 173.
[65] Simmons, *The Victorian Railway*, 70.

> I have considered over the matter of Loam and although concede him a clever man, I am unwilling to introduce him into our factory because it is only teaching another firm to manage the task of Locomotive Engineers - If Kennedy had not obtained a great deal of information from here we should have stood much higher in Locomotive Engine Makers than we do now. Bury never would have made an engine.[66]

In the event, Robert Stephenson gave way and Mathew Loam was engaged as head foreman and remained until 1841. Stephenson's mention of Kennedy is a reference to James Kennedy a former employee of the Company who left to join Stephenson's principal rival, Edward Bury, latterly Bury Curtis and Kennedy who operated from the Clarence Foundry in Liverpool.

Apprentices were certainly a problem for Robert Stephenson and Co. Warren, the Company's historian, records correspondence dating from 1836 where Robert Stephenson complains of the thankless task of training apprentices, 'they carry away what has cost us a great deal of money.'[67] Patents were one means of preventing ideas from being stolen by former employees and used by competitors. As discussed in chapter 2, the courts of Chancery allowed immediate relief in the form of *ex parte* injunctions and, eventually, the granting of remedies in instances of established infringement. Increasingly, Robert Stephenson and Co.'s considerable success was ensured by the utilisation of patents and the enforcement of patent rights. Robert Stephenson's preparedness to use legal process as a means of enforcement of patents is examined in more detail at section 5.4 of this chapter

Fourthly, Robert Stephenson knew that his competitors were copying aspects of his design; a problem that was to persist for several years. For example, and as already referenced in the previous chapter, in August 1845, David Joy who would later become a successful inventor of railway equipment and the recipient of a number of railway patents, recorded in his diary,

> Was very busy now, though pupil, acting as chief draughtsman on the drawings of Manchester Bury and Rossendale engine, as I had to do everything myself, picking up the information by copying the details from engines at the station, chiefly from Stephenson's outside cylinder long-barrelled engine.[68]

A study by Harris provides persuasive evidence that industrial espionage was common during the eighteenth century,[69] and Bertucci proposes the term 'intelligent travel'[70] to define journeys for the purpose of illicit information gathering. As early as 1784, James Watt in a letter to Josiah Wedgwood warns to be wary of the 'clever [French] scientific people'[71] who wished to visit their premises. Although

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[66] Robert Stephenson, letter to George Stephenson, December 18, 1832, Robert Stephenson and Co., GB 0756 1970-473, ROB 4/9/18/7.
[67] Warren, *A Century of Locomotive Building*, 89.
[68] David Joy's Diaries extracted from the "Diaries of the Late David Joy", ed. G.A. Sekon, *Railway Magazine* 22-23 (1908) http:www.steamindex.com/library/joydiary.htm [accessed March 13, 2012]
[69] John Harris, *Industrial Espionage and Technology Transfer* (Aldershot: Ashgate, 1998). Harris focuses his attention on French attempts to import British technology.
[70] Paola Bertucci, "Enlightenment Secrets: Silk, Intelligent Travel, and Industrial Espionage in Eighteenth Century France," *Technology and Culture* 54, no. 4 (October, 2013): 820-853, 822.
[71] James Watt, letter to Josiah Wedgwood, February 6, 1784, Boulton and Watt Papers, MS 3147/3/528. Birmingham Public Library.

there is no evidence of French espionage in relation to Robert Stephenson and Co., the Company surely would have been a prime target for French and other nationals keen to discover new developments in technology emerging from the leading railway engineering company of the time. Furthermore, English patents would have been no defence to French espionage. In 1829, John Farey giving evidence to a parliamentary select committee stated,

> I know practically the evils which have been experienced from useful workmen being enticed abroad, in order by their means to steal secret inventions of which they possessed an exclusive knowledge; the best remedy for it was to take out a patent in France and I was sent there to solicit the patent and thus prevent their exercising the invention there after they had stolen it.[72]

In France the planning of railroads was in the hands of the *Corps de Ports et Chausses* which was part of the bureaucracy and generally used its power despotically.[73] Levitt comments that the Industrial Revolution is never told as a French story, that France 'is the country that became eclipsed by Britain, too centralised, bureaucratic, and preoccupied by political turmoil to effect the same developments as its individualist entrepreneurial neighbor'.[74] The stage was therefore set, and in such circumstances it is unlikely that Robert Stephenson and Co. would not have been subject to espionage, or intelligent travel. The Company, being at the forefront of developing railway technology, would have needed to take action to protect its intellectual capital. Patents were one such method for security in England, and the Company recognised the further need to seek patent protection in other jurisdictions. Jeremy in his seminal study on the diffusion of innovations, a process he considers to be as important to economic development as invention itself, found that for a new technology still only partially understood or not yet reduced to verbal or mathematical forms, the 'experienced practitioner must be the most efficient agent of international diffusion'.[75]

It is clear from these four developments, and perhaps as a consequence of Pease's pressure, that there was a recognised and urgent need for Robert Stephenson and Co. to protect inventions from exploitation by competitors. As noted by Simmons, the early railways were great connectors and 'came to penetrate into every corner of the Victorian world'.[76] Inventive railway technology was no longer concentrated within the coalfields of the north east, but utilised on a national and international basis.

In 1841, Robert Stephenson took out a patent for his long boiler locomotive.[77] The partners' minutes for April 1841 record,

> Rob. Stephenson having stated that he has some improvements in Locomotives in view which he apprehends it would be to the advantage of this concern to take out a patent for, he is encouraged to effect the same in his own name on our behalf.[78]

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[72] John Farey, May 11, 1829, *Select Committee on the Law Relative to Patent Inventions* (1829), 36.
[73] Arthur Dunbar, *The Industrial Revolution in France* (New York: Exposition Press, 1955), 67.
[74] Theresa Levitt, "Liberty, Equality, Technology. Virtuous Inventors and Base Profiteers in the French Industrial Revolution and Beyond", *Technology and Culture* 54, no. 4 (October, 2013): 815-819, 815.
[75] David Jeremy, *Transatlantic Industrial Revolution* (Oxford: Basil Blackwell, 1981), 262.
[76] Simmons, *The Victorian Railway*, 376.
[77] Robert Stephenson, *Arrangement and combination of locomotive-engines.* Patent 8998. June 23, 1841.
[78] Minute Book of Robert Stephenson and Co., April, 1841, GB 0756 1947-134, ROB 1/1.

The long boiler engine, Stephenson's most successful patented invention, was widely adopted in England and Europe. Long boiler engines with four coupled wheels and outside cylinders became the classic design for mixed traffic, and by 1886 more than six hundred engines were in service in France alone.[79] These engines were constructed under licence by French manufacturers who appear to have respected Stephenson's patent protection. For example, in the case of a particular order for 34 locomotives, the royalty was recorded as 1,250 francs per engine.[80] By 1855, Robert Stephenson and Co. had built over 1000 locomotives of different types.[81]

As the locomotive manufacturing industry developed it became obvious that a successful patent was a method of making money. Robert Stephenson led the way with remarkable profits from the long boiler patent, and these financial returns likely would have incentivised other engineers. It is argued here that, increasingly, the patent system was seen as a route to financial success.[82] Furthermore, it would seem legitimate to make the concomitant argument, that the patent system may have served to encourage railway-related inventive activity.

Manufacturers such as Sharp Brothers and E.B. Wilson developed novel designs to avoid, for example, infringing Robert Stephenson's long boiler patent. In particular, they developed 'mixed frame' locomotives that came to be considered equal to, if not better than the long boiler versions.[83] Bury Curtis and Kennedy was probably the major manufacturer to rival Robert Stephenson and Co. in the national locomotive market place and in order to maintain their position sought to develop designs that did not infringe Robert Stephenson and Co.'s patents. Bury Curtis and Kennedy produced designs based on a 2-2-0 and 0-4-0 wheel arrangement that became known as the 'Bury type'. The firm gained a reputation for good workmanship and functional designs which enabled the locomotives to be free from mechanical failure. Some 415 locomotives were built in the twenty years that the firm was in business.[84]

There is also evidence that the existence of these innovative designs, which were as a direct result of seeking to avoid infringements, led to extensive debate concerning locomotive design, which in turn seems to have stimulated further inventive activity. For example, in a paper presented at the Institution of Civil Engineers on 8 January 1838, Edward Woods argued the respective merits of four and six wheel locomotives.[85] He sought to examine 'what general arrangements of the parts of the locomotive engine are most conducive to its efficiency and durability, under the requirements of a railway intended for the

[79] Warren, *A Century of Locomotive Building*, 355.
[80] Warren, *A Century of Locomotive Building*, 101.
[81] James W. Lowe, *British Steam Locomotive Builders* (Bath: Goose and Son, 1975), 612. By 1900 the number had risen to 3000.
[82] Bailey, "Decision making processes," 164.
[83] Ernest L. Ahrons, *The British Steam Railway Locomotive 1825-1925* (London: Locomotive Publishing Co., 1927), 131-136.
[84] Lowe, *British Steam Locomotive Builders*, 94.
[85] Edward Woods, "On certain Forms of Locomotive Engines," *Transactions of the Institution of Civil Engineers* 2, no. 1 (January 1838): 137-155.

transport of heavy loads at high speeds'.[86] Similarly, both Edward Bury and Robert Stephenson were asked to give evidence to a parliamentary select committee on railways when they each put forward cogent reasons for their respective patented designs.[87] It is argued here that such debate would have provided valuable motivation and stimulation for further inventive contributions to early railway technology.

Robert Stephenson is generally credited with the invention, in 1842, of the Stephenson link motion (a type of valve gear designed to provide continuous control of steam locomotives from full forward to full reverse gears and all expansions in between), which Warren has argued contributed more to the development of the steam engine than any single improvement introduced between Watt's time and the date at which he was writing, namely 1923.[88] Despite this being such an acknowledged important step, Robert Stephenson did not protect the invention with a patent. Had he done so, he would undoubtedly have received considerable royalty fees.

Stephenson may have neglected to apply for a patent because, as Warren suggests, the invention embodied the ideas and inventions of many engineers.[89] A short history appears in *Practical Mechanic and Engineers' Magazine*, in 1846, where it is stated that the link motion was invented by two of the Company's Forth Street employees, draughtsman William Williams and patternmaker William Howes. Williams is credited as the inventor, albeit followed, in the subsequent edition, by a claim from Howes to be the true owner of the invention.[90] There is no consensus over the identity of the original designer. William Marshall, then North Midland Railway Co. Superintendent, reported that on 15 December 1841, when conducting a trial of different valve motions for Robert Stephenson, 'Mr Stephenson came into the locomotive office at Derby, on his way back from Newcastle and said, "There is no occasion to try any further at scheming valve motions; one of our people has now hit on a plan that beats all other valve motions"'.[91] Interestingly, Stephenson did not specify the employee. There is some evidence that within Robert Stephenson and Co., the link motion was attributed to Robert Stephenson himself. Starbuck, writing to Messrs Moser and Hepple of aix-la-Chappelle, said of Robert Stephenson, 'his own link motion appears to be attended with increasing success and his new engines are gaining reputation on the continent'.[92]

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86 Woods, "On Certain Forms of Locomotive Engines," 138

87 *Second report from the Select committee on railway acts enactments; together with the minutes of evidence, appendix, and index*, (House of Commons, printed August 25, 1846): Robert Stephenson, July 2, 1839, 207-214, and Edward Bury, July 9, 1839, 230-239.

88 Warren, *A Century of Locomotive Building*, 359.

89 Warren, *A Century of Locomotive Building*, 359.

90 *Practical Mechanic and Engineers' Magazine* vol.1 (series 2, 1846): 165-168, 189-192.

91 William P. Marshall, "Evolution of the Locomotive Engine," *Minutes of the Proceedings of the Institution of Civil Engineers* 133, no. 3 (January,1898): 241-301, 277, n.1.

92 Starbuck, letter to Messrs Moser and Hepple, January 2, 1844, DT/STB/131/3.

The absence of a patent for the Stephenson link motion may be due to concerns about potential litigation given the presence of a patent taken out by John Gray in 1839, for a similar horse leg gear valve.[93] In 1851, John Gray brought an unsuccessful arbitration for patent infringement against the London and North Western Railway Company (LNWR) on account of one of its locomotives being fitted with the Stephenson link motion. The arbitration was held in London during October and November 1852, before Mr Pollock, and listed for four days. Many of the well-known pioneering consulting engineers of the day were called as witnesses including William Dodds, William Howe, William Carpmael, Bennet Woodcroft, Daniel Gooch and James Fenton.[94] Some decades later, A.N.P. Burgh produced a leaflet entitled *The History of the Invention of the Link Motion* (1870) in which he argued 'the purpose of this pamphlet is clearly to prove that Mr William Howes of Clay Cross Chesterfield originated and invented the Link Motion';[95] an argument that Burgh pursued in the columns of *The Engineer*.[96] As an aside, in July 1871, following a public appeal for subscriptions, a 'Testimonial for the Invention of the Link Motion' appeared in *The Engineer* in which the names of Williams and Howes were combined.[97]

Increasingly, both George and Robert Stephenson exhibited a commitment to the idea that in developing their inventive output, the protection offered by the patent system was crucial. Ultimately, they each took out five and six patents, respectively, as listed in Tables 6 and 7.

Table 6: Patents – George Stephenson

	Subject matter	no.	date
i.	*Construction of locomotive engines* (with Dodd) …………	**3887**	28.02.1815
ii.	*Carriages, carriage wheels, rail and chair* (with Losh)	**4067**	26.11.1816
iii.	*Steam engines*..	**4662**	21.03.1822
iv.	*Railway carriage wheels*..	**6111**	30.04.1831
v.	*Locomotive steam engines* (with Howe)	**11086**	11.02.1846

Table 7: Patents - Robert Stephenson

	Subject matter	no.	date
i.	*Axletrees*...	**5325**	23.01.1826
ii.	*Axles and bearings*..	**6092**	11.07.1831
iii.	*Steam locomotives*...	**6372**	26.01.1833
iv.	*Steam locomotive carriages*...	**6484**	07.10.1833
v.	*Supports for iron rails*...	**6524**	11.12.1833
vi.	*Long-boiler locomotives*..	**8998**	23.06.1841

Source: Woodcroft, *Alphabetical Index of Patentees*, 542.

[93] John Gray, *Horse-leg Motion*, Patent No. 7745, July 26, 1838. Bailey, *Decision making processes*, 359.
[94] R.T. Smith, "John Gray and his expansion valve gear," *Transactions of the Newcomen Society* 50, (1978): 139-154
[95] N.P. Burgh, *The History of the Invention of the Link Motion* (London: William Lownes and Co., 1870).
[96] N.P. Burgh, "The History of the Invention of the Link Motion," *The Engineer* 28, (November, 1869): 346.
[97] *The Engineer* 29, (April, 1872): 299-300.

However, successful application for a patent in respect of inventive activity was only the first step. It was also essential to monitor the activities of others in order to protect against infringements. Nevertheless, litigation would have been a last resort, and as is considered below, a number of other preliminary actions could have been taken to enforce patents without taking the ultimate step of court proceedings. The current historiography of the patent system relies heavily on reported decided court cases, which are generally regarded as the sole indicator of the extent of patent disputes. It is the position today that only a fraction of cases commencing in the High Court reach a hearing and, as suggested in chapter 2, it is unlikely to have been any different in the early nineteenth century. Grounded in the confidence of the presence of a patent, the process of negotiation prior to a concluded court hearing would have been a valuable means of enforcement, as exemplified by Edward Starbuck, who in today's language would be recognised as the Company's 'enforcer'.

5.4 Edward Starbuck

Edward Starbuck, engineer and iron merchant of London, was a significant figure in the Stephensons' enterprise, but his vital role has received little recognition in the literature. He appears to have started out as an agent of Longridge's Bedlington Ironworks, becoming freelance and taking on the Stephensons' work from 1840. The 1841 Post Office Directory lists him as a partner in the firm of Longridge, Starbuck and Co. of Walbrook, City of London, and agent for Robert Stephenson and Co.[98]

On 24 October 1840, Robert Stephenson reported to Joseph Pease, 'You have probably heard ... that [Starbuck] has applied to me to allow him to act for RS and Co more particularly on the Continent.'[99] The Company appointed Starbuck as an agent and he came to be highly regarded by Robert Stephenson owing to his ability to create sales for the Company, in England and overseas. In 1842 Robert Stephenson unsuccessfully proposed that Starbuck should become a partner, and when Robert Stephenson died (Edward Starbuck having pre-deceased him), he left £5,000 for the maintenance and education of Starbuck's children.[100] Although Starbuck's task was primarily to sell the Company's locomotives, he had the additional role of ensuring that patent rights were observed and royalties collected.

By the 1840s, Robert Stephenson and Co. was adopting a rigid stance towards the observance of its patent rights. An attitude expressed in Starbuck's correspondence, which reflected the strong message given by this now powerful locomotive manufacturer to those who sought to copy inventive activity without payment. For instance, Starbuck entered into detailed correspondence with Messrs Kitson Thompson and Hewitson who were attempting to manufacture long boilers for the English market, an

[98] Starbuck Papers DT.STB, Tyne and Wear Record Office, Newcastle upon Tyne. Starbuck's correspondence was discovered in a portion of the Stephenson iron foundry and locomotive works at Forth Banks, Newcastle, when the building was taken over by the Post Office at the beginning of the twentieth century.
[99] Robert Stephenson, letter to Joseph Pease, October 24, 1840, Pease-Stephenson Papers D/PS/2/56, Durham County Record Office.
[100] *Newcastle Guardian and Tyne Mercury*, November 5, 1859. Newcastle City Library.

alleged breach of Robert Stephenson's patent. A letter was written on 11 January 1844, demanding to know the names of 'all parties to whom he or other person had handed the specification in question ...'[101]

The following month Starbuck made a direct demand for fees for the patent,

> I am desired by Mr R Stephenson to inform you that his charge for licence to use his patent in such cases as he is induced to grant it is fifty pounds per engine, but on the understanding from you that you do not avail of the improvements contained in his patent in the construction of the five engines for the Altona and Kiel Co.[102]

Four months later, on 17 June 1844, Starbuck wrote again to Messrs Kitson Thompson and Hewitson,

> You are probably aware that [Robert Stephenson] has already repeatedly stated to parties both in England and on the continent his objection to this permission [to adopting his patent arrangement of Engine] and his interests have been so injuriously affected by the circumstance of other manufacturers having offered to undertake to make Engines on his patent arrange't that he is compelled to adhere to that decision and in so doing must decline to grant you the permission asked for in the case of the West London tender. I need hardly add that Mr Robert Stephenson's only wish is to protect himself without injury to yourselves or others.[103]

Another example, in 1844, involved R and W Hawthorn (the Stephensons' neighbours in Newcastle) who began making long boiler locomotives claiming that the positioning of their rear axle meant they were not infringing the Stephenson patent. Starbuck wrote on 28 May 1844,

> Having been credibly informed that you are about exporting one or more engines upon a construction which embraces our patent and is a manifest infringement of it we feel called upon for the protection of our interest to protect against such use being made by yourselves or any other engine builder of our patent right and state that we cannot consent to your delivery of such engines. The writer will be in Newcastle in the early part of next week. I will be glad to receive any communication you may be disposed to make on the subject.[104]

It is not known whether the meeting took place, but clearly R and W Hawthorn were not persuaded of the error of their ways because they continued with their infringement. It is an indication of the determination of Robert Stephenson and Co. to pursue the matter of patent enforcement, that advice was sought from Thomas Webster, a barrister whose specialisms included advising on patent law. Webster confirmed that infringement was occuring and this occasioned Starbuck to write in typically robust manner to R and W Hawthorn,

> ... as a matter of Equity H and Co must know themselves wrong-as a matter of <u>Law</u> the high opinion of Webster makes them so. The maintenance of our just right in this question will have great weight on the Continent; such affairs give a prestige in favour of the Inventor. [105]

A final example of many is Starbuck's correspondence with Jones and Potts Newton Willows, Warrington. On 6 February 1844, he wrote,

[101] Edward F. Starbuck, letter to Messers Kitson Thompson and Hewitson, January 11, 1844, Starbuck Papers, Letterbook January-August 1844 DT.STB 131/1/22.
[102] Starbuck, letter to Kitson, Thompson and Hewitson, February 5, 1844, Letterbook, DT.STB 131/1/85.
[103] Starbuck, letter to Kitson, Thompson and Hewitson, June 17, 1844, Letterbook, DT.STB 131/1/333.
[104] Starbuck, letter to R. and M. Hawthorn, May 28, 1844, Letterbook, DT.STB 131/1/291.
[105] Starbuck, letter to E.J. Cook, August 8, 1844, Letterbook, DT.STB 131/1.

> Mr Robert Stephenson has desired me to say that he has been informed that you have taken an order for two locomotives to be constructed on the plan of those made by him on the North Midland and York Railway. If this is the case you were probably not aware that he has a patent for this system of engine ... Several parties have already come to an arrangement with him in similar circumstances and with others he is now granting licences for a given number.[106]

Starbuck's role was vital to the marketing efforts of the Company. Robert Stephenson clearly relied heavily upon his advice and efforts. Surprisingly, it appears that Robert Stephenson was considering allowing other manufacturers to use his patents on advantageous terms, an action that caused Starbuck to 'dread the consequences'. A hugely significant letter to Robert dated 18 June 1844 demonstrates Starbuck's view of the importance of patents in maintaining the Company's prominent position, both home and abroad.

> I have thought a good deal as to the effect which would be produced by you admitting other manufacturers to use your patent in the construction of locomotives and I believe it will be this. You will find the Hawthorns, Kitson Jones and Co., Bury and Co. your competition at a price at least £125 or £150 below your present quotation … this will render our sales doubly difficult and our chance of success … Besides all of this you being the exclusive maker of the patent for the continent keeps us a prestige in your favour by no means unimportant, the refusal to licence is to prevent others injuring you; not to inflict an injustice on them. You still have a foremost place on the continent but I fear the continuance to permit others to make your new engine may sacrifice a good deal of this: at all events if you find other makers whose work is well known offering then at £125 or £150 under you I dread the consequence.[107]

Starbuck's advice appears to have been heeded, and the correspondence reveals his detailed understanding of foreign patent laws. In a letter written in 1844, in relation to six engines being constructed by a Dutch manufacturer for the Dutch Government, Starbuck states he is 'very anxious about our patent for Holland'.[108] He makes reference to 'our patent right of £125 for each engine,' and sets out that the Dutch patent could expire under Article 8E of the Dutch Code. According to Starbuck, under the Code, if the owner of a patent failed to make any use of it within the period of two years from the date of the patent (in this case 5 February 1842), it become null and void. Starbuck appears to have received a satisfactory response because in February 1844, in a letter to Mons Dudock van Heel, he states, 'we hereby grant to you the exclusive right in Holland to manufacture engines on this plan paying the sum of £25 for each engine constructed'. Starbuck makes it clear 'the use of our patent is for Holland only and any other country will require another arrangement'.[109]

During the 1840s, the structure of the locomotive industry was subject to profound change as a consequence of many major railway companies adopting an 'own build' policy. Increasingly, during the nineteenth century, private companies were regarded as a reserve source for the manufacture of locomotives, and Robert Stephenson and others started to devote attention to export markets, notably

[106] Starbuck, letter to Jones and Potts, February 6, 1844, Letterbook, DT.STB 131/1/86.
[107] Starbuck, letter to Stephenson, June 18, 1844, Letterbook DT.STB 131/336.
[108] Starbuck, letter to Conrad à la Haye, January 9, 1844, Letterbook DT.STB 131/20. Interestingly, Starbuck indicates that the Dutch patent was in his name; further evidence perhaps of the mutual trust Stephenson and Starbuck had for each other.
[109] Starbuck, letter to Mons Dudock van Heel, February 6, 1844, Letterbook DT.STB 131/91.

within the British Empire and South America.[110] Where possible, inventions were patented both at home and overseas.

As Biagioli has highlighted, patents for inventions evolved independently in different trading and capitalist cultures, at different times around the world.[111] Bently's seminal review identified that by 1864 seventeen British colonies had divergent patent laws where variations existed in all aspects, from the definition of patentable subject matter, duration, scope of rights, procedure, grounds of opposition, grounds on invalidity, definitions of novelty, disclosure requirements, requirements of working and compulsory licenses.[112] During the period of the early railways, each country had a different patent system which necessitated individual and separate scrutiny by railway entrepreneurs wishing to sell and or develop railway technology beyond England. Many of the products of early railway technology were sold abroad beyond the jurisdiction of the English patent system.

In the case of Robert Stephenson and Co., Starbuck made successful patent applications under foreign jurisdictions. There would have been some difficulties in seeking remedies for alleged infringements, but the threat of litigation would have been regarded as a powerful deterrent. Starbuck also negotiated royalties for locomotives to be manufactured abroad. He was a highly successful salesperson for the Company, a position made possible both by the flow of new ideas *and* the necessary patent protection. For instance, whilst the list price of a patented engine was in the region of £1,800,[113] in 1844 Starbuck offered French manufacturers an agreement with a choice either to make any number of locomotives for a royalty fee of £1,000, or to pay £50 for each.[114] Similarly, in 1854, the Company charged the Paris and Orleans Railway Co. £10 per locomotive for a fleet of twenty six.[115] Robert Stephenson and Co. recognised that the existence of a strong patent was a good selling point, and Edward Starbuck was never slow to press the advantage. In a letter dated May 1844, he stated,

> … we enclose an extract from the York and North Midland R.W. Co. on the working of engines similar to the one now required by you, which as you are probably aware, is our patent and cannot be supplied by any other maker.[116]

Warren makes the point that although rising customs duty in France was having a serious impact on English locomotive manufacturers, Robert Stephenson continued to receive the benefit of royalties.[117]

The patent system enabled Robert Stephenson and Co., largely as a consequence of the efforts of Edward Starbuck, to expand its business both home and abroad. As acknowledged by Tann, patents were an

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[110] Kirby, "Product Proliferation," 290.
[111] Biagioli, "Patent Republic," (2006).
[112] Lionel Bently, "The 'Extraordinary Multiplicity' of Intellectual Property Laws in the British Colonies in the Nineteenth Century," *Theoretical Inquiries in Law* 12, (2011): 161-200, 164.
[113] Company accounts indicate that in 1846 the average price of a locomotive was 'about £1,800 but expected shortly to be £2,000'; quoted in Warren, *A Century of Locomotive Building*, 101.
[114] Starbuck, letter to Emile Martin, February 5, 1844, Letterbook DT.STB 131/1.
[115] Starbuck, Accounts 1852-1855, DT.STB /131.
[116] Starbuck, letter to Eastern Counties Railway, London, May 27, 1844, Letterbook DT.STB 131/1.
[117] Warren, *A Century of Locomotive Building*, 101.

inspired form of advertising.[118] During the period Robert Stephenson and Co. was expanding its manufacturing base, the application for a patent in respect of inventive activity became standard practice. Any initial tardiness shown by the Stephensons towards patenting would have brought them into sharp contrast with the developing manufacturing sector of the time. It was in Starbuck's commercial interest to maintain a strict marketing regime, at home and abroad, because as demonstrated by his accounts, he received a 15 per cent commission.[119] By way of example, Starbuck's invoices to Robert Stephenson and Co. for the three months ending March 1854 show that the sum of £1,119.15.8 was claimed,[120] and for the three months ending June 1855 the sum of £149.13.11.[121] An examination of Starbuck's accounts indicates that Robert Stephenson himself earned several thousand pounds per annum from his patents. In the peak year of 1856 he grossed over £12,000 from royalties alone.[122] It is clear that Starbuck not only went to great lengths to place Robert Stephenson and Co. in a position where a sale of a locomotive could be achieved, but that Robert Stephenson held him in high regard. For instance, in a letter written on 18 September 1857 to William Budden, secretary and accountant at Forth Street, Robert Stephenson stated,

> I think under the circumstances to which the south eastern order was obtained Mr Starbuck is entitled to his two and a half percent commission although it may have been a loss to you. If he had not gained access to the Chairman after a very good deal of trouble we should have been shut out of tendering and that at a time when we were almost standing still for want of an order.[123]

There is also evidence that Starbuck's efforts were recognised and supported by John Sanderson, Robert Stephenson's father in law, who in a letter to Budden dated 6 February 1846, noted that Starbuck was owed for commission due on the Norfolk, and London and Birmingham Railways.[124] Similarly, in a letter written in 1848, Sanderson reminds Starbuck that his commission is due.[125] He makes the point that commission is due in respect of 'patent rights' and unconnected to the amount of locomotive building the works had to complete. The death of Starbuck in 1855 would have been a great loss to Robert Stephenson.

Another key player in the Stephensons' demonstrable, and growing reliance on the patent system, and one rarely mentioned in the considerable literature generated by academic interest, was the Company's solicitors, Stanton Croft and Co.

5.5 Stanton Croft and Co.

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[118] Jennifer Tann, "Marketing methods in the international steam engine market," *Journal of Economic History* 38, (1978): 363-391.
[119] Starbuck Accounts 1852-1855, DT.STB 131/73.
[120] Starbuck Accounts 1852-1855, March 1854, DT.STB 131/73.
[121] Starbuck Accounts 1852-1855, June 1855, DT.STB 131/81.
[122] Starbuck Accounts 1856, DT.STB 131/53.
[123] Stephenson, letter to W.H. Budden, September 18, 1857, Letterbook, DT.STB 131/45.
[124] Sanderson, letter to W.H. Budden, February 6, 1846, Letterbook, DT. STB 131/42.
[125] Sanderson, letter to E.F. Starbuck, November 13, 1848, Letterbook, DT.STB 131/81/7. J. E. Sanderson was the father of Fanny whom Robert Stephenson married in June 1829.

Stanton Croft and Co., solicitors, founded by Philip Holmes Stanton of Newcastle in 1821, acted for both George and Robert Stephenson, and latterly for Robert Stephenson and Co. The partners changed over the years, but the firm retained Robert Stephenson and Co., and was instructed in a number of litigation cases involving patents.[126] It is clear that Robert Stephenson and Co. not only robustly protected their own patents, but also took stout steps to defend cases of alleged patent infringements made against the Company. It is argued here that the Stephensons' approach and attitude to patents and patent rights would have been well known within the emerging locomotive manufacturing industry and could have served to encourage others to pursue innovative developments not protected by a Stephenson patent.

In this context it is also relevant to note that in contrast to Isambard Kingdom Brunel's practice (as explored in chapter 6), Robert Stephenson and Co. appears to have taken a pragmatic approach when the need arose to utilise an invention for which others held the patent. The strategy was perhaps led by Robert Stephenson himself, but there is evidence that the practice was continued by the Company after his death. William Weallens, an employee of Robert Stephenson and Co. who died on 2 November 1862, had taken out letters patent on 17 February 1861 for improvements in steam engines and boilers, and propelling steering vessels.[127] There is no evidence now available to demonstrate the circumstances of the patent, but it would not seem unreasonable to conclude that the Company was supportive of employees taking out patents and may have come to a financial arrangement with Weallans. A further example is provided by Thomas Mordue, employed by Robert Stephenson and Co. as marine draughtsman, who on 5 November 1868 assigned to the Company his patent for improvements to steam boilers.[128] These fragments of information suggest that Robert Stephenson and Co. recognised the value of patents held by others and took proper commercial steps to be in a position to utilise them.

Finally, in relation to Robert Stephenson's attitude to patents, his role in the setting up of the Electric Telegraph Co. is of significance for the arguments being made in this chapter. The Electric Telegraph Co. was a joint stock company with the primary objective of exploiting the electric telegraph patents of Cooke and Wheatstone. In chapter 7 it is argued that Robert Stephenson was a secret purchaser of a substantial interest in the Electric Telegraph Co. (whose overall value in today's money was said to be in the region of £9,000,000) with the aim of supplying the electric telegraph to the early railway companies. In October 1855 Robert Stephenson became Chairman of the Company before resigning in 1858. The evidence relating to Robert Stephenson's involvement with the Electric Telegraph Co. is

[126] *Robert Stephenson and Co. v Charles Mitchell and Co.; A. Leslie and Co. v Robert Stephenson and Co*. are two examples; see, Stanton Croft, DT/SC/310/10.
[127] William Weallens, Letters Patent, Stanton Croft, DT/SC/308/1-2.
[128] Thomas Mordue, Deed of Assignment to Robert Stephenson and Co., November 5, 1868, Stanton Croft, DT/SC/309.

explored in detail in chapter 7, but it suggests that Robert Stephenson's utilisation of the patent system was an essential element of the commercial fabric within which he and others operated.

Robert Stephenson died on 12 October 1859 at the age of fifty-six. Rolt in commenting on his death and that of George Stephenson said 'they were the pioneers, and with their deaths a great era of heroic endeavour drew to an end ... they laid the foundations of the modern world and all our subsequent achievements'.[129] Whilst Rolt's comments are undoubtedly sound, they fail to recognise the entire facts. In particular, they fail to give credit to those who supplied the business acumen, including the obtaining of patents in pursuit of the control and management of inventive knowledge, which enabled Robert Stephenson and Co. to develop and capitalise upon the extraordinary talents of their engineers.

5.6 Conclusion

It has been argued in this chapter that adequate remuneration was a significant motive for the railway pioneers who chose to patent their inventions. In considering this financial motivation, it has been important to place the heroic view of Victorian engineers in context and, in particular, to consider the influence and actions of those individuals who enabled George and Robert Stephenson to build their well-deserved reputations. This chapter has established that the business acumen of individuals such as Edward Pease, Thomas Richardson and Michael Longridge were central to this consideration. For example, Pease, an established Quaker businessman of the time, recognised the economic potential of railway innovation, and it was Pease who understood the need for patent protection if the combined talents of father and son were to be fully realised in terms of financial return. The foundation of Robert Stephenson and Co. in 1823 marked the inauguration of the modern locomotive industry and it has been argued in this chapter that the Company's use of the patent system was a key factor in its development into one of the most successful engineering manufacturers in Europe. The early failure (prior to 1833) fully to protect their inventive activity by patents, meant that competitors threatened the Stephensons' prime manufacturing position.

