Of Patents, Principles, and the Construction of Heroic Invention: The Case of Neilson's Hot Blast in Iron Production

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Introduction

On the evening of Saturday, 1 February 1845, the hall of the Tontine Hotel in Glasgow echoed to the sounds of a dinner, speeches, and numerous enthusiastic toasts celebrating the invention of the hot blast in iron manufacture.[1] The man recognized as the author of the invention, James Beaumont Neilson (1792–1865), was the guest of honor, seated at the right hand of the chairman of the meeting, the Lord Provost of the city. They were joined by many of the leaders and proprietors of the Scottish iron and coal trades, other industrialists, and key legal figures and officials. Neilson's partners in the hot-blast patent hosted the dinner (Figure 1). That patent had been taken out in 1828 and expired in late 1842, during which period it had earned a fortune for Neilson, his partners, and many others who benefited from the transformation of the Scottish iron trade, which it had helped to bring about. The patent had also been the focus of numerous legal actions to defend it, which had cost a great deal of money but had finally, when the dinner was held, reached a successful conclusion. So Neilson was being celebrated at this juncture because of this particular victory. It was not his triumph alone as the toasts of the evening made clear—glasses were raised to the proprietors of minerals in Scotland, the ironmasters of Scotland and England who gave evidence at the hot-blast trials, the Scottish Bar, and the iron and coal trades. But the particular victory was also seen as a step in much larger developments. Toasts were also proposed to "the progress of steam navigation," "the extension of railways all over the world," and "the extension of our commerce in the East Indies and China," all of which were seen as technological transformations dependent on the efficient and extensive production of iron. The figure of the inventor, as epitomized by Neilson, was also in mind—the inventor who through study, experiment, and industry makes discoveries and initiates improvements that transcend individual benefit to promote the commonwealth. To this idea were directed both the toast proposed by Professor Fleming to "Popular education, and the promotion of intelligence among the operative workmen of this country," and that offered by James Patrick Muirhead to "The Inventive Genius of Great Britain, and the Memories of Watt, Arkwright and Murdoch." Muirhead's toast made much of the similarities between Neilson and Watt:

> . . . it cannot, I think, fail to strike us how similar in many particulars has been the course, how kindred in some respects must have been the spirit of James Neilson, and James Watt. Born in the same district of country; the science of both cradled in the same City;—their merits recognized and fostered by patrons of similar eminence and similar benignity; —both in like manner observing, considering and investigating the nature, —the marvelous nature and properties of Heat; both with like felicity deducing consequences important and beneficial to Man;—with like perseverance elaborating and perfecting their respective inventions;—threatened alike with repeated illegal infringements of their just rights, and both alike, after an arduous contest, finally and triumphantly successful:—I know not what is wanting to the truthfulness and completeness of the parallel . . . [2]

While celebrating this supposed "second Watt," most of those present would also have joined, though with varying degrees of enthusiasm, in a celebration of the patent system itself as providing a reward for inventive genius, an incentive for investors in improvements, and a vehicle for obviating secrecy and securing inventions as public property once the limited monopoly of the patent had expired.

The Neilson patent, and legal deliberations about it, quickly became, and remain, an important case in the ongoing struggles over what is patentable subject matter. For example, in 1853, during contest over Samuel Morse's telegraph patent, Morse's lawyers used *Neilson v. Harford* to try to defend the infamous eighth claim of Morse's patent to all communication by electricity. They did so on the grounds that Neilson had been allowed to patent a principle—a contentious claim, and certainly not the intent or belief of the English judges involved in the case. The argument was not accepted, but that it was attempted indicates the ongoing salience of the decision.[3] In the 1920s and the 1930s, when the issue of "scientific property" was much debated, the Neilson patent was again discussed as a key precedent that shortened

FIGURE 1. Daniel Macnee, *The Hot Blast Partners*, ca. 1840. The characters depicted are the partners: (from left to right) James Beaumont Neilson; Charles Mackintosh; John Wilson of Dundyvan; James Dunlop of Tollcross; Robert Aitken, accountant and syndicate secretary; and the lawyers Anderson Kirkwood and Andrew Bannatyne. Source: University of Strathclyde Collection. (Reproduced by kind permission of the Department of Archives and Special Collections, University of Strathclyde Library).

the distance between "discovery" (i.e., the discovery of a principle) and "invention" (i.e., putting a principle into effect). The Neilson patent decision features today in the teaching of intellectual property law, especially in connection with the issue of software patents, and prominent lawyers, such as Jeffrey Lefstin, recall its importance in and modern relevance to recent cases on patent-eligible subject matter, where it continues to be cited and used by interested parties. [4] We see in the recent heated debates over the non-patentability of "products of nature" and how that is to be interpreted in contests over gene patents clear echoes and recapitulations of argument from the Neilson case.[5]

In what follows, I am concerned to tell the story of Neilson's invention and of his patent and the trials that it underwent. I do this with a particular eye on (a) the debate over whether the patent was illegitimate because of an attempted patent of a principle; (b) how that debate was conducted; and (c) how, in a limited sense, it was resolved. I will begin by outlining Neilson's career, his invention, his patent, and the legal wrangles to which it was subject. I will then explore in greater detail the arguments made during the patent trials and, in particular, how the issue of the patenting of a principle was dealt with. Here I will suggest the construction of the figure of the inventor and the negotiation of credibility played a crucial part, but so too did the public policy issue of rewarding (perhaps more particularly being seen to reward) the initiator of a transformative invention of great utility.

A growing number of historians have noted the strong link between the operation of patent systems and the cultivation of the myth of the heroic individual inventor.[6] The myth has helped to validate patent systems, and the systems, in their turn, perpetuate the myth; Neilson's career and that of his patent is a fine example of this. In addition, because Neilson's patent was so close to being a patent of a principle—today we would describe it as having very broad scope—the scale of mythmaking was correspondingly heroic, and it makes reconstructing the complex story of the hot blast difficult. Ironically, among the key sources for recovering that story are the detailed records of the trials that affirmed the validity of the patent.

Recently Paul Belford has offered a reappraisal of Neilson and the hot blast.[7] Like the current study, he points to the complexity of the development of the hot blast when compared to the simple accounts of it as Neilson's invention. Unlike the current study, Belford's account concentrates on another candidate inventor, Thomas Botfield, a Shropshire ironmaster, as anticipating Neilson. My approach is a skeptical one concerning the merit of the claims of any individual inventor. I do not seek to arbitrate the individual claims to invention. My primary purpose is to explain how it was that Neilson came to be seen, and celebrated, as *the* inventor. Because of this, unlike Belford I concentrate on a close reading of the trials of Neilson's patent and also give careful attention to the invention stories told by the Neilson camp in other forums, including scientific ones. The public debate over the invention of the hot blast scarcely featured Botfield at all. A strong case exists for seeing invention of the hot blast as a collective process involving a cast of characters working closely in the same environs as Neilson. It was their stories, mobilized in legal forums by powerful ironmasters, that posed a real threat to the Neilson camp. However, I will argue that astute legal tactics, the ability to garner scientific credibility, and luck concerning the currents of public policy on patents in the late 1830s and 1840s gave Neilson the victory and the laurels as sole inventor. In conclusion, I also reflect on the broader historical implications of the case in the light of a recent revisionist account of the history of the British patent system.

Neilson's Career

Neilson was born on 22 June 1792 at Shettleston outside Glasgow and was known in his inner circle as "Beaumont."[8] His father, Walter Neilson, was at that time engine-wright at Govan Colliery, having previously worked as an engineer in Dr. John Roebuck's Borrowstoneness colliery. On leaving school at about 14, Neilson assisted his father with colliery steam engines and then, in 1808, was apprenticed to his older brother John (who had established Oakbank Iron Works in Glasgow) before obtaining, in 1814, a post as engine-wright at a colliery in Irvine, Ayrshire. In 1817, when the Glasgow Gas Company was established, Neilson was appointed foreman. He became manager and engineer five years later and remained with the company until his resignation in 1847. He acquired a significant reputation as a gas engineer and was responsible for a number of improvements in that field: he devised the swallow-tail burner (which passed into general use), and he also used clay in the construction of gas retorts and employed waste coal tar for heating them. The practice of removing ammonia from coal gas by the use of iron sulphate solutions was another of his innovations, one that led indirectly to his development of the hot blast.

The knowledge that Neilson brought to these improvements had been gained partly from working with his father and brother, but when he joined the Gas Company, Neilson had also begun study at the Andersonian Institution. The knowledge of natural philosophy and chemistry so gained was reputedly important to his gas innovations and the hot blast in iron manufacture. Neilson took out the patent for the hot blast in September 1828 in England and the following month in Scotland and Ireland.

Although already a successful young man, Neilson could not develop the invention on his own. He entered into partnership to gain the capital and access to full-scale iron production, required to bring the hot blast into commercial operation. As the hot blast did come into widespread use in the 1830s, Neilson and his partners began to accumulate fortunes from the fee (i.e., one shilling per ton of iron produced) that they charged to licensees using the patented process. There were early signs of trouble in the working of the patent in 1832 when one licensee, the Bairds of Gartsherrie, refused to pay further fees and were threatened with legal action. Although the issue was resolved out of court for the time being, the Bairds remained the major force behind many subsequent challenges to the Neilson patent.[9]

In the 1830s, Neilson and his claimed invention became more widely known. He supplied the first detailed public account of his path to the invention in 1832 in a publication by James Cleland.[10] The following year, he published a similar account in the *Transactions of the Institution of Civil Engineers*.[11] These were, I think, strategic publications with an eye on not only publicizing the invention but also defending it. We will see, however, that Neilson's delineation of what he called his "discovery of the invention" also gave clues to his opponents about how they might claim lack of novelty in the invention due to the existence of prior art. For some of his licensees were restive—some of them were, in the nature of things, themselves making improvements in the use of the hot blast that considerably altered the design of the heating apparatus and increased the savings made. They began to question paying Neilson and his partners for the privilege of using what could be seen as a rather abstract depiction of the process in their patent. Was the process now in use really the same as that which Neilson had devised? Put another way: Had Neilson *really* invented the hot blast?

A number of iron producers formed a combination to fight the Neilson patent to the end, in what some characterized as a "conspiracy of capital against talent."[12] This fight produced a congeries of court actions in the late 1830s and early 1840s with, at one time, as many as 20 actions going on. Three main cases were, however, argued before juries, and it is these that we will study in detail, namely *Neilson et al. v. Harford* (1841), *Neilson et al. v. Househill Iron & Coal Company* (1842), and *Neilson et al. v. W. Baird & Co*. After the wash up from these cases, it was clear that Neilson and his partners had won a major victory, which was the cause of celebration at the Tontine Hotel in 1845.