There is no evidence to suggest that the Stephensons were deterred by any perceived shortcomings of the patent system. The approach and attitude of George and Robert Stephenson, and their business associates, to patented inventive activity does not support prevailing academic opinion that the patent system of the time was largely ineffective. There is no evidence to suggest that the Stephensons or their partners found the patent system to be costly, unworkable and or London-centric. On the contrary, the evidence considered in this chapter confirms that George and Robert Stephenson, pioneers of early railway technology, found great utility in the patent system and this may have served to encourage further railway-related inventive activity. The effectiveness of the patent system may have served to motivate and incentivise other engineers, and manufacturers seeking to maximise their profits, to seek

[129] Rolt, *George and Robert Stephenson*, 335.

alternative designs as they endeavoured to avoid infringing existing patents. As discussed in chapter 4, much of the literature concerning the patents taken out by James Watt seeks to argue that patents had a stifling effect upon railway-related inventive activity. However, the evidence presented here suggests that patents taken out by Robert Stephenson and Co. encouraged other locomotive manufacturers to look for new designs.

This chapter has considered evidence that, in the case of the George and Robert Stephenson, patents and the patent system encouraged and supported inventive activity and assisted in the diffusion and management of technological knowledge. In order to consolidate these arguments, the following chapter considers Isambard Kingdom Brunel, whose public persona as a patent abolitionist presents a substantial test to the premise of this thesis.

CHAPTER 6

MARC ISAMBARD BRUNEL AND ISAMBARD KINGDOM BRUNEL

> The whole system of patents is, in the present advanced state of arts and science and manufacturers, one productive of immense evil.
>
> Isambard Kingdom Brunel[1]

Introduction

In this chapter it is demonstrated that Isambard Kingdom Brunel's public stance on the value of patents differed substantially from his *modus operandi*. It is argued here that prevailing academic opinion as to Isambard Brunel's perceived involvement with patents should be reassessed. The evidence considered in this chapter demonstrates that Isambard Brunel, having declared patents to be 'productive of immense evil', nevertheless placed the patent system at the centre of particular aspects of his professional and commercial life. He was approached on numerous occasions by would-be inventors for his views as to their inventions, but would only engage with the inquirer provided they first applied for a patent. If they refused to do so, Brunel returned their correspondence on the basis, purportedly, that he wished to avoid any suggestion that he was in possession of secret information. If, and when a patent was obtained by the inquirer, it was Brunel's practice to use the patent as a base line invention and, subsequently, to make improvements which generally proved successful. It is argued in this chapter that in stark contrast to his public persona, Brunel's *modus operandi* had the effect of turning patents to his advantage. Inevitably, his stance led to incremental improvement of the original invention and it is argued here that Brunel's insistence on others' recourse to the patent system in effect encouraged inventive activity. Furthermore, the evidence considered in this chapter demonstrates that on occasion Brunel would recommend to his railway company clients that they enter into a licence arrangement with the original patentee, for the improved invention, thus diffusing the technology and, doubtless, adding to his own wealth.

6.1 Marc Isambard Brunel

Isambard's father, Marc Brunel, took out his first patent in 1799, and in the period to 1825 was granted some further sixteen patents (Table 8). This evidence, of early, regular use of the patent system supports one of the foundational arguments of this thesis, that the current historiography of the patent system should be reassessed. For all his inventive activity, Marc Brunel was often in financial difficulties and

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[1] Isambard Kingdom Brunel, *Memorandum for Evidence before the Select Committee of the House of Lords on the Patent Laws* (1851), Brunel Collection, Letterbook 8: 164-173, Bristol: SS Great Britain Trust.

spent periods of time in debtors' prison.[2] Nevertheless, he persisted with patenting his inventions. In 1818, his efforts came to fruition when he patented his most celebrated invention, a tunnelling shield, and he was able to realise the substantial sum of £5000. In 1829, giving evidence to a parliamentary select committee, Marc Brunel stated that he was supportive of the patent system. When asked whether he thought the patent laws benefitted the public, he replied 'very much so.'[3]

Table 8: Patents - Marc Brunel

	Subject matter	no.	date
i.	*Machine for writing and drawing ('Polygraph'*)	**2305**	11.04.1799
ii.	*Ships' blocks*	**2478**	10.02.1801
iii.	*Trimmings and borders for muslins, lawns & cambrics*	**2663**	25.11.1802
iv.	*Saws and machinery for timber sawing*	**2844**	07.05.1805
v.	*Cutting veneers*	**2968**	23.09.1806
vi.	*Circular saws*	**3116**	14.03.1808
vii.	*Boots and shoes*	**3369**	02.08.1810
viii.	*Apparatus for giving motion to machinery*	**3384**	01.10.1810
ix.	*Sawmills*	**3643**	26.01.1813
x.	*Rendering leather durable*	**3791**	12.03.1814
xi.	*Knitting machine*	**3993**	14.03.1816
xii.	*Forming drifts and tunnels underground*	**4204**	20.01.1818
xiii.	*Tinfoil manufacture*	**4301**	05.12.1818
xiv.	*Stereotype printing plates*	**4434**	25.01.1820
xv.	*Copying presses*	**4522**	22.12.1820
xvi.	*Marine steam engines*	**4683**	26.06.1822
xvii	*Gaz engines*	**5212**	16.07.1825

Source: Bennet Woodcroft, *Alphabetical Index of Patentees of Inventors from March 1617 to October 1852* (The Queens Printing Office, 1855; reprinted, London: Evelyn, Adams and Mackay, 1969), 76-77.

The achievements of Isambard Kingdom Brunel have somewhat overshadowed those of his father, Marc.[4] However, it is arguable that the technical feats achieved by Marc may make him the greater inventive genius.[5] For example, his manufacture of pulley blocks for the Royal Navy was a first occasion when machine tools were used for mass production.[6] He was also the first to utilise the 7ft railway gauge later adopted by Isambard Brunel, the first to design a bascule bridge and, most importantly, he designed and constructed the world's first tunnel beneath a river, for which he was

[2] He spent 88 days in the Kings Bench debtors' prison; Harold Bagust, *The Greater Genius? A Biography of Marc Isambard Brunel* (Hersham: Ian Allan Publishing, 2006), 55.
[3] Marc Brunel, May 11, 1829, *Select Committee on the Law Relative to Patent Inventions* (1829), 39.
[4] Marc Isambard Brunel was born on the 25 April 1769 at Hacqueville in France.
[5] Bagust, *The Greater Genius*? (2006).
[6] Keith Reginald Gilbert in *The Portsmouth Blockmaking Machinery* (London: H.M. Stationery Office, 1965), referenced by Caroline Cooper in "The Portsmouth System of Manufacture," *Technology and Culture* 25, (1984): 182-225, 182, n.1.

knighted.[7] The purpose of this section is not to seek to adjudicate as to whether it was the father or the son who was the greater creative talent, or to suggest whether it was the father or the son who should be credited with specific projects and designs. This section explores the role of patents in Marc Brunel's enterprises, in particular his tunnel boring machine, his renowned and most successful patented invention.

Marc Brunel's tunnel beneath the Thames was the first sub-aqueous tunnel in the world, save as to certain mine workings. A number of eminent engineers had made attempts to tunnel under the Thames, including Robert Vaize and Richard Trevithick, and Marc Brunel had previously drawn up plans for a tunnel under the Neva River at St. Petersburg, Russia, where spring ice floes threatened to carry away any bridge, but the scheme never came to fruition.[8] It is said that whilst working in Chatham dockyard, Marc observed and took inspiration from the activity of a ship worm, described by Bagust as responsible for the sinking of more ships than every canon in existence.[9] Whether or not Marc's innovative idea derived from the wood-boring mollusc, his tunnel shield has become the accepted method of tunnelling to this day. The shield consisted of a grid of iron frames pressed against the tunnel face and supported on a set of horizontal wooden planks (poling boards) that prevented the face from collapsing. The shield was topped by iron plates that formed a temporary roof to protect the labourers as they worked. Rather than hewing away at a large and exposed surface, they removed one poling board at a time. Brunel's basic ideas were used in the construction of the London Underground system and elements of his invention were present on the digging shields used during the construction of the Channel Tunnel. Lord Mair, in a recent Dickinson Memorial Lecture described the Thames Tunnel as a great legacy to modern tunnelling and the tunnelling machinery used today, particularly the Howden Back-Hoe Shield with its hydraulic back action.[10] As observed by Lydon, Brunel's Thames Tunnel spurred an innovation revolution in relation to tunnel design.[11]

In 1823, I.W. Tate, one of the promoters of the Archway Co., which had failed in its attempt to construct a tunnel under the Thames, learnt of Marc Brunel's tunnel shield invention and gathered together some influential friends to take the idea forward. Those discussions led to the formation of the Thames Tunnel

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[7] Marc Brunel was knighted in 1841, having previously received the French *Légion d'honneur* in 1829; Alan Muir Wood, "Brunel, Sir (Marc) Isambard (1769–1849)," in *Oxford Dictionary of National Biography*, ed. H. C. G. Matthew and Brian Harrison (Oxford: OUP, 2004); online ed., ed. David Cannadine, May 2005, http://www.oxforddnb.com/view/article/3774 [accessed 19 Sept 2015].

[8] Richard Beamish, *Memoir of the Life of Sir Marc Isambard Brunel* (Cambridge: Cambridge University Press, 2013), 189.

[9] The worm, *teredo navalis,* operated by digesting the wood and then excreting the residue in the form of a paste with which the tunnel behind it was then lined; Bagust, *The Greater Genius?* 65.

[10] Lord Mair, Dickinson Memorial Lecture, March 9, 2016, Science Museum, London; unpublished at time of writing.

[11] Rio Lydon, "The Eighth Wonder of the World: How might access for vehicles have prevented the economic failure of the Thames Tunnel 1843-1865?" *LSE Economic History*, Working Paper no.171, (London School of Economics, November 2012), 3, http://www.lse.ac.uk/economicHistory/workingPapers/2012/WP171.pdf [accessed September 20, 2015]

Co. which quickly attracted subscribers including a number of eminent engineers and professionals. The first General Meeting of the Company took place on 29 July 1824 when it was reported,

> Your Directors have made arrangements with Mr Brunel for the use of his patent, for which they have agreed to pay him £5,000 when the body of the tunnel shall be securely affected, and carried sixty feet beyond each embankment of the river, and a further and final sum of £5,000 when the first public toll under the Act of Parliament shall have been received for the use of the proprietors.[12]

Marc Brunel was appointed engineer to the Company at a salary of £1,000 per annum for a period of three years, 'the utmost limit which the Directors contemplate at this stage is necessary for the execution of the work'.[13] At that time, payment of £5,000 for the use of the patent was a considerable sum of money as was the promise of further payment of £5,000 which, in the event, failed to materialise. The tunnel opened on 25 March 1843, a construction period of significantly more than the three years originally envisaged.[14]

Marc Brunel went on to make several further applications for patents, and given the remuneration generated by his tunnelling shield, financial reward is likely to have been an incentive. Furthermore, it would be surprising if Brunel's hugely successful, lucrative patent didn't incentivise others to construct entirely novel boring machines. A notable example, perhaps, being Henri-Joseph Maus' 'mountain slicer', developed for the construction of the Frejus rail tunnel between France and Italy through the Alps. It would seem reasonable to suppose that Marc Brunel's resort to the patent system may have helped to shape the pace and direction of innovation.

Isambard Brunel assisted his father with the development of several of his patented inventions. For example, he conducted many of the experiments involved in the formulation of the specifications of the gaz engine project.[15] There is also some evidence that father and son were either experts or advisers in patent actions before the courts. In 1830, Isambard swore an affidavit for an infringement dispute between Alexander Galloway of the City of London Engine Manufactory and Braithwaite and Ericsson.[16] Also, Marc Brunel's involvement with patent litigation is evidenced in a number of legal reports in *The Times*.[17] The experience of developing an engine powered by gas, rather than steam, which proved entirely fruitless, caused Isambard to cite his father as evidence of the inequalities of the patent system. In 1851, giving evidence before a parliamentary select committee, Isambard Brunel stated,

> For twelve years ... I continued for my father, at very considerable expense, a long series of experiments for applying condensed gases as a motive power. Now, I believe, that if instead of working at it myself, it had been the subject of discussion and had been talked about more generally

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[12] Paul Clements, *Marc Isambard Brunel* (London: Longmans, 1970), 97.
[13] Bagust, *The Greater Genius?* 65.
[14] Bagust, *The Greater Genius?* 91.
[15] L.T.C. Rolt, *Isambard Kingdom Brunel* (London: Longmans Green and Co., 1960), 42.
[16] *The Times*, July 3, 1830.
[17] Including January 8, 1820; May 30, 1820; February 28, 1831; and, June 28, 1832.

in the world, it would either have failed a good deal sooner, and my father would have saved his money, or some good would have come out of it, instead of its becoming a dead letter.[18]

His point seems to be that working the patent had been a waste of time and money which could have been avoided had a more open forum approach been adopted. Nevertheless, it is possible to interpret his observation to the select committee as misleading since there was nothing to stop either of the Brunels from seeking further technical and commercial advice, but clearly they did not do so due, perhaps, to a desire to be in complete control of the project. Furthermore, Marc Brunel in giving evidence to a parliamentary select committee in 1829, in answer to the question as to whether a period of 14 years was long enough for a patent to be worked, replied, 'It is a great deal for some and not enough for some others; I shall lose probably six years before I come to make anything of my present patent.'[19] Buchanan has argued that the failure of Marc Brunel's gaz engine project coincided with Isambard Brunel's resolution never to take out a patent and to be an active opponent of the patent system.[20] This may be correct insofar as Isambard Brunel's public views were concerned, but in this chapter it is argued that a careful distinction needs to be drawn between his public views, and his professional dealings with others.

6.2 Isambard Kingdom Brunel: public persona

Isambard Kingdom Brunel's fame derives from his innovative engineering achievements, including railways, steamships, bridges, tunnels and viaducts. He is one of the great heroes of nineteenth century engineering. In 1910, he was described by *The Engineer* as 'all that constitutes an engineer in the highest fullest and best sense ... Brunel had no contemporary, no predecessor.'[21] More recently Brindle has accorded him with the epithet, 'the man who built the world'.[22]

Notwithstanding some very public failures, his status was such that, as observed by MacLeod, he was always able to 'wrench heroism out of the jaws of defeat'.[23] In 1845, the *Railway Times* commenting on the failure of the South Devon atmospheric railway, stated:

> We do not take him for either a rogue or a fool but an enthusiast, blinded by the light of his own genius, an engineering knight-errant, always on the lookout for magic caves to be penetrated and enchanted rivers to be crossed, never so happy as when engaged 'regardless of the cost' in conquering some, to ordinary mortals, impossibility.[24]

However, Buchanan has pointed out that a skewed approach to engineering biographical history has led to over-adulation of the leading engineers of the period. As a consequence, less prolific engineers have

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[18] I.K. Brunel, *Memorandum* (1851), Brunel Collection, Letterbook 8:164-173.
[19] Marc Brunel, June 8, 1829, *Select Committee on the Law Relative to Patent Inventions* (1829), 39.
[20] Angus Buchanan, *Brunel: The Life and Times of Isambard Kingdom Brunel* (London: Hambledon and London, 2002), 177.
[21] *The Engineer*, July, 1910.
[22] Steven Brindle, *Brunel. The Man Who Built the World* (London: Weidenfield and Nicholson, 2005).
[23] Christine MacLeod, "The nineteenth-century engineer as a cultural hero" in *Brunel: In love with the Impossible*, eds. Andrew Kelly and Melanie Kelly (Bristol: Bristol Cultural Development Partnership, 2006), 60-79, 62.
[24] *The Railway Times,* August 2, 1845, quoted in Adrian Vaughan, *Isambard Kingdom Brunel*. *Engineering knight-errant* (London: John Murray, 2003), 175

disappeared into anonymity.[25] More recent work has redressed the balance,[26] and chapter 8 of this thesis seeks to contribute to the literature in the context of early railway technology.

Isambard Kingdom Brunel was undoubtedly an engineer who made a substantial contribution to early railway technology. This chapter argues that it is important to examine how he went about his work, and the role played by patents in his professional strategies. It is proposed to examine firstly his publicly expressed views, and then to consider the inconsistent interpretations placed on those views by commentators. There are two documents upon which many commentators rely as to Brunel's opinion regarding patents. The first is a memorandum he prepared for a parliamentary select committee in 1851. The document contains conflicting views and most commentators have, unfairly, selected those aspects which are critical of the patent system, of which there are several, including,

> I have never taken out a Patent myself, or ever thought of doing so; and I have gradually become convinced that the whole system of Patents is ... one productive of immense evil. ... It impedes everything it means to encourage, and ruins the class it professes to protect. ... Patents are taken out even in very general terms, so as to embrace everything.[27]

The second documentary source is Brunel's reported observations on patent laws to the Meeting of the Society of Arts on March 28 1856. The contents are reproduced in full in a biography written by his son, Isambard Brunel (junior).[28] The account includes an oft repeated opinion by Isambard Brunel (senior) that the system of protecting invention by means of letters patent was 'productive of immense evil'. An opinion that exposed Isambard Brunel (senior) to much criticism.[29] Isambard Brunel (junior) stated that his father's opposition to patents was because he was 'continually being trammelled and thwarted in his various undertakings by patents'.[30] However, Isambard Brunel senior's approach to patents in his professional dealings, as explored below, suggests this analysis is incorrect.

Rolt considered Brunel's attitude to patents, but only in summary fashion restricting his examination within a narrow context. For example, in a chapter entitled 'Brunel Against Bureaucracy,' Rolt states,

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[25] Buchanan, *The Engineers: A History of the Engineering Profession in Britain 1750-1914* (University of Michigan: Kingsley, 1989).

[26] David Greenfield, "Brunel and William Gravitt, 1826-1841: Their Professional and Personal Relationship," (Ph.D thesis, University of Portsmouth, March 2011). Michael Corfield, "John Hore - Man of mystery? Man of genius!" *Journal of the Railway and Canal Historical Society*, 221, (November 2014):142-148.
Peter Cross-Rudkin and Mike Chrimes, eds. *Biographical Dictionary of Civil Engineers 1830-1890*, (London: Thomas Telford, 2008). Hugh Ferguson and Mike Chrimes, *The Contractors* (London: ICE Publishing, 2014). David Greenfield, "Brunel and William Gravitt, 1826-1841: Their Professional and Personal Relationship," (Ph.D, diss., University of Portsmouth, March 2011). See also Adrian Vaughan, "Who built Brunel?" in *Brunel: In love with the Impossible*, eds. Andrew Kelly and Melanie Kelly (Bristol: Bristol Cultural Development Partnership, 2006), 228-251. Vaughan examines those persons 'who helped [Brunel] achieve his fame and glory as a railway engineer [who] have been forgotten, or who were never known in the first place.'

[27] I.K. Brunel, *Memorandum* (1851), Brunel Collection, Letterbook 8:164-173, 164.

[28] Isambard Kingdom Brunel, *Life of Isambard Kingdom Brunel, Civil Engineer* (London: Longmans, Green and Co.,1870), 497-498.

[29] Brunel, *Life of Isambard Kingdom Brunel,* 489

[30] Brunel, *Life of Isambard Kingdom Brunel,* 490.

> Brunel's public life was remarkable for his roundly expressed hatred of government officials, and of any law, rule or regulation which interfered with individual responsibility or initiative. The patent laws were one of his anathemas ... they stifled invention instead of encouraging it.[31]

Citing the example of a rifle barrel designed by Brunel, Rolt states that Isambard Brunel refused to take out patents, an opinion offered without explanation. Rolt offers no analysis of Brunel's professed attitude to patents. Rather, he emphasises his observations to establish Brunel's disdain for bureaucracy.

The issue of Brunel's attitude to patents has also been addressed by Buchanan who, like Rolt, considers that Brunel's views on patents were part and parcel of his political principles. Buchanan suggests that many economic liberals of the day accepted that monopolies needed to be curbed in the interests of free trade and that there was a need for some state intervention. According to Buchanan, whereas Brunel remained with the 'ideological rearguard',[32] his views as expressed with regard to patent abolitionism were representative of his adoption of the *laissez-faire* principles of economic liberalism, but his eloquence of argument failed to change public opinion.[33]

It is proposed here that commentators concentrate on Brunel's negative comments and give insufficient weight to some of his more positive observations. For example, in his memorandum of 1851, Brunel wrote,

> I should, therefore, be an advocate for very cheap patents granted with great facility, to the poor illiterate workman, as well as to the rich manufacturer with his counsel and agents, and as well protected as legal ingenuity can devise.[34]

The commentaries by Brunel (junior), Rolt and Buchanan have over time created a crystallisation of Brunel's perceived views as those of an individual with a defiant and well-formed attitude against patents, and the patent system in general. However, given the complex character of Isambard Brunel, these views have not been subject to sufficiently careful analysis. Both Rolt and Buchanan reach conclusions as to his attitude to patents within a very narrow context, namely his economic liberalism. More detailed analysis is needed, and Miller goes some way to redress the balance.

6.3 Isambard Kingdom Brunel: inventive persona

Miller recognises that Brunel's historical reputation for taking a principled anti-patent stance has complex roots. In particular, he identifies the significance of Brunel's personality, his inventive persona, and proposes that Brunel got what he wanted when principle, practice and persona combined.[35] According to Miller, Brunel read every patent as a patent of method, or process, and complained about them being constraints upon progress.[36] Miller's analysis is relevant to the arguments presented in this

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[31] Rolt, *Isambard Kingdom Brunel*, 217.
[32] Buchanan, *Brunel*, 177.
[33] Buchanan, *Brunel*, 177-178.
[34] I.K. Brunel, *Memorandum* (1851), Brunel Collection, Letterbook 8:164-173.
[35] David Miller, "Principle, practice and persona in Isambard Kingdom Brunel's patent abolitionism," *The British Journal for the History of Science,* 41, no.1 (2008): 43-72.
[36] Miller, "Principle, practice and persona," 67.

thesis, but can be challenged in two important respects. Firstly, Miller's understanding of Brunel's objection to patents of 'principle', is based on a misconception that the law at the time did not allow patents of principle, there being a requirement that the specification be of a practical product. However, as discussed in chapter 2, the principle that a *process* could be the subject of a patent was established in 1774, with the case *Roebuck v Stirling*.[37] Secondly, Miller concurs, incorrectly, with MacLeod that the patent system was one of mere registration. As has been demonstrated in previous chapters, a system of adjudication was in existence and patent applications were frequently challenged at caveat hearings. Interestingly, there is evidence that Isambard Brunel appeared as an expert witness at caveat hearings.[38]

Miller proposes that once involved with a project, Brunel exhibited a compulsive inventive activity that led to almost maniacal experimentation.[39] As Rolt saw it, Brunel 'never stood still, never rested content with past achievements'.[40] According to Marsden and Smith, whilst Isambard Brunel was an engineer of extraordinary vision, he should also be understood as a systems builder, an individual with a grasp both of technological know-how, and business acumen, who sought to exercise supreme control over his various projects.[41] Brunel's exuberance and sheer courage were crucial elements of his heroic status, and yet he is one of the few engineers of his time whose relationship with his contractors deteriorated to the point of premeditated physical violence. In 1851, during the construction of the Chipping Campden Tunnel on the Oxford, Worcester and Wolverhampton Railway, Brunel assembled a force of 2000 to expel his contractor, Marchant, from the site. A pitched battle took place and Marchant conceded defeat, his men being outnumbered seven to one.[42]

The arguments presented in this chapter build on Miller's evaluation of Brunel's approach to some of the patented inventions that he aspired to use in his various ventures. There is compelling, contemporary evidence that patents played a significant role in his professional and private dealings. Prior to a detailed consideration of that evidence, the following section addresses Brunel's statement, made in 1851, 'I have never taken out a patent myself, *or ever thought of doing so* [author's italics].'[43]

6.4 Isambard Kingdom Brunel: the potential patentee

In 1841, during experimentation with locomotive design, Brunel explored the use of fans to aid exhaust of the steam engine. In particular, the process of venting waste steam up the chimney of a locomotive, which had the effect of creating a draught aiding fuel combustion. A number of patents were already in

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[37] *Roebuck v Stirling* (1774) 1HPC 174-177; Bottomley, *The British Patent System*, 150.
[38] *Select Committee on the Signet and Privy Seal Offices* (1849), 4.
[39] Miller, "Principle, practice and persona," 50.
[40] Rolt, *Isambard Kingdom Brunel*, 179.
[41] Ben Marsden and Crosbie Smith, *Engineering Empires: A Cultural History of Technology in Nineteenth-Century Britain* (Basingstoke: Palgrave Macmillan, 2005), 147.
[42] Martin Barnes, "Civil engineering management in the Industrial Revolution," *Minutes of Proceedings of Institution of Civil Engineers* 138, (August 2000): 135-144, 138.
[43] I.K. Brunel, *Memorandum* (1851), Brunel Collection, Letterbook 8:164-173, 164.

existence for fans designed to blow fires, but Brunel considered the use of a fan to aid exhaust to be 'an entirely new thing'.[44]

On 21 January 1841 he wrote to John Farey, consulting engineer and patent expert, seeking advice. It is clear from the letter that Brunel was contemplating taking out a patent in respect of his invention. His language is indicative of a patentee application, and suggests his motives were not limited to that of pecuniary advantage or monopoly,

> After a long period of experimentation which has cost a great deal of money ... the use of a fan for blowing fires is not very common ... I wish to know whether it is patentable. There is the peculiarity in the fan which is capable of being patented ... I think if patentable [it] would be very valuable ... I shall feel obliged if you will advise professionally on the point. I have reasons quite apart from any idea of pecuniary advantage or monopoly ... which makes me very desirous of securing a patent for my engine.[45]

In the event, the patent was not taken out and in the absence of further surviving correspondence there is no knowing either Farey's advice or whether it was heeded by Brunel. Nevertheless, the letter is important because ten years later, when Brunel drafted his memorandum for the parliamentary select committee, he was incorrect to state that in relation to patent applications he had 'never … or ever thought of doing so'.[46] There had been many events in the intervening years of Brunel's very full life and he may have forgotten his request to Farey, but the letter is evidence of Brunel's recognition of the potential economic value of a patented invention. Furthermore, the letter is not an isolated exception. Brunel's correspondence reveals that his public stance, was at variance with his professional and private dealings involving patents.

6.5 Isambard Kingdom Brunel: *modus operandi*

Brunel's extensive, surviving personal correspondence sheds light on his approach to patents.[47] A striking characteristic is the considerable number of letters from importunate and expectant patentees, whose number grew exponentially during the 1840s doubtless as a consequence of the railway mania and Brunel's increasing fame, and his association with well-publicised projects. An interesting insight is provided by his reply to the Reverend J. Hickman,

> You are perfectly right in supposing that I have frequent applications on the subject of new or supposed new inventions, but probably you have no idea of the number of such applications - the result is that I am compelled to attend to none - the mere replying to the letters as on the present occasion occupies more of my time than a professional man ought fairly to be called upon to give away.[48]

[44] I.K. Brunel, letter to John Farey, January 21, 1841, Brunel Collection, Letterbook 2A:44-45.
[45] I.K. Brunel, letter to John Farey, January 21, 1841, Brunel Collection, Letterbook 2A:44-45.
[46] I.K. Brunel, *Memorandum* (1851), Brunel Collection, Letterbook 8:164-173, 164.
[47] The letters are contained in the Brunel Collection Letterbooks, SS Great Britain Trust, Bristol. The handwriting of Brunel and his clerks is at times difficult to decipher and the symbol '?' is used to designate meaning that is unclear.
[48] I.K. Brunel, letter to Revd. J. Hickman, July 7, 1848, Brunel Collection, Letterbook 6:63-64.

Despite Brunel's claim that he did not reply to such approaches, the evidence demonstrates otherwise. Furthermore, anyone who approached him with an invention, and sought his advice, had to abide by Brunel's rule that they must first have patented their idea. Brunel would ask for a positive indication that the idea being considered had been patented and if the answer was no, then Brunel would not enter into further correspondence. It could be argued that Brunel was being reasonable in protecting his own reputation, that he wished to avoid accusations of plagiarism. However, such protection could have been achieved in a number of ways without the need for Brunel to insist on a patent application. In today's terminology, there could have been a non-disclosure agreement (NDA) which would have afforded him full protection.

Writing to E. Sheldon on 25 November 1840, Brunel stated,

> I make it a rule of never receiving communications on the subject of inventions until they have been secured by patent in order that I may not be in possession of any information regarding secrecy which that communication receipt of which involves. [49]

On 16 July 1841 Brunel wrote to Charles Russell MP,

> I have seen Mr Lee who has brought a letter from you but his inventions are numerous and all to be the subjects of patents and consequently as yet secrets which I am obliged to make a rule never to allow to be communicated to me.[50]

Brunel's insistence, that his correspondent should first take out a patent, was an interesting response. A simple agreement as to confidentiality would have protected all parties' interests. Furthermore, his subsequent insistence on improving the patent demonstrates that he was moving beyond the protection of his own reputation, to a point where he was seeking to enhance his heroic status. Brunel's correspondence provides clear evidence that the inventors of the day had no choice but to take out a patent if they wished to engage his attention. The evidence demonstrates that patents were an essential component of Brunel's professional dealings.

Brunel's attitude towards individuals who approached him with a patented invention that was of interest to him, or might potentially create an obstacle as he sought to advance one of his own ideas, is of particular significance to the arguments developed in this thesis. As is demonstrated below, Brunel would bring his extensive inventive mind to the proposed invention and then claim (as was often true) that he could make considerable improvements. He would argue that he had transformed a patent into a useful commercial invention that released the financial potential of the original patent. This was not normal commercial negotiation as to fees or royalties or the enhancement of reputation, but Isambard Brunel using his engineering genius and public standing to present himself as a co-inventor. In extreme cases Brunel would argue that his developments had produced a new invention such that the original patent had no standing.

[49] I.K. Brunel, letter to E. Sheldon, November 25, 1840, Brunel Collection, Letterbook 2b:118.
[50] I.K. Brunel, letter to Charles Russell MP, July 16, 1841, Brunel Collection, Letterbook 2b:198.

Those who were not prepared to allow Brunel to suggest improvements, but sought to impose upon Brunel their patented rights, received short shrift. For instance, John Barton suggested to Brunel that he might purchase his patented invention.[51] Brunel was not interested and his explanation to his son, in 1842, was to the point,

> Mr Barton has certainly hit upon a mode of effectively preventing my considering his invention ... He thinks one of its principal merits is its applicability to a line of country which might afford an opportunity for a line competing and therefore injure the lines I am interested in and suggests the buying of the invention to prevent its being used. I would as willingly discourage an improvement by throwing doubts upon its merits as buy it up when its merits were proved and as I should not like to be suspected of the former I would rather not receive any communication on the subject.[52]

The Brunel correspondence reveals many examples of his consistent approach to, and use of patents as set out above, but three particular examples suffice to demonstrate the detail. Firstly, John Howard Kyan, an inventor who recognised the potential for patents to secure financial reward, took out patents in 1832 and 1836 for timber treatments and promptly sold them to the Anti-Dry Rot Company. 'Kyanizing', the subject of these patents, was appropriate for the treatment and preservation of wooden railway timber sleepers. Brunel's various railway company clients had obtained licences for kyanising, but in 1850 Brunel showed interest in another process known as 'burnettizing', patented by Sir William Burnett. In his letter to Sir William's agent on 5 April 1850, Brunel made it clear he had scant regard for the existence of the patent. He claimed that what was important to Burnett's process was Brunel's knowledge and experience which, he claimed, was superior to that of the patentee.[53] Brunel opined that he considered it necessary to throw away the solution that had absorbed impurities from the timber. He observed,

> I should be afraid to depend on [the process] unless I could afford to use the solution almost wastefully to inject a much larger quantity per load into the timber than recommended by you … a precaution which has never been sufficiently attended to but of which I soon discovered the necessity.[54]

The correspondence does not identify the outcome, but it serves to demonstrate Brunel's approach to achieving a price he was prepared to pay, or the payment of a minimal royalty.

Characteristically, Brunel would slowly and methodically build up a case to argue that he was in effect a co-inventor. There is no evidence that he ever became a formal co-patentee, but rather he negotiated a settlement with the enquirer that suited Brunel's own interests. Brunel would demand a price ('at which [original, asking] price I shall not trouble to make it')[55] and subsequently obtain a licence for a number of railway companies with whom he had projects. This was not a negotiating method to achieve a reduction in royalty payments *per se*, but Brunel using his reputation to argue that he had the better grasp

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[51] Between 1809 and 1850, John Barton took out 10 patents; Bennet Woodcroft, *Alphabetical Index of Patentees of Inventors from March 1617 to October 1852* (The Queens Printing Office, 1855; reprinted, London: Evelyn, Adams and Mackay, 1969), 28-29.
[52] I.K. Brunel, letter to Sir I. Brunel, October 17, 1842, Brunel Collection, Letterbook 2c:73.
[53] I.K. Brunel, letter to Charles Jackson, April 5, 1850, Brunel Collection, Letterbook 7:178-180.
[54] I.K. Brunel, letter to Charles Jackson, April 5, 1850, Brunel Collection, Letterbook 7:178-180.
[55] Miller, "Principle, practice and persona," 59.

of the engineering practicalities. The important point for this thesis is that irrespective of the view taken as to his methods, the patent system played a vital role in Isambard Brunel's *modus operandi*. There is good evidence that Brunel recognised the value of the patent system, and made use of it albeit indirectly in that he encouraged others to take out patents. To attract and to hold Brunel's attention with an idea an inventor had first to obtain a patent and then be prepared to negotiate with Brunel as to improvements. It is argued here that his insistence on recourse to the patent system (despite public statements to the contrary) had the two-fold effect of incentivising patented inventive activity and contributing to the developing database of technological knowledge.

A second, pertinent example of Isambard Brunel's attitude towards patents, though not directly related to railway technology, is his adoption of marine screw propulsion rather than the paddle-wheel system for his *SS Great Britain*. Brunel had been impressed by the new technology, but was faced with a multiplicity of existing patented designs. Caldwell suggests there may have been as many as ninety,[56]and at that time a number of patentees of screw propellers were involved in heavy, expensive litigation.[57] In 1840, financial backers of the pioneering work of Francis Pettit Smith formed the Ship Propeller Co. to fund the construction of a trials ship, *Archimedes*, to demonstrate the new form of screw propulsion to the Royal Navy. In 1841, the Admiralty approached Brunel in his capacity as Consulting Engineer and asked him to advise on the adoption of screw propulsion for *Rattler*.[58] The Ship Propeller Co. supplied essential development research and, from 1843 to 1845, *Rattler* underwent extensive trials. Between them, Smith and Brunel produced an efficient screw. It was their conjoint work that took the screw to a position where it operated efficiently. Ultimately, the Ship Propeller Co. went into liquidation.[59] Prior to that happening, Brunel had established himself as co-inventor with Smith of the new screw propeller, claiming that it was he, Isambard Kingdom Brunel, who had carried out further work to determine the size, shape and fitting for the screw. Brunel's involvement in these trials, conducted at public expense, provided him with the valuable information he needed for the design of screw-steam propulsion for his own project, the *SS Great Britain*.[60] According to Lambert, Brunel was the master of negotiation in obtaining free advice and avoiding infringement of competing patents, and or litigation.

It is not clear whether Brunel sought to place pressure on Smith, but on 1 April 1844, he wrote to Smith in the following dismissive terms, setting out that he had little regard for the existing patents.

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[56] J.B. Caldwell, "The three great ships," in *The Works of Isambard Kingdom: An engineering appreciation*, ed. Alfred Pugsley (Cambridge: Cambridge University Press, 2010): 137-62, 158.
[57] *Lowe v Penn*, "Court of Queen's Bench, Westminster, May 11." *Times* May 12, 1846: 7, *The Times Digital Archive*. [accessed March 19, 2016]. *Woodcroft v Smith*, "The Judicial Committee of The Privy Council," *Times*, March 12, 1846: 7, *The Times Digital Archive*. [accessed March 19, 2016].
[58] Andrew Lambert, "The SS Great Britain," in *Brunel: in Love with the Impossible*, eds. by Andrew Kelly and Melanie Kelly, (Bristol: Bristol Cultural Development Partnership, 2006), 163-180, 169.
[59] Buchanan, *Brunel*, 179.
[60] Andrew Lambert, "The Royal Navy and the introduction of screw propellers,1837-1847," in *Innovation in shipping and trade*, ed. Stephen Fisher (Exeter: Exeter University Press, 1989), 61-88.

> According to your requests I applied to the Admiralty on the 23rd for an order to make the screw of which I had a drawing. In their reply this application was not referred to. I therefore spoke again on the 29th and have just received a copy of which I enclose a copy. I do not understand the distinction drawn as all the screws are the subjects of patents but of course I can say no more.[61]

On 4 April 1844, Brunel wrote to the Admiralty to inform them that Smith,

> … does not propose to take out a patent for the modification of the screw ... and I therefore convey Mr Smith's request that the Lords of the Admiralty order the construction of the screw... in order that the screw may be fixed to *The Rattler*.[62]

There is no evidence to suggest why Smith did not take out a patent for the improvements, which may have proved to be very profitable, but it is likely that Brunel used his powers of persuasion if not his celebrity status to persuade Smith of the futility from Isambard Brunel's perspective. Brunel extracted information, for no payment, from the Ship Propeller Co. before it went into liquidation and then navigated his way through an array of patents, which could perhaps be interpreted as an exploitation of Smith.

The third and final example of Brunel's *modus operandi* is illustrative of his approach in situations where he found himself unable to suggest substantive improvements to patents. In correspondence with Hunt and Hunt, agents for the patentee of Wrights Patent Steam Generator, Brunel stated that he would 'almost certainly find defects and difficulties'.[63] The agents persisted with their request for Brunel's advice, and he embarked on a series of experiments.[64] On 10 August 1850, Brunel reported to the agents, 'I must therefore ascribe the satisfactory results obtained as to the operation of the patent'.[65] However, he concluded his letter with the sceptical advice that,

> … several mechanical difficulties will arise and these no doubt may be overcome but everything will depend upon the judgement with which such difficulties are met … the peculiar operation of the Gridiron forming a number of distinct jets of flame to which the oxygen could more freely have access and the combustion be thus rendered more perfect.[66]

Even in circumstances where Brunel found satisfactory test results, he still went on to suggest alternatives. Furthermore, he left the patentee in no doubt that even in those cases where he could advise no substantial improvement, there would come a time when the patentee would need to refer back to Brunel.

In 1851, Brunel's *modus operandi* was threatened by the formation of the Permanent Way Co. In January 1852, the following advertisement appeared in the *Times*:

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61 I.K. Brunel, letter to F.P. Smith, April 1, 1844, Brunel Collection, Letterbook 3:8.
62 I.K. Brunel, letter to Sir John Barrow, April 4, 1844, Brunel Collection, Letterbook 3:8-9.
63 I.K. Brunel, letter to Messrs W. O. Hunt and W. Hunt, June 17, 1850, Brunel Collection, 7.
64 I.K. Kingdom Brunel, letter to Messrs. W. O. Hunt and W. Hunt, July 15, 1850 and July 24, 1850, Brunel Collection, Letterbook 7: 267, 276-277.
65 I.K. Brunel, letter to Messrs W. O. Hunt and W. Hunt, August 10, 1850, Brunel Collection, Letterbook 7:286-288.
66 I.K. Brunel, letter to Messrs W. O. Hunt and W. Hunt, August 10, 1850, Brunel Collection, Letterbook 7: 286-288.

> THE PERMANENT WAY COMPANY, in connexion with Contractors of eminence are prepared to make arrangements for the CONSTRUCTION and MAINTENANCE of PERMANENT WAY, under their patents, on terms offering important advantages to railway companies.[67]

The Company, whose members included many of the leading engineer patentees of the day,[68] possessed resources, intellectual, financial and organisational, that could have proved resilient to Brunel's methods of working around existing patents. It may also have presented as an alternative organisation for the provision of advice to potential patentees. In many respects, the Permanent Way Co. posed a threat to Isambard Brunel's reputation.

Brunel chose the forum of the Institution of Civil Engineers to voice his objection to the Permanent Way Co.'s operations. On 10 February 1852, within months of Brunel's infamous anti-patent statement to the parliamentary select committee, and in the presence of a number of members of the Permanent Way Co., William Bridges Adams, respected engineer and member of the Company, presented a paper entitled "The construction and duration of the permanent way of railways in Europe and the modifications most suitable to Egypt, India etc." At the meeting Brunel was very critical, noting that the modifications discussed were subject to patents. Brunel stated that the patents had not been tried, and probably never would be,

> The only effect therefore from this accumulating of numerous fanciful forms in one patent was, that when a really good form was devised it would be found to bear so close a resemblance to some of these imagined sections that either the use of the positive improvements would be prohibitive or a fertile field would be open to litigation ... it was notorious that engineers found their practices restricted by the claims of some potential patentee.[69]

Brunel was correct to draw attention to the multiplicity of often finely differentiated patented rails, but as will be discussed in some detail in chapter 8, the proliferation was mostly in direct response to the demands of rapid developments in steam locomotives and engineers' mindfulness not to infringe existing patents. This resulted in the patenting of many incremental improvements.

In a letter to Charles May (who was in effect the managing director of the Permanent Way Co.) Brunel warned of the dangers of a 'combination', that he would 'watch its proceedings with anxiety and even with suspicion, because it is capable of much evil'.[70] Brunel described the Permanent Way Co. as representing a possible obstacle to attempts at further improvements. His strident opposition to the Permanent Way Co. is interesting, and in keeping with his public persona,

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[67] "The Tradesman's Journal," *Times*, January 31, 1852: 2, *The Times Digital Archive*, [accessed on 19 March 19, 2016].

[68] W.B. Adams, P. Ashcroft, P.W. Barlow, P.S. Bruff, John Gardener, L.D. B. Gordon, C.F. Guitard, J.W. Hoby, Sir John Macneill, Charles May, Robert Richardson, James Samuel and Charles H. Wild; quoted in Miller, "Principle, practice and persona," 61, n.59.

[69] William Bridges Adams *et al*, "Discussion. The construction and duration of the permanent way of railways in Europe, and the modifications most suitable to Egypt, India etc.," *Minutes of the Proceedings of the Institution of Civil Engineers* 11, (1852): 273-298, 287.

[70] I.K. Brunel, Letter to Charles May, May 14, 1852, Brunel Collection, Letterbook 9:20-22.

> If you should unadvisably [sic] begin to throw the network of your combined patents about so as to entangle or embarrass our free movement and strain the line at all tight, you will find ... that the fish is much too strong for your health, the whale will disappear and be swallowed up.[71]

Yet the actions of the Permanent Way Co. were not so very different in nature to those of Brunel who sought by a variety of different means to gain control of a patent where it suited his own commercial advantage. Whereas the Permanent Way Co. was concerned to exploit existing patents, it is of relevance for the arguments developed in this thesis, that in conducting further experimentation and achieving improvements of the original patented invention, Brunel's *modus operandi* indirectly encouraged further inventive activity.

6.6 The atmospheric railway

The career of Isambard Kingdom Brunel was distinguished not only by his great achievements, but also by some engineering catastrophes. It is illustrative for the purposes of this chapter to examine the part played by patents in Brunel's dalliance with the most celebrated of his disasters, the collapse of the atmospheric system on the South Devon Railway.[72]

The atmospheric system involved a pneumatic device which relied on the pressure difference in a partial vacuum to propel a piston or capsule along a tube. Motive power was achieved for the railway by attaching the piston to a wheeled vehicle. During the 1840s, four atmospheric railways were built in England, Ireland and France. The French system lasted until 1860, the Irish system at Dalkey until 1854 and the two systems in England lasted just over a year. A number of other atmospheric schemes were considered, none of which materialised.[73] The failure of the atmospheric system has been attributed to a number of causes.[74] Atmore has argued it was a failure to consider contingent railway interests, principally operational, professional, corporate, financial and regulatory, as well as media and public interest.[75] According to Atmore, although the failure of atmospheric traction served many interests including that of the locomotive industry, mechanical problems combined with the financial crisis created by the railway mania bubble hindered further development. Buchanan, on the other hand, proposes that the atmospheric system was overtaken by improvements in steam locomotives thereby

[71] I.K. Brunel, letter to Charles May, May 14, 1852, Brunel Collection, Letterbook 9:20-22. Miller points out that the use of the word 'fish' goes deeper than just a simile, it being one of the key components of the rail construction for which the Permanent Way Co. held the patents; Miller, "Principle, practice and persona," 64.
[72] Charles Hadfield, *Atmospheric Railways. A Victorian venture in silent speed,* (Newton Abbot: David & Charles, 1967). Also F. Howard Clayton, *The Atmospheric Railways* (Lichfield: Clayton, self-published, 1966).
[73] Adrian Nicholls, *The London and Portsmouth Direct Atmospheric Railway: 'A mere puff of wind'.* (Fairford: Fonthill Media, 2013).
[74] Gooday suggests it is 'possible to claim that what 'fails' is *human expectations* of hardware performance and distribution - or rather a 'failure' of socio-technical relations: a failure of humans' effort to make technologies behave as if they were transparently simple and reliable of their own bodily agency'. Graeme Gooday, "Re-writing the 'book of blots': Critical reflections on histories of technological 'failure'," *History and Technology* 14, no.4 (1998): 265-291 286.
[75] Henry Atmore, "Railway Interests and the 'Rope of Air'," *British Journal for the History of Science* 37, no. 3 (2004): 245-279.

reducing the atmospheric system to a failed innovation.[76] Buchanan also draws attention to the railway mania which in the 1840s produced substantial capital for a variety of new schemes. This situation advanced railway systems, but when the mania ended, those railway schemes like the atmospheric, which were experiencing technical difficulties, found themselves short of funds.

In August 1844 Brunel produced a report for the directors of the South Devon Railway Co. where he stated,

> Gentlemen: I have given much consideration to the question referred to me by you at your last meeting – namely that of the advantage of the application of the atmospheric system to the South Devon Railway ... I have no hesitation in taking upon myself the full and entire responsibility of recommending the adoption of the atmospheric system on the South Devon Railway and of recommending as a consequence that the line should be constructed for single line only.[77]

In 1845, Brunel informed a parliamentary select committee that such railways had ‘a character of the travelling [which] may be rendered much more luxurious and more agreeable by the atmospheric system than by the locomotive’.[78] The select committee, appointed to enquire into ‘the merits of the Atmospheric System of Railway’, was convinced by Brunel’s (and others) arguments as to the ‘mechanical efficiency’ of the system.[79] Interestingly, the Committee rejected the views of Stephenson and Locke who were against the adoption of the atmospheric principle on the ground of their preference for ‘the Locomotive now in use’.[80] The Committee concluded with a strong opinion in favour of the general merits of the atmospheric principle, but that ‘experience can alone determine under what circumstances of traffic or of country the preference to either system should be given’.[81]

Many of the proponents of the atmospheric system claimed it guaranteed what traditional railways could not, namely, ‘perfect’ safety.[82] A pumping house could propel trains in only one direction along a particular stretch of line and there was no danger of collision, the common cause of many railway accidents. Brunel had been impressed (in stark contrast to Robert Stephenson)[83] with the emerging technology and in particular the demonstrations of atmospheric systems both at Wormwood Scrubs and on the Kingstown and Dalkey Railway. By 1847 some fifteen miles of single track railway had been laid between Exeter St. David’s and Teignmouth, and in 1848 it was extended a further five miles to Newton Abbott. Brunel’s support for the atmospheric system carried great weight given his reputation,

[76] R. Angus Buchanan, “The Atmospheric Railway of I.K.Brunel,” *Social Studies of Science* 22, (1992), 231-243.
[77] Isambard Kingdom Brunel, Report to the Directors of the South Devon Railway, August 19, 1844, Brunel Collection, Letterbook 2:261-267. The Report is reproduced in full in Adrian Vaughan, *The Intemperate Engineer. Isambard Kingdom Brunel in his words* (Hersham: Ian Allan, 2010), 234-238.
[78] Isambard Kingdom Brunel, April 4, 1845, *Report from the Select Committee on Atmospheric Railways together the minutes of evidence, appendix and index* (House of Commons, 1845), 14, 39.
[79] *Report from the Select Committee on Atmospheric Railways* (1845), iii.
[80] *Report from the Select Committee on Atmospheric Railways* (1845), iv.
[81] *Report from the Select Committee on Atmospheric Railways* (1845), v.
[82] Atmore, “Railway Interests,” 275.
[83] Robert Stephenson, *Chester and Holyhead Railway: Statistical Memoranda and Tubular Bridge Reports* (London: Smith and Gibbs, 1846).

and it gave the project a respectability and credibility which it had not possessed previously.[84] However, the following year, on 5 September 1848 the whole system was abandoned. Brunel wrote a long report to his directors where he concluded, 'from the foregoing observations, it will be evident that I cannot consider the result of our experience of the working between Exeter and Newton such as to induce one to recommend the extension of the system'.[85] As a consequence of this recommendation, the line was immediately converted to locomotive operation.

Sir Daniel Gooch later declared, 'this is certainly the greatest blunder that has been made in railways',[86] and Simmons in a telling conclusion stated it was a case of 'demand defeated by an insufficient technology'.[87] The insufficient technology extended to the pumping engines which were unable to cope with the irregular demands and unevenness of loading, and the poor communications between the pumping houses, even though the line was equipped with the latest Cooke and Wheatstone electric telegraph facilities which were by then being adopted for signalling on all major railways.[88] However, the foremost problem was the longitudinal valve in the piston in the tube between the rails. The valve depended on a leather flange fixed to the tube and sealed with a form of sealant which was subject to being soaked by rain and frozen by frost. Furthermore, according to South Devon legend the flap suffered from the depredations of rats attracted by the wax used to keep the leather supple.[89] It is significant for the arguments developed in this chapter that according to Atmore, had the directors and shareholders exhibited more patience, the problems would probably have been solved with attention being given to more powerful pumps and a new sealant developed.[90]

The atmospheric system in its various forms had resulted in numerous patents since George Medhurst, a manufacturer of scales, first took out a patent in 1799 for transporting goods and mail at high speed through an iron tube, intending to use a mixture of compressed air and atmospheric pressure.[91] There followed a procession of inventors including John Vallance, John Hague and Henry Pinkus, who in 1834 took out a patent and the following year launched the National Pneumatic Railway Association with the objective of promoting the adoption of atmospheric railways on 'all the railroads of England'.[92]

However, it was a gas engineer, Samuel Clegg, and brothers Jacob and Joseph Samuda, shipbuilders and marine engineers, who led the way in the development of the longitudinal valve. In 1838 they took

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[84] Buchanan, "The Atmospheric Railway," 233.
[85] Isambard Kingdom Brunel, Report to the directors of South Devon Railway recommending abandonment of the atmospheric system, August 19, 1848, Brunel Collection, Letterbook, 2:316-322.
[86] R.B. Wilson, ed., *Sir Daniel Gooch: Memoirs and Diary* (Newton Abbott: David and Charles, 1972), 47.
[87] Simmons, *The Victorian Railway*, 73.
[88] Buchanan, "The Atmospheric Railway," 231-243.
[89] Buchanan, *Brunel*, 110.
[90] Atmore, "Railway Interests," 277.
[91] George Medhurst, *Patent for a Condensing Wind Engine*, Patent No. 2299, February 28, 1799.
[92] Extracts from the Prospectus of the National Pneumatic Railway Association are quoted in *Mechanics' Magazine and Journal of Science, Arts, and Manufactures* 23, (1835): 66-72, 66.

out a patent for a 'new' improvement in valves.[93] Although a parliamentary select committee expressed some caution, the Clegg-Samuda system was recommended in 1845 by Charles Vignoles, William Cubitt and, notably, Isambard Kingdom Brunel.[94]

Brunel worked closely with Clegg and Samuda and the latter worked on the South Devon Railway from 1844 to 1847.[95] There is scant evidence of Brunel's approach to the existing patents for atmospheric railway technology. The preserved correspondence makes little reference to a professional enterprise, which he doubtless sought to erase from his memory. As wryly observed by Rolt, it was an 'atmospheric catastrophe'.[96] It is not clear whether Brunel approached Clegg and Samuda and whether or to what extent he sought to improve their invention. The valve problem was crucial to the success of the atmospheric system and the solving of the problem would have been of considerable importance to Brunel personally in the shoring up of his reputation following the debacle. Indeed his recommendation not to extend the system came exactly four years after the recommendation to proceed, a relatively short period in technology development.

Rolt opines that no fewer than seventeen patents had been taken out by patentees for the continuous valve alone,[97] but as with the screw propulsion Brunel was not fazed by the number of patentees with whom he had to deal. Brunel had proposed a hydraulic accumulator at each pumping station which would enable the engines to work more economically and the pipe to be exhausted more rapidly. However, it was clear that the real answers to the problem of the valve could only be provided by the patent holder Samuda who designed a second 'weather valve' to protect the continuous valve. Therefore, in this instance, Samuda's action frustrated Brunel's *modus operandi*. He was unable to convert the theoretical into the practical.

There is little documentary evidence as to the relationship between Samuda and Brunel. In particular, whether Brunel sought to be a co-patentee, and if Samuda was resistant to such a proposal. There is some evidence of tension between them because when Brunel recommended to the directors of the South Devon Railway Co. that the atmospheric experiment should be pursued no further, he added the rider that Samuda should be given the opportunity to renew the valve at his own expense.[98] The suggestion may have been to pass the blame to Samuda, but it was a wholly unrealistic proposal. Commentators agree that in June 1848 the cost of the renewal of the valve was an estimated £25,000 and it is not

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[93] Samuel Clegg, *A New Improvement in Valves, and the combination of them with machinery,* Patent No. 7920, January 3, 1839.
[94]The Committee concluded that they felt 'that experience can alone determine under what circumstances of traffic or of country the preference to either system should be given'; *Select Committee on Atmospheric Railways* (1845), v.
[95] Buchanan, "The Atmospheric Railway," 236.
[96] Rolt, *Isambard Kingdom Brunel*, 175.
[97] Rolt, *Isambard Kingdom Brunel*, 172.
[98] Isambard Kingdom Brunel, Report to the directors of South Devon Railway, August 19, 1848.

surprising that Samuda did not or could not take up such an invitation.[99] The demise of the South Devon Railway was followed by the closure of other atmospheric lines. Rolt, rather unfairly as it will be argued, described the atmospheric railway as ‘a fantastic mechanical joke’.[100]

It is surmised here that if Brunel had allowed Samuda sufficient time to solve the technical problems, the very early failure of the atmospheric railway may have been avoided. The key person at the time was Jacob Samuda (his brother had died in an accident in 1844) and he might have succeeded had he been granted additional time and the protection of patents for his continuing inventive activity. He was devising improvements to the valve right up to the time of the closure of the working South Devon line.[101] Brunel’s recommendation to close the project after four years was an insufficient period of time to perfect a new technology. Rather than provide an implied criticism of Samuda, a preferred course for Brunel might have been to persuade the directors to invest in Samuda’s continuing search for a technical solution. If a solution had been found, and made the subject of a patent, it would have provided a source of income from those other railway companies considering the atmospheric system. Steam locomotives were improving, but it is suggested here that there was ample room for a variety of systems of rail transportation, as is seen today.

At Dalkey a small plate was fitted by engineers to the longitudinal slit to protect the valve from the extremes of hot and cold. This improvement enabled the line to remain in operation for 10 years and the system was only abandoned as a consequence of the gauge conversion.[102] It is not clear why Brunel did not consider this improvement. It may have been an argument over royalty payments. Isambard Brunel may have been seduced by the lure of new projects, but it would have been advisable to support Samuda in the inventive process to find a solution. Such an approach would have prevented the damage to his reputation and atmospheric railways may have had a different future in England. Solutions to the difficulties have subsequently proved possible. Atmospheric railways have emerged later in time and in different forms, based on the core principles initially promoted by Brunel.

The concept of the Aeromovel invented by Oskar H.W. Coester, a Brazillan aerospace engineer, is employed in railway systems in Brazil and Indonesia.[103] Aeromovel is a reversed type of the atmospheric railway of Brunel. Instead of being propelled by a vacuum in a pipe line, the system uses a pneumatic blower which pushes air into the duct, or extracts air from the duct allowing the vehicle to be either pushed from the rear by positive pressure or pulled from the front by negative pressure, or a combination of both. Significantly, in contrast to Brunel’s atmospheric railway, each development of the Aeromovel

[99] Rolt, *Isambard Kingdom Brunel*, 171.
[100] Rolt, *Isambard Kingdom Brunel*, 174.
[101] Buchanan, “The Atmospheric Railway,” 239.
[102] Clayton, *The Atmospheric Railways*, 28.
[103] See, Aeromovel USA Inc., *Slot sealing system for a pneumatic transportation system guideway.* European Patent EP1028879. Appl. November 12, 1998.http://www.google.com/patents/US5845582

has been protected by the grant of a patent thus ensuring proper investment. The successful commercial application of Aeromovel suggests that had Brunel continued his search for a technical solution, and patented his incremental improvements, then the atmospheric system may have been a more significant feature of the early railways.

6.7 Conclusion

This chapter has considered the evidence that Marc Brunel took out seventeen patents, likely spurred on by the possibility of financial reward, and that his tunnel shield in particular secured him a significant sum. Moreover, the evidence considered in this chapter has challenged the scholarly consensus that Marc Brunel's championing of the patent system was not shared by his son. It has been argued here that the populist reading of Isambard Kingdom Brunel's stance as a patent abolitionist must be reassessed.

Notwithstanding his father's extensive patenting, Isambard Kingdom Brunel made public statements condemning the 'evils' of the patent system. However, the evidence considered in this chapter has demonstrated that his public utterances do not sit comfortably with the evidence. Several commentators have cited Brunel's public anti-patent statements as examples of his entrenched attitude to bureaucratic government officials and their intervention in matters of individual responsibility or initiative, whereas it has been argued here that Brunel's rhetoric should be re-evaluated. The more considered approach which has been undertaken here, including examination of his private and professional dealings, has generated a more nuanced understanding of Isambard Kingdom Brunel's attitude to patents. The evidence presented in this chapter demonstrates that Brunel's dealings with the 'smaller men' of invention amounted to the conversion of others' labour into his own heroic status.

As one of the great nineteenth century engineers, Brunel's fame and fortune attracted numerous enquirers and frequent applications on the subject of new or supposed new inventions. It has been argued here that Brunel went beyond an acceptable commercial stance to protect his reputation or accusations of breaching secrecy. His approach may not have been morally commendable, but Brunel's insistence that anyone seeking his opinion regarding potential technical advances should first take out a patent, is clear evidence that he regarded the patent system to be effective. It has been argued in this chapter that patents played an extensive role in Isambard Kingdom Brunel's business affairs, that he utilised the effective patent system to his commercial advantage. Furthermore, his exploitation of the patent system, through the agency of others, contributed to the accumulating database of technical specifications and the diffusion of technological knowledge.

CHAPTER 7

JOHN RAMSBOTTOM, WILLIAM COOKE AND CHARLES WHEATSTONE

Diligent, intelligent, dutiful, sober and conscientious personnel
... able to meet the demands of the emerging railways.
Duffy[1]

An army of mostly anonymous artisans and mechanics, the unsung foot soldiers of the Industrial Revolution who supplied that indispensable workmanship on which technological progress depended
Mokyr[2]

Introduction

This chapter considers three contributors to railway-related technologies whose legacies have not attracted the heroic status of some of their more famous associates. These three individuals fall comfortably into Duffy's classification of the intelligent and conscientious personnel who were able to meet the demands of the emerging railways.[3] The discussion is focused on John Ramsbottom, William Cooke and Charles Wheatstone, all of whom made extensive use of the patent system. John Ramsbottom, whose considerable accomplishments have attracted a number of accolades including, Victorian engineering giant,[4] and greatest locomotive engineer of the mid-Victorian period,[5] was a prolific inventor. His innovative output is relevant to the arguments developed in this thesis because he patented many of his inventions, across a number of technologies, including the early railways. Similarly, examination of the partnership of Cooke and Wheatstone, both of whom exploited the benefits of the patent system, reveals much about patentees' motives, and the role of patents in the pursuit of railway-related market dominance.

7.1 John Ramsbottom

Father of the modern locomotive.
Hambleton [6]

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[1] Duffy, *Electric Railways1880-1890*, 1.
[2] Mokyr, *The Enlightened Economy*, 108.
[3] Duffy, *Electric Railways*, 1. Cunningham's appraisal of David Joy's valve gear, refers to another generation of engineers who were equally talented but largely overlooked. James Cunningham, "David Joy and his Radical Valve Gear," (MA. Diss., University of York, 2001).
[4] Robin Pennie, *John Ramsbottom: Locomotive Engineer. A Victorian Engineering Giant* (Chester: Lancashire and Yorkshire Railway Society, 2008).
[5] O.S. Nock, *The Railway Engineers* (London: B.T.Batsford, 1955), 130.
[6] F.C. Hambleton, "John Ramsbottom. The Father of the Modern Locomotive," lecture delivered to the Stephenson Locomotive Society on March 9, 1936; partly reprinted in the *Journal of the Stephenson Locomotive Society* (February 1937): 1-30.

John Ramsbottom is representative of those engineers who responded to the many technical demands of rapidly developing railway technology. As the national network developed, the early railway companies entered into intense competition to secure freight and passengers, and to maintain a return to shareholders. They sought innovation in many aspects of their operations. In order fully to appreciate Ramsbottom's contribution to railway technology and the role of patents in his professional life, it is necessary to look briefly beyond 1852.

Described by his contemporary, Cusack Roney, as 'earnest, persevering, never tiring',[7] Ramsbottom joined Sharp Roberts and Co. of Manchester in 1839. In 1842 he was appointed Locomotive Superintendent of the Manchester and Birmingham Railway Co., which became part of the LNWR in 1846. In 1857, upon the retirement of Trevithick, he was promoted to Locomotive Superintendent based at Crewe Works, retiring through ill health in 1871. He later regained his health to become Consulting Engineer for the Lancashire and Yorkshire Railway Co. and a director of Beyer Peacock and Co.[8]

Ramsbottom's contribution to railway technology was significant. As observed by Hambleton, in 1936, his remarkable number of inventions 'by reason of their excellence' remained in universal use in the steam locomotives of the day.[9] It is argued here that many of Ramsbottom's patented inventions were incremental innovations, improving on previous, patented designs, and his patent rights would have caused others to seek additional improvements that avoided infringement of existing patents. The evidence considered in this chapter supports Rosenberg's work on technological diffusion which highlighted the importance of incremental or cumulative innovation as the driving force of mechanical progress.[10]

It was Ramsbottom's practice to take out a patent for each of his inventions, and during his lifetime he was granted twenty-four,[11] only three of which related to non-railway use (see Table 9). Two of his noteworthy inventions found universal application to steam engines. One of his earliest, the split piston ring proved very successful and is still used in almost all internal combustion engines. Ramsbottom took out the patent in 1852, and presented papers on the patented piston ring to the Institution of Mechanical Engineers (IMechE) in 1854 and 1855 (see Table 10).[12] His invention established a steam-

[7] Cusack Roney, *Rambles on Railways* (London: Effingham Wilson,1868), quoted in *Railway Magazine* 5, (1899): 232.
[8] Pennie, *John Ramsbottom*, 52.
[9] Hambleton, "John Ramsbottom," 1.
[10] Nathan Rosenberg, *Inside the Black Box: Technology and Economics* (Cambridge: Cambridge University Press, 1983)
[11] There were three engineers of the name John Ramsbottom and some authorities credit Ramsbottom with the total of all of their patents (40). See, Pennie, *John Ramsbottom*, 70.
[12] John Ramsbottom, "An improved piston for steam engines," *Proceedings of the Institution of Mechanical Engineers* 5, (1854): 70-74. John Ramsbottom, "On the construction of packing for pistons," *Proceedings of the Institution of Mechanical Engineers* 6, (1855): 206-208.

tight fit between the piston and cylinder wall involving circumferential grooves cut in the piston, into which were fitted narrow cast iron split rings. The split piston ring replaced the hemp packing used hitherto in steam engines, and the piston, with three piston rings, soon became the adopted standard. One of Ramsbottom's pistons tried out in Manchester ran 19,650 miles in 15 months, the rings doing 3,000-4,000 miles before being renewed. According to Hambleton, 'the rings cost a modest half-crown and their use resulted in an economy of 12 per cent.'[13]

Table 9: Patents - John Ramsbottom

	Subject matter	No.	Date
i.	*Vertical loom and weft-lock (with Richard Holt)*	**6644**	1834
ii.	*Rowing, spinning, and doubling of fibres*	**6975**	1836
iii.	*Railway wheels, and turntables (with William Baker)*	**12384**	1848
iv.	*Metallic piston and piston rings, and hydraulic throttle valve*	**767**	1852
v.	*Hydraulic hoist for rolling stock*	**309**	1854
vi.	*Improvements in welding*	**408**	1854
vii.	*Piston rings improvements*	**322**	1855
viii.	*Safety valves, and feed water cistern*	**1299**	1855
ix.	*Wrought iron rail chair*	**1047**	1857
x.	*Water trough and scoop*	**1527**	1860
xi.	*Displacement lubricator*	**2460**	1860
xii.	*Duplex steam hammer and cogging mill*	**924**	1863
xiii.	*Manufacture of hoops and tyres*	**48**	1864
xiv.	*Bessemer Converter improvements*	**3073**	1864
xv.	*Steam hammer improvements*	**89**	1865
xvi.	*Hammering and rolling machinery*	**375**	1865
xvii.	*Improvements to No.924 (1863)*	**736**	1865
xviii.	*Improvements to No.48 (1864)*	**1425**	1865
xix.	*Improvement processes for hoops and tyres*	**1975**	1865
xx.	*Supporting ingots for steam hammer*	**342**	1867
xxi.	*Traverser for rolling stock*	**386**	1867
xxii.	*Communication cord (provisional only)*	**2956**	1868
xxiii.	*Ventilating tunnels*	**820**	1869
xxiv.	*Trip gear for steam and gas engines*	**1060**	1880

Source: Robin Pennie, *John Ramsbottom: A Victorian Engineering Giant* (Chester: Lancashire and Yorkshire Railway Society, 2008), 70.

Ramsbottom's second major breakthrough was the safety valve. He took out a patent for the valve in June 1855,[14] and presented a paper to the IMechE in 1856.[15] The safety valve consisted of two parallel pipes projecting vertically from the top of the boiler, and between them a spring-loaded lever. As the pressure rose, the valve started to vibrate and produced a characteristic hum. Many of the antecedent safety valves could be secured down by the locomotive's fireman. Under circumstances where a

[13] Hambleton, "John Ramsbottom," 10.
[14] John Ramsbottom, *Safety valves, and feed water cistern*. Patent No. 1299. June 7, 1855.
[15] John Ramsbottom, "On an Improved Safety Valve," *Proceedings of the Institution of Mechanical Engineers* 7, (1856): 37-41.

locomotive stalled when hauling a long string of wagons up a gradient, it was quicker to increase the boiler pressure by screwing down the wing nut on the safety valve than to divide the train and take half the wagons up the hill at a time.[16] This practice of increasing boiler pressure was also used on occasions to make up for lost time, sometimes with tragic results. According to Pennie, Ramsbottom may have focused on the need for a safety valve as a consequence of events on 16 March 1853, when an elderly locomotive at one of LNWR's locomotive works exploded inside the shed. It was a substantial blast in which six men died.[17] Ramsbottom's design of a tamper-proof safety valve had the additional advantage over previous valves in that it did not 'go off' when the locomotive travelled over uneven track.