Neilson settled to enjoy his success. Already a member of the Institution of Engineers and of the Chemical Society, he received the imprimatur of the scientific community by his election on 15 January 1846 as a Fellow of the Royal Society of London. His election certificate is terse and to the point, describing him as the discoverer of "'The Hot Blast' system of manufacturing iron" and as distinguished for his acquaintance with the science of "mechanical philosophy." The end of patent hostilities would have been regarded by many Fellows as a suitable point at which to welcome Neilson to their midst as a discoverer and national benefactor.[13] After his retirement from the Glasgow Gas Company in 1847, Neilson purchased a property on the Isle of Bute. Then, in 1851, he moved to an estate at Queenshill, near Tongland, Kirkcudbrightshire. There he was active particularly in the promotion of workers' education. He died at Queenshill on 18 January 1865.

The making of Neilson into a legendary figure began even as his patent victory was secured. The writer of an 1845 article on the Scottish iron manufacture took this view of him:

> His name is identified with the greatest improvement that has yet been discovered in one of our staple manufactures; and will pass down to posterity, as not unfit to be associated, in point of usefulness to his country, with the names of Watt, and Arkwright, and Cartwright. Were any tribute to be paid him, either now or hereafter, the most appropriate device that could be placed upon it would be to present him as standing betwixt the blowing cylinder and the blast-furnace, intercepting and heating the air in its passage from the one to the other. Such would be a vivid picture of Neilson's invention.[14]

To my knowledge, no such immortal image was ever created, but Neilson was commemorated in Smiles' *Industrial Biography* and other publications devoted to self-help and uplift.[15] Neilson had not only exhibited the impulse to self-improvement in his own life but also encouraged it in others. He had been a founder of the Glasgow Mechanics' Institute in 1824 and, as we have seen, pioneered other similar ventures in retirement. In 1883, his son, Walter Montgomerie Neilson, erected the 35-foot high obelisk, reminiscent of a blast furnace, which stands on Barstobrick Hill on Neilson's former Queenshill estate near Ringford. The text on the obelisk reads, simply: "NEILSON HOT BLAST 1828."

The Invention of the Hot Blast

So, how did the invention of the hot blast come about? The story as told by Neilson has been repeated by numerous secondary accounts and histories, including that written by Samuel Smiles. In the literature of the patent trials, there is another version given by Neilson's opponents— itself perhaps no more reliable than Neilson's version given the context of its telling—which paints him as ignorant of the iron trade, arriving at his basic insight by accident rather than by scientific deduction, crucially dependent on others in developing the technique, and usurping the credit due elsewhere for the plant design, which rendered the hot blast immensely profitable and transformed the iron industry.[16]

According to his own account, Neilson's first study of blast furnaces was stimulated when an ironmaster consulted him in 1824 on whether the air blast to a furnace might be purified. This individual, like many others in the trade, had noted that iron smelting proceeded less satisfactorily in summer. Indeed it was commonly accepted that winter air was best for the blast. The ironmaster's interest in purifying the air for the blast, specifically to remove sulphur from that air, must have been based on the idea that greater sulphur content in the air in the summer months might be responsible for the seasonal variation in productivity. So

Neilson was first drawn into work on the blast because of his expertise in purifying gases. But Neilson rejected the sulphur hypothesis even as he accepted at this stage, at least indirectly, that cold air was best. In a paper titled "On the Smelting of Iron" read in 1825 to the Glasgow Philosophical Society, Neilson argued that the summer effect was more likely due to an increase in the vapor pressure, as there was more water in the air in summer when temperatures were higher. In that case, drying the air with quicklime would be a remedy. Another hypothesis that he suggested was that the air in summer contained insufficient oxygen.

Neilson claims that this latter idea was suggested by an observation by James Ewing of the Muirkirk Ironworks, who had found that one of his blast furnaces, which was about a half-mile away from the blowing engine, did not work as well as the furnaces located near the source of the blast. Neilson reasoned that friction involved in the travel of the blast from the blowing engine to the distant furnace reduced the volume of air, and hence of oxygen, being delivered to the furnace. If the air were heated, then its volume would increase and the problem would be lessened. To investigate the effect of heating the blast air, Neilson reports that he performed a simple experiment:

> To the nozzle of a pair of common smith's bellows, I attached a cast iron vessel heated from beneath, in the manner of a retort for generating gas, and to this vessel, the blow pipe by which the forge or furnace was blown, was also attached. The air from the bellows having thus to pass through the heated vessel above mentioned, was consequently heated to a high temperature before it entered the forge fire, and the result produced, in increasing the intensity of the heat in the furnace, was far beyond my expectation, and so evident as to make apparent to me the fallacy of the generally received opinion, that the coldness of the air of the atmosphere in the winter months, was the cause of the best iron being then produced.[17]

Neilson portrays himself as consciously "overthrowing the old theory" and establishing "new principles and facts" in the process of iron making.[18] The "old theory" was more than a passive belief. Ironmasters actively sought to cool the blast—the regulator[19] was painted white, air was passed over cold water on its way to the furnace, and sometimes ice was packed around the pipes carrying the air. Nor was this belief just in the realm of tacit knowledge and working practice. Keeping the blast cold was endorsed in *Rees' Cyclopaedia* and the *London Cyclopaedia*.[20] So Neilson was changing understanding as well as technique.

The small-scale experiments that led Neilson to believe in the superiority of the hot blast were conducted in the gasworks with apparatus standard in gas production. Neilson was not himself in the iron trade at that point and had to work with what he had available. To test the process "in the large" required access to a full-scale iron works and the proprietors' willingness to take risks with their production process. Neilson also required capital to pursue the patenting and development of the invention. To secure these things, he took into partnership in the patent Charles Macintosh of Crossbasket, Colin Dunlop of Clyde Iron Works, and John Wilson of Dundyvan Iron Works.[21]

A surviving documentary record of the process of drawing up the patent specification provides an interesting picture of how that was done.[22] Neilson had no prior experience with drawing up patents, unlike his newly recruited partner Charles Macintosh.[23] One of the most interesting of the Neilson specification documents is a draft bearing marginal annotations by James Watt, Jr. that was posted to Macintosh in Glasgow from Birmingham on 20 January 1829. Macintosh annotated the document "Copy of Neilson's specification as first drawn corrected by James Watt." In his annotations, Watt Jr. advised that there should be consistency of terminology, suggested that in some places rough dimensions of apparatus might be given, and wondered whether the proportionate saving of fuel that was mentioned in the draft patent had been ascertained subsequent to the experiment that he [Watt Jr.] had witnessed. Clearly, Watt Jr. had been closely consulted in person, too. He must have visited Neilson during one of his trips to Scotland from his home in Birmingham and been shown an experimental demonstration of the hot blast, presumably in a forge. We also know that Henry Brougham was involved with the specification and gave it its title. That title, "An Invention for the improved application of Air to produce heat in fires, forges, and furnaces, where Bellows or other Blowing Apparatus are required," is certainly broader than the specific technique that came to be known as the hot blast in iron production. Brougham was contributing his ingenuity to capturing as much as possible for the patent. It appears that Macintosh (or Neilson) brought "team Watt" in to help with the specification early in the piece.[24] Another annotated draft shows that the resulting version was then sent to Charles Bompas,[25] Serjeant at Law of the Inner Temple in London, whose returned advice is dated 19 February 1829. Bompas, like Watt Jr., focused on the places in the patent specification where, in his view, too little, or too much, detail was given. The message was, in Bompas' words, "If this is not necessary to the beneficial use of the patent it is better omitted."

The various drafts of the specification and comments on them show, not surprisingly, that the major concern of all parties to the process was that the specification be drawn up in a way that provided enough detail for it to be passable as a viable set of instructions to a person versed in the art that would plausibly enable them to use the invention, but not so much detail that the patent might be readily circumvented by making minor variations. The broader the characterization of the invention, the more it comes to look like an idea or a principle that cannot in itself be patented, but the more it takes this risk, the more it acts as a general exclusion on a wide range of possible set-ups. Also, the broader the specification the more likely it is that it will be rejected in a court of law as insufficient because it does not provide adequate information for the realization of the invention. The specification as finally submitted was thus a negotiated compromise, agreed on by Neilson, Macintosh, Watt Jr., Brougham, and Bompas, between too narrow and too broad a specification.

The drawing up of the specification preceded the practical development of the technique "in the large." Neilson was assisted by his other two partners, Colin Dunlop and John Wilson, in applying the principle of the hot blast to the realities of blast furnace operation. At Dunlop's Clyde Iron Works in early 1829, the first full scale hot-blast apparatus was constructed. We will see later that the character of this apparatus, Neilson's contribution to it, and, most particularly, its relation with the patent specification were contested in the patent trials of the early 1840s. For the moment, I will provide an overview of the design development process derived ultimately, and retrospectively, from the Neilson camp.[26]

As illustrated in Figure A by the interior Fig. 1. and Fig. 2., the Clyde Iron Works hot-blast apparatus of early 1829 was a simple "box" construction, made of wrought iron, interposed between the blowing apparatus and the tuyères conducting the heated air into the furnace. This construction succeeded in heating the air of the blast to a temperature of about 200°F. In the later part of 1829, still at the Clyde Iron Works, Neilson replaced the boiler-plate heating chamber with a cast iron, retort-shaped vessel (Fig. 3. of Figure A). This alteration drew on Neilson's experience with the design of retorts used in gas making and achieved a blast temperature of 280°F. Neilson's next design, built in 1830, raised the temperature of the blast to more than 600°F, essentially by increasing the surface area of the air conduit that was in contact with the heating grates by using a continuous large bore pipe for the purpose (Fig. 4. and Fig. 5. of Figure A). The continuous pipe design, however, proved rather fragile under constant heating, especially at flange joints, so Neilson sought alternative ways of generating a blast temperature of 600°F. According to Marten, this search led him to conceive of the cast iron tubular arch oven (Fig. 6. and Fig. 7. of

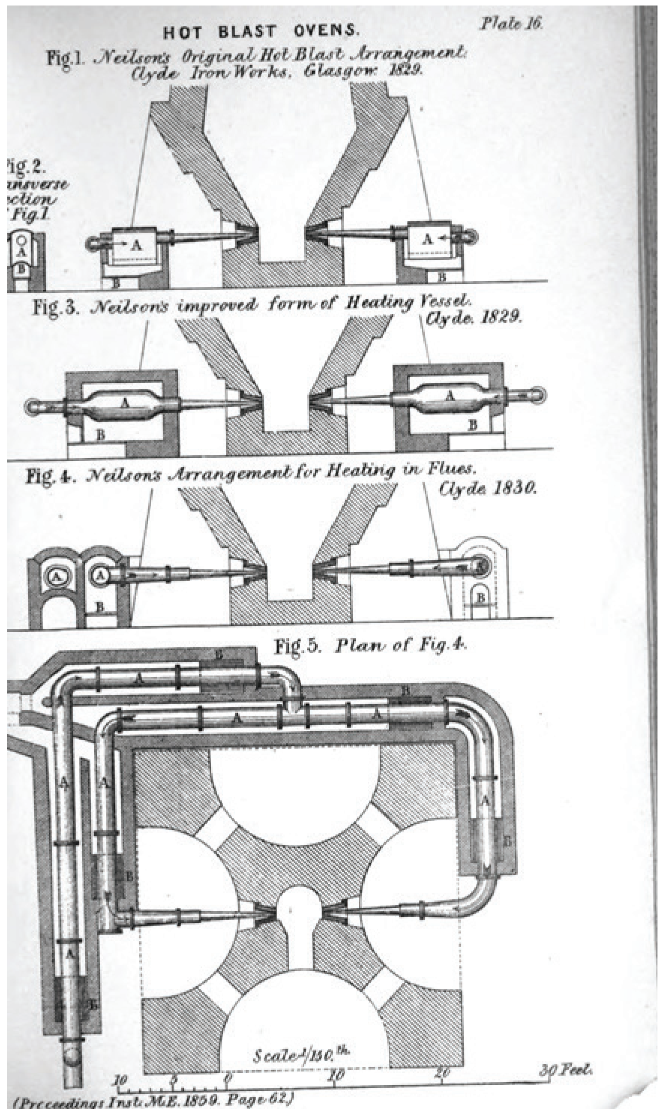

FIGURE A. Early Designs of Hot Blast Apparatus. Source: Henry Marten, "On the Construction of Hot Blast Ovens for Iron Furnaces," *Proceedings of the Institution of Mechanical Engineers* 10 (1859): 62–91, 97–108.

Figure B), as erected at the Clyde works in 1832. Marten makes an important claim about this last design:

> . . . this apparatus, owing to its improved construction, maintained as efficient a temperature with less than two thirds of the heating surface per tuyere [twire] and little more than half the grate area. This oven was found to be a great improvement on the one

> previously described; raising the temperature with less expenditure of fuel, less leakage, and greater regularity.[27]

Thus, while increasing the area of heating surface to which the incoming blast air was exposed was, other things being equal, the most important principle guiding successive designs, other things were not always equal, and as in this case, other considerations could mean that a design presenting less heating surface could be favored and, in practice, superior.

Improvements in the design of the blast heating arrangements continued, as Marten shows, in many places where the hot blast had been implemented in Scotland, England, and Wales. It is not necessary to follow these further. It is necessary, however, to make a few observations about the overly neat account of these design developments that Marten presents.

First, Neilson is the hero of Marten's account and is presented as the driver of design. Thus, we are told of Neilson's systematic and scientific approach to the construction and testing of successive early designs, culminating in the tubular oven, which, Marten carefully notes, "has been the parent of all subsequent arrangements."[28] Second, the early phase of design development is credited to "Mr. Neilson and his friends" in Scotland. This account entirely overlooks, or at least obfuscates, some important issues. One of the great advantages of the mature hot-blast process was that it could burn raw coal rather than coke. This possibility was first realized by William Dixon of the Calder Iron Works, not by Neilson or his immediate circle. Dixon had experimented with the hot blast and was dissuaded by the Neilson partnership from patenting the use of raw coal in that process thanks to their decision to sign an agreement with him allowing his use of the hot blast at two furnaces without duty and promising him a cut of any license duty that they might earn from their licensees above one shilling per ton.[29] It was at Dixon's Wilsontown Iron Works that John Condie is widely believed to have developed, or greatly improved, a device known as the water–twyer, which plays an important part in the hot-blast story. Condie also has a claim to the development of the tubular oven-style vessel for heating the air, sometimes referred to as the "Condie pipes," that Marten presented as Neilson's.[30]

Condie was certainly a crucial figure in the design development of the hot blast. His testimony in the last great trial of the Neilson patent clarifies his story somewhat.[31] Condie was well acquainted with Neilson in the mid-1820s as the latter was developing his ideas. They were both associated with the Glasgow Mechanics' Institute, and Condie saw Neilson's early experiments with the hot blast in a forge at

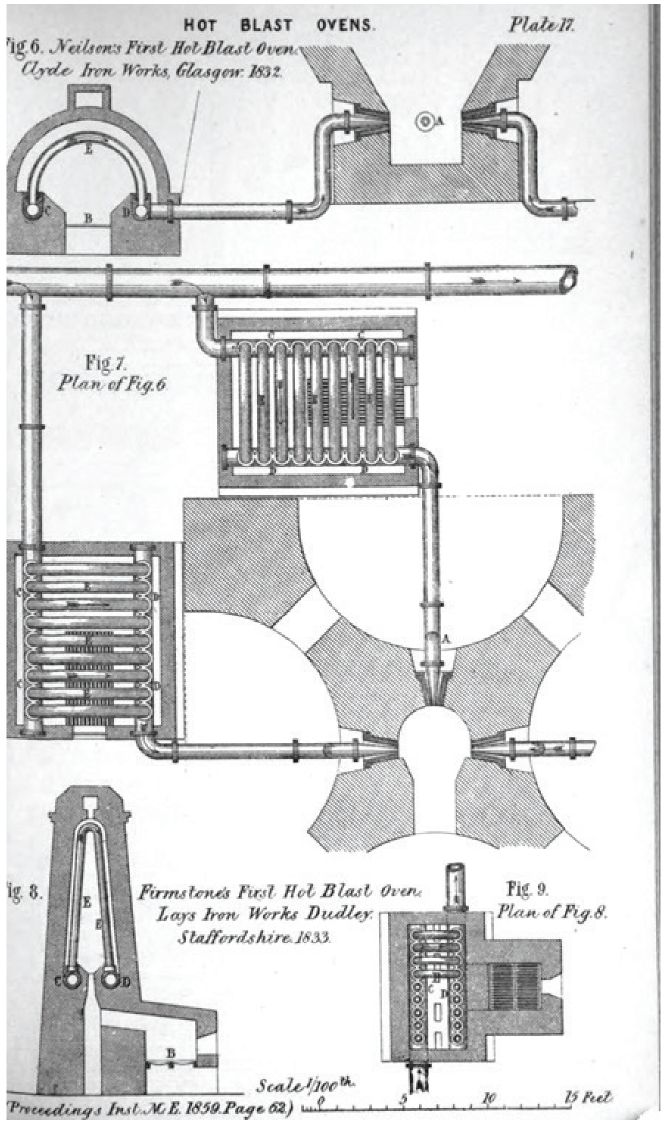

Figure B. Further Early Designs of Hot Blast Apparatus. Source: Henry Marten, "On the Construction of Hot Blast Ovens for Iron Furnaces," *Proceedings of the Institution of Mechanical Engineers* 10 (1859): 62–91, 97–108.

the gasworks. He first saw the hot blast used in a blast furnace at Wilsontown Iron Works, of which William Dixon of Calder Ironworks was also the proprietor. When the manager of Calder Ironworks, Mr. Christie, tired of the disruption caused by the experiments, Dixon appointed Condie manager at the Wilsontown works with a brief to pursue the experiments there. It was at Wilsontown that Condie developed a tubular oven-heating apparatus and also the improved water-cooled twire.

It is important to note that into the mid-1830s, Dixon was collaborating with Neilson and his partners, and Condie was, at various times, seconded by Dixon to work for the patentees. One such occasion was at the Dowlais Ironworks in Wales in 1836, where a heating apparatus made up of ranges of pipes laid alongside each other was in use. Condie recalled:

> I was very hard pressed by Mr Mackintosh and Mr Neilson to say plainly that it [i.e. the Dowlais pipe arrangement] fell within Mr Neilson's Patent, and I said I would not say so—that I had not time to give an opinion—but to state what I had seen, and in my statement I said that the arrangements were similar to what I had seen applied at the Calder and the Clyde.[32]

Condie ended up supplying an affidavit acknowledging the novelty and scope of the Neilson patent and in particular stating that the Dowlais works was putting Neilson's invention into use.[33] Apparently, Neilson and his partners were attempting to build a legally employable consensus that various designs of heating apparatus developed in cooperation with or independently by others should be included within the scope of the patent.

Some of the development work was done by agreement between Macintosh and the Bairds.[34] The latter were, virtually from the beginning, unhappy with the Neilson patent and were to be the central orchestrators of most of the patent litigation. Yet that opposition gestated in, and in part stemmed from, the experience of Neilson (or perhaps Macintosh) seeking to *cooperate* with the Bairds. Dunlop and Wilson, quite reasonably, found the ongoing experimentation at the Clyde works rather disconcerting since the sensitivity of blast furnaces induced a degree of conservatism in their owners. Once a furnace was working well, there was great reluctance to interfere with it further. It was because of this that Macintosh also sought cooperation with the Bairds, who in 1829 were newcomers to the trade and less subject to such inhibitions. Thus, they were conscious at the time that many were working on improving the hot blast and acted to shore up the claim that these improvements should be seen as covered by Neilson's patent.

The Bairds commenced use of the hot blast on 4 May 1830 after Neilson had supervised its installation in the Bairds' No. 1 furnace. They dropped it in November 1830 but resumed it on 5 October 1831. Even as they were trialling the technology, supposedly in cooperation with Neilson, they were playing a very hard game about taking out a license. In fact, they refused to take one out until Neilson and his partners threatened to cease negotiations altogether. The Bairds signed a license agreement in April 1832, but only three months later once again refused to pay fees on the grounds that another patent claim to the hot blast had been brought to their attention and that, in any case, they doubted the validity of Neilson's patent in other respects. Finally, they argued, the design of apparatus that they used was different and not covered by the Neilson patent. In July 1832, James Baird was thinking of patenting a heating system for the blast air that he had developed using small pipes, and which was installed in the Bairds' No. 2 furnace. He contended that since the Neilson patent specified that larger heating vessels for the blast air should be used as the size of the furnace increased, and since his own design tended in the opposite direction, that design was genuinely novel and deserved patent protection itself.[35] Baird acknowledged the construction of a similar design by John Condie but claimed that Condie's did not achieve so high a temperature because of crucial design differences. Baird never took out that patent. As we have seen, Marten's account of the development of the hot-blast oven claims a similar design for Neilson installed at the Clyde Iron Works in that same year.[36]

Another perspective on the design development of the hot-blast apparatus comes from a report written for the French government by the geologist and mineralogist Armand Dufrénoy.[37] Dufrénoy's tour of ironworks began at the Clyde works, and the Neilson group shaped his view of the whole subject. The Frenchman begins by discussing Neilson's patented invention and the experiments conducted by Neilson, Macintosh, and Wilson at the Clyde works. They are the only individual inventors/experimenters named in the account. Dufrénoy then recounts visits in 1832 to virtually all the ironworks in Scotland and England. Key to our present interest, he describes the air-heating apparatus in use at each works: at the Clyde works, a range of large horizontal pipes was employed (Figure C); at Calder, two furnaces were served by a heating apparatus similar to that used at Clyde, but the other Calder furnaces used small pipes crossing vertically between the horizontal pipes (Figure D, bottom). At Monkland Ironworks, he reports that a tubular arrangement similar to that at Calder was employed with the variation that the large pipes were in a vertical horseshoe shape with small pipes between them (Figure D, top). It may be that a tubular oven was in use at Clyde in 1832, as the Neilson camp accounts claim, but if so, it antedated Dufrénoy's visit. If his report is to be believed, we can say that tubular ovens were in use at Calder and Monkland before they were in use at Clyde.[38] This finding directly contradicts Marten's later version of events as endorsed by Neilson (see Fig. 6. and Fig. 7. in Figure B). Dufrénoy appears not to have visited the Bairds' works at Gartsherrie.