Table 10: Papers presented by John Ramsbottom to the IMechE

1849	*On an Improved Locomotive Boiler*
1853	*Description of an Improved Coking Crane for Supplying Locomotive Tenders*
1854	*On an Improved Piston for Steam Engines*
1855	*On the Construction of Packing Rings for Pistons*
1856	*On an Improved Safety Valve*
1857	*Description of a Safety Escape Pipe for Steam Boilers*
1861	*Description of a Method of Supplying Water to Locomotive Tenders whilst running*
1864	*On the Improved Traversing Cranes at Crewe Locomotive Works*
1866	*Description of an Improved Reversing Rolling Mill*
1867	*On an Improved Mode of Manufacture of Steel Tyres*
1867	*Description of a 30-ton Horizontal Duplex Hammer*
1871	*On the Mechanical Ventilation of the Liverpool Passenger Tunnel on the London and North Western Railway*
1871	*Supplementary Paper on the above*

Source: Robin Pennie, *John Ramsbottom: A Victorian Engineering Giant* (Chester: Lancashire and Yorkshire Railway Society, 2008), 72.

Ramsbottom also invented the displacement or hydrostatic lubricator for which he first took out a patent in November 1858. As locomotive design developed, the need arose for an automatic supply of oil to the cylinders. A year earlier he had obtained a patent for a mechanical lubricator,[18] but not satisfied with its performance he continued the development of an automatic lubricator on the hydrostatic principle. A more advanced design was patented in October 1860.[19] The Midland Railway Co. soon equipped all of its engines with Ramsbottom's lubricator.[20] Valve and cylinder lubrication of early steam

[16] C.H. Hewison, *Locomotive Boiler Explosions* (Newton Abbott: David and Charles,1983), 18.
[17] 'The blast not only lifted the whole roof several inches but blew away one sixth of its entirety, besides shattering every pane of glass;' Pennie, *John Ramsbottom*, 18. As observed by Rolt, "John Ramsbottom delivered us from evil by inventing a valve which the most ingenious engineman could not alter;" L.C.T. Rolt, *Red for Danger* (Stroud: Sutton Publishing 2007 reprint), 69.
[18] John White, *A History of the American Locomotive. Its development: 1830-1880* (New York: Dover Publications, Inc, 1979), 205.
[19] John Ramsbottom, *Displacement lubricator.* Patent No. 2460. October 10, 1860.
[20] Ernest L. Ahrons, *The British Steam Locomotive 1825-1925* (London: Locomotive Publishing Company, 1927), 166.

locomotives was the subject of much innovation. Many inventors sought to improve on Ramsbottom's automatic lubricator, the most successful being James Roscoe whose 1862 patent[21] (he was also granted a patent in the United States in 1862)[22] was widely used in England for the next 25 years.[23] Wilson Eddy, a master mechanic of the Boston and Albany Railway Co. in the United States, was active in lubricator improvements and in particular sought to avoid the hazardous journey of the fireman who on early locomotives would walk along the running board of a moving locomotive in order to oil the valve boxes.[24]

In 1860, Ramsbottom turned his attention to the need for accelerated working of the Irish Mail train with a view to achieving non-stop running from Chester to Holyhead, a distance of 84 miles. The locomotive tenders of the day had a maximum capacity of 2,000 gallons and in rough weather 2,400 gallons were needed to complete the journey.[25] The solution was either to increase the tender size, or to take on water whilst running. Ramsbottom's remedy was to design, and patent, water troughs laid between the rails in such a way as to allow locomotives in motion to pick up water. The patent was granted on 23 June 1860, and a paper presented to the IMechE a year later.[26]

A very brief consideration of Ramsbottom's approach to standardisation during the 1860s contributes to this examination of the role of patents in his professional life. The firm of Henry Bessemer and Co. started to produce steel rails in 1860, but the railway companies were slow to purchase. They were wary about the inherent strength and safety of the new rails. Bessemer records that on suggesting to Ramsbottom that he should invest in steel rails, he received the reply, 'Mr Bessemer, do you wish to see me tried for manslaughter?'[27] In the event, Ramsbottom did decide to use steel rails and the first lengths were laid in Camden goods shed on 8 May 1862.[28] Ramsbottom considered the steel rail a great success and in 1865 set up a steel works at Crewe. In 1880, Crewe works started to build boilers using steel. Characteristically he constructed a powerful togging mill, as well as a duplex steam hammer.

[21] James Roscoe, *Displacement lubricator.* Patent No. 1337. 1862. See John White, "Some Notes on Early Railway Lubrication," *Transactions of the Newcomen Society* 74, (2004): 293-307, 304.
[22] James Roscoe, *Displacement lubricator.* US Patent 37243. December 23, 1862,
[23] White, "Some Notes on Early Railway Lubrication," 304.
[24] White, "Some Notes on Early Railway Lubrication," 302. Eddy devised the simple method of placing the cylinder oil cup in the cab with an oil line running to the cylinders, and by 1860 the concept was well established in American locomotive design.
[25] John Ramsbottom, "Apparatus for supplying water to locomotive tenders whilst running," *Proceedings of the Institution of Mechanical Engineers* 12, (1861): 43-52
[26] John Ramsbottom, *Supplying the tenders, or tanks of locomotive engines,* with water, Patent No. 1527. June 23, 1860.
[27] Bessemer, *Autobiography,* 335.
[28] 'Probably no other technological development has done so much to increase the capacity of the railroads and to reduce their operating costs as [the] substitution of steel for iron rails'; George H. Burgess and Miles C. Kennedy, *Centennial history of the Pennsylvania Railroad Company* (Pennsylvania: Pennsylvania Railroad Company, 1949), quoted in Andrew Dow, *The Railway. British Track since 1804* (Barnsley: Pen and Sword Books Ltd., 2014), 170.

Ramsbottom took out several patents in respect of these various, innovative processes, and presented associated papers at the IMechE.[29]

Ramsbottom took standardisation (encouraged by his Chairman Richard Moon) to an unprecedented level. He laid the foundations for the development of Crewe such that during the second half of the nineteenth century Crewe developed into the largest and technically most advanced railway works in the world. On the basis of output per square foot, Crewe was never equalled by any other steam locomotive works.[30] As observed by Drummond, building a locomotive at Crewe works was transformed from a predominantly manual process to machine work.[31] By 1866, the Crewe works was repairing 15 engines and tenders each week, constructing a new goods engine every 2¼ working days, as well as rebuilding 20 or more older engines and making 6,000 tons of iron rails per year.[32]

From 1860, Ramsbottom worked determinedly to introduce standardisation both within and between locomotive classes. A practice maintained by his successor Francis Webb.[33] Kirby points to the proliferation and diversity of designs for locomotive building amongst the railway companies, but establishes two exceptions, the Crewe works of the LNWR, and the Swindon works of the Great Western Railway Co. (GWR). Simmons described the own-build policy of many of the leading railway companies as having a serious and adverse long term effect of inducing insularity in workshop practices, to the detriment of innovation.[34] It may be the case, as proposed by Simmons, that insularity stifled novelty, but Ramsbottom's programme for standardisation afforded opportunities for incremental innovative improvements of established patented designs. The patent data collated by Woodcroft demonstrates that many of these advances were made the subject of patents. As observed by Brown, locomotives were a novel technology in a state of design flux.[35]

Ramsbottom's practice of standardisation can best be seen in his production of steam locomotives for goods train use. In the fourteen years following 1857, 1,035 locomotives were built at Crewe embracing no more than six classes. Similarly, in the United States in 1840, Baldwin Locomotive works, offered three sizes of engines all with the same wheel configuration, but differing in power and weight. Between 1833 and 1866, Matthias Baldwin took out seventeen patents relating to locomotive design. He granted

[29] John Ramsbottom, "On the improved traversing cranes at Crewe Locomotive Works," *Proceedings of the Institution of Mechanical Engineers* 15, (1864): 44-58. John Ramsbottom, "Description of a 30 ton horizontal duplex hammer," *Proceedings of the Institution of Mechanical Engineers* 18, (1867): 18, 218-231.
[30] Pennie, *John Ramsbottom*, 60.
[31] Drummond, "Building a locomotive," 1.
[32] Drummond, "Building a locomotive," 26.
[33] M.W. Kirby, "Product Proliferation in the British Locomotive Building Industry, 1850-1914: An Engineer's Paradise," *Business History* 30, (1988): 287-305, 294.
[34] Jack Simmons, *The Railways in England and Wales: Volume 1: The System and its Working* (Leicester: Leicester University Press,1978), 176.
[35] John Brown, *The Baldwin Locomotive Works 1831-1915* (Baltimore, The John Hopkins University Press,1995), 61-62.

licences for most patents save in a few cases when he gained a competitive advantage for his firm. Brown has argued that this practice promoted diversity in the designs of locomotives.[36]

Ramsbottom achieved a greater degree of standardisation than any other British railway company of the day. He transformed the organisation of Crewe works to facilitate the repair and construction of specific classes of locomotives in designated workshops.[37] Furthermore, he appears to have had no hesitation or difficulty in utilising the patent system to his advantage. Recognising the commercial value of patented innovations, the LNWR issued regulations pertaining to patenting. Board minutes, dated 12 January 1850, record,

> … resolves to itself the right to adopt and use any improvement whether patent or otherwise introduced by any servant in the employ of the company, subject only to such payment in the form of a gratuity as in the opinion of the Board shall be justified by the special circumstances of the case.[38]

The Company made no regular payments in respect of the patents, but permitted its engineers to collect royalties from third parties. A practice not universally adopted by all railway companies. In 1863, Archibald Sturrock, Great Northern Railway (GNR) Locomotive Superintendent, patented a steam or auxiliary steam tender. He invited the GNR to pay him a royalty of £100 per engine, but they negotiated a maximum royalty of £50.[39] The Liverpool and Manchester Railway Co. also encouraged its employees to invent, but it was the Company that took out the patent.[40] In the case of Robert Stephenson and Co., as detailed in Chapter 5, a number of employees took out patents and in some cases the patents were transferred to and for the benefit of the Company.

It is argued here that the directors of the nascent railway companies needed to keep control of their inventive knowledge, and the patent system provided an effective means. The LNWR's practice of encouraging its engineers to profit from patent royalties enabled the directors to attract and keep the leading engineers of the day. Railway companies relied on their engineers' innovative expertise, and the LNWR was able to attract outstanding engineers such as Joseph Locke, Francis Trevithick, John Ramsbottom and Francis Webb. The LNWR would have been aware that it was a dispute over patent royalties that caused the disappearance of John Melling and John Gray from the Grand Junction and Liverpool Railway Co. and the Manchester Railway Co., respectively, during the 1840s.[41] Furthermore, and of considerable significance for the arguments constructed in this thesis, the practice of encouraging employees to take out patents meant that the LNWR was able to capture, keep and protect the latest

[36] Brown, *The Baldwin Locomotive Works*, 61-62.
[37] Pennie, *John Ramsbottom*, 24.
[38] London North Western Railway, Board and Committee Minutes, RAIL 410/21/73, National Archives, Kew.
[39] Great Northern Railway Minutes, Executive and Traffic Committee minutes, June 17, 1864, PRO RAIL 236/90, National Archives, Kew.
[40] Frank Ferneyhough, *Liverpool and Manchester Railway 1830-1980* (London: Book Club Associates, 1980), 88.
[41] Reed, *Crewe Locomotive Works*, 234.

railway technological advancements of the day, a practice continued by the successors of Ramsbottom. When a senior employee left the Company, the LNWR took steps to obtain a free licence of any of the individual's patented inventions that were being utilised by the Company.[42] Writing in 1893, Bowen Clarke made reference to the LNWR having the benefit of over 50 patents.[43]

Ramsbottom was a regular contributor to the technical press of the day, usually in the form of papers delivered to the IMechE. He was a founding member of the IMechE when it was established in 1847, and President in 1870 and 1871. He contributed no fewer than twelve papers all of which related to his inventions, and made a contribution to an additional paper with Siemens.[44] The evidence considered here establishes that Ramsbottom was a significant contributor to the management and diffusion of railway-related technological knowledge during the mid-nineteenth century.

It is likely that financial reward would have been an important motive for Ramsbottom's extensive use of the patent system.[45] In addition to any pecuniary consideration, the existence of his patented inventions would have served to enhance his reputation as an engineer. The following section considers Cooke and Wheatstone, inventors of the electric telegraph, whose approach to patents exemplifies the tension between the priorities of financial return and reputational status.

7.2 William Fothergill Cooke and Charles Wheatstone

> … an electric telegraph which will convey intelligence from station to station as the train passes, and therefore the whole line will be informed if the progress made by the train, and consequently risk from collision, even supposing we worked the engines through, is impossible.
>
> Robert Stephenson[46]

It is significant for the arguments developed in this thesis that the electric telegraph was developed as a specific solution to a specific early railway problem.[47] There is much debate as to the origins of the

[42] When, in 1866, F.W. Webb gave notice to the LNWR of his intention to leave, the minutes of the locomotive committee for 8 June1866 record that, 'The Committee concur in Mr Ramsbottom's suggestion that a gratuity be presented to Mr Webb, being partly in recognition of the curved surface shaping machine and the steel-headed rail, both of which inventions, as Mr Ramsbottom informs them, are due to him, and they recommend that the sum of £500 be presented to Mr Webb, subject, however, to his executing such a document as Mr Blenkinsop (LNWR solicitor) may advise for the purpose of securing to the Company in a more formal manner the free use of such of Mr Webb's inventions as they are now employing': London North Western Railway Company, Board meetings, RAIL 410/21, National Archives, Kew.

[43] C. Bowen Cooke, "The London and North Western Railway works at Crewe" in C. Bowen Cooke *et al, Round the Works of Our Great Railways* (London: Edward Arnold, 1893), 1-34, 6.

[44] William Siemens, "On Le Chatelier's plan of using counter-pressure steam as a break (sic) in locomotive engines," *Proceedings of the Institution of Mechanical Engineers* 21, (1870): 21-36.

[45] As perhaps evidenced by his substantial probate estate of £144,372 in 1898£144,372 5*s*. 5*d*.: resworn probate, Jan 1898, *Calendar of the Grants of Probate and Letters of Administration Eng. & Wales*

[46] Robert Stephenson, April 10, 1845, *Select Committee on Atmospheric Railways*, 127.

[47] Barton, "Construction of the Network Society," 41. See also, the evidence of Thomas Webster QC to the Select Committee on Patent Law Amendment 1851 when he advised: 'Some want arises: [inventors] exert themselves to supply it; considerable expenses may frequently be incurred in experiments; these can only be recovered by securing the protection of the invention for a limited time … Take for example the case of the electric telegraph ...' Thomas Webster, April 15, 1851, *Report and Minutes of Evidence taken before the Select*

telegraph. Morus argues that the telegraph was developed by a group of electricians who were interested in showmanship, display and discovery.[48] Nevertheless, and notwithstanding the roots of electrical telegraphy, as acknowledged by Briggs and Burke amongst others, the history of communication is interwoven with the history of transportation[49]

For the purposes of this thesis it is necessary to place the development of the electric telegraph within its contextual setting. As the railway system evolved, operations were governed by the time interval system with trains sent out from stations over a designated route guided by a working timetable. Increasingly, train speeds were high enough for stopping distances to exceed sighted distances, the vision of the engine driver, and together with the frequency of the services and the intersection by trains of other trains' paths, it became necessary to monitor movements in distant sections. It was becoming necessary on the grounds of safety to monitor the position of each train. For example, long dark tunnels represented a significant safety hazard. Some railway companies employed a 'policeman' positioned at the tunnel entrance to signal to the driver that it was safe to proceed. However, there was no way of the policeman knowing whether the previous train had passed through the tunnel safely. Much of the history of railway signalling and communications concerns apparatus for monitoring and controlling larger sections from fewer centres, by fewer personnel, a trend that continues to the present day.[50] The electric telegraph achieved such a position.

William Fothergill Cooke, as will be shown later in this section, was interested in developing the telegraph for the early railways, with little interest in any wider application. In that endeavour he was supported by Robert Stephenson, who had been involved in experimentation with the electric telegraph since 1837, and who, in 1846, giving evidence before a parliamentary select committee with regard to the formation of the Electric Telegraph Co., stated that he was convinced the electric telegraph 'earns safety'.[51] As explored in more detail later in this chapter, not only were Stephenson and his associates responsible for many of Cooke's early contracts, but Stephenson may have been one of a group of

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Committee of the House of Lords appointed to consider of the Bill, intituled, "An ACT Further to Amend the Law Touching Letters Patent for Inventions, (House of Lords, July 4, 1851) 16, para.53.

48 Iwan Morus, "Currents from the Underworld: Electricity and the Technology of Display in Early Victorian England," *Isis* 84 (1993): 50-69.

49 Asa Briggs and Peter Burke, *A Social History of the Media: From Gutenburg to the Internet* (Cambridge: Polity Press, 2002), 133. Barton, "Construction of the Network Society," (2007).

50 Duffy, *Electric Railways*, 3.

51 Robert Stephenson's evidence before a parliamentary select committee, in May 1846, with regard to the formation of the Electric Telegraph Company: HL/PO/PB/2/20/35, 31 May 1846. The Electric Telegraph Company Bill passed relatively easily through parliamentary scrutiny. Despite the novelty of its objectives hardly anything was reported in the press on its progress. Its petition for the Bill was submitted on February 16, 1846 to parliamentary sub-committee no. 5 (many sub-committees were needed in that year to process the mass of railway legislation), and passed standing-orders. It had a second reading before the full House of Commons on March 2, 1846. Given the unusual nature of its proposed business a report was required, this was received on May 8, and the third and final reading of the Bill was heard in the Commons on May 13, 1846, and passed. It was signed by the Queen as the Electric Telegraph Company Act, 1846, on June 19, 1846.

railway engineers who covertly purchased electric telegraph patents, for the modern equivalent of some £9,000,000.[52]

Cooke is an excellent example of an inventor who focused on converting ideas into money and used the patent system to his financial advantage.[53] Paradoxically, in March 1837, Cooke chose to go into partnership with Professor Wheatstone who was more interested in publishing the results of their joint inventions, than any financial reward. The partnership provides a striking illustration of Biagioli's distinction between credit as credibility and credit as rewards.[54] Wheatstone was interested primarily in enhancing his academic reputation, whereas Cooke's key motivation was financial gain. In the event their partnership did not survive the inherent tensions. Initially, their joint enterprise was successful, but subsequently became the subject of arbitration proceedings between the two partners. The demise of the partnership was a result of a polarisation of their two positions, and neatly exemplifies the transcultural opposition proposed by Biagioli. The partnership was eventually dissolved and the patents ultimately transferred to the Electric Telegraph Co., a joint stock company, at a substantial profit to both partners.[55] The patents of William Cooke and Charles Wheatstone are listed in Tables 11 and 12, respectively.

Table 11: Patents - William Fothergill Cooke

	Subject matter	No.	Date
i.	*Winding up springs to produce motion*	**7174**	17.08.1836
ii.	*Giving signals and sounding alarms at distant places (joint)*	**7390**	12.06.1837
iii.	*Giving signals and sounding alarms at distant places*	**7614**	18.04.1838
iv.	*Giving signals and sounding alarms at distant places (joint)*	**8345**	21.01.1840
v.	*Apparatus for transmitting electricity*	**9465**	08.09.1842
vi.	*Electric telegraph. and apparatus (joint)*	**10655**	06.05.1845

Table 12: Patents - Charles Wheatstone

	Subject matter	No.	Date
i.	*Construction of wind musical instruments*	**5803**	19.06.1829
ii.	*Musical instruments*	**7154**	27.07.1836
iii.	*Giving signals and sounding alarms at distant places (joint)*	**7390**	12.06.1837
iv.	*Giving signals and sounding alarms at distant places (joint)*	**8345**	21.01.1840
v.	*Producing, regulating and applying electric currents*	**9022**	07.07.1841
vi.	*Musical instruments*	**10041**	08.02.1814
vii.	*Electric telegraph and apparatus*	**10655**	06.05.1845

Source: Woodcroft, *Alphabetical Index of Patentees of Invention 1617-1852*, 124-125 and 607-608.

[52] E. F. Clarke, *George Parker Bidder: The Calculating Boy* (Bedford: KSL Publications, 1983), 271. n.16.
[53] Obituary, "Sir Charles Wheatstone, 1802-1875," *Minutes of the Proceedings of the Institution of Civil Engineers* 47 (1877): 283-290, 287; 'Wheatstone was plodding quietly along very scientifically, whilst Cooke more practical was casting about him how to turn his ideas into money'.
[54] Mario Biagioli, *Galileo's Instruments of Credit: Telescopes, Images, Secrecy* (Chicago: University of Chicago Press, 2006), 73.
[55] The Electric Telegraph Company formed in June 1846.

The electric telegraph sector was vibrant during the mid-nineteenth century and, as Beauchamp confirms, numerous companies were seeking to develop their own electrical technology. He observes,

> Patents were ultimately a tool of business, not simply a means to gain inventive credit, and they exist as landmarks in the history of technology only because economically motivated actors were willing and able to seek particular articles of intellectual property at particular times … historians must constantly remind themselves that the patent record is not the record of inventions, only attempts at appropriation.[56]

Beauchamp's comments are in the context of the early telephone industry in Britain and the United States, but are equally relevant to the circumstances of Cooke and Wheatstone's enterprise during the 1830s. Cooke, who recognised that to 'break out into the wider world' the telegraph needed to have strong commercial applications, identified the early railways as an area ripe for exploitation.[57]

Prior to the advent of the electric telegraph, unless a semaphore telegraph had been installed, news and messages could travel no faster than a horse or carrier pigeon. The best-known line of semaphore telegraph in Britain linked the Admiralty in London with Portsmouth, there being relay stations sending messages from one hill to the next. For example, the Battle of Trafalgar was fought on 21 October 1805, but news of the victory did not reach London until 2 November.[58] The emergence of the electric telegraph changed beyond all measure the speed of communication. That transformation was firstly experienced by the early railways, but was later recognised as having application of military, social, political and strategic importance to central government. The telegraph system was nationalised in 1871.

Cooke and Wheatstone patented the first practical electric telegraph system in 1837.[59] Cooke wrote private letters to his mother recording progress in the development of the invention.[60] Letters which Liffen considers to have been written with the intention of providing evidence of the state of Cooke's innovations at any given time, and with a view to any future litigation over priority.[61] When Cooke was in Heidelberg in March 1836, he observed a demonstration by Professor Muncke. In a letter to his mother dated 5 April 1836, he stated, 'while completing the model of my original plan, others on entirely fresh systems suggested themselves, and I have succeeded in combining the *utile* of each'.[62] He returned to England and teamed up with Professor Wheatstone of Kings College, London. Together they carried out a number of experiments, and in letters to his mother Cooke expressed concern about his

[56] Christopher Beauchamp, *Invented by Law: Alexander Graham Bell and the Patent that Changed America* (Cambridge Mass.: Harvard University Press, 2015), 206.
[57] John Liffen, "The Introduction of the Electric Telegraph in Britain, a Reappraisal of the Work of Cooke and Wheatstone," *International Journal for the History of Engineering and Technology* 80, (2010): 268-299, 269.
[58] Brian Bowers, *Sir Charles Wheatstone* (London: Her Majesty's Station Office, 1975), 102.
[59] William Fothergill Cooke and Charles Wheatstone, *Giving signals and sounding alarms at distant places.* Patent No. 7390. June 12, 1837.
[60] W. H. Webb, ed. *Extracts from the private letters of the late Sir William Cooke relating to the invention and development of the Electric Telegraph* (London: E. and F.N. Spon, 1895).
[61] Liffen, "The Introduction of the Electric Telegraph," 270.
[62] Webb, *Extracts from the private letters*, 5.

experiments becoming public, but on the back of a letter written to his mother on 10 June 1837, he wrote,

> Cooke's and Wheatstone Patent signed by His Majesty, and receiving the Great Seal this day, June 10th!!! 1837 for Electric Telegraph Alarums. I had intended to send you some small present but now send you this instead.[63]

The *British Quarterly Review* of 1867 retrospectively detailed the first experiment in the presence of Robert Stephenson (in Cooke's words, 'a convert to our system'),[64] that took place on 25 June 1837, when a mile and a half of telegraphic wire was laid between Euston (where Wheatstone sat) and Camden Town (where Cooke sat). The experiment was successful and the *Review* was fulsome in its praise,

> ... not only is the telegraph one of the most brilliant achievements of science ... [it] exerts a direct and powerful influence on the political and commercial relationship of every country in the world; more so than any other discovery of recent years ... [but] to get it adopted as a medium of intercommunication was another.[65]

Cooke was excited by the success of the experiments, and particularly delighted with the support of Robert Stephenson. On 25 July 1837, Cooke wrote to his mother,

> Yesterday Mr Stevenson witnessed our experiments through 19 miles of wire, extended from Euston Square to Camden Town, and declared himself so satisfied with result that he begged me to lay down my wires permanently between those two points on my best plan, with a view to extending the communication hereafter, if the Directors approved ... Mr Stevenson was quite childish in the delight he took in the working of our Telegraphs, and seems now to have taken it entirely under his patronage; and a more influential one we could not desire.[66]

The London and Birmingham Railway Co. installed a rope hauled system whereby trains leaving Euston were pulled up the hill to Camden, where a locomotive would be coupled on. Trains returning to London were detached from the locomotive at Camden and ran under gravity into Euston. Robert Stephenson required a means of communication between Euston and Camden so that the individual operating the winding engine would know when the train was ready to depart. Stephenson was very interested in the electric telegraph, but unfortunately for Cooke and Wheatstone, Stephenson's influence proved insufficient at least insofar as some of the directors of the London and Birmingham Railway Co. were concerned. They had received reports on the experiments and recommended no extension of the telegraph beyond Camden Town until 'further experience shall have tested its practical utility'.[67] The following week the directors decided that they were not prepared to enter into further expenditure on trials without clear evidence of its usefulness.[68] The Board decided to go back to a pneumatic (steam

[63] Webb, *Extracts from the private letters*, 35.
[64] Webb, *Extracts from the private letters*, 41.
[65] Henry R. Reynolds and Henry Allon, "Twelfth Report of the Postmaster-General on the Post Office, 1866," *British Quarterly Review* 45, (1867): 442-477, 442-443. In a letter to his mother, Cooke suggests the date to be 25 July 1837: Webb, *Extracts from the private letters*, 41.
[66] Webb, *Extracts from the private letters*, 41-42.
[67] London and Birmingham Railway Company, minutes of meeting of non-resident directors, September 30, 1837, RAIL 384/62, National Archives, Kew.
[68] London and Birmingham Railway Company, minutes of meeting of non-resident directors, October 7, 1837, RAIL 384/62.

whistle) system between Euston and Camden, involving a whistle being blown in the engine house to indicate the train was ready.[69]

The disappointment for Cooke, of this loss of business, would have been mitigated by a letter from Isambard Kingdom Brunel who, on 22 September 1837, invited Cooke to call and see him on either the ‘following Sunday or Monday.'[70] Brunel was involved in the construction of the line between London and Bristol for the GWR, and although no immediate business was forthcoming, the GWR London committee did formally open negotiations with Cooke in February 1838.[71] While these were in progress, Cooke and Wheatstone enrolled patents, covering further improvements, in Scotland and Ireland.[72]

Cooke took a strong line in the GWR negotiations relying on the existence of his patent. At one point he withdrew altogether, no doubt because he was aware that his patent meant that the directors faced a lack of alternatives.[73] Eventually, the agreement was signed on 28 May 1838 and Cooke wrote to his mother that same day, 'now comes the proof of the patent'.[74] The contract was for the construction of six wires between Paddington and West Drayton and, although during October and November the installation was worked intensively, it played no part in the regulation of train services. It was used solely for messages of a general nature. It was little used after December 1839, and was probably defunct by December 1840.[75] It was however the first permanent line of electric telegraph in England and laid the foundations for later developments in electric telegraphy.

The second railway company to take up the electric telegraph was the London and Blackwall, a cable worked railway when it opened in July 1840. Cooke installed an electric telegraph system where communication was achieved with repeater instruments in the winding engines at each end of the line. Signals were sent indicating when the engines were to be started and stopped. The adoption by the London and Blackwall Railway Co. of the telegraph was heavily influenced by George Parker Bidder, railway engineer and colleague of Robert Stephenson. As is explored late in this chapter, Bidder was an important advocate of the electric telegraph and a pivotal figure in its early development. The success of train control by the London and Blackwall Railway Co. inspired other railway companies to adopt the Cooke and Wheatstone telegraph, including the twenty miles of single track Yarmouth and Norwich Railway, which was controlled by their telegraph from May 1844.[76]

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[69] Bowers, *Sir Charles Wheatstone*, 117.
[70] I.K. Brunel, letter to William Cooke, September 22, 1837, Cooke Papers GB 0108 SC MSS 007/11/017, Institution of Engineering and Technology Archives, London.
[71] Great Western Railway Company, London Committee, abstract of minutes, February 22, 1838, PRO RAIL 250/83.
[72] Brian Bowers, *Sir Charles Wheatstone* (London: Her Majesty's Station Office, 1975), 126.
[73] Webb, *Extracts from the private letters*, 50-52.
[74] Webb, *Extracts from the private letters*, 55.
[75] Liffen, "The Introduction of the Electric Telegraph," 278.
[76] W.H. Preece, "On Railway Telegraphs and the application of Electricity to the Signalling and Working of Trains," *Minutes of the Proceedings of the Institution of Civil Engineers* 22, (January 1863): 167-192, 172.

In 1841, a parliamentary select committee examined aspects of railway safety, with George Stephenson giving evidence.[77] C.A. Saunders, secretary of the GWR, drew the attention of the committee to the many causes that placed safety at risk including severe fogs, and the dangers of collision arising from following trains. During his evidence, Saunders promoted the advantages of installing the electric telegraph: 'for the purpose of the Railway itself, this Telegraph may also be frequently used to prevent the risk of accidents and to obviate delay and inconvenience'.[78]

Cooke was keen to introduce automatic electric signalling with 'engine warners'. In 1841 he patented an engine warner whereby an electrical rod protruded through the flanges of the rail and was depressed by a passing train causing a circuit to be completed and registered on a needle telegraph. Cooke's innovative idea was radical by the standards of the day. Railway companies failed to perceive its importance and the invention was never adopted.[79] In 1842, Cooke published a book encouraging railway companies to consider the adoption of electric telegraphy, of which he claimed to be the first and true inventor. Cooke examined the then various methods of safety relied upon by the railway companies and drew attention to their limitations. He argued, with conviction, that,

> … at once safe, economical, and efficient, the Electric Telegraph may diffuse the blessings of rapid intercourse to districts which can never otherwise enjoy them ... above all it may accomplish the otherwise scarcely attainable union by Railway between England and Scotland.[80]

In 1843, Cooke renegotiated his agreement with the GWR extending the electric telegraph a further four miles to Slough station. The real breakthrough came in August 1844 when Cooke negotiated with the Board of Admiralty for the erection of a private line from Whitehall in London to the Naval Headquarters in Portsmouth, alongside the London and South Western Railway. In May 1845 Cooke was able to report to the press that the electric telegraph had been adopted by nine railway companies over a total distance of 550 miles.[81]

The partnership of Cooke and Wheatstone was an uneasy one with tensions as to who had invented the electric telegraph. Cooke wanted fully to utilise the commercial value of the patents, whereas Wheatstone's inclination, as an academic, was to publish their work, even before patent protection had been obtained. The dispute went to arbitration in 1841. To substantiate their arguments, both parties placed extensive material before the arbitrators, Sir Marc Isambard Brunel and Professor John Frederic

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[77] George Stephenson, March 29, 1841, *Select Committee on Railways*. *Sessional Papers of the House of Lords, Vol 26,* Reports and Evidence of the Session 40 & 50 Victoriæ (26th January-22nd June) and the Session 50 Victoriæ (19th August-7th October) 1841, (House of Lords, 1841); paragraph 1321.
[78] Charles Clarke, July 2, 1840, *Report to the Select Committee on Railway Communication,* quoted in William Cooke, *Telegraphic Railways; or The Single Way recommended by Safety, Economy and Efficiency under the Safeguard and Control of the Electric Telegraph: with particular reference to Railway Communication with Scotland, and to Irish Railways* (London: Simpkin, Marshall and Co, 1842), 39.
[79] Anon (ed.), "Messrs Cooke and Wheatstone's Electric Telegraph," *The Civil Engineer and Architect's Journal, and Scientific and Railway Gazette* 4, (1841): 237-241.
[80] Cooke, *Telegraphic Railways*, 34.
[81] Kieve, *The Electric Telegraph*, 37.

Daniell, who decided, in a short carefully worded statement, that Cooke and Wheatstone were jointly responsible for the invention.[82] The partnership continued, despite the tensions, with further patents (as to improvements) being awarded to them both in 1842 and 1843. Neither Cooke nor Wheatstone appear to have been satisfied with the arbitrators' award as they continued to publicise their respective grievances. In 1854, Cooke published a pamphlet entitled *The Electric Telegraph; was it invented by Professor Wheatstone*?[83] In January of 1856, Wheatstone published a response, [84] and in March of the same year Cooke produced a further pamphlet. In 1857, Cooke re-published his two pamphlets, as well as the arbitration papers.[85] On 12 April 1843 the partnership between Cooke and Wheatstone came to a formal end with Cooke becoming sole proprietor of their British patents. Wheatstone, in exchange for surrendering his interest in the patents, was to receive a royalty on all telegraph lines constructed adjacent to railways, including any in the future, on a sliding scale dependent on the length of line.