The general point to be drawn from all this is that the design development of the hot-blast apparatus was neither so neat nor so entirely his own as Neilson and his friends claimed.

The Patent Contested

Neilson and his partners always expected a challenge to the patent. Indeed, the main reason why so much care and consultation had been invested in drawing up the specification was to minimize opportunities for a successful challenge, while remaining within the bounds of patentable subject matter. It must also be borne in mind that the patent contest was not an academic exercise in defining the true inventor and invention; rather it was, for both sides, a matter of business strategy. Decisions to challenge the patent by refusing to pay license fees, and decisions to settle disputes out of court or pursue them to the limit of the law were, as Corrins shows, a matter of business tactics. It was a high-stakes game, with large sums of money being spent on legal action and with significant earnings from license fees as a result of, and despite, that action. Although the Bairds organized a concerted opposition, Neilson and his partners continued to make large sums of money from compliant licensees.

Neilson and his partners actively shaped the narratives about the hot blast. I have shown how Neilson published accounts of his path to the invention in the early 1830s, which were cast in a way that emphasized his own creative efforts. Other accounts of the hot-blast invention given in scientific fora betray strong rhetorical purpose in the search for scientific credibility, an important coinage in the patent struggle. Particularly interesting are the accounts given in the mid-1830s by Thomas Clark, recently appointed Professor of Chemistry at Marischal College Aberdeen.

Clark presented a paper on the success of the hot blast and his understanding of why it worked to the Chemistry Section at the Edinburgh meeting of the British Association in 1834.[39] To judge by the published account, in tracing the design changes to the hot-blast apparatus and the fuel and other savings that they produced, Clark mentioned only the Clyde Iron Works and attributed everything to Neilson's invention. Dixon is not mentioned as making the discovery that raw coal could be used directly without the need for coking it first. Instead the passive voice is used to note that this "had been discovered," and the distinct impression is given that this was all part and parcel of Neilson's invention.

A very similar paper by Clark was read to the Royal Society of Edinburgh on 16 March 1835 and published a year later.[40] It provided, as had the British Association paper, an account of the increasing

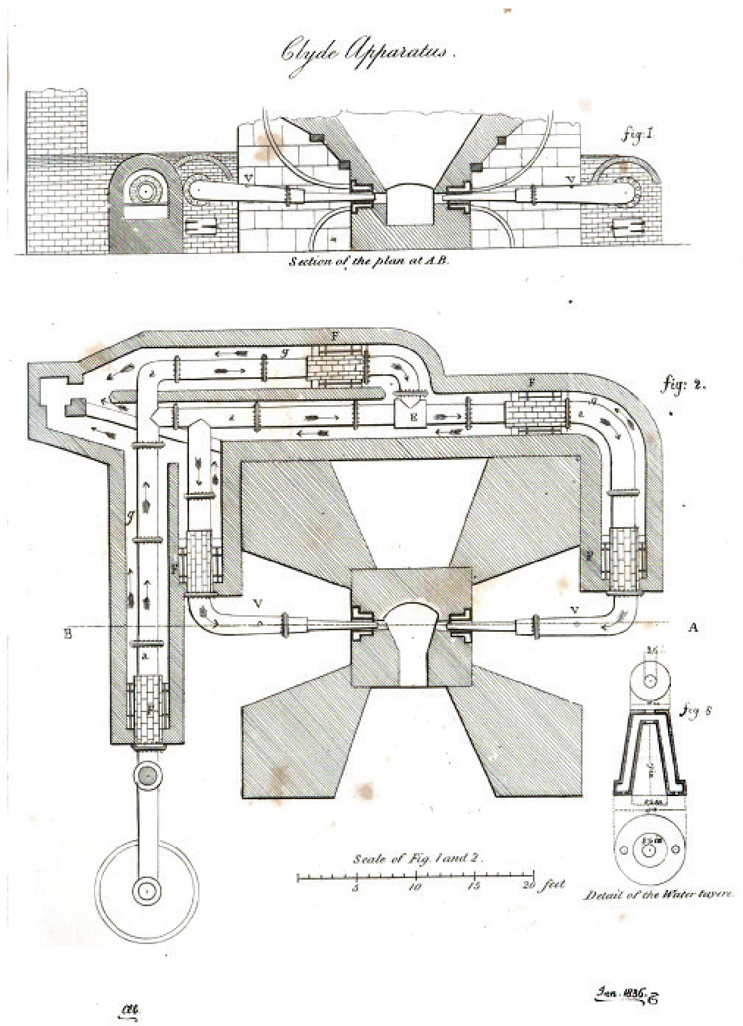

FIGURE C. The Clyde Iron Works Heating Apparatus in 1832, according to Dufrénoy's Report. Source: Ours-Pierre-Armand Petit-Dufrénoy, *On the Use of Hot Air in the Iron Works of England and Scotland. Translated from a Report made to the Director General of Mines in France by M. Dufrénoy, in 1834* (London: J. Murray, 1836). The plate was drawn by Charlotte Guest in January 1836 but is consistent with the textual description.

productivity of the hot blast in the early 1830s, once again concentrating on what had been done at the Clyde Iron Works, whose proprietor Mr. Dunlop had supplied the information on which Clark's account was based. Here the efforts of Dixon are mentioned but are effectively incorporated into Neilson's invention by describing them as proceeding "on the ascertained advantages of the hot blast." Clark also

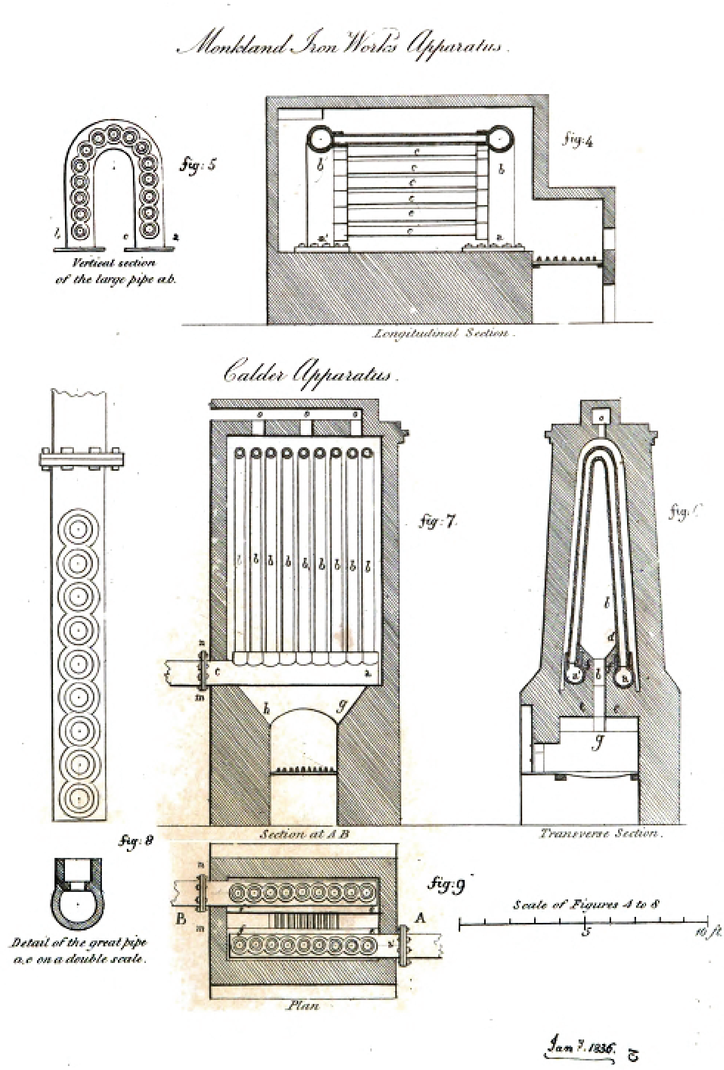

Figure D. The Calder and Monklands Ironworks Heating Apparatus in 1832, according to Dufrénoy's Report. Source: Ours-Pierre-Armand Petit-Dufrénoy, *On the Use of Hot Air in the Iron Works of England and Scotland. Translated from a Report made to the Director General of Mines in France by M. Dufrénoy, in 1834* (London: J. Murray, 1836). The plate was drawn by Charlotte Guest in January 1836 but is consistent with the textual description.

discussed another design development that contributed to the increasing productivity that he had charted—the water-cooled twire (or "tweer," as he renders the term), which was to become, as we will see, a major focus of contest in the patent trials. Having explained the overheating of the twire at the much higher temperatures created by the hot blast, Clark explained that "to prevent such an accident [that is the over-heating] an old invention called the water tweer was made available."[41] This characterization of the water-cooled twire as old anticipated the line taken by the Neilson camp in the patent trials. Although the Bairds claimed that the water-cooled twire was invented at the Calder Iron Works in 1832 or 1833, and that without it the hot blast could not be beneficially employed, Neilson et al. maintained that it was an old technology redeployed in new circumstances that further improved the savings from the hot blast but was not necessary to achieve some benefit from it.

When we learn a little more about Thomas Clark (a lecturer prone to digression, who became known among his students as "Hot Blast" Clark), suspicion mounts that he was simply an agent of the Neilson camp. The career that took him to the Professorship of Chemistry at Marischal College had begun at the age of 15 (in about 1816) in the counting house of Charles Macintosh & Co, whose proprietor was, of course, to be one of the partners in the hot-blast patent. The Macintoshes had recommended that he study chemistry, and within 10 years, Clark was lecturing at the Glasgow Mechanics' Institute, an institution with which Neilson was closely involved. Just before his appointment at Marischal, Clark was recruited to support Neilson's cause (also Macintosh's) in what was probably the first legal skirmish with the Bairds about the hot-blast patent.[42] It was in the wake of that, or perhaps even as part of it, that the papers read to the British Association and the Royal Society of Edinburgh were produced. The rhetorical sleights of hand that they exhibit become understandable in light of this.

For those of us interested in the public arguments made by both sides of the dispute, the primary focus is not on scientific fora but on the three major trials concerning the hot-blast patent where those arguments are preserved in detail. But we must bear in mind that these trials were not, from the protagonists' point of view, truth-seeking exercises so much as strategic moves in a larger game pursuing both business advantage and, in its service, scientific and technical credibility. In what follows, I will deal with the first trial *Neilson et al. v. Harford Company* in considerable depth and then consider the other two major jury trials insofar as they added to, or departed from, the arguments, insights, and judgments of the first.

Neilson et al. v. Harford Co.

Neilson and his partners engaged the English opposition to their patent in the first of these major trials when they began litigation against the

Harford Company on 18 January 1841.[43] Initial pleadings before the judge framed the issues to be tried. The plaintiffs identified the breaches of the patent of which the defendants were accused, and the defendants proffered the grounds of their defense. The actual jury trial took place in early May that year, and the case was closed on 16 November with a decision in favor of the patentees.[44] Sir William Follett[45] and Mr. Fitzroy Kelly were the counsel for the plaintiffs, whereas the Attorney General (Sir John Campbell) put the case for the defendants, along with Sir Frederick Pollock and Mr. Richards. The plaintiffs called 16 witnesses who were examined and cross-examined. The defendants called no witnesses—the Attorney General insisted, and argued, that the plaintiffs' witnesses had proven his case. Let us now examine the case in detail.

It is important to recognize that initial pleadings before the trial were important in establishing the dimensions of the case. The plaintiffs declared that the defendants had imitated and used Neilson's invention; produced tons of iron on his "improved plan and principle"; and made "divers colourable additions thereto, and subtractions therefrom, whereby to pretend themselves to be the inventors and devisers thereof."[46] For their part, the defendants pleaded not guilty to these charges, contending that Neilson was not the "true and first" inventor, that the said invention had been used publicly prior to Neilson's patent, and that the specification "did not particularly describe and ascertain the nature of his said supposed invention, and in what manner the same was to be performed." Finally, the defendants stated that Neilson's invention as specified had never been "of any public or general use, benefit, or advantage, whatsoever."[47] In giving notice of their objections, the defendants elaborated on these points and also gave other grounds for their case, including that the Neilson patent was void because it was a patent of a principle and because of its general vagueness, and that the apparatus used by the defendants, far from being a counterfeit of Neilson's, was "wholly different from that described in [Neilson's] specification."[48]

The issues having been earlier set up in this fashion, at the trial itself Sir William Follett began the case for the plaintiffs. He commenced with an account of Neilson's "discovery," a discovery that he was sure nobody would dispute was of immense value to iron manufacture. To explain the nature of that discovery, Follett described the basic operation of a blast furnace with the aid of a diagram and a model of a set of bellows of the type used to generate the blast, a blast that before Neilson's discovery was, of course, a cold one. He characterized the state of knowledge and opinion among both practical men and men of science as strongly in favor of keeping the blast cold. But "Mr. Neilson, who is a person of very considerable scientific attainments, and also very great practical knowledge, was led to conceive a contrary notion" as a result of observation of a common blacksmith's forge and subsequent experiments (drawing on both his practical skill and scientific knowledge). Neilson concluded that introducing the air as a hot blast would greatly improve the iron production process.

Follett then described the simple means by which Neilson's patent put this discovery into effect:

> . . . his plan is to have between the blowing apparatus . . . and the furnace an air-vessel or vessels, which shall be air-tight or tight enough to receive the air, that those vessels shall be subject to heat, that they shall be placed over the fire or over the furnace and heated, and that the air from the blowing power should pass into those air-vessels so subject to heat, so as very materially and considerably to increase the temperature of the air, and then that from those air-vessels it shall pass along the tubes in the usual way through the arches or twires into the furnace.[49]

Acknowledging that this was a simple process (indeed its extreme simplicity was to be the key point in defending the specification), Follett made the point that it had never been used before Neilson came up with the idea.

The grounds on which the defendants challenged the Neilson patent to deny the charge of infringement were then addressed. Most of those grounds pertained directly to the specification, which was short, so Follett read it out. He drew particular attention to what was said about the vessel or vessels in which the air was to be heated. Although the specification did suggest particular dimensions for the air vessel for a smith's forge and for melting iron, little was said about the vessel to be used with a blast furnace beyond the point that the size and number of the vessels interposed between the bellows and the furnace would increase proportionally as the size of the furnace increased: "for forges or furnaces upon a greater scale, such as blast furnaces &c air vessels of proportionally increased dimensions and numbers will be required." To the defendants' claim that the specification was invalid because it failed to give proper dimensions and details, Follett responded that:

> . . . Mr. Neilson here never could, nor would anyone who was intending that this should be of practical use or benefit, have laid down any particular mode or shape in which these vessels were to be constructed. Any person of ordinary skill would know this, that the larger the surface of the vessel which was exposed to the fire, the greater would be the heat, therefore you will get the greater

> heat by making your vessel in such a way as to expose a larger surface to the fire . . . . this discovery of Mr Neilson's is now in general use in this country [but] the shape and the form of the air vessel through which it passes varies according to the judgment, or according to the intelligence, or the use to which they are intended to be applied by the parties using them, and the space in which the furnace can be placed. It depends on various circumstances.[50]

Thus, although the defendants treated the lack of detail in the patent specification as a sign of its inadequacy, the plaintiffs treated that same lack of detail as a positive, indeed a necessary, feature since it left users to realize the benefits of the basic process in the most effective way for them in their particular circumstances.

Sir William Follett explained the nature of the patent:

> Whilst Mr Neilson's patent is in force, every vessel, no matter what its shape—no matter what its size, through which the air passes from the blowing power, for the purpose of being heated to go into the furnace, would be protected and covered by this patent, because the patent is for that discovery of applying the heated air to the furnace, and pointing out the mode in which that heated air may be applied.[51]

This statement gets us to the crux of the matter. Follett *almost* says that this patent is a patent on the discovery, but he cannot say that since discoveries, or principles, are not patentable subject matter. So he adds the words "and pointing out the mode in which that heated air may be applied."

The crucial issue then becomes: How is it decided whether the specification—"the pointing out of the mode"—is detailed enough? The legal answer is that there must be enough detail for a person "skilled in the art" to be able to implement the invention with benefit flowing. We are left in the end with the testimony of those skilled in the art that enough detail is, or is not, provided. If, as usually happens, those with a claim to such skill do not agree on the question of the sufficiency of the specification, then we have to decide which experts to believe. We are caught in what I have called, following an idea of Harry Collins about the problems of experimental evidence, the "patent specifier's regress."[52] This term conveys the idea that the issue of whether a principle (or discovery) is being patented is decided in the same way and at the same time as it is decided who is credible as "one skilled in the art," or who is credible in defining who is "one skilled in the art." When a specification does not provide the necessary detail of mode of application for one skilled in the art to realize it, it necessarily provides only a principle or an idea.

The centrality of the testimony of those "skilled in the art" is a key reason why witnesses are summoned in patent cases. Follett noted his intention of calling witnesses to testify to the question of whether the specification is good:

> I will call before you men of the highest science, I will call before you men of the greatest practical experience, you shall have both classes and both descriptions, non-manufacturers and iron masters, persons long acquainted with this trade both before and since, gentlemen of the highest skill in chemistry and in science generally. You shall have these witnesses before you, they will tell you that that specification is perfectly plain and perfectly intelligible . . . . They will tell you also that this vessel of the defendants . . . is in point of fact, a carrying into effect the directions given in that specification.[53]

So let us follow the examination and cross-examination of witnesses. As Follett advised, these were variously scientific and practical men.

The Examination and Cross-Examination of Witnesses

The first witness was John Scott Russell,[54] who quickly identified himself as an engineer, a Fellow of the Royal Society of Edinburgh, and Vice-President of the Society of Arts in that city, and as thoroughly acquainted both theoretically and practically with the manufacture of iron and Neilson's patent. Russell was asked by Mr. Kelly whether in his knowledge and experience Neilson's invention was new. The answer, of course, was "yes." The question of its utility, though scarcely requiring an answer in Russell's view, elicited the same response. Despite the protest of counsel for the defendants that the utility of the hot blast was not disputed, Mr. Kelly took Russell through a sequence of questions designed to bring out in just what ways it was useful (i.e., the obviation of the need to coke the coal, the saving of fuel, etc.). Then Russell testified to the great variety of vessels and arrangements of pipes, designed to accomplish a hot blast that he had seen at ironworks in various parts of the country. Mr. Kelly asked: "Are those different collections of pipes, whatever may be the precise form of them, do they appear to have been on the same principle?" To which he received the answer: "They are all mere sets of apparatus for heating the air, and the manner in which they accomplish it, is to a certain extent similar."[55] On such judgments of similarity and difference the business of interpretation depends.

To this point, Russell's testimony had gone smoothly, but now the road became rockier as he was asked whether the specification would enable someone "skilled in the art" to construct a productive hot-blast apparatus. Russell began, to Kelly's consternation, to articulate the difficulties that a normally skilled person would have in arriving at the more advanced tubular design on the basis of the specification. It was explained to him that that was not the question. Rather the question was whether a person skilled in the art could use the specification to build an apparatus, perhaps not the best apparatus, but one that would improve iron production. Russell halted and equivocated about the precise identity of one skilled in the art. Which art was meant? Was it the art of designing blowing apparatus or heating systems in general or blast furnaces? He took a long time to settle this question in his own mind. Although he eventually did so, cracks had appeared that would be exploited in cross-examination.

The Attorney General's first line of questioning in that cross-examination homed in on the years 1828 to 1834—the crucial period of the patent and the extended design of hot-blast apparatus by Neilson and others. Russell was pressed on whether he had seen the hot blast beneficially employed before his first sight of an apparatus in 1834 at what turned out to be the Gartsherrie Iron Works (a Baird operation). The implication was that earlier forms of hot-blast apparatus had not been economically viable. Russell maintained that he did know of an apparatus in the simple form of a box that had been used for some time at Wednesbury Iron Works, but the Attorney created doubt about whether Russell was in a position to judge its real productive success. The next line of cross-examination pursued the idea that, armed with the specification, one skilled in the art would still need to conduct experiments to produce a viable apparatus. Russell talked around the issue (much to the Attorney's exasperation), seeking to avoid the implication that if further experimentation was required, then the specification did not give enough information for a beneficial apparatus to be built and so was inadequate and invalid. The point was made that Neilson himself undertook such experiments between 1828 and 1834, the implication being that even the inventor needed more than the specification that he had drawn up to make the hot blast viable.