The partnership dissolution agreement is significant for the questions addressed in this thesis in that it is illustrative of the connection between patents and the development of the early railways. Electric telegraphy was suited to sending messages many miles, almost instantaneously, and could make an important contribution to the safety of the developing railway network. Cooke identified railway companies as ideal customers. The railway companies had already purchased long strips of land so there was no need to negotiate with a large number of separate landowners. Cooke, foresaw the commercial application of the electric telegraph to the railway companies, but also that patent protection would ensure lucrative exploitation of the invention.[86] Cooke was correct in his assessment. By 1868 there were over 90,000 miles of telegraph wire in the United Kingdom, transmitting 6,000,000 messages annually, with much of the sector being developed under patent protection.[87] There is a distinction to be made between railway rights of way being utilised to install electric telegraphy, and the explicit use of the electric telegraph for railway purposes. Nevertheless, electric telegraphy was a substantial railway-related technology, and patent protection was a significant feature of its development.

Kieve has suggested that Cooke's actions were a preliminary step towards his self-professed, long held ambition to sell his 'unfettered share in the patents to an influential capitalist',[88] and that with that in mind Cooke made an approach to John Lewis Ricardo, MP for Stoke, and Chairman of the North

[82] Arbitration papers: Cooke, Sir William Fothergill (1806-1879), Institute of Engineering and Technology in 7 volumes; GB 0108 SC MSS 007, xxxvii-xxix.
[83] William Fothergill Cooke, *The Electric Telegraph. Was it invented by Professor Wheatstone?* (London: WH Smith & Son, 1854).
[84] Charles Wheatstone, *A Reply to Mr Cooke's Pamphlet, The Electric Telegraph. Was it Invented by Professor Wheatstone?1855* (London: Richard Taylor and William Francis, 1856).
[85] William Fothergill Cooke, *The Electric Telegraph. Was it invented by Professor Wheatstone? Vol.I - The pamphlets of 1854-6; Vol.II - Arbitration Papers* (London: WH Smith Son, 1857).
[86] Jeffrey Kieve, *The Electric Telegraph: A Social and Economic History* (Newton Abbot: David and Charles, 1973), 22.
[87] Bowers, *Sir Charles Wheatstone*, 102.
[88] Kieve, *The Electric Telegraph*, 42, n.48.

Staffordshire Railway Co. and the Metropolitan Railway Co.[89] However, Kieve's suggestion fails to take account of the relationship between realisation of patent investment and 'railway mania', a significant stock market bubble of the 1840s. Furthermore, Kieve does not investigate why Cooke sold the patents. Nor does he explore the objectives and reasons of the eventual purchasers, the shareholders of the Electric Telegraph Co. It is argued here that such an investigation could prove central to an understanding of how and why electric telegraphy developed, its pivotal relationship with the early railways and the role of the patent system in its development. Fundamental to these questions is an examination of the promotors of the Electric Telegraph Co., and their motives.

7.3 The Electric Telegraph Company

An appropriate starting point for such an enquiry is the relationship between Robert Stephenson and George Parker Bidder, a fellow engineer whose achievements have been largely overlooked in engineering literature.[90] Stephenson described Bidder as a 'valued and esteemed friend … whose experience in railway engineering is scarcely inferior to my own'.[91] Stephenson and Bidder had been students together at Edinburgh University (although Bidder's studies were more extensive than the six month stay of Stephenson)[92] and at one time they shared an office in Great George Street, London.[93] Bidder was involved in many of Stephenson's projects and there is considerable evidence that they enjoyed a very close professional relationship.[94] Stephenson, in a letter inviting Bidder to his birthday party, declared their relationship to be 'a course of engineering which can scarcely be said to have had a parallel'.[95]

According to Kieve, Bidder and Ricardo purchased Cooke's patents in late 1845, two years after Cooke had acquired sole ownership of the Cooke Wheatstone patents.[96] Cooke clearly enjoyed a professional

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[89] Kieve, *The Electric Telegraph*, 42.
[90] To date, the only substantial study of Bidder's engineering achievements is Clark, *George Parker Bidder*, (1983).
[91] Robert Stephenson was speaking at a dinner after the ceremony of turning the first sod of the Norwegian Trunk Railway in August 1851; *Illustrated London News,* (September 13, 1851): 324.
[92] Bidder was Stephenson's junior by some three years and had shown a precocious talent for arithmetic at a young age. Known to mathematical historians as the 'calculating boy' of the early nineteenth century, he began studying at Edinburgh University when just 13 years old where he remained for three years. See, *Edinburgh's Place in Scientific Progress,* a paper (undated) prepared for an Edinburgh meeting of the British Association by the local editorial committee. Bidder Papers, GPB 5/10/2b, Science Museum Library and Archives, Wroughton. In contrast, Stephenson left Edinburgh University after six months, aged 19 years, to take up the post of Managing Director of Robert Stephenson and Co. See, Bailey, *Robert Stephenson*, 9.
[93] A letter from one Cambridge details the writer's interpretation of the professional relationship and friendship between Robert Stephenson and George Parker Bidder ('Grandpa'). Cambridge, letter to Maurice Bidder (George Bidder's brother), June 25, 1923, Bidder Papers GPB 5/8/3.
[94]The correspondence between Bidder and his wife contains many references to Robert Stephenson, often in affectionate terms. See, Bidder Papers, GPB 4/5. The families were close. Bidder's eldest daughter, Elizabeth (George's goddaughter), married John Stanton son of the Company's solicitor. Bidder was also one of the three executors of Robert Stephenson's will and a substantial legatee.
[95] Robert Stephenson, letter to George Parker Bidder, [November 1852], Bidder Papers, GPB 5/12/5a.
[96] Kieve, *The Electric Telegraph*, 42.

relationship with Bidder, extending over a long period of time. In May 1845, he had requested assistance from Bidder to obtain a contract for the installation of the electric telegraph on LNWR lines from London to Manchester, and to Liverpool and Holyhead. He stated 'the profits derived from those arrangements shall be shared between us'.[97] Nothing appears to have come of this suggestion as the LNWR did not install telegraphs until sometime later. In any event, by July 1845 Cooke was in discussion with Wheatstone as to the termination of their remaining arrangements, in particular the purchase of Wheatstone's royalty rights.[98] Simultaneous to his discussions with Wheatstone, Cooke was already negotiating the sale of his patents, and Bidder would play a decisive role in that onward sale.

On 10 September 1845, Cooke wrote to Bidder expressing concern that he had seen an advertisement for a new competitor company. Cooke proposed to Bidder,

> Might not a directory be obtained of the Chairmen and Directors of the Chief Lines of Railway in England? If a Company so formed could be brought to act in unison, the most magnificent results in the rapid extension of the Telegraph all over England might be anticipated.[99]

Clarke suggests that Robert Stephenson played a passive role in the purchase of Cooke's patents and the subsequent creation of the Electric Telegraph Co. However, as explored below, there is evidence to suggest that Stephenson played a very active role, probably using Bidder as his undisclosed agent.

The agreement for the sale of Cooke's patents preceded the formation of the Electric Telegraph Co. The law at the time allowed only twelve persons to be the formal owners of a patent and if there were more than twelve, then the patent was void.[100] A practice therefore developed of nominee interests whereby the formal owner, or part owner of a patent held the patent on trust for an undisclosed nominee. The purchase of Cooke's patents required considerable investment,[101] and it is likely that such a sum would have been difficult to achieve with only twelve investors. Bidder's correspondence demonstrates that he was able to collect, at very short notice, substantial sums of money from Edward Tootal (£3,636.16.8),[102] Morton Peto (£1,813.3.8)[103] and Joseph Paxton (£1,813.3.9).[104] These letters are the only ones to have survived, but it is possible there would have been others as Bidder sought to accumulate the required monies. Ricardo and Bidder formally completed the purchase of Cooke's

[97] Cooke, letter to Bidder, May 5, 1845. Bidder Papers, GPB 2/3h.
[98] William Fothergill Cooke, *The Electric Telegraph: Was it invented by Professor Wheatstone? Part 1* (London: W.H.Smith & Son, 1868) 123.
[99] Cooke, letter to Bidder, September 10, 1845, Bidder Papers, GPB 2/3j.
[100] Prior to 1832, ownership of a patent could not be vested in more than five people. In 1832, following representations by William Carpmael to the Attorney General, Sir T Denman, the maximum number of partner investors was increased to twelve. Carpmael commented that this was a 'boom to patentees … as an inventor may now have the assistance of a sufficient number of persons to enable him to mature an invention'. Carpmael, *The Law of Patents for Inventions*, 41.
[101] Barton estimates that in today's terms it was possibly as high as £9 million. Barton, "Construction of the Network Society," 100.
[102] Bidder, letter to Edward Tootal, October 16, 1845. Bidder Papers, GPB 2/4i.
[103] Bidder, letter to Morton Peto, October 16, 1845. Bidder Papers, GPB 2/4h.
[104] Bidder, letter to Joseph Paxton, October 16, 1845. Bidder Papers, GPB 2/4j.

patents on 23 December 1845.[105] Wheatstone agreed to commute his royalty rights on all lines for £30,000 in cash: £20,000 for his royalty rights and £10,000 for the rights in his share of the Scottish, Irish and Belgian patents.[106] Cooke received £90,000, together with the receipt of a substantial number of shares.[107] A memorandum signed on 23 December 1845 shows that the patents purchased from Cooke were held by three individuals on behalf of three groups of investors, namely Cooke 9/32, Bidder 11/32 and Ricardo 12/32.[108]

Robert Stephenson appears not to have been involved in any of these transactions. However, as part of the process of the collection of funds by Bidder, one Cardwell, on 20 October 1845, sent Bidder a cheque for £308.3.8 on behalf of Paxton and, interestingly, sent it c/o Robert Stephenson.[109] This could suggest that the investors were well aware of the involvement of Robert Stephenson. An involvement which becomes clearer when the funding arrangements for the Electric Telegraph Co. are considered. The Company was incorporated in June 1846 and the patents were then transferred from Cooke, Bidder and Ricardo to the Company, creating the first joint stock company in the world, with an objective of a network of communication across the country. Barton suggests that the shareholders of the patents purchased from Cooke, and the subsequent shareholders in the Electric Telegraph Co., were virtually identical and remained unchanged between 1845 and 1849. Barton uses various sources to identify the shareholders of the Company as disclosed in the public Share Register, as well as those individuals who were undisclosed shareholders. Barton's list is reproduced in Tables 13 and 14.

Most of the shareholders appearing in these tables were close business associates of Robert Stephenson, or related to him, and in some cases, on the basis of their professional designations, it seems reasonable to surmise that some individuals were not in a position to fund the purchase of their shareholding. Whilst there is no evidence to suggest that Stephenson assisted with the purchase of their shares, it is possible that he had a discrete financial involvement both in the purchase of the patents and the subsequent incorporation of the Company. Clarke suggests that Bidder was acting as nominee within his own shareholding for ten individuals. His list is reproduced in Table 15.

[105] Kieve, *Electric Telegraph*, 43.
[106] Russell W. Burns, *Communications: An International History of the Formative Years* (London: The Institution of Electrical Engineers, 2004), 93-94.
[107] Cooke, *The Electric Telegraph*, 232. Cooke subsequently lost most of his money in a slate mining enterprise in Wales. In 1871, he was granted a civil list pension of £100 per annum. When he died in 1876, he left the sum of £16. James Burnley, "Cooke, Sir William Fothergill (1806–1879)," in *Oxford Dictionary of National Biography*, ed. H. C. G. Matthew and Brian Harrison (Oxford: OUP, 2004); online ed., ed. David Cannadine, January 2011, http://www.oxforddnb.com/view/article/6192 [accessed 19 Sept 2015]. The Civil List Act 1837 applied the condition that any new pensions should be 'granted to such persons only as have just claims on the royal beneficence or who by their personal services to the Crown, or by the performance of duties to the public, or by their useful discoveries in science and attainments in literature and the arts, have merited the gracious consideration of their sovereign and the gratitude of their country.' Civil List Act 1837 (c.2).
[108] Clark, *George Parker Bidder*, 454.
[109] Cardwell, letter to Bidder c/o Robert Stephenson, October 20, 1845. Bidder Papers, GPB 2/3k.

Table 13: Electric Telegraph Patent and Company Shareholders 1845-1849

From Share Register	Position	Other appointments/Relationship
George Bidder	Director	Railway Engineer, Associate of Robert Stephenson
Thomas Boulton	-	Stock-broking partner of Lewis Ricardo
William Fothergill Cooke	Director	Entrepreneur
Benjamin Hawes MP	-	Brother-in-law of I.K.Brunel, Member Select Committee
Albert Ricardo	-	Uncle?
Frederic Ricardo	-	Uncle?
John Lewis Ricardo	Chairman	Anti-Corn Law League; Chairman, North Staffs Rly
Samson Ricardo MP	Auditor	Uncle
John Sanderson	Auditor	Robert Stephenson's secretary (and brother-in-law)
Alexander Bain	-	Clockmaker and telegraph inventor
George Wilson	Director	Chairman, Anti-Corn Law League; Dir M&L Rly (1847)

Source: Barton, "Construction of the Network Society," 73.

Table 14: Known Undeclared Shares (held covertly by Bidder and Ricardo)

B. P. Bidder	George Bidder's brother, Manager of Preston and Wyre Railway
M. A. Borthwick	Railway Engineer, Associate of Robert Stephenson
Charles Cheffins	Map maker, Associate of Robert Stephenson
John Hawkshaw	Chief Engineer, Manchester and Leeds Railway
Joseph Paxton	Director, York and North Midland Railway
Samuel M. Peto MP	Construction Engineer; Chairman, Chester and Holyhead Railway
Robert Stephenson MP	Railway Consulting Engineer
Richard Till	Secretary, Eastern Counties and formerly Lon and Brighton Railway
Edward Tootal	Director, Trent Valley Railway

Source: Barton, "Construction of the Network Society," 73.

Table 15: Nominee shares in The Electric Telegraph Company held by G. P. Bidder

	Original	Additional	Total
Jos. Paxton	140	35	175
R. Till	28	7	35
R. Stephenson	140	35	175
S.M. Peto	140	35	175
M.A Borthwick	28	7	35
B.P. Bidder	28	7	35
E. Tootal	280	70	350
J.E. Sanderson	?	20	20
a.n. other	?	200	200
J. Hawkshaw	?	20	20

Source: Clarke, *George Parker Bidder,* 455

It is unclear why Stephenson's involvement in the Electric Telegraph Co. should, at least for a time, have been kept secret. However, when Stephenson was constructing the London and Birmingham Railway in the 1830s, he sought to purchase locomotives from his own company, Robert Stephenson and Co., but in order to do so was forced first to sell his shares in the Company.[110] He had become involved in a dispute with two of the London and Birmingham Railway Co.'s directors, James Cropper and Theodore Rathbone, who accused him of a conflict of interest. Stephenson was clearly affected by the dispute. In a letter to Longridge in January 1835, he stated, 'the revenge [the Company] seek[s] is quite insatiable. This dissatisfies me very much.'[111] Stephenson resolved the issue by selling his shares to his father, George Stephenson, which allowed the London and Birmingham Railway Co. to purchase the locomotives from Robert Stephenson and Co. It may be the position, therefore, that Robert Stephenson and his railway associates sought to remain as undisclosed shareholders of the Electric Telegraph Co. A stance adopted precisely to avoid any similar accusations of conflict of interest and personal attacks, particularly given their future intentions to sell electric telegraphy to competitor engineers and railway companies.

There is little academic comment in relation to the involvement of Robert Stephenson in the purchase of Cooke's patents and the incorporation of the Electric Telegraph Co. However, examination of the Bidder papers demonstrates that Stephenson, who was undoubtedly a significant contributor to early railway technology, identified the emerging railway companies as a potential customer base and recognised patents as a significant means to achieve sales. There is good evidence that Stephenson committed substantial funds to the development of the Electric Telegraph Co., and may have persuaded others to do so. Stephenson's objective to supply electric telegraphy to the many emerging railway companies brought him into conflict with Ricardo who wanted to utilise the railway way-leaves to provide an information service to the wider financial community. Ricardo resigned as chairman in February 1858 and Stephenson was elected in his place, remaining in post until July 1859, three months before his death.[112]

According to *Tuck's Railway Shareholding Manual*, in 1847 some seventy engineers were associated with over a thousand railway projects.[113] Apart from Robert Stephenson, hardly any other engineer constructed a railway which included installation of the electric telegraph. Perhaps (as it happens, incorrectly) Stephenson anticipated that the Government would insist on safety measures being taken by the emerging railway companies, and that by keeping his identity secret the Electric Telegraph Co. would appeal to a wider potential target market and thus maximise financial reward.[114] Barton develops

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[110] Bailey, *Robert Stephenson*, 177-184.
[111] Stephenson, letter to Michael Longridge, January 26, 1835, Pease-Stephenson Papers D/PS/2/67.
[112] Barton, "Construction of the Network Society," 155.
[113] Henry Tuck, *The Railway Shareholders Manual: or Practical Guide to all the Railways in the World, Completed, in Progress and Projected* (London: Effingham Wilson, 1847, 8th edn.), 103.
[114] Barton, "Construction of the Network Society," 100.

the argument that in order to manage his substantial investment in the Electric Telegraph Co., Stephenson would have needed to recruit a team of people with relevant financial, engineering and management skills.[115] The eventual recruitment of Ricardo would have met a number of Stephenson's objectives. He had the necessary proven expertise, and it would have been advantageous to remove a key financial advisor from Brunel and the new atmospheric railways. Barton further postulates that whilst Ricardo was recruited to manage the patents, following their purchase it was in fact Stephenson who made strategic decisions concerning choice of railways and towns to be served.[116]

The Electric Telegraph Co.'s investors and supporters were impressive individuals including Alexander Bain, who held a number of patents for electric clocks and the needle telegraph, Samuel Morton Peto, philanthropist and engineering entrepreneur,[117] and Benjamin Hawes, brother-in-law to Isambard Kingdom Brunel. Charles Walker, Superintendent of Telegraphs for the South Eastern Railway Co., records that the Act, passed on 18 June 1846, granted the Company 'power to purchase letters patent, which may be prolonged to them, should the Crown think fit: they may grant licences to use such patented inventions, or they may sell, let, or dispose of their telegraphs'.[118] Between 1846 and 1850 the company acquired a suite of other telegraphic and electrical patents in order to expand the platform of their various enterprises. In a letter dated 3 March 1847, Bain wrote to the directors of the Electric Telegraph Co. in the following terms,

> As it is my anxious wish to be engaged with none other regarding the electric telegraph and more especially engaged with your Company respecting the electric clocks. I hereby offer you the purchase for this country of my recently patented electric telegraph. The price asked is twelve thousand pounds.[119]

The Civil Engineer and Architect's Journal for January 1848 listed the names of the railway companies and their miles of electric telegraph noting that, by 1845 fewer than 45 miles had been constructed, in 1845 a further 500 miles were laid, 600 miles in 1846, and 1,100 miles in 1847, 'the total done and in hand is above 2,300 miles'.[120] By the time of the Telegraph Act (1868), when the Electric Telegraph Co. was nationalised and became part of the General Post Office, the Company owned 10,000 miles of line, 1,300 telegraph stations in Britain and Ireland, and employed 3,000 skilled operators. It also had control of three continental cables.[121] Robert Stephenson's association with the electric telegraph has virtually been forgotten, but his involvement is pertinent to this thesis in that it illuminates Stephenson's recognition of the potency of patents in relation to the developing railways.

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[115] Barton, "Construction of the Network Society," 100.
[116] Barton, "Construction of the Network Society," 101.
[117] Adrian Vaughan, *Samuel Morton Peto. A Victorian Entrepreneur* (Hersham: Ian Allan, 2009)
[118] Charles Walker, *Electric Telegraph Manipulation being the theory and plain instructions in the art of transmitting signals to distant places as practised in England through the combined agency of electricity and magnetism,* (London: George Knight and Son, 1850), 94-95.
[119] Alexander Bain, letter to directors of Electric Telegraph Company, March 3, 1847, Bidder Papers, GPB 2/3e.
[120] *The Civil Engineer and Architect's Journal, Scientific and Railway Gazette* 11, (January, 1848): 9-14, 12.
[121] Kenneth Beauchamp, *History of Telegraphy* (London: Institution of Electrical Engineers, 2001), 75.

The Great Exhibition of 1851 is widely recognised to have changed perceptions of the electric telegraph,[122] and three substantial shareholders of the Electric Telegraph Co. played a crucial role in the organisation. The Exhibition building committee included Robert Stephenson, Joseph Paxton (designer of the Crystal Palace) and Morton Peto (original guarantor of £50,000 which enabled organisers to begin financing the construction). The Electric Telegraph Co. had a large display at the south entrance of the Exhibition demonstrating its substantial investment in the railway industry. Telegraph stations were arranged in the many galleries of the Exhibition with the Cooke and Wheatstone patented apparatus in pride of place. It is relevant to this discussion that over 6,000,000 people attended the Great Exhibition, a figure which has been estimated to represent one fifth of the population, and that most would have travelled by train.[123] During the 1840s the railways had developed into a national network and it is unlikely that the Exhibition could have taken the form it did prior to the construction of the railway network.

The Exhibition demonstrated that as a consequence of holding the majority of the telegraphy patents, the Electric Telegraph Co. dominated the market. Nevertheless, many other companies and 'private experimenters' exhibited attempts to circumvent Cooke and Wheatstone's invention. Some thirteen telegraph instruments were on display, at a time when thousands of miles of railway were without telegraph systems.[124] According to Beauchamp, these were less effective and less commercially viable than those of the Electric Telegraph Co.[125] Significantly, whilst the Electric Telegraph Co. maintained something of a monopoly in railway communication and safety, the Great Exhibition would have identified a consumer market beyond the railway companies. It was an express purpose of the organisers of the Exhibition to connect finance and industry, to construct a certain kind of market society.[126]

It is possible to argue that the patents of Cooke and Wheatstone and latterly of the Electric Telegraph Co. stimulated a vibrant electric telegraph sector with numerous individuals seeking to develop and

[122] Following a visit to the Great Exhibition in July 1851, Queen Victoria recorded in her diary, "We went to the Exhibition and had the electric telegraph show explained and demonstrated before us. It is the most wonderful thing and the boy who works it does so with the greatest of ease and rapidity. Messages were sent out to Manchester, Edinburgh, &c., and answers received in a few seconds – truly marvellous!" Queen Victoria, "Journal Entry: Wednesday July 9, 1851," *Queen Victoria's Journal Volume 32,* (July to December 1851) Royal Archives Online Collection, http://www.queenvictoriasjournals.org/search/displayItemFromId.do?FormatType=fulltextimgsrc&QueryType=articles&ItemID=18510709 [accessed on April 13, 2017].
[123] Jeffrey A. Auerbach, *The Great Exhibition of 1851: A Nation on Display* (New Haven: Yale University Press, 1999), 137. Auerbach's estimate has been challenged by those who recognise visitors may have attended the Exhibition on more than one occasion. For example, Pettitt identifies that Charlotte Bronte made five visits; Clare Pettitt, *Patent Invention: Intellectual Property and the Victorian Novel* (Oxford: Oxford University Press, 2004), 84.
[124] Kieve, *Electric Telegraph*, 51.
[125] Kenneth Beauchamp, *Exhibiting Electricity* (London: Institution of Electrical Engineers, 1997), 81.
[126] Auerbach, *The Great Exhibition of 1851*, 126.

capitalise on their technology both for the railways and other industries.[127] There is good evidence that the developing consumer market incentivised inventors to seek alternative solutions to existing patents. Five examples suffice to demonstrate this point. In May 1843, in direct competition with Cooke and Wheatstone, Alexander Bain patented the so-called 'I & V' telegraph. Its principle was based on a single wire circuit and was employed widely in Austria.[128] Bain's apparatus was used in December 1845 when the first line of electric telegraph was completed alongside the Edinburgh and Glasgow Railway. It ran for forty-six miles with seven telegraph stations and was installed at a cost of less than £50 a mile.[129] A Bain instrument was also used to manage traffic on the single-track 1,540 yard Shildon Tunnel of the Stockton and Darlington Railway, for which the Company agreed to pay Bain £50 to use his patent rights.[130]

Secondly, Stephenson who always remained a great supporter of Cooke, continued to consider the many other inventors who were keen to offer their telegraphic inventions to railway companies. In 1844, Reverend Henry Highton, Assistant Master of Rugby School, took out a telegraphy patent and in 1845 was party to a pilot scheme sponsored by Stephenson and funded by the London and Birmingham Railway Co. Ten miles of wire on the Highton system were erected between Rugby and Blisworth.[131] Henry Highton's patent was subsequently purchased by the Electric Telegraph Co. Meanwhile, during 1845 and 1846, the LNWR had employed his brother, Edward Highton, to develop new, patent-evading apparatus. The Company installed his instruments experimentally on its long single-track branch between Northampton and Peterborough, and on its Liverpool and Manchester, Leeds and Dewsbury and Manchester and Huddersfield subsidiaries.[132] In 1848 the Highton brothers jointly took out a patent for 'Improvements in Electric Telegraphy',[133] and in 1850, perhaps in anticipation of the imminent

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[127] Such developments took place in America but at a slower pace. Granville Woods (1856-1910) registered some 50 patents, including 'the telegraphony' and the Synchronous Multiplex Railway Telegraph. David L. Head, *Granville T. Woods. African-American Communications and Transportation Pioneer* (Pittsburgh: Rose Dog Books, 2013).
[128] Alexander Bain, *Production and regulation of electric currents: electric time-pieces, and electric printing and signal telegraphs.* Patent No. 9745. May 27, 1843. See also, R.William Burns, "Alexander Bain, a most ingenious and meritorious inventor," *Engineering Science and Education Journal* 2, no.2, (April 1993): 85–93. It was similar in appearance to the Cooke & Wheatstone single-needle telegraph, but with the needle on the dial of the "indicator" worked left (I) or right (V) by two vertical semi-circular electro-magnets, as the polarity of the current was altered by twin finger pedals or keys. The code for this device was based on numerical combinations of 1 and 5, the roman I and V.
[129] John Finlaison, *An Account of Some Remarkable Applications of the Electric Fluid to the Useful Arts, by Mr. Alexander Bain: With a Vindication of His Claim to be the First Inventor of the Electro-magnetic Printing Telegraph, and Also of the Electro-magnetic Clock* (London: Chapman and Hall, 1843), 20. Ivan S. Ruddock, "Alexander Bain: The Real Father of Television?" *Scottish Local History Forum* 83 (2012): 3-13, 7-8.
[130] Bain made a considerable sum from his inventions but lost his wealth largely through litigation initially with Wheatstone and latterly with Morse in the United States. In 1873 Sir William Thomson and Sir William Siemens (the first President of the Society of Telegraph Engineers) persuaded Prime Minister Gladstone to pay Bain a civil list pension of £80 per year. Burns, "Alexander Bain," 91.
[131] Edward Highton, *The Electric Telegraph, its history and progress*, (London: John Weale, 1852), 87-88.
[132] Steven Roberts, *A History of the Telegraph Companies in Britain between 1838 and 1868*, https://www.scribd.com/doc/175548241/BR-TELEGR-1881 [accessed June 14, 2016], 26.
[133] Edward and Henry Highton, *Electric-Telegraph*, Patent No. 12039, January 25, 1848.

expiration of the Cooke and Wheatstone master patent the following year, Edward Highton, incorporated the British Electric Telegraph Co., later the British Telegraph Co., to work the patents of both brothers.[134] This initiative was the first real challenge to the Electric Telegraph Co.'s market monopoly.

Thirdly, in September 1845, J.B. Morse arrived in London keen to exploit his own inventions with the railway companies. He investigated the Cooke and Wheatstone installations and entered into unsuccessful negotiations with a number of railway companies. He returned to the United States and together with Alfred Vail took out a patent for what became known as the American Telegraph.[135]

Fourthly, Edward Tyer took out patents in 1852 and 1854 for a pointer signal telegraph originally developed and used on the South Eastern Railway before being adopted by several other companies in both England and France.[136] Tyer formed the Railway Signal Co. to promote ingenious and often elaborate systems of train control.

Fifthly, in May 1855, Charles Spagnoletti whose family came from Sardinia but who was born in London, joined the GWR as its first telegraph clerk. He was subsequently promoted to the post of Chief Electrical and Telegraph Superintendent (a position which confirmed the importance of this area of developing technology to the Company). When the Metropolitan Railway opened in 1863 he was appointed as the first Telegraph Superintendent. He patented a disc block telegraph which was used throughout the GWR. His other inventions including a portable apparatus transported by train, which could be used to establish communication at any point on the route.[137] These are all examples of a technology sector stimulated initially by Cooke and Wheatstone, but exploited by others who used the patent system to protect their inventions whilst they sought the attention of the railway companies.

Finally, on a wider point, it is important to consider the practice of forming joint stock companies to work patents, and whether this had any effect on the rate of technological progress. The Electric Telegraph Co. was one such patent company and one of the most successful. Its capital in 1847 was £104,500 and by 1854 stood at £702,720. The Company produced increasing profits over the same period, and between 1851 and 1854 was making a dividend of 6.5 per cent for its shareholders. Cooke personally earned £25,000 in dividend payments from 1849 until 1853, exclusive of his income from

[134] Kieve, *Electric Telegraph*, 50-51.
[135] The patent was granted in June 1847; extended in 1854 for another seven years, but in 1861 Congress refused a further extension. Burns, *Communications*, 83-86.
[136] Obituary, "Edward Tyer (1832-1912)," *Minutes of the Proceedings of the Institution of Civil Engineers* 196, (1914): 379.
[137] Henry Parris, "Spagnoletti, Charles Ernest Paolo della Diana (1832–1915)," in *Oxford Dictionary of National Biography*, ed. H. C. G. Matthew and Brian Harrison (Oxford: OUP, 2004); online ed., ed. David Cannadine, January 2008, http://www.oxforddnb.com/view/article/48202 [accessed January 10, 2015]

share sales.[138] Bottomley has established by reference to the Board of Trade files in the National Archives that a number of companies (in excess of thirty) were formed between 1845 and 1852 with the principal object of working patents. He argues that despite the limitations of the data it is clear that capital was readily available for investment in patents. This made it easier for both inventors and manufacturers to turn their patents into profit, which in turn engendered further inventive activities.[139]

The Electric Telegraph Co.'s dominance of the market in England and Wales was a direct result of its acquisition of intellectual property rights, through the negotiation and financing of patents. Although beyond the remit of this thesis, the Company's market dominance could perhaps represent an interesting case study of the Nordhaus 'trade off' between the positive and negative economic effects associated with monopolies. Nevertheless, the evidence considered in this chapter would seem to support Nordhaus' long-standing, unchallenged argument that the incentive to invent increases with the strength of monopoly rights that are granted for successful innovations.[140]

7.4 Conclusion

In this chapter it has been demonstrated that Ramsbottom, Cooke and Wheatstone relied upon the patent system to capitalise on their inventions, whether for financial return, enhancement of reputation or a combination of both. There is compelling evidence that Cooke was primarily incentivised to make a profit, whereas Wheatstone claimed to be interested mainly in his reputation and academic status. Whatever his stated claim, Wheatstone took out seven patents as compared with Cooke's six, and made himself a considerable fortune from the sale of the Cooke Wheatstone joint patents.

Ramsbottom was a prolific inventor and his twenty-four patented inventions made a substantial contribution to the demands of the emerging railways. His patent specifications, together with the twelve papers he delivered to the IMechE, added to the technical database of the day and contributed to the management of technical knowledge, in terms of codification and accessibility.

The Cooke and Wheatstone partnership, and the partners' respective attitudes to the role and purpose of patents, illustrates Biagioli's perceived tension between financial reward and reputational status as motivation for utilising the patent system. Cooke was driven to turn ideas into money and the financial return achieved by Cooke and Wheatstone, and latterly by the Electric Telegraph Co., was considerable by the standards of the day. The evidence considered in this chapter suggests that the extraordinary proceeds received by Cooke and Wheatstone would have sent a clear message to others involved in railway-related inventive activity, that patented inventions could be developed with considerable

[138] Electric Telegraph Company shareholders book TGA/1/6, British Telecom Archives, London; quoted in Bottomley, *The British Patent System,* 275, n.29.
[139] Bottomley, *The British Patent System*, 279.
[140] William Nordhaus, "An Economic Theory of Technological Change," *American Economic Review* 59, (1969): 18-28.

financial success. Bain, Highton, Morse, Tyer and Spagnoletti are representative of inventors who, confronted by an existing patent, developed and patented alternative technology that did not infringe patent rights. These examples of subsequent, patented innovation can be understood to have contributed to the diffusion of technological knowledge.

Robert Stephenson was a substantial contributor to early railway technology but to date there has been little emphasis placed on his role in the purchase of the Cooke Wheatstone patents and the incorporation of the Electric Telegraph Co. The papers of George Parker Bidder provide some evidence that Stephenson, through the agency of Bidder, committed substantial funds to both transactions. Although he later became the Chairman of the Company, initially his involvement was kept secret. Stephenson and his associates recognised that the emerging railway companies would have a requirement for electric telegraphy, and that patents were one means by which monopoly profits could be achieved. Subsequent developments have proved their foresight to be accurate. The Electric Telegraph Co. was one of the first successful joint stock companies incorporated with an express object to work patents. The emerging joint stock companies provided a means for capital to be made readily available, which in turn allowed both inventor, funder and manufacturer to make a profit and, arguably, encouraged further inventive activity.

This chapter has demonstrated that during the first half of the nineteenth century, many of those who sought to exploit markets associated with the early railways recognised the potential of the patent system. Furthermore, recourse to an effective patent system, as reassessed in this thesis, served to incentivise railway-related inventive activity. It has been argued in this chapter that the patent system facilitated the disclosure and dissemination of technical information, which resulted in the management and diffusion of technological knowledge.