The next witness was of a rather different stamp—William Jessop, the proprietor of Butterley Ironworks.[56] Follett sought to draw from Jessop, who had 40 years' experience in the industry, the extent and depth of prior belief among ironmasters in the necessity of a cold blast, when he first learned of the hot blast and whether it was a novel proposition at that time. Jessop testified that he first saw the hot blast on 9 September 1830 at the Low Moor Iron Works where a retort-shaped vessel was used for heating the air. Jessop stated that he had noted from his own observation that there was considerable saving of fuel. Speaking of his own experience of constructing a hot-blast apparatus, Jessop testified that he had been able to do it even without the specification, relying only on the information that the blast air needed to be heated. Clearly, the conclusion was meant to be that if even such basic information was adequate to the task, how could the patent specification itself not be?

If the plaintiffs had sought from Jessop the evidence of a practical man about the novelty of the hot blast and the adequacy of the specification, the cross-examination of Jessop concentrated almost entirely on an apparently obscure issue concerning the "twires" (or tuyères) of a blast furnace. As we have already noted, twires had been a standard feature of furnaces using the cold blast, but when the hot blast was introduced, the twires gave trouble because of the greatly increased temperatures to which they were exposed. They burnt out regularly and had to be replaced, during which time the blast had to be suspended. Such interruptions to production clearly had consequences for the economics of the process. One account has it that at this juncture, Condie invented a water-cooled twire, which came to be known as the Scottish twire.[57] The Attorney's cross-examination of Jessop was concerned to show that the water-cooled twire was yet another improvement that was necessary before the hot blast could be beneficially employed. Jessop, in fact, maintained that water-cooled twires had been used with the cold blast and so were not original with Condie, who had merely improved them. Although Jessop conceded that a new design of water-cooled twire was used with the hot blast, he maintained that the old style water-cooled twire would have done the job. Here was another instance of the defendants seeking to emphasize the differences between the invention as patented, on the one hand, and the invention as implemented to realize beneficial results, on the other hand. The plaintiffs, of course, pursued the opposite course, seeking to bring out and emphasize the underlying similarities between the invention as patented and supplemented by many "minor" design features introduced as it was brought into practice.

The issue of the twires was pursued with other witnesses. David Mushet,[58] a widely known authority on iron manufacture, who had just published his book on that topic, observed that water-cooled twires had sometimes been used with the cold blast so they would not be damaged by heat from the furnace. This observation by Mushet was important to the plaintiffs' case because it meant that the water-cooled twire was not a necessary improvement developed after the hot-blast patent. If it had been necessary, then doubt would have been cast on the sufficiency of that patent for productive use of the invention. Mushet's authority backed the idea that rather than being a necessary improvement subsequent to the patent, the water-cooled twire was part of the existing art and should be treated as assumed knowledge of one skilled in it.

Another witness, Alvan Penrice,[59] was also quizzed on the twires. Penrice was an important witness because he had worked at the Clyde Iron Works during the period when Neilson's experiments were done. Cross-examined on the twires by Sir Frederick Pollock, Penrice testified that for some time after the hot blast had been instituted at Clyde Iron Works, "dry" twires had been used. He acknowledged that these failed frequently, and a long sparring match ensued with Pollock regarding what "frequently" meant. Pollock sought to establish that dry twires failed so frequently that they continually interrupted work, with a detrimental effect on the economics of the hot blast. Once again, counsel for the defendants were arguing that water-cooled twires were necessary to the beneficial effect of the hot blast and were not mentioned in the specification, and so that specification was insufficient. Pollock eventually wrung admission from Penrice that the twires might burn out a number of times a day and that the blast had to be stopped for 15 to 30 minutes each time for the twire to be replaced. But under re-examination by Follett, Penrice established that he had access to the books, which showed that all the hot-blast arrangements operated profitably despite these problems. It was also brought out that changing the twires was not so great a problem because it was usually done at casting time, (that is, when the smelted iron was run off) and so the blast was suspended anyway (for other reasons) and no extra time was lost because of the twire replacement. Although the water-cooled twire was an improvement, it was not indispensable to effective and beneficial working. In this way, the issue of the sufficiency of the specification was pursued into the contingencies of the iron manufacturing process and its work practices.

John Farey,[60] the next witness, was especially interesting because of the exchanges that his testimony provoked about the precise definition of "one skilled in the art." Farey was asked the standard question addressed to every witness about whether the specification was adequate in the sense that a person skilled in the art could achieve the benefit of the invention on the basis of it. His answer was that a competent engineer accustomed to building blowing machinery would be able to build the beneficial apparatus. But rather than stop there, Farey ventured further to state that these were engineers of the "higher class."[61]

Under cross-examination, Farey argued that first, second, and third class engineers could all in greater or lesser degree achieve beneficial effect in building a vessel for heating air. When pressed on whether an "ordinary workman" could do this, Farey replied "no," not without guidance from others. Farey identified the locus of highest expertise as being among the makers of steam engines because they made a variety of blowing apparatus and boilers. Preeminently, he mentioned Bolton [sic] and Watt, and other steam engine producers as representing this first class expertise. Sir Frederick Pollock tried to draw from Farey just what the knowledge was that guided the expert in construction of heating apparatus. Farey's response was that there were a couple of important conditions that had to qualify the general objective of having as large a surface area of the vessel as possible exposed to the fire. The first was that there should be sufficient passage through the vessel to allow the current of air to pass readily through it. The second qualifying condition was that the blast should be guided so as to come into contact with the heated surface. As Farey noted, these conditions were "rather contrary"[62] in that achieving one might reduce the extent to which the other could be satisfied. There were, he testified, rules that were well known to engineers for designing vessels and boilers and fires to achieve a suitable balance between these objectives. First class engineers would come up with inventive solutions; third class engineers could only copy the solutions of others.

There followed a long and confusing exchange between Sir Frederick Pollock, Farey, and Baron Parke concerning the relationship between specifying form and shape, on the one hand, and meeting the conditions of which Farey spoke, on the other. The import of this, from Farey's point of view, seems to have been that if the conditions were not observed, then form and shape would be material in the sense that they would affect the outcome (i.e., the effectiveness with which the air was heated). On the other hand, if the conditions were observed, then form and shape of the vessel were immaterial. This exchange related, of course, to the question of whether the specification ought to have said more than it did about the form and shape of the heating vessel. Farey's implication was that it ought not to have said more because a skilled person would know to apply the conditions that he had discussed and in doing so would arrive at a form and shape that worked in the particular circumstances that local conditions and arrangements presented. The protagonists were to return to this matter.

Samuel Peake, Manager of Silverdale Iron Works in Staffordshire, was next examined. Counsel for the plaintiffs (this time Mr. Kelly) ran through Peake's experience with the cold blast, how he learned of the hot blast, and the form of the heating vessel employed (a serpentine tube). Cross-examination was directed at the issue of what shape of vessel Peake would have designed given the specification of Neilson's patent in 1828. He denied that it would have been a square box, maintaining that he would have tried to find out the most efficient way of accomplishing the object. The Attorney concluded the exchange by suggesting that Peake had needed to conduct experiments to find out how it ought to be done. The witness did not disagree. From the defendants' position, if the witness would not admit he would start with a box (an answer that could be used to generate distance between the specification and the defendants' apparatus), then an admission that experimentation would have to take place was the next best thing (an answer that could be used to argue the insufficiency of the specification because experiments were needed before it could be put into effect).

The testimony of John Kirkham, engineer to the Imperial Gas Light Company, added a new twist in that he had been given the specification by the plaintiffs and asked to make an apparatus accordingly in what purported to be an experimental test of what one skilled in the art could achieve with it. He reported using two retorts that were lying around the gas works, connecting them and building a fire underneath them and thereby managing to heat the air to 612°F. Kirkham said he had no difficulty in this and he considered that anyone of experience, given the specification, could do the same.

The next two witnesses represented another change of pace. First was Professor Daniels [sic][63] followed by Professor Thomas Graham, both chemists. Daniell confessed that he had not paid particular attention to the making of iron but knew the operation and had seen it in practice. He had seen the specification only recently (presumably because of his role as a witness at this trial). Asked the standard question about the sufficiency of the specification, Daniell considered that it made the grade. Pressed by the counsel for the defendants, he conceded that he would have had to make experiments to establish the best way to achieve beneficial effect but under re-examination stated that he could have created an effective apparatus without experiment. Professor Graham[64] too was taken through the standard questions, adding his authority to the sufficiency of the specification. The counsel for the defendants sought to undermine Graham's credibility by peppering him with questions concerning the size and shape of blast furnaces and the quantity of blast required. On the latter point, Graham stumbled, his evidence fell apart, and everyone seemed to lose interest. Scientific witnesses, even such eminent ones, were not always a success!

Three more witnesses rounded out proceedings on the second day of the trial. Another manager was called in the person of William Johnson, of Horsley Iron Works in Staffordshire. He was called because at that works in 1831, a Mr. George Kirk had erected an apparatus for using hot-air blast in the cupola for smelting iron. The plaintiffs had then submitted an account for payment to the Horsley Works since the latter had not taken out a license. The account was paid. Baron Peake ruled as inadmissible evidence that others had acquiesced to the plaintiffs' demands for recognition of their patent rights—it signified nothing. But the testimony did establish a key point: that Horsley Iron Works did not employ the hot blast before the Neilson patent as the defendants had claimed. Next, Robert Aitken, the agent of the patentees, gave evidence concerning the numbers of licenses taken out (about 64 in England and 16 in Scotland). This information further demonstrated what was not really in contest—that the hot blast was beneficial. The final witness, John Thomas Cooper, chemist, was asked the standard questions and testified that the specification would readily lead him to construct a beneficial apparatus, if not necessarily the best. In cross-examination, Sir Frederick Pollock brought out the variety of vessels that could be constructed:

> So that one man, who, by his own experience or good luck, has stumbled upon a very beneficial plan a great deal of good would come, and another man, who has stumbled upon a less beneficial plan, less good would come, but everybody would get some result.[65]

The Attorney General, in what was clearly a staged move, interjected: "It is Neilson's lottery."[66] The implication was that Neilson had approached the very serious business of specifying an invention in a cavalier fashion, leaving it to fate what benefit might result.

The Attorney General's Address for the Defendants

On the third day of the trial, 4 May 1841, the Attorney General made his address to the jury on behalf of the defendants. The Attorney presented the latter as highly respectable and honest businessmen. There was no subterfuge or deception in the stance they took. They placed before the court a model of the apparatus for the hot blast that they had developed and used. The Attorney described it thus:

> It consists of a series of pipes, two of them horizontal, and the others vertical, and by this apparatus the air being introduced into one of the horizontal pipes, there is a stop hereabouts which prevents it from going further in the horizontal pipe. It is then obliged to cross over [to] the other horizontal pipe. It then makes a progress in that horizontal pipe until there is another stop that makes it cross over again to the other side, and so it traverses from side to side until at last, passing through a great number of these heated tubes it reaches a temperature of 600 or 700 degrees, and at that temperature is introduced into the blast furnace by means of the water twire.[67]

The issue, then, was whether any point in law prevented Messrs Harford & Co from manufacturing iron using the apparatus described.