CHAPTER 8

MATERIALS AND EQUIPMENT

Transport is a very wide ranging subject.
Simmons[1]

Introduction

The current literature on the historiography of the early railways generally focuses on individual railway companies, their conception, amalgamation and operation. In 1968, Simmons described academic thinking as bedevilled by accounts of individual railways, there being no attempt to form a carefully compared view of the whole subject.[2] The situation has altered little in recent decades. However, the evolving railways were a key component of an unprecedented era of substantial technological development and in order to analyse fully the effectiveness of the patent system in relation to early railway technology, it is vital to move beyond the railway proper, as advocated by Divall, and to consider the influence of the patent system on related developing technologies.

An earlier generation of economic historians has stressed the importance of the railways by reference to their backward- and forward-linkages with associated industries.[3] For example, Gourvish has drawn attention to the early railways as having their greatest impact in the backward-linkage effects on the iron industry.[4] Due to the significance of linkages between the developing railways and other industries, it is essential to consider the influence of the patent system on early railway technology in the context of associated technologies. The granting of wayleaves by railway companies to the Electric Telegraph Company, as discussed in the previous chapter, is a pertinent example of the early railways promoting a new technology (telegraphy) through forward-linkage. Nevertheless, this chapter is concerned with backward-linkages that existed with industries associated with the supply of raw materials used in the construction, operation and maintenance of the railways.

The early railways rapidly established themselves as a national institution, both relied upon and admired, and their success was reflected in the financial esteem in which they were held. In 1851 when the initial speculative boom was on the wane, John Francis of the Bank of England observed that during the 1840s the railways had been ‘as good as consols … they formed an investment for surplus capital

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[1] Jack Simmons, *Transportation: a tour of museums* (New York: A.S. Barnes, 1970), 18.
[2] An opinion from an incomplete manuscript prepared by the late Jack Simmons; Biddle “British Railway History,” 327.
[3] For a detailed analysis of backward, and forward linkages, see Colin Divall, "Technical change and railway systems," in *The History and Practice of Britain’s Railways: A New Research*, eds. Rod Ambler, Howard Newby, and David Dilks, (Aldershot: Ashgate Publishing, 1999), 97-111.
[4] Terry Gourvish, *Railways and the British Economy* (London: The Macmillan Press, 1980), 22.

into which safe men entered with a conviction of their stability'.[5] In 1830, when the Liverpool and Manchester Railway opened, the railways accounted for less than four per cent of the value of the London Stock Exchange and by 1844 railway stocks accounted for 52 per cent. Foreign and domestic railway stocks maintained this pre-eminent position until the late 1930s.[6]

During the first half of the nineteenth century a number of developing technologies would have found application across a spectrum of industries, including the early railways, and in this chapter consideration is given to the role of patents in the developing technologies associated with water treatments, timber preservatives, rubber products, rail track and safety valves. The approach adopted here reflects that of Hughes who documented the role of invention and entrepreneurship in the growth of the electric power distribution system during the period 1880 to 1930. According to Hughes, a technological system embodies the physical, intellectual and symbolic resources of the society that constructs it and, when it has been constructed, should be expected to continue to interact with that society.[7] Significantly, Hughes' concept of the reverse salient, an understanding that system growth is dependent on finding solutions for critical problems, and his proposal that patents tend to cluster around critical problems, find resonance within all five of the associated technologies.

By examining developing technologies in the context of the early railways this chapter demonstrates the extensive role of the patent system in serving to incentivise the development and diffusion of early railway and related technologies. Inventors of ancillary railway equipment recognised and exploited the early railway companies as reliable purchasers of patented products. Whilst the motives for patenting an invention were various, the dominant motive of many of the patentees of ancillary railway equipment and associated processes was that of financial return, with a consequential invigoration of the pace and direction of innovation.

Water was, of course, one of the most important resources of the time, and was an essential feature of a number of developing technologies, including the early railways.

8.1 Water.

The search for a supply of good quality water was one of a number of significant tasks for the early railway companies. As locomotives increased in power, and pressures increased steadily from 60psi to an eventual 250psi in the twentieth century, so demands grew on locomotive boilers. One of the technical advantages incorporated by the Stephensons into the locomotive *Rocket*, in 1829, was the multi-tubed boiler: a boiler with 25 tubes, each of three inches in diameter, thereby significantly

[5] John Francis, *A History of the English Railway: its social relations and revelations 1820-1845*, vol.2 (London: Longman, Brown, Green and Longmans, 1851), 132-133.
[6] Andrew Jones, "The Finance of Railways," in *How Railways Changed Britain. A New Social and Economic History*, ed. David St. John Thomas (Derby: Railway & Canal Historical Society, 2015), 59-75, 59.
[7] Thomas Parke Hughes, *Networks of Power: Electrification in Western Society, 1880-1930* (Baltimore: John Hopkins University Press, 3rd edn., 1993), 2.

increasing the heating surface.[8] Progress in the development of steam boilers was rapid. In 1830, the locomotive *Northumbrian* delivered to the Liverpool and Manchester Railway Co. a few weeks before opening day, had 132 tubes, each of 1⅝ inch diameter.[9] However, a persistent problem with the boilers was the build-up of scale deposits, which at its extreme caused or led to boiler explosions, and in any event reduced the working efficiency of the boiler. Bore holes, rivers and canals were gradually replaced as sources of water by the placing of treated water supplies at stations and depots.[10]

At a board meeting on 10 May 1830, the directors of the Liverpool and Manchester Railway Co. discussed the issue of the quality of the water they were considering purchasing from the Manchester and Salford Waterworks, 10,000 gallons per day at a cost of £70 per annum. George Stephenson was asked to report on the suitability of the water, and on 9 August 1830 it was agreed to purchase on the terms offered.[11] A failure to carry out such checks would have led to problems. In 1842 the directors of the Newcastle and Carlisle Railway Co. recorded in their minutes that the water supplied at Newcastle 'was found to be injurious to the engines' and the Secretary was instructed to write to the water company to negotiate a reduction in the charge levied for the supply. A course of action that does not appear to have addressed the problem.[12]

William West is believed to have be the first to have carried out water analysis for a railway company, namely the Stockton and Darlington in 1835, when he confirmed, 'I have analysed the four waters sent to me in order to ascertain their fitness for Engine Boilers ...'.[13] In 1830, West had published a paper in which he discussed the chemical nature of scale formed in the boilers of stationary steam engines, [14] and in 1839 he took out a patent for a valve for machinery raising water and other liquids.[15] In 1846 he presented a paper at a meeting of the Institution of Civil Engineers (ICE) on the chemical analysis of water for locomotive engines. West stated that the object of his paper was 'to point out to engineers how they may best apply the resources of chemistry in their own hands, or those of others, to the selection

[8] G. D. Dempsey and D. Kinnear Clark, *The Victorian Steam Locomotive: It's Design & Development 1804-1879* (Barnsley, Pen & Sword Books Ltd, 2014), 12.
[9] Warren, *A Century of Locomotive Building*, 239.
[10] Jack Simmons and Gordon Biddle, *The Oxford Companion to British Railway History* (Oxford: Oxford University Press, 2003), 557.
[11] Manchester and Liverpool Railway Co., Board meetings, May 1826 - June 1830, and June 1930 - February 1833, RAIL 371/1-2.
[12] Minutes, April 18, 1842. Newcastle and Carlisle Railway, shareholders, directors and committee meetings, RAIL 509/7.
[13] William West, "Report for Stockton and Darlington Railway", September 23, 1835, quoted in Colin Russell and John Hudson in *Early Railway Chemistry and its Legacy* (London: The Royal Society of Chemistry, 2012), 48-49. West may have been chosen to conduct the water analysis for the Stockton and Darlington Railway on account of his professional reputation, or perhaps because Edward and Joseph Pease (major shareholders) were, like West, Quakers; Russell and Hudson, *Early Railway Chemistry*, 48.
[14] William West, "Practical and Philosophical Observations on Natural Waters," *The Journal of the Royal Institution of Great Britain* 1, (1830): 38-48.
[15] William West, *Valve for machine for raising water and other liquids*. Patent No. 8103. June 12, 1809.

of water...'.[16] The meeting was chaired by John Rennie, and a discussion then took place in the company of several of the leading engineers of the day, including Robert Stephenson, John Gooch, and Samuel Peto, when a number of chemists debated their discoveries and solutions to the problems of water quality.

The ensuing discussion illustrated the importance of the subject of incrustation in a steam boiler and the need for railway engineers of the time to seek answers which were not available within their own organisations. Peto stated that everyone who used steam power must, he thought, feel 'indebted to Dr Ritterbandt (who was present) for bringing forward so valuable a discovery'.[17] In 1844, Ritterbandt had patented a widely used method of softening water, which both dissolved any scale already formed and prevented further precipitation.[18] The process was first tested successfully by the London and Southampton Railway Co.'s Engineer, John Viret Gooch.[19] Robert Stephenson referred to the experiments he was organising on the Norfolk Railway to ascertain whether the addition of chemicals to the water had a detrimental effect on the metal, confirming such experiments were important, 'and if found to be successful, it would be of the greatest importance to everyone having a steam engine'.[20]

Three years later, the quality of the water available for locomotives at LNWR's Camden station was debated at the ICE when both chemists and engineers were again present. The eminent well-sinker Robert Paten had sunk a well at Camden, but the water contained carbonate of soda which was detrimental to locomotive boilers and therefore an alternative supply had to be obtained from the Regents Canal. In the ensuing debate the subject matter was broadened into a more general discussion concerning water and the considerable volume of water required by the railway companies. Robert Benson observed,

> … the [LNWR] received an excellent return for the amount expended in the supply of the Euston hotels and their own tenants ... the gross annual consumption is 22,880,000 gallons of which Euston station takes 7,358,000 gallons.[21]

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[16] William West, "On Water for Locomotive Engines, and its Chemical Analysis," *Minutes of the Proceedings of the Institution of Civil Engineers* 5, (February 17, 1846): 182-216, 191.
[17] West, "On Water for Locomotive Engines," 206.
[18] Ritterbandt added 'ammoniacal salt' (ammonium carbonate) to the water to prevent encrustation of the boiler which received glowing endorsement from, among others, *The Times*, 'The invention has been tried for nearly twelve months upon the boilers of the engines printing the Times, working on an average seventeen hours per diem throughout the year. Not only have the boilers been kept perfectly free from deposit, but an incrustation which has formed previously to the application of the invention has been completely removed. We can further state, that neither the boilers nor any part of the machinery, has been in any, even the slightest degree acted upon or injured by the action of the remedy in question'. "Incrustation of Steam Boilers," *Times*, December 23, 1846, 4. Ritterbrandt registered two patents, in 1844 and 1845. Louis Antoine Ritterbrandt, *Preventing and removing encrustation in steam boilers*. Patent 10409. December 12, 1844; *Application of heat to boilers*. Patent 10672. January 17, 1845.
[19] London and Southampton Railway Co., locomotive engine, locomotive way and works, locomotive power, and traffic police and goods committee minutes 1839-1845, August 22, 1845, RAIL 412/4.
[20] West, "On Water for Locomotive Engines," 209.
[21] Robert Benson, "Discussion, Description of the Camden Station of the London and North Western Railway," *Minutes of the Proceedings of the Institution of Civil Engineers* 8, (January 1849): 164-185, 173.

During the meeting, Robert Stephenson argued that the presence of oil within a locomotive's water supply was a cause of priming, whereas Isambard Kingdom Brunel argued the action of priming was 'more mechanical than chemical'.[22] Once again a number of chemists offered solutions to the general problems, in the probable hope of financial gain if taken up by the railway companies.[23] West's advice that analysis of water might exert an influence on civil engineering operations was adopted by railway directors, and they sought advice from those skilled in testing water quality. The emerging profession of chemists undertook this task. Edward Frankland, eventual founding President of the Institute of Chemistry in 1877, carried out work for the Lancaster and Carlisle Railway Co., and Thomas Richardson for the South Durham and Lancashire Union Railway Co. Richardson, who took out a number of patents for processes, was a leading figure in the railway industry.

There were no standards or specifications for the quality of water, and the general rule was to make the water as soft as possible. A water source that was neither a naturally soft supply nor contained any undesirable substances was rarely found. This situation meant the application of a water treatment process was essential. However, the railway companies did not employ chemists or consultants until the appointment of E. Swann at Crewe in 1864.[24] Russell and Hudson cite compelling evidence of chemists who took out patents to protect their ideas with a view to securing profits from railway companies and other industrial sectors. In 1841, one such chemist, Thomas Clark, having discovered the softening properties of phosphate of soda, took out a patent for the process which became known as the Clark process.[25] He tried, unsuccessfully, to persuade Brunel to accept the process on the GWR.[26]

At a time when railway companies did not employ expertise in water analysis, it became established practice when a new process was patented, for the inventor to seek to persuade railway companies to purchase the method. There is good evidence patenting was the order of the day for managing and protecting inventive information, that the patent system served as an incentive. Chemists competed for the work, and looked for new patentable processes. In 1851, A.V. Newton presented a paper at the ICE on the nature of patent protection.[27] During the discussion, which was lively, Newton argued that the government fee should be reduced but that 'patent laws were just and necessary'.[28] Ritterbandt responded with a criticism of the then patent system drawing attention to the lack of protection offered

[22] Benson, "Discussion," 183.
[23] Russell and Hudson, *Early Railway Chemistry*, 54.
[24] Crewe remained the solitary case of a railway laboratory anywhere in Britain for a further twelve years. Russell and Hudson, *Early Railway Chemistry*, 79.
[25] Thomas Clark, *A new mode of rendering certain waters (the waters of the Thames being amongst the number) less impure and less hard for the supply and use of manufactories, villages, towns and cities.* Patent No. 8875, March 8, 1841.
[26] Russell and Hudson, *Early Railway Chemistry*, 54.
[27] A.V. Newton, "The Nature of Patent law protection, with a view to the better appreciation and security of the inventor's rights," *Minutes of the Proceedings of the Institution of Civil Engineers* 10, (1851): 193-209.
[28] T. Webster *et al*., "Discussion. The Nature of Patent law protection, with a view to the better appreciation and security of the inventor's rights," *Minutes of the Proceedings of the Institution of Civil Engineers* 10, (1851): 209-219, 217.

by the law to scientific inventors. He was also disparaging of the system which in his view allowed 'frivolous' inventions.[29]

The supply of water and, importantly, its quality was a regular agenda item at board meetings of many of the early railway companies. The evidence considered here establishes that a number of chemists recognised the economic potential of their patented processes. A similar picture emerges when the subject of timber is considered.

8.2 Timber

A huge quantity of treated timber was consumed by the early railway companies for a variety of uses from wagons and carriages to small items such as pick handles and curtain rings.[30] Initially timber was used for railway constructional works.[31] William Maddocks is said to have used wooden rails and sleepers in 1800 to build the Cob embankment to reclaim part of the Traeth Mawr in North Wales, but the evidence is not certain.[32] The Liverpool and Manchester Railway Co., like others, initially used stone blocks to support rails, but the blocks tended to sink and distort the rails. A practice therefore evolved of using traverse wooden sleepers resting on ballast which spread the load more evenly and resulted in a smoother ride. During the period 1845 to 1850, some 12,000,000 wooden sleepers were required for new railway lines alone.[33]

The evolving railway system increased the demand for imported foreign timber. Isambard Kingdom Brunel specified yellow pine for his numerous viaducts in Devon, Cornwall and South Wales. Significantly, writing to Michael Faraday in 1837, he stated he had 40,000 to 50,000 loads of timber to treat.[34] Parliamentary records for 1849 show that 1,733,617 loads or 88,680,850 cubic feet of timber were imported and in 1853 it was anticipated that the introduction of railways would require the same supply for many years to come.[35] The problem with timber is its predisposition to decay and many remedies were sought, the impetus being generated initially by the shipbuilding industry[36] and subsequently by the introduction of railways. Many of the early methods of preservation were made the

[29] Webster "Discussion," 217.
[30] Much later, in 1900, F.W. Webb was able to comment in the *Railway Magazine* 'we make all sorts of things in Crewe works - down to artificial legs and arms for the poor fellows who lose their limbs by accident in service to the LNWR.' The LNWR employed 1,600 people in its Earleston wagon works in 1889, with most employed in woodworking trades: *Railway Magazine* 6, (1900): 104. These were not occasional manufacturers as noted by Acworth who stated, 'two men are constantly employed making artificial limbs'; William M. Acworth, *The Railways of England,* (London: John Murray, 1899), 59.
[31] Michael Lewis, *Early Wooden Railways* (London: Routledge and Kegan Paul Ltd., 1970), 26-27.
[32] Michael Lewis, *How Ffestiniog got its Railway* (Caterham: The Railway & Canal Historical Society, 1965), 2.
[33] Simmons and Biddle, *The Oxford Companion,* 511. A century later, in 1938, some 4.4 million were used.
[34] Isambard K. Brunel, letter to M. Faraday, June 1837, The Correspondence of Michael Faraday, (London: Institution of Electrical Engineers, 1993), 2, quoted in Russell and Hudson, *Early Railway Chemistry,* 62.
[35] Burt, "On the Nature and Properties of Timber," 222.
[36] Traditional wooden hulls were subject to dry rot and woodworm.

subject of patents, the first being granted to Alexander Emerson in 1737.[37] From 1808 to 1830 some 47 patents were granted for preservation for substances including timber.[38] Preserved timber, in quantities, was a vital procurement for railway companies for a variety of purposes and there is evidence that the presence of a patent was a qualitative consideration in relation to the purchase.

In 1832, John Kyan was granted a patent for a process to preserve wood which involved soaking the timber in a solution of corrosive sublimate (mercury chloride). This became known as Kyanizing,[39] a process that had the support of Michael Faraday who, in 1833, on his appointment as Fullerian Professor of Chemistry delivered his inaugural lecture favouring the method.[40] Kyan, who took out six patents (Table 16), is a good example of an inventor who protected his various processes by applying for a patent, and for whom it paid to patent.

Table 16: Patents - John Howard Kyan

	Subject matter	**no.**	**date**
i.	*Preserving certain vegetable substances from decay*…...	**6253**	31.03.1832
ii.	*Preserving paper, canvas, cloth and cordage*..................	**6309**	22.09.1832
iii.	*Combination of machinery for steam navigation*.............	**6534**	21.12.1833
iv.	*Preserving certain vegetable substances from decay*.......	**7001**	11.02.1836
v.	*Extracting ammoniacal salts from gas liquor*...……….....	**7460**	04.11.1837
vi.	*Steam engines*..	**7952**	29.01.1839

Source: Woodcroft, *Alphabetical Index of Patentees of Inventions*, 325.

In 1836, Kyan sold his existing patent rights to a statutory company, the Patent Anti-Dry Rot Co., with a share capital of £250,000.[41] The sale of his patent rights, even by today's standards, produced a substantial sum of money. It was an active market and, as demonstrated below, inventors were incentivised to find alternative methods of timber preservation, both to avoid infringing the Kyan patent and to secure lucrative returns.

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[37] Alexander Emerson, *Covering and painting timbers, planks and boards …* Patent No. 557, June 13, 1737.
[38] Burt, "On the Nature and Properties of Timber," 222.
[39] John Kyan, *Preserving certain vegetable substances from decay*, Patent No. 6253, March 31, 1832. Russell and Hudson, *Early Railway Chemistry*, 62.
[40] Michael Faraday, *On the Practical Prevention of Dry Rot in Timber: Being the Substance of a Lecture Delivered by Professor Faraday at the Royal Institution, February 22, 1833 with Observations, &c* (London: J. and C. Adlard, 1833).
[41] R. B. Prosser, "Kyan, John Howard (1774–1850)," in *Oxford Dictionary of National Biography*, ed. H. C. G. Matthew and Brian Harrison (Oxford: OUP, 2004); online ed., ed. David Cannadine, May 2006, http://www.oxforddnb.com/view/article/15813 [accessed January 4, 2016].

The Patent Anti-Dry Rot Co. regarded the early railway companies as significant, potential purchasers. Isambard Kingdom Brunel adopted Kyanizing,[42] and the minutes of the Hull and Selby Railway Co.'s directors meeting on 24 August 1840 record,

> The Secretary informed the Board that he had conversed with Mr Persall, the Chemist, relative to the Kyanizing Timber, and that he gave a very decided opinion in favour of the process.[43]

In 1839, John Herapath wrote a strident article criticising the Admiralty for its failure to adopt the kyanising process despite 'having been patronised by every architect of eminence in the county'.[44] In support of his argument, Herapath cited some eighteen railway companies and their engineers who were using the process (Table 17).

Table 17: Railway company purchasers, and their leading engineers, of Kyan's patented process for timber preservation

London and Birmingham	R. Stephenson
Great Western	I. K. Brunel
North Midland	G. Stephenson
Manchester, Bolton and Bury	J. Hawkshaw
London and Croydon	Joseph Gibbs
Liverpool and Manchester	G. Stephenson
London and Southampton	J. Locke
Ulster York and Midland	G. Stephenson
Newcastle and N. Midlands	G. Stephenson
Midlands Grand Junction	W.D. Holme
York and N. Midland	Thomas Cabry
London and Greenwich	Colonel Laudmann
Dublin and Kingston	Charles Vignoles
Birmingham and Gloucester	Captain Moorson
Maryport and Carlisle	G. Stephenson
Llanelly	Alfred Thomas
Birmingham and Derby	G. Stephenson & Birkenshaw
Ulster	Godwin

Source: J. Herapath, "The Government and Kyan's Anti Dry-rot," *The Railway Magazine* 6, (1839): 468- 475, 472.

It was maintained by Kyan that permanent chemical combination took place between the mercurial salt and the woody fibre, but this was contested. When wooden railway sleepers became standard, in place of stone blocks, it was found that iron fastenings could not be used in wood treated by Kyan's method, because the wood became brittle.[45] Doubts began to be expressed as to the true effectiveness of kyanizing and the process gradually ceased to be employed. In 1838 Sir William Burnett took out a patent for impregnating wood with zinc chloride.[46] Also in 1838, John Bethell, patented a very

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[42] Great Western Railway Co., correspondence concerning engineering work (1835-1839), including Kyanising sleepers, RAIL 1008/62.
[43] Hull and Selby Railway Co., directors' minutes, August 24, 1840, RAIL 315/7, minute 24.
[44] Herapath "The Government and Kyan's Anti Dry-rot," 472.
[45] Prosser, "Kyan, John Howard (1774–1850)."
[46] William Burnett, *Preserving wood and other vegetable matters from decay*, Patent 7747, July 26, 1838.

successful timber preservation process which proved a credible alternative to Kyanizing[47] and, in 1841, Charles Payne patented a process which involved introducing a metallic substance into the pores of the wood and then drawing it off and replacing with decomposing fluid.[48]

Russell and Hudson argue that the growth of the railway system acted as a spur for the invention of new treatments.[49] The early railway companies were faced with an array of timber preservation products and the North Eastern Railway Co. turned to Thomas Richardson, Professor of Chemistry at Durham University, to investigate the various options. Richardson provided a report for the directors to which he appended abstracts of patent specifications relating to the preservation of timber which had been taken out between 1728 and 1858.[50] It is pertinent to this thesis that Richardson identified no fewer than 50 patents that had been taken out between Kyan's patent of 1832 and the submission of his Report in 1858. During the three years preceding Richardson's report, the North Eastern Railway Co. was spending £60,000 per annum on the purchase of timber. It is perhaps no surprise, therefore, that the dominance of Kyanising for the preservation of timber was subject to intense challenge by those who recognised the importance of timber and its preservation to the railway companies.

Richardson was a leading consultant in the railway industry and took out a number of patents.[51] His experiments for the North Eastern Railway Co., which included the analysis of coke, were carried out at their Gateshead works. Prior to the completion of his report, Richardson and Browell invented a new timber preservative for which they jointly took out a patent in April 1857.[52] Undoubtedly the North Eastern Railway Co. directors were looking for an option that did not require the payment of royalties, but that was difficult to achieve with so many of the options being subject to patents, and their own consultant taking out yet a further patent upon the completion of their experiments, possibly at their expense. According to Russell and Hudson, there is no record of the process being adopted by the Company, and no comment by any official has survived.[53]

It was coal tar creosote that eventually became the substance of choice for most of the early railway companies. In 1848, two railway engineers, Henry Burt and Samuel Boulton, founded the eventual company of Burt Boulton and Hayward, established for the production of railway sleepers using coal

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[47] John Bethell, *Rendering wood ... stones, and plasters or compositions, more durable, less pervious to water, or less inflammable.* Patent No. 7731. July 11, 1838.
[48] Charles Payne, *Preserving vegetable matters where metallic and earthy* solutions, July 9, 1841. Burt, "On the Nature and Properties of Timber," 217.
[49] Russell and Hudson, *Early Railway Chemistry*, 64.
[50]Thomas Richardson, "Report on the Preservation of Timber," *Journal of the Royal Agricultural Society of England 20* (1859): 1-22.
[51] C.D.Watkinson, "Richardson, Thomas (1816–1867)," in *Oxford Dictionary of National Biography*, online ed., ed. David Cannadine, Oxford: OUP, 2004, http://www.oxforddnb.com/view/article/23586 [accessed June 24, 2016].
[52] Thomas Richardson and E.J.J. Browell, *Treating old or waste railway wood sleepers and bearers; preparing or preserving wood for railway sleepers and bearers and other works*. Patent No. 1036. April 13, 1857.
[53] Russell and Hudson, *Early Railway Chemistry*, 65.

tar as a preservative.[54] Coal tar had long been used for the preservation of timber in ships, but Burt and Boulton were able to capitalise on the reduced cost of creosote that resulted from the huge expansion of the gas industry in the nineteenth century. Between 1855 and 1858, coal tonnage shipped from the north eastern coalfields to London increased dramatically from 85,000 to 600,000.[55] In 1856 Burt Boulton and Hayward moved their tar distillery enterprise to Silverton, London, to take advantage of cheap abundant coal.[56] The Company became, and claims to remain, the world's largest supplier of preserved timber, taking out patents for each incremental improvement to the preservation process. A success achieved initially through supplying the railway industry.

It has been demonstrated in this section that many of the substantial treatments for the preservation of timber were made the subject of patents, and if successful in securing sales in the rapidly developing railway sector, patentees would have been guaranteed a financial return. Companies such as Burt Boulton and Hayward achieved considerable commercial success through supplying the railway industry with patented processes. Similarly, Kyan is representative of many inventors of ancillary railway products who made a substantial, if short-lived, return on patents. An examination of the part played by rubber establishes a similar position.

8.3 Rubber

The successful mechanical application of rubber was developed at the time of the emerging early railways, and in due course rubber became an important product for a whole range of railway-related functions. This chapter can only deal with the commencement of the use of rubber by the emerging railways because the full flowering of the relationship occurred during a period beyond the remit of this thesis. Examination is valid, however, because it informs understanding as to the role of patents in the embryonic alliance between the early railway companies and the rubber industry.

The successful mechanical application of rubber became possible when Charles Goodyear discovered the process of vulcanization in 1839. However, it was Thomas Hancock who took out a patent, in America and England, in November 1843,[57] some eight weeks before Goodyear's own application arrived at the office of Chancery in London.[58] Stephen Moulton took out a patent in England in 1847 for the vulcanization process, but the chemicals he used differed from those of Hancock (lead

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[54] For an early history see: S.B. Boulton, "On the Antiseptic Treatment of Timber," *Minutes of the Proceedings of the Institution of Civil Engineers* 78, (1884): 97-156. The word 'antiseptic' translates as an engineering term for 'creosoting.'

[55] Philip Cohen and Michael J. Rustin eds., *London's Turning: Thames Gateway-prospects and Legacy* (Aldershot: Ashgate Publishing, 2008), 22.

[56] Cohen, *London's Turning*, 25.

[57] Thomas Hancock, *Preparation or manufacture of caoutchouc in combination with other substances …* Patent No. 7549, January 23, 1838.

[58] Charles Slack, *Nobel Obsession: Charles Goodyear, Thomas Hancock and the Race to Unlock the Greatest Industrial Secret of the Nineteenth Century* (London: Texere Publishing Ltd, 2002), 134

hyposulphite instead of sulphur).[59] Hancock claimed that Moulton had copied his patented vulcanization process and this led to a long and bitter dispute which eventually reached the High Court in July 1855, just two years before Hancock's patent expired. Hancock ultimately won, but probably destroyed his reputation in the process, because it became clear that Goodyear was the inventor and Hancock had merely won the race to the patent office. Lord Campbell who presided over the case stated,

> If Goodyear's invention was prior in point of time, it was not handsome in Hancock to look at his specimens and try to find out his discovery; and if Goodyear was the inventor, it was to be regretted that he did not have the benefit of his inventions.[60]

The legal issue of precedence was clear, and Moulton eventually agreed to receive a licence from Hancock for the manufacture of rubber products at an annual sum of £600.[61] Edward Jennings, solicitor, advised Moulton on the Hancock litigation. As demonstrated by Jennings' fee notes, Moulton engaged actively in the process of acquiring and protecting patents and regularly took advice on matters concerning his patent rights. [62]

Moulton sought to engage the attention of the railway companies, and there is good evidence that he maintained business relationships with the leading railway engineers of the day. On 9 November 1850 Daniel Gooch wrote to Moulton inviting him to visit him in Swindon, and on 19 August 1857 Gooch writing from the engineers' office in Swindon asked Moulton to make him some rubber rings.[63] On 23 and 30 March 1857, Isambard Kingdom Brunel wrote to Moulton with an inquiry as to mountings for flange joints and mask mounting for a ship.[64] The major products of the company were railway and carriage springs and in 1891, Moulton and Co. merged with George Spencer and Co., with George Spencer retaining the dominant influence. The merged company, George Spencer, Moulton and Co. continued in business until 1956 when it was taken over by Avon Rubber Co. Ltd.[65]

The archive of George Spencer and Co. reveals a significant number of agreements entered into by George Spencer for the supply of rubber rings for almost every purpose, most of them with patent

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[59] Stephen Moulton, *Elastic and impermeable compounds*, Patent No. 11567, February 2, 1847.
[60] R.A. Brooman, ed., "Hancock's Caoutchouc Patent: Law Case. Court of Queen's Bench, Guildhall, July 7-9, 1855," *Mechanics' Magazine* 63, (London: Knight and Lacey, 1855), 80 – 81, 81.
[61] Woodruff, *The Rise of the British Rubber Industry*, 154.
[62] In March 1864, Jennings took advice from a barrister, Mr Hindmarsh. Moulton had invented a model but had exhibited it at a public meeting and was concerned that the exhibition of the model would prevent him from applying for a patent. Mr Hindmarsh gave reassuring advice. Spencer & Co. miscellaneous papers (uncatalogued), 2610/13655, Wiltshire and Swindon History Centre, Chippenham. Jennings' fee note for 5 December 1860 sets out the detail of a dispute with one Palairel to whom Moulton had sold a share of a patent. The dispute was settled by Moulton making a payment to Parlairel. Spencer & Co. miscellaneous papers (uncatalogued), 2610/13655, Wiltshire and Swindon History Centre, Chippenham.
[63] Spencer & Co. miscellaneous papers (uncatalogued), 2610/13655, Wiltshire and Swindon History Centre, Chippenham.
[64] Spencer & Co. miscellaneous papers (uncatalogued), 2610/13655, Wiltshire and Swindon History Centre, Chippenham.
[65] William Woodruff, *The Rise of the British Rubber Industry During the Nineteenth Century* (Liverpool: Liverpool University Press, 1958).

protection.[66] Little is known about the early life of George Spencer, but he was an engineering draughtsman in the employment of Fox Henderson and Co., one of the foremost railway contracting firms of Victorian England. Sir Charles Fox, who formed the partnership, had driven *Novelty* at the Rainhill trials. One of Fox's earliest inventions was the railway point switch, which he patented in 1838,[67] and Spencer assisted him with the preparation of drawings for the construction of the Crystal Palace that housed the Great Exhibition of 1851. Spencer would have learnt much during his employment as to the emerging railway industry and the use made by Charles Fox of patents to protect his railway sector inventions.

Spencer took out his first patent in 1845 for a haulage apparatus,[68] but nothing came of it and in 1852 he took out another for an improved method of using vulcanized india-rubber for the buffer, draw and bearing springs of railway carriages, wagons and trucks.[69] He had insufficient funds to apply for the patent and entered into an agreement with one Richard Lane who agreed to pay all the expenses in return for a share in the proceeds.[70] Spencer then resigned from Fox Henderson and Co. and entered into a series of partnerships to raise sufficient capital to work the patent, to turn the invention into an industrial and commercial success.[71] A process he repeated with subsequent patents throughout his professional life. Another patent was taken out in 1853 to protect further improvements.[72] The rubber spring had considerable advantages over the steel helical or volute spring commonly in use, and was far more efficient in absorbing shock. From the outset Spencer decided to purchase the various parts and then assemble them, rather than manufacture from scratch.

The maintenance of patent protection was a crucial element of the developing Spencer business. Between 1845 and 1890, Spencer applied for, or acquired an interest in no fewer than 86 patents.[73] He went to great lengths to protect his inventions, and was careful to protect his business interests from allegations of infringement. In circumstances where he wished to allege infringement of one of his own patents, he adopted a robust approach. In order to protect against the possibility of legal action, and to extend the range of rubber products he could offer, Spencer sought either to purchase rubber spring

[66] Spencer & Co. miscellaneous papers (uncatalogued), 2610/13655, Wiltshire and Swindon History Centre, Chippenham.
[67] Charles Fox, *Arrangement of rails, for causing a train to pass from one line to another*. Patent No. 7773. August 15, 1838.
[68] George Spencer, *Propelling vessels on inland waters.* Patent No. 10458. January 11, 1845.
[69] George Spencer, *Improvements in the springs of Railway Carriages, Trucks and Waggons.* Patent No. 13951. February 2, 1852.
[70] Lane's investment was in return for 'one moiety of all right, title, and interest, benefit, and advantage' in the invention. Agreements between George Spencer and Richard Kirkman Lane, December 23, 1851 and April 27, 1852, quoted in Payne, *Rubber and Railways*, 3-5. According to Payne the second agreement indicates that Spencer had taken out letters patent for England, Wales, France, Belgium, Holland, Austria, Prussia, Bavaria, Saxony, Hanover, Wurtemburg, Hesse Cassell, Darmstadt, Baden, Lippe, Brunswick, Sardinia and the USA.
[71] Payne, *Rubber and Railways*, 3.
[72] George Spencer, *Improvements in Springs for Carriages*. Patent No. 1733. July 22, 1853.
[73] Payne, *Rubber and Railways*, appendix 1.

patents outright or to secure control of their use. For example, worried that his 1853 patented spring design may have infringed Hodge's earlier patent of 1852,[74] Spencer entered into an agreement for the sole right to manufacture Hodge's patented rubber and steel springs. The Hodge Spring was already used widely by a number of locomotive builders including Robert Stephenson and Co. and Beyer Peacock, and had been adopted by the GWR and the Bristol and Exeter Railway Co. By the end of 1855, a total of 271 steam locomotive engines were equipped with Hodge's springs.[75]

In circumstances where Spencer received financial investment he would agree to share the resulting profits. His trade was mainly conducted with railway companies in the British Isles, and purchases from railway companies rarely fell below 70 per cent of annual sales.[76] The Company was highly dependent on the railways as customers and clearly orientated towards meeting their needs for new products. Spencer sought to impress upon railway engineers that his products were of the highest quality which justified their expense. He never failed to underline the importance of the existing patents. Although beyond the remit of this thesis, it is interesting to note that in correspondence in 1868 with Richard Galbraith, the Company's agent in Vienna, Spencer stated, 'we need scarcely point out to you the great advantages of working under a patent'.[77] The Company had an established network of agents in Britain and eventually in France, India, Australia, China, Italy and Ireland, to name but a few.[78]

There is evidence that Spencer operated price discrimination for his patented springs, depending on the railway company concerned. Surprisingly, he charged the London and South Western Railway Co. a premium on the basis that Spencer and Co. 'worked' the patents of two of their celebrated engineers, W. Beattie and W. Adams. As *quid pro quo,* the Company's storekeepers always purchased their rubber products from Spencer.[79] Spencer managed his relationships with the railway companies (and the retained knowledge of his patents) by maintaining close contact with those responsible for the purchase of railway equipment. For example, his diary for 22 May 1854 has the entry, 'took Mr Brassey[80] double cone with ring and 2 single cones and end plates'.[81] Spencer's undoubted and considerable entrepreneurial skills included a vigorous stance on patent protection. His significant use of patents in many forms allowed him to attract and retain the business of railway companies in the purchase of his

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[74] Paul Rapsey Hodge, *Construction of railways and railway carriages.* Patent No.14018. March 8, 1852.
[75] Payne *Rubber and Railways*, 14-15, n.13.
[76] Payne, *Rubber and Railways*, 135.
[77] George Spencer & Co., Letter to Richard Galbraith December 12, 1868, Spencer & Co. miscellaneous papers (uncatalogued), 2610/13655, Wiltshire and Swindon History Centre, Chippenham. Spencer continued to make improvements to his products ensuring he took out a patent each time. In 1877, three years before his 1866 patent expired, he took out a patent for an embedded plate spring, and in 1890 when the 1877 patent had fewer than two years to run, the company began to market the spring patented by George Spencer in 1886.
[78] Spencer & Co. miscellaneous papers (uncatalogued), 2610/13736, Wiltshire and Swindon History Centre, Chippenham
[79] Payne *Rubber and Railways*, 104.
[80] It is not clear whether this was Thomas Brassey (1805-1870), the railway civil engineer. See, Charles Walker, *Thomas Brassey Railway Builder* (London: Frederick Muller, 1969).
[81] Spencer & Co. miscellaneous papers (uncatalogued), 2610/13736.

rubber goods. He was at the forefront of developing railway technology in relation to the increasing use of rubber for railway apparatus, and an examination of his sales books for 1855 to 1868 reveals a significant number of railway companies as customers.[82] A list of railway companies is reproduced in Table 18.

Table 18: Railway companies on the order books of George Spencer & Co., 1853-1891

Ayrshire & Wigtownshire Rly Co
Barry Rly Co
Belfast & Ballymena Rly Co
Belfast & Northern Counties Rly Co
Birkenhead, Lancashire & Cheshire Junction Rly Co
Bishops Castle Rly Co.
Blythe & Tyne Rly Co.
Bodmin & Wadebridge Rly Co.
Brecon & Merthyr Tydvil Jct Rly Co.
Bristol & Exeter Rly Co.
Caledonian Rly Co.
Cambrian Rly Co.
Cheshire Lines Committee
Colne Valley Rly Co.
Cork & Bandon Rly Co.
Cork, Blackrock & Passage Rly Co.
Cornwall Rly Co.
Cromford & High Peak Rly Co.
Deeside Rly Co.
Dublin & Drogheda Rly Co.
Dublin, Wicklow & Wexford Rly Co.
Dundalk & Enniskillen Rly Co.
Dundee & Arbroath Rly Co.
Dundee, Perth & Aberdeen Rly Co.
Eastern Counties Rly Co.
Eastern & Midlands Rly Co.
East Lancashire Rly Co.
Edinburgh & Glasgow Rly Co.
Furness Rly Co.
Glasgow & South Western Rly Co.
Great Eastern Rly Co.
Great North of Scotland Rly Co.
Great Northern Rly Co.
Great Norther Rly Co. of Ireland
Great Southern & Western Rly Co. of Ireland
Great Western Rly Co.
Highland Rly Co.
Hull, Barnsley & West Riding Junction Rly & Docks Co.
Isle of Man Rly Co.
Jersey Rly Co.
Lancashire & Yorkshire Rly Co.
Lancaster & Carlisle Rly Co.
Listowel & Bally Bunion Rly Co.
Llanelly Rly & Dock Co.
Llynwi & Ogmore Rly Co.
London & Blackwall Rly Co.
London & North Western Rly Co.
London & South Western Rly Co.
London, Brighton & South Coast Rly Co.
London, Chatham & Dover Rly Co.
London, Tilbury & Southend Rly Co.
Lynn & Fakenham Rly Co.
Manchester, Sheffield & Lincolnshire Rly Co.
Maryport & Carlisle Rly Co.
Mersey Rly Co.
Metropolitan Rly Co.
Metropolitan District Rly Co.
Midland Rly Co.
Midland Great Western Junction Rly Co.
Mid-Wales Rly Co.
Monmouthshire Canal & Rly Co.
Neath & Brecon Rly Co.
Newport, Abergavenny & Hereford Rly Co.
Northern Rly Co. of Ireland
North British Rly Co.
North Devon Rly Co.
North Eastern Rly Co.
North London Rly Co.
North Staffordshire Rly Co.
Oxford, Worcester & Wolverhampton Rly Co.
Port of Carlisle Dock & Rly Co.
Ryde, Newport & Cowes Rly Co.
St Helens Rly Co.
Scottish Central Rly Co.
Shrewsbury & Hereford Rly Co.
Somerset & Dorset Rly Co.
South Devon Rly Co.
South Eastern Rly Co.
South Wales Rly Co.
Stockton & Darlington Rly Co.
Swansea Vale Rly Co.
Taff Vale Rly Co.
Vale of Neath Rly Co.
Waterford & Tramore Rly Co.
Waterford & Limerick Rly Co.
West Hartlepool Harbour & Rly Co.
West Midland Rly Co.

Source: George Spencer & Co. Sales Book, Spencer & Co. miscellaneous papers (uncatalogued), 2610/13772.

[82] Extracted from George Spencer & Co. Sales Book, Spencer & Co. miscellaneous papers (uncatalogued), 2610/13772.

In summary, it has been argued in this section that Spencer and Co. relied upon and exploited the benefits of the patent system in at least three important respects. Firstly, Spencer achieved and maintained market dominance by means of a stream of patented improvements. Secondly, his practice of purchasing patents for associated railway equipment would likely have generated a demand amongst inventors who knew that in Spencer they had a willing buyer, enthusiastic to preserve his market and to avoid litigation. Thirdly, the sales figures speak for themselves. Rubber vulcanization created a number of opportunities for inventive activity in relation to the early railway companies' need for equipment, and the role of patents as adopted by Spencer created a very successful company. Railway companies were no doubt keen to avoid the payment of royalties for rubber products. Spencer continually took out patents for improvements so that his merchandise remained at the forefront of rubber development. Railway companies were given little choice if they required the most advanced materials.

Cooper has introduced the term patent management to demonstrate how status, ownership and originality of an invention were negotiated in both the legal and market domains. She argues that patent management functioned historically as a social subsection that not only guided inventors' technical choices, but has 'shaped our very ways' of perceiving technological objects.[83] Spencer and Co., was mainly concerned with sales to railway companies, and provides a good example of patent management in practice. Spencer and Co. purchased numerous patents outside their normal core business in order to build relationships with railway companies in the hope they would purchase their products.

8.4 Rail

> Even at that early period, [George Stephenson] was in the habit of regarding the road and the locomotive as one machine, speaking of the rail and the wheel as "man and wife".
>
> Smiles[84]

It is argued in this thesis that the patent system served as a driver of early railway technology, and rail track provides a relevant and important case study. Despite its vital function in the establishment of the railway system, the development of rail track has not been the subject of much detailed academic analysis. Two notable exceptions are Lewis' seminal account of wooden railways in the two hundred years prior to 1804 and Dow's recent study of rail track since 1804, and upon which this section draws.[85] Track, as described by Dow, was one of the four fundamental disciplines of the early railways, with an integral link to the more popular topic of the railway locomotive, and yet rail track remains a cinderella subject.[86] Dow traces the development of rail track and cites patent specifications as an 'occasional'

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[83] Carolyn C. Cooper, "Social Construction of Invention through Patent Management: Thomas Blanchard's Woodworking Machinery," *Technology and Culture* 32, (1991): 960-998, 997.
[84] Samuel Smiles, *The Life of George Stephenson. Railway Engineer* (London: John Murray, 1857), 134.
[85] Lewis, *Early Wooden Railways* (1970). Andrew Dow, *The Railway. British Track Since 1804* (Barnsley: Pen & Sword Books, 2014).
[86] Dow identifies the four disciplines as rail, signalling, timetabling, and the rulebook. Dow, *The Railway,* xvii, x.

source of data. Acknowledging that patent numbers *per se* are of limited value, he limits his remit to patented rails where he found evidence they had been adopted by at least one railway company. As a result, his study is restricted to a consideration of the development of rail track by reference to only 24 patented rails (see Table 19).

Table 19: Rail patents, as selected by Dow

Patentee	Subject matter	no.	date
Woodhouse, Jonathan	cast iron rail or plate	**2682**	28.02.1803
Chapman, William	pivoted locomotive bogie	**3632**	30.12.1812
Losh, W. & Stephenson, R.	springs, wheels, cast iron rails	**4067**	30.09.1816
Birkenshaw, John	malleable iron rails	**4503**	23.10.1820
Losh, William	iron rails	**4591**	14.09.1821
Losh, William	iron rails and chairs	**5704**	18.09.1828
Stephenson, Robert	modes of supporting iron rails	**6524**	11.12.1833
Reynolds, John	railways	**6827**	05.05.1835
Vaile, Henry	rails for railroads	**7487**	25.11.1837
Fox, Charles	arrangement of rail for transfer	7**773**	12.10.1838
Faram, John	railway switches	**8276**	21.11.1839
Ransome, J. & May, C.	railway chairs, pins, bolts	**8847**	15.02.1841
Wild, Charles	switches for railway purposes	**9535**	03.12.1843
Buck, George & Lacy, Henr	sustaining rails of railway	**10467**	14.01.1845
Adams, W.B & Richardson, R.	construction of railways	**11715**	24.05.1847
Baines, William	construction of railways	**11819**	29.07.1847
Barlow, William	permanent way of railways	**12438**	23.01.1849
Barlow, Peter William	permanent ways of railways	**12659**	14.06.1849
Barlow, Peter William	permanent ways of railways	**12917**	03.01.1850
Samuel, James	construction of railways	**13029**	05.04.1850
Hoby, James	construction of railways	**13158**	03.07.1850
Hoby, James	construction of railways	**13394**	07.12.1850
Adams, W.B	girder rails	**13653**	03.12.1851
MacConochie	chair and key	**14189**	24.06.1852

Source: Dow, *The Railway*, xii, and Woodcroft, *Alphabetical Index of Patentees of Invention 1617-1852.*

It is argued in this section that Dow's arbitrary constraint undervalues the significance of patenting for the development of rail track. He does not commence his analysis until 1803 and as discussed earlier, many if not most patents of the time covered a multiplicity of inventions. Prior to 1852, the period under consideration here, William Bridges Adams took out seven railway-related patents[87] (see Table 20). Patent No. 11715 covered no fewer than thirty inventions, and patent No.13653 covered over fifty designs of girder rail. Adams, described by Robbins as one of the half dozen most important names in the history of railway civil engineering,[88] was a prolific patentee. This is confirmed by Adams' reply

[87] H. T. Wood, "Adams, William Bridges (1797–1872)," in *Oxford Dictionary of National Biography*, ed. H. C. G. Matthew and Brian Harrison (Oxford: OUP, 2004); online ed., ed. David Cannadine, January 2015, http://www.oxforddnb.com/view/article/140, http://www.oxforddnb.com/view/article/140 [accessed December 13, 2015].
[88] Michael Robbins, *Points and Signals* (London: George Unwin Ltd, 1967), 56-60.

to Isambard Kingdom Brunel during a meeting at the ICE in 1852, when he intimated that he and others relied upon the patent system. He also stated that it was well known that,

> … upon all lines of railway, there were used a multitude of patented inventions, and therefore, inventors might be permitted to hope that even Mr Brunel's antipathy to patented inventions would eventually be modified …[89]

As will be established by the evidence to be considered later in this section, patented processes and designs were a significant feature of the development of rail track. Inventors and investors relied on the patent system for reasons many and various, but financial considerations were paramount.

Table 20: Patents - William Bridges Adams, prior to 1852

	Subject matter	no.	date
i.	*Construction of wheels and springs*	**6790**	13.03.1835
ii.	*Wheel carriages*	**7212**	20.10.1836
iii.	*Construction of wheel carriages*	**8197**	16.08.1839
iv.	*Construction of wheel carriages and appendages*	**8756**	28.12.1840
v.	*Construction of wheel carriages*	**11445**	12.11.1846
vi.	*Construction of railways*	**11715**	24.05.1847
vii.	*Construction of roads and ways*	**13653**	03.06.1851

Source: Woodcroft, *Alphabetical Index of Patentees of Invention 1617-1852*, 2.

In 1767, Richard Reynolds of Coalbrookdale was the first to use cast iron for the construction of rails.[90] Previously the majority of tramroads were constructed entirely of wood. It was a further two decades, in 1785, before the first rails of malleable iron were made and used on a railway in Alloa, Scotland.[91] In 1808, wrought iron was laid at Tindale Fell on the Brampton Mineral Railway, near Carlisle, and at about the same time, at Walbottle Colliery, Tyne and Wear.[92] As discussed in chapter 5, the Stockton and Darlington Railway constructed in 1825 was laid partly with cast iron, and partly with wrought iron rails.

Rapid development in steam locomotive technology required continuous, and sustained improvements in rail track. Trevithick's early demonstration of his steam locomotive in 1808 in London where Euston

[89] William Bridges Adams *et al*, "Discussion. The Construction and Duration of the Permanent Ways of Railways in Europe, and the modifications most suitable to Egypt," *Minutes of the Proceedings of the Institution of Civil Engineers* 11, (1852): 273-298, 291. Due to increasing traffic and ever-heavier locomotives the subject of rails was often discussed at the ICE. For example, in 1857, Adams presented a further paper on the subject. William Bridges Adams, "The Varieties of Permanent Way, practically used, or tried, on Railways, up to the present Period," *Minutes of the Proceedings of the Institution of Civil Engineers* 16, (1857): 226-259.
[90] Coalbrookdale was run by a succession of Darbys and their relatives including Richard Reynolds. Lewis argues the establishment influenced the course of the Industrial Revolution more profoundly than any other and by 1851 it was the largest foundry in the world. Lewis, *Early Wooden Railways*, 240.
[91] William W. Tomlinson, *The North Eastern Railway: its rise and development* (Newcastle-Upon-Tyne: A. Reid, 1914), 13.
[92] Nicholas Wood, *A Practical Treatise on Rail Roads* (London: Longman, Orme, Brown, Green and Longmans,1825), 61.

station now stands was marred by the breaking of the iron plate rails. The rails were unable to take the weight of the locomotive combined with the wagons, each containing ten tons.[93] It was George Stephenson's recognition of the damage that locomotives could cause to the track that occasioned him, jointly with William Losh, to take out a patent for cast iron rails in September 1816. As was the custom of the day it was a compound patent covering a number of inventions including steam springs. The patent specification detailed that by ensuring the adjoining rails presented a smooth surface to the vehicles forming the train, the cast iron rails would remove the 'blows and shocks' to the wheels of the vehicles and the 'great breakage which often occurs on railways'.[94]

As has already been noted in chapter 5, the Stephenson Losh patent was followed by another taken out in 1820 by John Birkinshaw of Bedlington Ironworks, who produced wrought iron rails in 15 foot lengths. In his patent specification Birkinshaw stated that his rail could carry 'six times the weight intended to be carried along the road'.[95] However, Losh led the way to find a more durable form of rail despite the fact that his partnership with George Stephenson had suffered as a result of the latter refusing to recommend (as discussed in chapter 5) their patented rail for use on the Stockton and Darlington Railway. In 1821, Losh took out a patent for rails bearing a malleable iron running surface that was riveted or bolted on.[96] Writing to Edward Pease in 1821, Losh remarked,

> … the Travellers and one of them the enormous weight of nearly nine tons and without springs or pistons, yet the Patent Rails of the above weight stand without an instance of breakage, altho' the engine goes with a velocity of at least 7 miles an hour very frequently down a Plane.[97]

Seven years later, in 1828, Losh took out another patent for a rolled form of rail which sat in a concave seat in the chair.[98]

In 1835 John Reynolds patented a form of cast iron longitudinal rail support which was experimented with before the transverse sleeper became the norm.[99] Reynolds subsequently presented a paper, in 1838, at the ICE and confirmed that his rails had been given an experimental trial in 1836 at Chat Moss on the Liverpool and Manchester Railway.[100] In the late 1830s many patents, with subsequently

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[93] Philip Payton, "Trevithick, Richard (1771–1833)", *Oxford Dictionary of National Biography*, (Oxford University Press, 2004); online edn, Oct 2007 http://www.oxforddnb.com/view/article/27723, [accessed January 2, 2016]
[94] William Losh and George Stephenson, *Construction of machines ... railways ... and materials along the said ways.* Patent No. 4067. September 30, 1816.
[95] John Birkinshaw, *Manufacturing, and construction of, a wrought or malleable iron rail-road or way.* Patent No. 4503. October 23, 1820.
[96] William Losh, *Construction of iron-rails for railways.* Patent No. 4591. September 14, 1821
[97] William Losh, letter to Edward Pease, November 3, 1821, quoted Jim Rees, "The strange story of the *Steam Elephant*," in *Early Railways 1*, eds. Andy Guy and Jim Rees, (London: The Newcomen Society, 2001), 145-170, 159-60.
[98] William Losh, *Formation of iron-rails for railroads, and chairs or pedestals upon which the rails may be placed.* Patent No. 5704. September 18, 1828.
[99] John Reynolds, *Railways.* Patent No. 6827. May 5, 1835.
[100] John Reynolds, "On the Principle and Construction of Railways of Continuous Bearing,*" Transactions of the Institution of Civil Engineers* 2, (1838): 73-86.

differing success rates, were taken out in relation to track. In 1837, Henry Vaile patented rails constructed in a waveform to counteract the problem of railway vehicles 'hunting'.[101] His invention saw limited adoption. In 1838, Charles Fox commenced the patenting of equipment known today as points,[102] devices by which trains are able to move from one rail track to another.[103] His patent was accepted by the London and Birmingham Railway Co. and subsequently adopted by several other railway companies. In 1839, John Faram obtained a patent for a point switch designed to be operated by the driver of the train, but there is little evidence of its use.[104] A much more successful patented invention was the sliding point switch by Charles Wild, in 1842,[105] and which appeared in four varieties. Patented improvements in point design continued apace, including William Baines' taken out in 1847.[106]

The increasing number of patented rail designs caused the railway companies difficulties in the selection of their track. For instance, the London and Birmingham Railway Co. received conflicting advice from Charles Vignoles and Robert Stephenson, both of whom were highly respected engineers of the day. In 1841, the Company decided to hold a competition for the strongest and most economical form of rail, the best constructed chair and the best construction to fix the chairs to sleepers.[107] An advertisement in the *Times* was answered by no fewer than seventy-two competitors and, in the event, the premium of £100 was awarded to Robert Daglish whose rail and pedestal or chair became generally adopted.[108] Stephenson submitted his patented method of fastening rails to sleepers, but was unsuccessful. The London and Birmingham Railway Co. did not adopt his ideas. However, the Grand Junction Railway Co. did, on an experimental basis.[109]

Increasingly, inventors became interested in the chairs or the means by which the rails were fastened to the sleepers. In 1841, Ransome and May took out a patent for cast chairs in which the seat of the rail was so designed to hold the rail at an angle. Included within the patent was a new means of making

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[101] Henry Purser Vaile, *Rails for Railroads.* Patent No. 7487. November 25, 1837. 'Hunting' is the term used to describe the wheels hunting for equilibrium between two rails. Vaile used the expression 'lounging' which may have been an early version of 'lunging'. There are relatively limited papers on the subject of hunting but see H.M. Pearson, "Relationship Between the Permanent Way and the Locomotive," *Permanent Way Institution Journal* (1937); quoted in Dow, *The Railway*, 278.
[102] Points are complex items of equipment and may be classified as shifting rail, stub, single switch, double switch, fixed, Lambton and treadguide. Michael Lewis, "Points," paper given at *Early Railways Conference* 6, Newcastle, June 2016, (unpublished).
[103] Charles Fox, *Arrangement of rails, for causing a train to pass from one line to another*. Patent No. 7773. August 15, 1838.
[104] John Faram, *Constructing, using, and applying railway-switches ...*, Patent No. 8276, November 21, 1839.
[105] Charles Heard Wild, *Switch for Railway Purposes.* Patent No. 9535. December 3, 1842.
[106] William Baines, *Manufacture of parts of railways; bearings of machinery; apparatus used in constructing railways.* Patent No. 11819. July 29, 1847.
[107] A possible parallel with the Rainhill Locomotive Trials held by the Liverpool and Manchester Railway Co. in 1829.
[108] Obituary, "Robert Daglish 1779-1865," *Minutes of the Proceedings of the Institution of Civil Engineers* 26, (1867): 561-563.
[109] Robert Stephenson, *Supports for iron rails.* Patent No. 6524. December 11, 1833.

compressed wood keys, which fastened the rail to the chair.[110] The early inventors also paid attention to the sleepers, both stone and otherwise, upon which the chairs were fixed, and much of the developing technology was made the subject of patents. In 1845 George Buck and Henry Lacy patented a transverse sleeper of iron in the form of an inverted trough designed to carry a rail in a chair with an iron key, all resting on a wooden pad, but there is little evidence of its adoption.[111] In 1849 William Barlow invented and patented a rail of sufficiently broad foot for it to sit directly on the ballast thus avoiding the cost of a sleeper.[112] In 1857, Barlow maintained that over 800 miles of his rails had been laid in Great Britain.[113] In a discussion at the ICE, in 1861, he confirmed that the Barlow rail was at one time 'in great request' and 'had been laid down much more rapidly even than he as the inventor desired.'[114] His note of hesitation was because he had come to the conclusion that bearing loads and high speeds meant that the employment of wooden sleepers was unavoidable.

As locomotives and rolling stock grew heavier, a number of accidents occurred due to the track's inability to withstand the greater strain. From 1847, it was possible to strengthen the track by the use of a 'fish plate' securing one rail to the next, an invention patented by William Bridges Adams and Robert Richardson.[115] As discussed previously, the Adams Richardson patent of 1847 covered multiple inventions, but the fish plate was the first listed in the specification and it has been suggested that the co-patentees charged a royalty of 6d per joint.[116] Adams subsequently modified the design and in due course fish plate joints were accepted universally. Adams presented a paper at the ICE, in 1852, when a number of eminent engineers, including Isambard Kingdom Brunel and Robert Stephenson, debated his contention that he had invented the fish plate. The controversy rumbled on for several years. In 1866, during a discussion at the ICE, Charles Vignoles stated that 'the fishing of the rails was the greatest improvement that had been made, but was not an English invention, as long before it was used in this country he had seen it abroad'.[117]

The rate of development of the permanent way following the appearance of Trevithick's steam locomotive in 1804 was remarkable, posing challenges to the early railway pioneers as to the durability

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[110] James Ransome and Charles May, *Manufacture of railway-chairs, railway and other pins or bolts,woodfastenings and trenails.* Patent No. 8847. February 15,1841.
[111] George Watson Buck and Henry Charles Lacy, *Manufacture for, and method of, sustaining the rails of railways.* Patent No. 10467, January 14, 1845.
[112] William Henry Barlow, *Construction of the permanent ways of railways.* Patent No.12438. January 1, 1849.
[113] J. Dutton Steel and Albert D. Briggs, "Discussion of "A Memoir on Rails"," *Transactions of the American Society of Civil Engineers* 1872-1963 vol. 3, no.2 (1874):110; quoted in Dow, *The Railway*, 126.
[114] Francis Fox *et al*, "Discussion. The Results of Trials of Varieties of Iron Permanent Way," *Minutes of the Proceedings of the Institution of Civil Engineers* 20, (1861): 275-291, 282.
[115] William Bridges Adams and Robert Richardson, *Construction of railways, and engines and carriages used thereon...* Patent No. 11715. May 24, 1847. All types of fish plate took their name from nautical use where 'fishing' was a term used to describe repairing a broken spar by using rope to bind splints of supporting spars.
[116] Cecil J. Allen, *Modern British Permanent Way* (The Railway News, 1915), quoted in Dow, *The Railway,* 156.
[117] R.P. Williams *et al,* "Discussion. The Maintenance and Renewal of Permanent Way," *Minutes of the Proceedings of the Institution of Civil Engineers* 25, (1866): 375-428, 380.

of materials and the ever increasing demands of the mechanical engineers.. As George Stephenson commented, the locomotive and the track are in reality two halves of the same machine. The evidence presented in this section has established that rails and their ancillary fixings were crucial components in the development of the early railways, and it is argued in this chapter that the protection provided by an effective patent system encouraged investment in rail improvements, both in terms of creative talent and money.

8.5 Safety Valves.

> It is in the property which the steam-engine possesses of regulating itself, and providing for all of its wants, that the great beauty of the invention consists ... Heat is the principle of its movement ... having valves which open and shut in proper periods ...The steam engine, then, we may look upon as the noblest machine ever invented by man.
>
> Alderson[118]

The buoyant sector of the early railways created numerous opportunities for inventors to make money and enhance reputations. Steam locomotive technology developed over a relatively short period and urgent, concomitant need arose for micro inventions to keep pace with the 'stuttering evolution of the iron horse'.[119] The evidence considered in this section demonstrates that in the specific instance of safety valves, inventors exhibited a marked propensity for the taking out of patents. As acknowledged by Brown, in his study of the development of the American locomotive industry, patented component designs enjoyed considerable success in the nascent market of the 1830s and 1840s.[120] As railway technology developed and strong steam and increasing boiler pressures became prevalent, so the need for efficient safety valves increased. The vibrant market was not restricted to safety valves for railways, but extended to marine and general industrial use.[121]

The very early boilers were not fitted with safety valves, water level indicators or other safety features. With the introduction of strong steam, this absence of efficient safety valves led to an increase in boiler explosions. On 18 September 1803, one of Trevithick's early high pressure stationary engines exploded at Greenwich, causing Trevithick to complain that Boulton and Watt reported the explosion, both in newspapers and private letters, 'very different to what it really is'.[122] It was Trevithick's view that the boy who had been trained to work the engine went off to catch eels and the labourer stopped the engine

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[118] M.A. Alderson, *An Essay on the Nature and Application of Steam, with an Historical Note of the Rise and Progressive Improvement of the Steam Engine* (London: Sherwood Gilbert and Piper, 1834), 43-44.
[119] Miles Macnair, *William James (1771-1837) The man who discovered George Stephenson* (Railway and Canal Historical Society, 2007), 56.
[120] John Brown, *The Baldwin Locomotive Works 1831-1915* (Baltimore, The John Hopkins University Press,1995), 61.
[121] Edward Pease noted in his diary for 9 March 1853 that Robert Stephenson and Co. was constructing war steam engines for the King of Sardina and the company competed for the growing Tyneside shipbuilding Industry which built vessels for Egypt, China, Hong Kong and Norway. Michael Bailey, ed., *Robert Stephenson - The Eminent Engineer* (Aldershot: Ashgate Publishing, 2003), 204.
[122] Richard L. Hills, *Power from Steam. A History of the Stationary Steam Engine* (Cambridge, Cambridge University Press, 1993), 102.

without releasing the safety valve. In 1817, an early parliamentary select committee was appointed ‘to consider the means of preventing the mischief of explosions from happening ... to the danger or destruction of His Majesty's subjects'.[123] The committee concluded that high pressure engines could be ‘safely used with the precaution of well-constructed boilers and properly adapted safety valves’,[124] but boiler explosions continued to occur.

The first rack and pinion locomotive, *Salamanca*, John Blenkinsop's patented design for rack propulsion, exploded in 1818[125] (some years later George Stephenson told a parliamentary select committee that the driver had tampered with the safety valve),[126] and on 19 March 1828 on the Stockton and Darlington Railway, outside Shildon, an engine boiler blew up killing the fireman. The driver, George Stephenson's brother, escaped unhurt. Four months later, the boiler of *Locomotion* exploded at Aycliffe Lane, on the Newcastle and Durham Junction Railway, killing the driver.[127] The first substantive legislation, the Boiler Explosion Act 1852, provided for the investigation of all boiler explosions in the United Kingdom, but it was not until 1901 that Section 11 of the Factory and Workshop Act made provision for periodic examination of boilers. The first British standards for safety valves appeared in 1933.[128] During the period of the early railways, therefore, there was little parliamentary scrutiny as to safety valves, and market forces played a dominant role in determining the pattern of innovation.

The earliest reference to the design of a safety valve is credited to Denis Papin who left his native France to come to England in 1670. In 1680 he invented the common lever safety valve and in his published treatise acknowledged that the inspiration had come from the design of the Roman balance or stilyard.[129] The safety valve was held closed by a weighted lever which lifted when the pressure rose above a safe limit. The valve was used extensively and worked well on slow moving engines. However, the valve was not satisfactory on public railways when the vibration of the engine caused the valve to open.[130]

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[123] *Report and Minutes of Evidence taken before a Select Committee on means of preventing explosions on Steam Boats* (House of Commons, 1817), 422. The focus of the enquiry was the destruction of property (primarily in shipping) as opposed to lives lost.
[124] Quoted in J.A. Fuller, "The history of safety valves leading to the development of British Standards for safety valves," *Proceedings of the Institution of Mechanical Engineers* 199, (1985): 107-116, 111.
[125] *Leeds Mercury*, March 7, 1818.
[126] According to Smiles, the Liverpool and Manchester Bill went into Committee on 21 March 1825. In giving evidence on 21 April, George Stephenson told the Committee that no accidents had occurred with his engines but that a Blenkinsop engine at the Middleton Colliery, near Leeds, had exploded killing the driver. He stated that the driver had been in liquor, and had put a considerable load on the safety valve so that going forward the engine blew up and the man had been killed. Smiles, *The Life of George Stephenson*, 229.
[127] Hewison, *Locomotive Boiler Explosions*, 26.
[128] Quoted in Fuller, "The history of safety valves,” 113
[129] Quoted in Fuller, "The history of safety valves,” 107.
[130] John White, *A History of the American Locomotive. Its Development 1830-1880* (New York: Dover Publications, 1979), 146.

To counter vibration, spring safety valves were developed. In 1828, Timothy Hackworth developed an (unpatented) lightweight spring safety valve for his locomotive *Royal George*, said to be the most powerful locomotive of its day. The spring safety valve soon became very popular and used by many manufacturers for the next fifty years both in England and America.[131] In the development of safety valves for locomotives, the prevention of tampering with the valve by the enginemen was a prime consideration. On 25 April 1829, the directors of the Liverpool and Manchester Railway Co. stipulated as one of the conditions for the Rainhill Trials that, 'there must be two safety valves, one of which must be completely out of the reach or control of the engine-man, and neither of which must be fastened down while the engine is working'.[132]

Richard Salter constructed the first spring balance and in 1838 patented a spring balance safety valve. Locomotives incorporating the valve were referred to as having 'Salter patent spring valves'. Large numbers of the Salter valves were used in England and exported to America. The Bowles Railroad Supply Co. announced in its 1860 catalogue that Salter valves were 'very much superior to those made in this country.'[133] Following the introduction of the Salter patent spring valve in the United States, a number of American inventors patented incremental, innovative improvements, including Charles Graham[134]and George Richardson.[135] The Richardson valve continued to be adopted by American manufacturers such that by 1872 the *Master Mechanics Report* reported that all of its thirty-five members observed the 'Richardson valve *alone* of those tried fills the requirements of a good safety valve'.[136]

In 1843, Joseph Hopkinson, one of the engineers involved with the early introduction of steam power to the mills of Huddersfield and district, started a business in an upstairs room in Huddersfield. In 1851 he invented and patented the compound safety valve which received a medal at the Great Exhibition. In 1852 he published an advertisement: 'Important Invention! Steam boiler explosions rendered impossible'. The advertisement explained the features of Hopkinson's patented compound safety valve and stated: '£200 reward is hereby offered and will be paid by the inventor to any person who shall demonstrate the possibility of an explosion in a boiler ... if fitted with the new patent compound safety valve'. The Steam Users Association (later the Boiler Insurance Co.) offered a 10 per cent reduction in premium if a boiler was fitted with a Hopkinson patent safety valve. Hopkinson later invented the Hopkinson Deadweight safety valve.[137]

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131 White, *A History of the American Locomotive,* 147.
132 Stipulation 3 of Stipulations and Conditions for the Rainhill Trials; Henry Booth, *An Account of the Liverpool and Manchester Railway* (Liverpool: Wales and Bond Baines, 1830), 63.
133 White, *A History of the American Locomotive*, 147.
134 Charles Graham, *Spring-balance for safety-valves to boilers*. US Patent 30964. December 18, 1860
135 George W. Richardson, *An Improvement in Steam Safety Valves*. US Patent 58294. September 25, 1866
136 White, *A History of the American Locomotive*, 149.
137 *Hopkinsons Product Support Manual*, https://www.global.weir/products/product-catalogue/, [accessed March 20, 2016].