The Attorney then turned to Neilson and his patent. Neilson had been presented in a sympathetic light by Sir William Follett as a man of science devoted to improving the manufacture of iron, a man who pursued his inquiries over days and nights and applied his genius and his labor to the job. In short, although Follett did not use the term, Neilson had been presented as a heroic inventor.[68] A very different picture of Neilson had come out in the evidence of the witnesses, or so the Attorney claimed. Rather than being intensely engaged, Neilson was not much in evidence as "his" technique was worked out. He was ignorant of iron manufacture, and in fact, his idea had been developed in relation to smiths' forges and cupolas. He had little to offer so far as the smelting of iron in furnaces was concerned, which was reflected in the vagueness of his patent specification. In fact, the Attorney undertook to show that the specification was not only defective in failing to provide necessary information required to bring the process into effect but also that it actively misled the reader.

It is undeniable, the Attorney happily conceded, that the hot blast *as currently practiced* was enormously beneficial. That was not at issue. The question was whether it was beneficial in the state that the technique or idea had reached when the patent was taken out. Follett had attributed the slow take-up of the hot blast after it was patented to the "prejudice in the trade in favour of the cold blast." On the contrary, the Attorney argued, the tardy response reflected the simple fact that no apparatus for heating the air was effectual until the tubular pipe apparatus was developed. The hot blast was "confined to two or three manufactories in Scotland, where they were making experiment after experiment in vain."[69] As soon as the tubular form, or arched pipes, was introduced, the hot blast was taken up in not only Scotland but also Staffordshire, Shropshire, and South Wales:

> Is this, then, a case where a discoverer has made an invention, where it is perfect, where he discloses it to the world, and where it does not at first meet with approbation and applause? No, Gentlemen, it is a case where, as far as the smelting of iron is concerned the patentee himself was ignorant, he gives no information, because I believe he possessed none. The mode that was attempted when experiments were made was found quite ineffectual, and for that reason during half the period, or nearly half the period, for which the patent was granted, it might be considered a dead letter. Gentlemen, that is the reason, and the true reason, why it did not come into general use for years and years . . . [70]

Given this, when a "new mode" was discovered, of which "Neilson had no notion" and which could be advantageously employed, it was surely unjust that the use of this discovery should be treated as "illegal and wrong." The question, as the attorney argued, was whether Neilson had any claim to the invention that lay before them. The existence of such a claim had to be judged by deciding whether the specification covered the invention.

The first issue he raised was that of the title of the patent. Rather than "An improved mode of smelting iron by means of hot air," the title was "The improved application of air to produce heat in fires, forges, and furnaces, where bellows or other blowing apparatus are required." In a technical sense, this latter title does not describe a process of heating the air but of applying the air. There is, as a result, a mismatch between the title and the content of the specification. Legal decisions had been made time and again, the attorney noted, that "the specification must be within the scope of the title."

Leaving that issue on one side, however, the specification itself was next considered, especially in relation to the requirement that both the nature of the invention and the manner in which it is to be performed are required of the patentee. The six-month period of grace given before the specification is due was designed to allow the patentee to perform any necessary experiments to fully specify the invention in this way. The legal requirement was, as we have seen, that the information required by "one skilled in the art" was the measure of how detailed the specification was required to be. The Attorney cited Lord Tenterden's judgment in *King v. Wheeler* on this question:

> . . . if a person of moderate capacity having a little knowledge of the science which led to the invention can immediately see the method pointed out and can easily apprehend the purport for which the subject was invented, without study, without any invention of his own, and without experiments the disclosure is fully and fairly made.[71]

The Attorney noted that all the witnesses had, in one way or another, conceded that, if armed only with the specification, experiments had been, or needed to be, made to determine how to put the hot blast into effect beneficially. In particular, the use of a tubular vessel for treating the air was the result of a long process of experimentation post-dating the specification. When we look at what the specification actually does specify, what do we find?

> Does he specify a principle? Does he claim all modes by which heat is to be communicated to the air between the blowing-apparatus and the blast furnace? I think my learned friend says that he does. He says, that any mode whatsoever, by which, in the intermediate space

> between the regulator . . . and the blast-furnace heat is communicated, by whatever means . . . [72]

In this respect, the Attorney claimed to find a *contrast* between the current case and the famous case of James Watt's patent on the separate condenser. Watt's invention was properly specified because according to the decision of the court, a common mechanic acquainted with the old steam engine before Watt's improvements and armed with Watt's specification and nothing else could make all Watt's improvements. It was proven, said the Attorney, that such common mechanics did make those improvements.[73] By contrast, in the case of the hot blast, this was not so. Scientific witnesses had speculated that a common mechanic could do it, although Farey had seemed to deny this. But there had been no evidence that anyone had beneficially applied the hot blast from the specification alone.

Turning to the detail of the specification, the Attorney argued that it was no surprise that it had been useless as a guide to practice because it failed to provide necessary information, it misled the reader about the size and proportions of the vessel required, and it also misled on the importance of the shape and form of the vessel. Since the specification talks of "*a* vessel" where the air is heated, it conveys nothing resembling the complex system of tubes that Harford Company used to heat the air. The specification indicates a tube only at the point where air from the vessel enters the blast furnace and so, according to the Attorney, the specification actually *excludes* a tubular form for the vessel itself. Just as a single vessel was specified for heating air supplied to a smith's forge or to a cupola for melting iron, so a single vessel, but scaled up, is what Neilson stipulated for the blast furnace.

Next the instructions as to the size of the vessel were dissected. The specification stated that as the quantity of blast was increased so the size of the heating vessel should be proportionally increased. But if that instruction was followed, then failure would result because there would be less and less heating surface relative to the volume of the air to be heated, since as we make a vessel bigger, its volume increases at a greater rate than its surface area. These instructions amounted, the Attorney suggested, to a misrepresentation that would produce a failure in the process: "It is from disregarding these directions—from violating them—from going upon a totally different principle—from just taking the reverse of what is here described, it is by that process that the hot blast has been at last beneficially used." The specification states that "the form or shape of the air-vessel or receptacle is immaterial to the effect, and may be adapted to the local circumstances and situation."[74] However, the Attorney argued it was precisely a shift to the tubular form of heating vessel that made the hot blast viable. The tubular form increases the surface area to be heated in proportion to the contents to be heated. Whether from ignorance or deliberate deceit, the specification was misleading: "Gentlemen, you may call Mr. Russell, or Mr. Farey, or Professor Daniell, or Mr. Cooper, and all the chemists and all the philosophers of England, and they will never cure the defects of this specification."[75] No wonder, the Attorney continued, that these witnesses twisted and turned and prevaricated under close questioning on the matter of whether one familiar with the state of the art could achieve the hot blast using only the specification. They hesitated to say that one of ordinary skill could do so. They frequently said this could happen after experimentation, the very sort of extra experimentation that recent legal judgments had maintained should *not* be necessary. It was not convincing to be told by Farey that his "first class engineer," epitomized by Watt, could at once have applied it:

> I believe that if Watt whom I consider as one of the greatest philosophers, if that specification had been put into his hand . . . he would have been obliged to set in exercise his own inventive powers, that he would have said, there is no direction given to me here. I am told the form of the vessel is immaterial. I, a great philosopher, know, that if I were to double the cube, I should certainly very much increase the volume to be heated, and decrease the heating surface . . . . It would not be until he had exercised his invention—until he had made various experiments that he would have been able at all to put this proposed discovery in practice.[76]

But it should not require a Watt to decipher or extend the inquiry. A mechanic of the ordinary sort should be able to achieve the result from the specification without experiment or further instruction. Farey, by showing it to be otherwise, had been, the Attorney suggested, "a witness in my favour."[77]

The Attorney's final substantive point concerned the much discussed water-cooled twire. He contended that the water-cooled twire was clearly necessary for effective use of the hot blast, that Neilson was either ignorant of it or deliberately failed to mention it in the specification. No amount of pretending that the water-cooled twire had long been known and was part of background knowledge could explain why, at the Calder Iron Works, the dry twire was persisted with for so long. The truth was that the water-cooled twire was developed later, and it, in conjunction with the tubular form of heating apparatus, made beneficial use of the hot blast possible.

Returning in conclusion to Neilson himself, the Attorney suggested that this supposedly great inventor had done little so far as the improvement of blast furnace operation was concerned. Although Neilson was familiar with the forge and the cupola, he had over extended himself when applying what he knew about them to the blast furnace:

> . . . he merely throws out a hint, it is a mere idea, it is a patent for an idea, not so much as a principle, he just suggests that it is possible this process . . . might likewise be employed in the smelting furnace, but as to the manner in which it was to be conducted, of that he was grossly and densely ignorant.[78]

For all these reasons, the Attorney trusted that the jury would, without doubt, find the patent invalid so that the mode of iron smelting actually developed by others, but monopolized by Neilson and his partners, could be "thrown open to all the manufacturers of iron throughout the United Kingdom."

The Summing Up

As first Sir William Follett and then Sir John Campbell wove their magic and cajoled and befuddled witnesses, the jury must have been persuaded alternately of the merits of both sides as they approached issues of similarity and difference between the Neilson patent specification and the hot blast as successfully practiced. If anything, the Attorney General perhaps had done the better job in emphasizing the differences and raising doubts about Neilson's credibility as an innovator, certainly as sole inventor. However, Baron Parke in his summing up brought matters back to earth.

After the legal preliminaries, Parke commented on the general treatment of patent rights by the courts, especially with regard to highly valuable inventions, such as the hot blast was universally conceded to be. There was a time when even valuable patents were destroyed by judges and juries by taking objection to the title of the patent or the specification. But within the last 10 years or so, he observed, "Courts have not been so strict . . . and they have endeavoured to hold a fair hand between the patentee and the public . . . . "[79] He advised that if they, the jury, found the Neilson patent valid then there was no doubt that the defendants had infringed it. The question of validity so far as the specification was concerned depended on whether one took the plaintiffs' or the defendants' construal of it:

> If the specification is to be understood in the sense claimed by the plaintiff, the invention of heating the air, between the time it leaves the blowing apparatus, and is introduced into the furnace in any

> way, in any close vessel which is exposed to the action of heat there is no doubt that the defendant's machinery is an infringement of that patent . . . [80]

On the question of whether the patent was invalid because the invention was not novel—that others had anticipated Neilson—Parke suggested that there had been no solid evidence to that effect. Turning to the specification, he believed strongly that the title of the patent was not defective and certainly not grounds for declaring the patent void. So the substance of the specification was the key point at issue. Here Parke expressed a strong view that the statement in the specification that the size and the form of the vessel are immaterial was quite wrong and prevented the patent from being a good one. Nevertheless, he advised the jury that he would be asking them whether, despite this erroneous clause, "such persons as would be likely to work under the patent would, by their own judgment and good sense, correct that error in the patent."[81] The next question for the jury was whether a workman of ordinary skill could, using the specification only, construct an apparatus that would be an improvement, that is, would provide some practical benefit, the expense being taken into account.