A problem with the early safety valves was that the apparatus was unable to register the actual pressure in the boiler and therefore failed to release the pressure as it approached a critical level. One of the first to counter this problem was Charles Ritchie who in 1848 patented a reactionary safety valve that allowed steam to be opposed by a 'stricture' prior to its final exit into the atmosphere.[138] He set out the principles in his specification in the following terms, 'as soon as the pressure of the steam raises the valve from its sit, the flange (H), being exposed to the pressure of the steam, presents an increased surface which compensates for the increasing resistance of the helical spring'.[139]

Ramsbottom patented his safety valve in 1855 and on 1 June 1856 addressed the IMechE. He confirmed that engineers were giving greater attention to the design and construction of steam boilers and their fittings 'and amongst the latter the safety valve has received much consideration.' Ramsbottom told the assembled company that the safety valves had proved satisfactory and were found to be 'very sensitive, having such freedom of action as to get into a state of vibration producing in some cases a musical note when at the point of blowing off.'[140]

Most of the significant, incremental developments of steam safety valves were made the subject of patents. Following Ramsbottom's patent, Charles Webster was granted a patent in 1857 for improvements in safety valves.[141] In the same year, about a month later, William Hartley was granted a patent where he described the novelty as 'a safety valve for steam boilers made to open so as to discharge a volume of steam equal to the discharge of an *unobstructed passage* through the valve sit'.[142] Whilst beyond the period under consideration in this thesis, it is of interest that in 1863 Charles Beyer took out a patent for a safety valve when he claimed the novelty aspect to be that the valve opened to a greater extent than ordinary safety valves. Writing in 1892, Barnet commented that, in view of Ritchie (1848), Webster (1857) and Hartley (1857) there was in Beyer's device 'only a very narrow margin of novelty, if indeed, there is anything beyond mere forms, wholly without effect upon the action of a safety valve'.[143]

It is reasonable to surmise that many of the inventors of safety valves would have either assigned or licensed their patented inventions for financial consideration. For the relevant period there is no register of these patent assignments or licences. Such a record was not maintained until 1852.[144] However, as discussed in chapter 2, an assessment of the frequency of assignments and licences by a consideration of the reported law cases, demonstrates both practices were common during the period of the evolving

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[138] Charles Ritchie, *Locomotive and other engines.* Patent No. 12078. March 2, 1848.
[139] William B. Le Van, *Safety Valves: Their History, Antecedents, Invention and Calculation - Primary Source Edition* (New York: Norman Henley and Co,1892), 96.
[140] John Ramsbottom, "On an Improved Safety Valve," *Proceedings of the Institution of Mechanical Engineers* 7, (1856): 37-41, 39.
[141] Charles Webster, *Damper-Regulator for Steam-Boilers.* US Patent 16664. February 17, 1857.
[142] Le Van, *Safety Valves*, 101.
[143] Le Van, *Safety Valves*, 104.
[144] The Patent Law Amendment Act 1852 required a 'Register of Subsequent Proprietors'.

early railways. Similarly, between 1835 and 1852, in relation to seventy-five applications to the Privy Council for prolongation of the patent, 25 per cent of the patents had been assigned.[145] Licensing provided third parties with access to new technology making it less likely that patent rights would frustrate the process of sequential technological development. Furthermore, the sale and licencing of patent rights would have been an important factor in the physical dissemination of technological knowledge.

Safety valves and their development were a response to the critical problem of preventing boiler explosions. The evidence considered in this chapter has demonstrated that inventors with the ability to conceptualise problems sought to achieve novelty and to patent their inventions, perhaps exemplifying Hughes' concept of reverse salience.[146] Hughes' integrative model for a technological system is applicable to the early railway industry which was shaped by technical, geographical, institutional, professional and economic factors. Although his seminal study was concerned with a comparative history of the evolution of modern electric power systems of the late nineteenth and early twentieth centuries, Hughes' proposed four stage process for the formation and growth of a technological system finds resonance with the evidence considered in this chapter. Hughes' four stages comprise invention and development, technology transfer, system growth and system momentum. Nevertheless, it is suggested here that Hughes' proposal that the fourth stage of technological momentum is created in part by available capital, the growth of manufacturing capability, the development of education institutions and by emerging professional societies, could be modified. In the light of the evidence presented in this chapter, which is concerned with the earlier period, pre-1852, rather than the development of education institutions, it is proposed here that the patent system should be considered an effective and influential factor in the momentum of early railway technology.

8.6 Conclusion

The directors of the early railway companies needed to find safe, financially sustainable solutions to the technological problems presented by essentially entrepreneurial, but rapidly developing railway technology. They were receptive to approaches by inventors, often providing facilities for testing and developing innovative ideas. The evidence presented in this chapter has established that the principal inventors in the associated technologies of water analysis, timber preservation and rubber products, as well as rails and safety valves, found great utility in the patent system. They relied on the period of exclusivity that maximised opportunities for monopoly profits.

Russell and Hudson's argument that the growth of the railway system acted as a spur for the invention of new treatments has found expression in this chapter. The technological differences between these

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145 Dutton, *The Patent System*, 125.
146 Hughes, *Networks of Power* (1987)

inventions were often minor and yet there is compelling evidence that patenting played a major role in the innovative process where avoiding infringement of existing patents was deemed to be crucial. The evidence considered in this chapter demonstrates that patents worked for those who invested in them. Individuals were incentivised to find novel, alternative treatments, and any suggestion that financial reward was not a major motivation, has to be doubtful in the extreme.

The increasing amount of work undertaken by external consultants rapidly became indispensable to railway operations, and in the case of chemistry this remained the position until the LNWR appointed the first full time railway chemist in 1864. In this chapter it has been demonstrated that the early railway companies were major participants in the vibrant market of the late eighteenth and early nineteenth centuries, a period when a professional sector began to emerge. Many of these professionals, perhaps content in the knowledge that their invention was safe from piracy, shared detailed technical knowledge by means of publications and the presentation of papers at meetings of professional institutions, which were subsequently published in the relevant *Proceedings*.

The evidence considered in this chapter suggests that financial motive was paramount for many inventive individuals, who recognised the potential purchasing power of the railway companies. It is also likely that the sale and licencing of patents rights characterised the professional enterprises involved in some of the ancillary technologies, in their pursuit of market dominance. Furthermore, the evidence presented in this chapter has demonstrated that, in several respects, the patent system encouraged inventive activity. With a view to securing lucrative sales, but needing to find a way of avoiding the infringement of existing patent rights, inventors sought patents for innovative, incremental improvements. This incentive, of a share in profitable enterprise, led to technological diversity and a concomitant acceleration of technological progress. The contingency of the purchasing power of the early railway companies, the intensity of inventive activity and an effective patent system conspired to promote the development and diffusion of railway technological knowledge.

CHAPTER 9

CONCLUSION

> ... [P]erhaps the most striking result produced by the completion [in 1830] of [the Liverpool and Manchester] railway, is the sudden and marvellous change which has been effected in our ideas of time and space ... Speed-despatch-distance - are still relative terms, but their meaning has been totally changed within a few months: what was quick is now slow; what was distant is now near; and this change in our ideas will ... pervade society at large.
>
> Henry Booth[1]

It has been argued in this thesis that during the first half of the nineteenth century the patent system provided an effective means for the control and management of early railway-related knowledge and served to incentivise the development and diffusion of early railway technology. The contemporary evidence has demonstrated that the early railway inventors, and their funders, found great utility in a unique patent system, unavailable elsewhere in the world, which they used, relied upon and promoted to their peers. Many of the leading railway engineers of the day placed on public record that had it not been for the protection and encouragement offered by the patent system numerous significant inventions of the age would not have materialised, that the patent system was intrinsic to successful, profitable inventive activity.

Contrary to prevailing academic opinion that prior to the Patent Law Amendment Act (1852) the patent system was largely ineffective, it has been argued in this thesis that the patent system, as reassessed in chapter 2, served to protect the interests of investors, to incentivise inventive activities and to facilitate the dissemination of technical knowledge. Hitherto, in relation to early railway technology, any perceived shortcomings of the patent system pre-1852, including the application process for a patent, the complexities of the Offices of Chancery and anti-patent prejudice on the part of the judiciary, have been overstated.

Prior to 1852, the application process for a patent involved an element of adjudication as to novelty by respected Law Officers. Such consideration amounted to far more than the mere registration of a patent in the records of the offices of Chancery. The number of general or special caveat hearings has been demonstrated to have been substantial, with inventors, funders and contemporary commentators generally supportive of the Law Officers' adjudication. Furthermore, in relation to early railway technology, the evidence suggests that the cost of applying for a patent was not regarded by potential patentees to have been a major obstacle. In 1829, giving evidence before the Select Committee on the

[1] Booth, *An Account of the Liverpool and Manchester Railway*, 89-90.

Law Relating to Patent Inventions, many respected and prolific inventors, including Marc Brunel and Samuel Clegg, argued for higher patent fees.

Similarly, the location of the Offices of Chancery in London was not, as has been argued in the literature, considered to be a significant obstacle by potential investors and patentees who lived and worked at a distance from the capital. George Stephenson, a quasi-illiterate brakesman at Killingworth Colliery, Newcastle, applied for his first locomotive patent in 1815. He was of limited means and living in the north-east of England, at a considerable distance from London, neither of which appears to have hindered his successful patent application. In 1816 he took out a second patent, followed by three further patents in ensuing years. George Stephenson, who went on to establish himself as an eminent railway engineer of the age, is but one example of many whose demonstrable, repeated use of the patent system does not support prevailing scholarly consensus that the patent system was ineffective. Significantly, the evidence considered in this thesis has also demonstrated that the emerging profession of patent agents played a constructive and significant role in the workings of the patent system far earlier than is generally recognised. These agents offered a number of services, including receiving written instructions from anywhere in the country, consulting the official registers of patent specifications and often contributing to the publication and circulation of patented technical knowledge. Their efforts contributed to the effectiveness of the patent system.

It has been a foundational premise of this thesis, that a procedural requirement of potential patentees that was introduced during the early eighteenth century, had significant consequences which have received little academic interest to date. From 1733, or thereabouts, patentees were required, within three months of the initial patent application, to file a specification outlining the details of a proposed patent. This filing of a detailed specification, together with the increasing availability of respected technical publications, facilitated access to technological information for those involved in early railway-related inventive activity. The evidence demonstrates that inventors, investors, patent agents and manufacturers made recourse to the patent system and associated publications, for a variety of reasons including the advancement of their business interests. The disclosure of the salient details of an invention in a specification, represented the conversion of privileges granted by the Crown, into modern intellectual property rights. The patent system created an evolving database of railway-related technical knowledge, that the resultant control, circulation and commercial exploitation of codified information amounted to what today might be described as knowledge management.

A reassessment of the historiography of the patent system has identified the pivotal role of the judiciary in the crafting of the principles of patent law. This challenges prevailing academic opinion that prior to 1830, the legal situation with regard to patents was uncertain, that the courts were rarely guided by precedent and judges were, in general, prejudiced against patentees. Furthermore, the transfer of jurisdiction for patent disputes from the Privy Council (where adjudication of the Monarch's privilege was based on a consideration of the public good) to the common law and equity courts (where adjudication was based on merit) took place in 1688, much earlier than is generally recognised.

The Statute of Monopolies of 1624, the first to be concerned with patents, was largely declaratory of existing common law principles, and it was not until the passing of the Patent Law Amendment Act in 1852 that Parliament provided further substantial guidance as to the principles of patent law. Prior to 1852, therefore, in the absence of parliamentary intervention or assistance, it was the judges who shaped patent law and its remedies. The contribution of the judiciary placed England in an exceptional position. In England the common law had been developing since 1176, whereas no other country (with the exception of the Venetian Republic) enacted patent laws earlier than the 1790s, or had an equivalent common law system. During the late eighteenth and early nineteenth centuries, it was at the behest of the judiciary that the principles of patent law evolved and responded to the needs of an expanding industrial economy, including the rapid development of the railways where innovations were entirely novel or required adaptation from existing technologies. The law responds to and reflects social norms, those behaviours seen as desirable or legitimate in the shared interests of society. Accordingly, the legal system is itself creative and plays an important role in the shaping of intangible property.

In exploring the significance of judicial influence on the development of patent principles, the evidence considered in this thesis has established that parties to a patent dispute resorted to the common law and equity courts to a far greater extent than has previously been recognised. The evidence suggests a preparedness on the part of patentees to allow their disputes to be decided by the courts. An examination of the pleadings in the court of Chancery, filed in all divisions of the Six Clerks Office for the period 1714 to 1800, has identified a significant number of unreported patent dispute cases. Furthermore, the publication of *Hayward's Patent Cases* in 1987, has revealed many more patent dispute cases than have been identified, hitherto, in the literature.

This thesis has moved away from an assessment of the adequacy of the patent system by reference only to *decided* reported patent dispute cases, an approach adopted broadly in the literature, and which ignores the majority of cases that were settled prior to a hearing. A consideration of the *process* of litigation leads to a more nuanced understanding of the effectiveness of the patent system because it takes into account the high number of patent disputes that were settled by agreement between the dispute parties. Litigation costs then, as now, would have been a major factor in deciding whether to settle a patent dispute on financial terms, or to proceed to a hearing before a judge (and jury in the common law courts). All parties would have wanted to avoid the costs and risks associated with deferring a decision to a court on matters concerning patent validity, patent infringement and remedies for infringement including injunctive relief or damages. Consequently, most patent disputes would not have been pursued to trial. Patent litigation was largely, as today, a settlement mechanism. The modern position is that a mere 3.5 per cent of all civil claims commenced in the courts reach final hearing and judgement, and it is reasonable to suppose that the position may not have been so very different during the eighteenth and nineteenth centuries. Furthermore, and notwithstanding that contemporary records of patent cases issued and settled are difficult to trace, there is good evidence that the granting of a licence by a patentee was a common outcome of patent disputes. Many assignments and licences were unregistered, and the true figures are likely to be higher, but the evidence has identified that between 1770 and 1845, some 50 per cent of patents were assigned, either in full or in part, or licensed.

The contemporary evidence has included judicial statements in reported patent dispute cases where there were no issues relating to novelty or fraud, that were consistently supportive of patentees. Such evidence undermines much current academic opinion that pre-1830 the judiciary adopted a hostile stance towards patents. However, it is difficult to argue that the key inventors of the day who utilised the patent system would have done so had they anticipated judicial antipathy. Furthermore, the advent and development of the reporting of judgements in patent dispute cases allowed the common law relating to patents to develop by reference to the doctrine of precedent. By 1818 the equity courts had established a system of precedent rules, procedures and novel remedies (particularly injunctions) which reflected the precedent basis of the common law. Patent litigants would have sought certainty of legal principles, and the doctrine of precedent created patent law principles by reference to settled, decided case law. This in turn provided the necessary confidence for parties involved in the adjudication of patent disputes.

Many of the significant aspects of the judicial function during the late eighteenth and early nineteenth centuries, for example directing juries to find for a particular party, and the practice of nonsuit when the judge, on a number of grounds, could dismiss a case, have received little academic interest to date. Nevertheless, the prominent role of the judiciary in shaping the essence of intellectual property has been an important premise of this thesis. Equity judges, who sat without a jury, had available to them a raft of equitable remedies that were attractive to patentees, such as the issuing of interim injunctions thereby providing immediate relief to a patentee, or the taking of an account of profits wrongfully obtained by an alleged infringer. The primary influence of the judiciary on the development of patent law is unsurprising. The common law reflects, and has done since its inception in 1176, the interaction of justice and fluctuating social realities, of which the emerging industrial economy of the eighteenth century provides a pertinent example.

Much academic literature as to the workings of the early patent system is concerned with its role during the Industrial Revolution across a range of sectors. However, a consideration of the definitive, diverse features of an individual industry allows a clearer picture to emerge of the role of the patent system during the period of early industrialisation. By focusing on early railway technology and the characteristics and operations of the early railway companies, it has been demonstrated that the patent system was effective prior to the development of the early railways. Many historians of early railway technology concentrate on railway company history, a historiographical emphasis that fails to appreciate the evolutionary framework of the early railways. However, the railways were central to Britain's extraordinary contribution to technological and industrial development during the early part of the nineteenth century. Hence this analysis has been rooted in an understanding of the early railways as a fully cultural artefact, an approach that has offered insights into the technological processes and economic development of early railway technology, and has moved beyond the railway proper, since nascent railway technology was but one of a number of emerging, interwoven technologies.

It was a principal characteristic of the early railway companies that they were litigated into existence before parliamentary select committees. This gave rise to further important distinguishing features, not least that the directors of the early railway companies would have been aware of the processes and cost of litigation and the need to preserve assets, including acquired railway-related technical knowledge. The early railway enterprise was essentially entrepreneurial, involving risk taking, alertness to opportunity and innovation. Financiers organised and assumed the risk of a business in return for profit, and it would have been necessary to synthesise a great deal of technical information. The evidence considered here has identified important funders of the early railways who recognised patents as a means of preserving the commercial value of inventive knowledge. Whilst it was the pioneering engineers who were the strategic thinkers behind the creation of the early railways, they often relied upon their funders' business acumen. For example, the Stephenson enterprise was dependent on the support and funding of their entrepreneurial sponsors. This reliance entirely on private funding, distinguished the English early railway network from its European equivalents. In England, the construction and operation of a national rail network represented a major experiment in private enterprise. Uniquely, the Government of the day sought to foster competition whilst securing private profit for socially beneficial schemes with the result that in England, it was the companies, rather than the State, who bore the risk of the railway enterprise. In the absence of formal research and public subsidy, the funders of the early railways were looking for a return on their investments. The contemporary evidence demonstrates that the English patent system offered entrepreneurs, whether inventor or investor, a means to achieve financial returns.

The evidence in relation to early railway pioneers who made use of the patent system strongly suggests that financial considerations were paramount. Strategies, in terms of motivation for seeking patent protection and securing financial benefit, included exploiting the patent directly as a sole proprietor or partner of an enterprise, assigning the property rights either in total or in part, or licensing the technology. Accepting that inventors' motives were diverse, including the establishment and maintenance of reputation, these findings challenge scholarly opinion that inventive genius during the Industrial Revolution was poorly rewarded. The evidence is not always direct, but the primary sources indicate that for inventors and funders alike monetary issues were a priority. Many railway-related inventions, particularly the development of the steam locomotive, required a number of years of design commitment, succinctly described by Robert Stephenson as 'expensive experiments'. There was, therefore, a need for a sufficient period of protection for a design before the finished product was marketable, and a profit secured. A number of contemporary inventors argued before parliamentary select committees convened to consider patent reform, that the monopoly period of a patent should be extended as and where necessary to ensure adequate, compensatory remuneration. Furthermore, when patentees applied, either to Parliament or the Privy Council, for the prolongation of an existing patent they were obliged to establish that a further period of protection was required in order to realise a profit commensurate with their inventive effort.

Notwithstanding an extensive literature, principally by economists and patent law scholars, on empirical approaches to understanding the patent system and its workings, patent numbers in and of themselves are unreliable indicators of patenting activity. Patent counting *per se* is unhelpful in several respects, but evaluation of patent data through an industry-specific lens, contributes to the literature. In particular, the workings of the patent system as reassessed in the context of early railway technology, has identified two, significant overarching themes which may pose some important questions. Firstly, the contribution of the patent system to what today might be called knowledge management and, secondly, the influence of the institutional framework on railway-related inventive activity.

Insufficient consideration has been given, hitherto, to the quality and quantity of patented technical information that was available to the pioneers of the early railways and the implications of that accessibility for the rate of innovation and diffusion within early railway technology. The systematic and purposeful organisation of technical information has been an important premise of this thesis and challenges much academic opinion that the codification of technical knowledge had little or no application to any industries prior to 1850. The codification that commenced in 1733 with the requirement for the filing of a patent specification, had the effect of converting tacit knowledge into explicit knowledge. Increasingly, from the mid-eighteenth century, technical knowledge was organised, categorised, indexed and accessible. By 1854, when the first official collation of patent data was published, patent numbers exceeded 14,000, and given the practice of the day whereby a patent generally covered multiple inventions, this figure is almost certainly understated. The evidence suggests that the patent system understood as a contemporary database of invention would have been consulted regularly by the engineers of the day and their agents, for a variety of purposes. The extensive, original and comprehensive record of patent specifications that was created by the patent system, offered practitioners, including inventors, investors, lawyers and patent agents, an effective means of controlling and managing technical knowledge.

This industry-specific examination of early railway technology has identified that tacit knowledge may have been far less influential than is suggested in much of the current literature. A number of scholars argue that during the period of early industrialisation, the dissemination of technological knowledge was constrained because knowledge was held in tacit form. In relation to early railway technology, there are strong indications based on the evidence that the patent system comprised an effective means for the capture, retrieval, distribution, sharing and use of technical information. Specifications were registered and available for inspection in one of three offices of Chancery, and many specifications were reproduced in the growing number of respected technical publications of the day which enjoyed wide circulation. For example, during the 1820s, *Mechanics Magazine* boasted a significant distribution of some 16,000 copies per week. There is good evidence that those involved with early railway technology made regular recourse to such publications. It was on the basis of patent details published in *The Repertory of Arts*, that in 1831 Robert Stephenson and Co. was able to advise Timothy Hackworth that his proposed design for a new locomotive boiler appeared to infringe an existing patent. Increasingly, from the mid eighteenth century, patent specifications represented a widely available, reliable and up-to-date source of technological knowledge, and it is likely that this availability translated into the circulation of knowledge.

There is good evidence that in order to preserve economic advantage over their competitors, the directors of the early railway companies sought to manage their inventive knowledge. Furthermore, that the impetus for the control and management of inventive knowledge derived from an assortment of sources, including those who funded railway-related innovation. Edward Pease is a good example of an investor who recognised that in order for Robert Stephenson and Co. to retain its world leading position as a locomotive manufacturer, it was vital for the Company to keep the management of technical know-how under constant review. The contemporary evidence has identified that those with business acumen within Robert Stephenson and Co., considered that such knowledge management was often best achieved through recourse to the patent system. Also, a number of the railway companies sought to control the commercial value of technological knowledge by actively encouraging their employees to engage in patentable inventive activity. The circumstances of these arrangements varied. For example, the Liverpool and Manchester Railway Co. reserved the right to adopt and use any patented invention of a director or employee. The London North Western Region Railway Co., by encouraging its engineers to profit from patent royalties, enabled the directors to attract and keep the leading engineers of the day. The directors of the early railway companies recognised and utilised the patent system as an effective means of knowledge management, and that economic factors were a key consideration. Furthermore, whilst the alternative inventive settings of secret working and collective invention were environments for the control and exchange of knowledge in some sectors, the early railway pioneers made only limited use of either.

Having reassessed the historiography of the patent system, and its role in the management of technical knowledge, a second, related theme has been identified, that of the effect of the institutional framework on railway-related inventive activity. The literature as to the effect of the patent system on inventive activity in general is immense, with widely divergent opinions. The reassessment of the patent system undertaken here, by reference to the specific industrial setting of the early railways, has established identifiable, positive effects on railway-related inventive activity, and endorses Arrow's classic exposition that awarding patents encourages inventive activity.

The patent system was not of itself a cause for industrialisation, but the availability of the English patent system to those involved in the early railways served to reduce the threshold at which it became commercially viable to develop new technology. It has been argued here that inventors and investors alike required a period of monopoly to recover the cost of production, particularly for complex, large scale inventions. The contemporary evidence has established that many of those involved in railway-related inventive activity expressed confidence in, and demonstrated reliance upon the patent system.

When locomotive manufacturers such as Robert Stephenson and Co., secured and extended their significant patents, it left competitors with the choice of either negotiating to manufacture under licence, or developing and patenting novel locomotive designs. Either scenario would have contributed to the development and diffusion of railway-related technological knowledge. The evidence has demonstrated that evolving railway technology was characterised by numerous patented innovative improvements, or 'tweaks' to existing patented inventions, a practice particularly prevalent in the development of rail track and ancillary equipment such as safety valves. Incremental improvements within early railway technology were often made the subject of patents and there is good evidence that inventors' recognition of, and confidence in the effectiveness of the patent system further encouraged inventive activity.

During the intense period of expansion of the early railways, the railway companies became increasingly reliant on technologies that were developing in other industrial settings. There is good evidence that the inventors of ancillary railway equipment identified and exploited the early railway companies as reliable purchasers. Furthermore, and significantly, they recognised the economic advantage of marketing patented products. An examination of the supply to the railway companies of rubber products and processes for water treatment and timber preservation, has demonstrated that the patent system was often relied upon in order to secure financial returns. In view of the fact that during the period 1832 to 1858 no fewer than fifty patents were granted for the preservation of wood, it would seem reasonable to suppose that the opportunities for remuneration offered by the patent system encouraged inventive activity. The flourishing market for patented inventions within the early railway industry provided an incentive for specialisation and further inventive activity by individuals who could appropriate returns from their efforts. Furthermore, the ability of other parties to purchase the rights to own or use inventions also enhanced the link between patents and inventive activity.

The early railways offered diverse opportunities for those inventive individuals with the creativity and skills to overcome critical problems. Technical articles, whether authored by inventors themselves or technical journalists, publicised the commercial value of patented inventions, but also identified problematic areas. Keeping abreast of published patented technical information informed inventors of problem areas, and experienced inventors of the day would have appreciated that a problem could be resolvable in a variety of ways, including a solution of their own. This may help to explain why, over a period of years patents tended to cluster around critical issues, perhaps exemplifying the influence of reverse salience on the momentum of the growth of technological systems. It is in this sense that the patent system can be understood to have encouraged railway-related inventive activity. Furthermore, in relation to the pre-1852 period of industrialisation, Hughes' model for understanding technological momentum is open to modification. Hughes' proposed four stages, namely available capital, growth of manufacturing capability, development of education institutions and the emergence of professional societies, may be modified in the light of the evidence presented in this thesis, where it is proposed that education institutions should be understood to include the knowledge management function of the patent system. That is to say the patent system was an effective and influential factor in the momentum of early railway technology.

As early railway technology developed, a number of critical problem areas became apparent. Not least of these was the need to identify the precise location of a particular train at any given time. As the speed of train travel increased, safety became a paramount consideration and electric telegraphy emerged as the leading technology for railway safety. This developing market for communication systems incentivised investors and inventors. Furthermore, the Electric Telegraph Co., one of the first companies formed with the express object of acquiring and working patents, came to dominate a vibrant electric telegraph sector principally through its association with the early railways. Some thirty such companies were formed between 1845 and 1852 with the principal object of working patents, and there is evidence that these companies attracted investors of limited financial means, who were unable to invest directly in patents in their own right. The readily available capital of these early joint stock companies allowed inventors, funders and manufacturers to make a profit and, arguably, encouraged inventive activity.

This thesis seeks to contribute to the literature by providing a sector-specific analysis of the workings of the patent system prior to 1852. The arguments presented here have focused on, and been informed by particular characteristics of the early railways, and it has been suggested here that such an approach may prove beneficial in relation to other technologies emerging during the period of early industrialisation. An industry-specific approach applied to other, early industries would contribute to an assessment of the workings of the patent system prior to 1852, and the extent to which the influence of the patent system may have been a contributing factor in the emergence of the Industrial Revolution in England. Furthermore, the inter-disciplinary approach adopted here has highlighted that the professional interests of patent agents prior to 1852 deserves more systematic empirical research. The evidence considered here has identified that from the mid-eighteenth century, far earlier than is generally recognised, patent agents were assimilating the outcome of court decisions and contributing to the availability of a substantial body of knowledge on patent literature and practice.

In conclusion, it is widely recognised that the early railways made an extraordinary contribution to emerging technology and business development during the eighteenth and early nineteenth centuries. Booth's reflective comment in 1830, following the completion of the Liverpool and Manchester Railway, the first 'modern' railway, that it represented a 'sudden and marvellous change which has been effected in our ideas of time and space … which pervaded society at large' has proved to be accurate. Great Britain was for a time the workshop of the railway world and no other country had a functioning, effective patent system that inventors chose to use on such a regular basis. For patentees of railway-related inventions, financial return was a key motivation. The substantial and increasing number of patents granted during the period 1733 to 1852 played a significant role in the codification of technical knowledge, far earlier than is generally recognised in contemporary scholarship. The English patent system, supported by a judiciary that crafted and developed principles of patent law, provided a means of access to, and management of technical knowledge for the early railway inventors. The patent system, which was far more effective than scholarly consensus allows, served to encourage the development and diffusion of early railway technology.

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APPENDIX A

Total number of patents registered per annum, as collated by Woodcroft

Year	Patents	Year	Patents	Year	Patents	Year	Patents
1750	7	1776	29	1802	107	1828	154
1751	8	1777	33	1803	73	1829	130
1752	7	1778	30	1804	60	1830	180
1753	13	1779	37	1805	95	1831	151
1754	9	1780	33	1806	99	1832	147
1755	12	1781	34	1807	94	1833	180
1756	3	1782	39	1808	95	1834	207
1757	9	1783	64	1809	101	1835	231
1758	14	1784	46	1810	108	1836	296
1759	10	1785	61	1811	115	1837	256
1760	14	1786	60	1812	118	1838	394
1761	9	1787	55	1813	131	1839	411
1762	17	1788	42	1814	96	1840	440
1763	20	1789	43	1815	102	1841	440
1764	18	1790	68	1816	118	1842	371
1765	14	1791	57	1817	103	1843	420
1766	31	1792	85	1818	132	1844	450
1767	23	1793	43	1819	101	1845	572
1768	23	1794	55	1820	97	1846	493
1769	36	1795	51	1821	109	1847	493
1770	30	1796	75	1822	113	1848	388
1771	22	1797	54	1823	138	1849	514
1772	29	1798	77	1824	180	1850	513
1773	29	1799	82	1825	250	1851	455
1774	35	1800	96	1826	141	1852	465
1775	20	1801	104	1827	150	**Total**	**13,692**

Source: Bennet Woodcroft, Titles of Patents of Invention Chronologically Arranged, 1617-1852 (London: Eyre and Spottiswoode, 1854), 122-1518.

APPENDIX B

Number of patents relating to railways registered per annum, as collated by Woodcroft

Year	Patents	Year	Patents
1800	0	1827	0
1801	0	1828	2
1802	0	1829	1
1803	1	1830	0
1804	0	1831	2
1805	0	1832	4
1806	0	1833	4
1807	0	1834	1
1808	0	1835	5
1809	0	1836	8
1810	0	1837	3
1811	1	1838	12
1812	1	1839	8
1813	0	1840	10
1814	0	1841	7
1815	1	1842	6
1816	1	1843	4
1817	1	1844	10
1818	0	1845	29
1819	0	1846	25
1820	1	1847	22
1821	2	1848	6
1822	0	1849	14
1823	0	1850	11
1824	2	1851	16
1825	5	1852	13
1826	0	**Total**	**238**

Source: Bennet Woodcroft, Subject-matter Index (made from titles only) of Patents of Invention 1617-1852, (London: Eyre and Spottiswoode, 1854), 523-536.

APPENDIX C

Number of patents relating to railways ranked according to process for the period 1800-1852, as collated by Woodcroft.

Process	**Patents**
Regulating & ascertaining arrival & departure	4
Signals, communicating apparatus, steam whistles	25
Railway transit, clearing of rails	12
Railway-breaks, adhesion of wheels to rails	35
Connecting & detaching carriages	16
Buffers & springs	32
Wheels, axles, axletrees & boxes	104
Locomotive & steam carriages	123
Trenails & other fastenings	8
Turntables & switches, raising & lowering carriages	31
Rails, chairs & sleepers	53
Making and working atmospheric railways	31
Making and working railways	125
Steam, locomotive-engines & apparatus	115
Motive power, propelling railway and other carriages	142
Total	**887**

Source: Bennet Woodcroft, Subject-matter Index (made from titles only) of Patents of Invention 1617-1852, (London: Eyre and Spottiswoode, 1854), 523-536.

ABBREVIATIONS

LAW REPORTS

Bull.N.P.	*Buller's Law of Nisi Prius*
Co. Ins	*Coke's Institutes of the Lawes of England*
CPC	*Cooper's Chancery Patent Cases*
DPC	*Davies' Patent Cases*
ER	*English Reports*
FC	*Federal Cases*
HPC	*Hayward's Patent Cases*
KB	*King's Bench*
QB	*Queen's Bench*
WPC	*Webster's Patent Cases*
WR	*Weekly Reporter*

RAILWAY COMPANIES

GWR	Great Western Railway Company
LNWR	London and North Western Railway Company

INSTITUTIONS

IMechE	Institution of Mechanical Engineers
ICE	Institution of Civil Engineers

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