Baron Parke then rehearsed the key elements of the evidence given by each witness, and along the way, a number of other points were made. First, there was conflicting evidence on the question of the significance of the water-cooled twire. The jury should weigh this evidence up and decide on balance whether some beneficial effect could be had without it. If so, the specification was sound on this point. Second, that the patent was valid providing that a person of ordinary knowledge and skill in the art could implement the specification with some beneficial effect. It was not necessary that the level of beneficial effect attained by current best practice be so attainable. Third, the evidence of Neilson's own actions suggests that "he really was not fully aware either of the great value of his patent, and still more was not fully aware of the most beneficial mode of carrying it into effect. That was discovered by persons more acquainted than he himself was with the science of heating air." However, Parke noted, this estimation of the man did not mean that the patent was void as a result.

When the key questions were put to the jury, they found on all points for the plaintiffs. Baron Parke ruled in their favor on four counts but referred a fifth to further deliberation among his fellow judges, that being the issue of the sufficiency or otherwise of the specification. This referral led to a further round of legal argument by Follett and Campbell before the full bench of judges.

In that further argument,[82] many points put forward in the trial were repeated, mostly for the benefit of the judges other than Parke. The focus of attention, though, was the specification and particularly that part of it that spoke of the size and form of the heating vessel being immaterial to the effect. It was this that Baron Parke had firmly declared wrong and making for a bad specification. It was this that caused him to ensure the further consideration of the point by his fellow judges before a final decision was reached. Counsel for both sides made their pitch on this question. Campbell, for the defendants, maintained the position that "effect" must refer to the extent of heating of the air, that this was most clearly and decidedly dependent on the shape and form of the vessel, and that his clients' vessel was effective whereas Neilson's, as specified, was not. Follett, for the plaintiffs, put forward the alternative point of view much more clearly than in the jury trial, specifically that the "effect" referred not to the heating of the air but to the overall effect that was the purpose of that heating, namely the improvement of the operation of the blast furnace. To state that shape and form were immaterial to effect was to say that whatever shape or form of heating vessel might be adopted, some improvement in the operation of the furnace would result. This simple interpretation of the wording was plausible when taken in conjunction with the simple interpretation of the way the principle had been put to use, as it was required to be, in the specification. It had been put to use in the general sense, in that it was specified that some form of heating vessel be interposed between the blowing apparatus and the furnace. It was the judges' willingness to give the benefit of the doubt to this interpretation that turned the final phase of the case in *Neilson et al. v. Harford* in the patentees' favor.[83] But, of course, the judges' interpretation put the finishing touches on what the jury itself had decided.

What had shaped the jury's judgment of similarity and difference between Neilson's specification and the Harford Company apparatus? It is impossible to know for certain. However, it seems reasonable to think that the credibility of witnesses was probably not decisive. The performances of some of the plaintiffs' most "scientific" witnesses left a great deal to be desired even before they were caught up in cross-examination. Parke's summing up would have been influential in the thinking of the jury in some respects, perhaps particularly his indication of the recent legal trend, on grounds of public policy, toward not attacking patents unduly. One gets the impression that what broke the patent specifier's regress here was not so much the credibility of witnesses as a generalized feeling among the jury and judiciary that given the importance of the hot blast to iron manufacture and the country, the initiator of the move to hot blast from cold ought to be rewarded, even though the best practical realization of the invention did not spring fully formed from his mind and hand.

Matters of public policy can and do tilt these arguments.[84] In that sense, they are part of the context that shaped judgment on whether a "principle" or a "principle put into effect" was the subject of Neilson's patent. Put another way, the public policy "climate" can strongly shape the latitude granted in judging whether a principle has been put into effect. In the Neilson case (as, it seems to me, in the Watt case), a vague, thoroughly schematic description of putting the principle into effect was found acceptable as a valid specification. Its acceptability was more readily conceded given its apparently demonstrated utility. Design development of the sort that occurred between 1828 and 1834 was designated as occurring after the fact of invention rather than being a constitutive part of it. Neilson was endorsed as *the* individual inventor of the hot blast.

The Other Jury Trials of the Neilson Patent

Late in 1840, the members of the Bairds-led pact of ironmasters who had confederated against the Neilson patent decided that the Househill Coal and Iron Company would be the next to defy the patent claim. In September 1840, Househill had refused a license from Neilson, and when challenged by the patentees, the company joined the anti-Neilson pact. The Bairds' lawyers mounted the case for Househill and did so in almost identical terms to those used subsequently by the Bairds themselves. The case came to trial on 1 April 1842. [85]

Neilson and Others v. Househill Coal Co.

The defense given by counsel for Househill, as in the Harford case, was that the process being used was not Neilson's and that they could not have profited by Neilson's process as described in his specification. Further, it was contended that the patent was void for a number of reasons (these also familiar from the Harford trial): the title was inconsistent with the patent specification, the specification was defective, and Neilson's process was known and publicly practiced prior to the patent being taken out. Overall the specification was vague and calculated to mislead.

In opening for the pursuers, Mr. Andrew Rutherfurd[86] stressed the novelty of Neilson's invention by drawing attention to the prevalence and depth of belief in the cold blast until Neilson's patent was taken out in 1828. Like Follett in the earlier trial, he painted a picture of Neilson as a deliberate, scientific man: "a man of very acute observation, a person of great knowledge, one possessing not only scientific attainments, but possessing that which also distinguished his and your illustrious countryman Watt—practical knowledge and great mother wit . . . . "[87] Also like Follett, Rutherfurd emphasized from the beginning the deliberately general nature of the specification:

> The specification is general—it intelligibly describes a particular invention, and the course in which it is to be used and performed but it does so in a language meant to be general—not *unintentionally*, but *necessarily* general—as intended to cover all the description of ways in which it can be used. It is not an air-vessel of a particular form or size, or an air vessel heated to a particular temperature . . . . All machinery and apparatus substantially the same as that described in the specification, or machinery, or apparatus as to which it is impossible for you or others who apply their minds to the matter, to say, that it is substantially different, is covered by [the] specification . . . [88]

Rutherfurd challenged the claimed anticipations of Neilson's invention in some detail before concluding that these "miserable" attempts to deprive Neilson of the "merit of his discovery" would not be successful and that "the name of the inventor, like that of his countryman Watt, will go down to posterity, and entitle him to be enrolled among those who have been great benefactors to their country."[89]

The pursuers' evidence came from a number of variously scientific and practical witnesses. David Mushet reappeared to lead the charge. He recalled that when he first heard of Neilson's invention, he thought the man "must be a Lunatic." Mushet and all the trade were fully convinced on the value of a cold blast. But he soon changed his mind and recognized the hot blast as a true invention that produced a powerful sensation and was acknowledged as such by "scientific and other persons." Of practical men, John Houldsworth of Glasgow reappeared, while William Silverwood, civil and mining engineer of Derbyshire, and John Walkinshaw, a founder at Doncaster, were new recruits to the cause to provide testimony that the specification was sufficient for a workman to construct an effective apparatus. The elite scientific witnesses were: James David Forbes, Professor of Natural Philosophy at Edinburgh University; William Gregory, Professor of Medicine and Chemistry at Aberdeen; and Dr. Andrew Fyffe, a longstanding lecturer on chemistry at Edinburgh.[90] We know from his correspondence with counsel for Neilson and with George Dunlop, one of the partners in the patent, that Forbes—unlike his counterparts in the English trial—was well prepared and had gone to some trouble to explore the legal dimensions of the case. He had also studied the transcript of the action against Harford, as well as its scientific and technical aspects, including a survey of work on iron smelting done in Europe.[91] Forbes had been discussing and rehearsing testimony and evidence with counsel since December 1840.[92] When his examination finally came about, on 2 April 1842 Forbes confirmed that Neilson's invention was recognized as his by the scientific world. Forbes was encouraged by counsel to provide chapter and verse about experiments on iron smelting in England, France, and Russia, presumably with a view to displaying Forbes' erudition. He was then brought back to testify that he never saw a clearer specification than Neilson's.[93] The Househill apparatus, Forbes testified, was an apparatus fitted for the hot blast as described by Neilson's patent.

Professor Gregory and Dr. Fyffe testified in a very similar vein, although Fyffe, having taught chemistry in Edinburgh for 20 years, could recall the first announcement of the hot blast and the response to it at the time. The remaining witnesses for the pursuers were mainly practical men and engineers working in ironworks and gas works who testified to the sufficiency of the specification.

Opening the case for the defenders, the Solicitor General[94] concentrated on what the specification did not say, how it deprived the public of any knowledge of the size and shape of the vessel, and the materials of which it was to be made or how it was to be heated. As a description of a patent, he found it "totally and absolutely defective and incapable of being sustained." If it were to be followed, the specification could never, he contended, produce the apparatus that Househill were employing, an apparatus that was of a distinctly different type from the simple "solid" vessel that it described. The Solicitor General declared incredible the testimony of the pursuers' witnesses that an ordinary workman, given the specification, would come up with the Househill apparatus or something like it.

Echoing the line taken by the defendants in the Harford case, the Solicitor General contended that Neilson had no idea in the beginning what he was doing and that the generality of the specification was a result of ignorance and, if not that, duplicity. It was "easy now to get philosophers such as Forbes and Gregory to say that the import of the specification is elementary and obvious" and tacitly incorporates the idea that increasing surface area heated is central to the process. It was easy to have them tell you that, but such was not Neilson's understanding when he took out his patent. Men of ordinary skill could not build an effective apparatus from the patent alone and had to perform experiments to do so. Thus, the patent specification was not sufficient.

At the very end of his address, the Solicitor General briefly rehearsed the argument that Neilson's patent was "an attempt to seize a principle." It was significant that he did not wish to make more of this argument, and the judge was to refer to this reticence in his summing up, as we will see.

The witnesses for the defenders were mainly practical workmen in the industry. There were three major, and by now familiar, dimensions of their testimony: that the specification was insufficient, that the apparatus used in effective deployment of the hot blast was distinctly different from anything reasonably derivable from Neilson's specification, and that the hot blast was not novel because of prior use. The latter argument relied on the testimony of a number of witnesses who had been employed in the Bradley Iron Works of Mr. John Wilkinson. They claimed that at Bradley, air was heated in a cylinder before being used in a blast furnace. The defense wanted to question the novelty of the hot blast even further by bringing witnesses to testify to its use in smiths' forges. However, the counsel for the pursuers objected strenuously that this line of inquiry was inadmissible because it was irrelevant to the matter at issue. In the end, the Lord Justice rejected this line of evidence, and these witnesses were not examined.

The witnesses who appeared next were probably the most "scientific" of those called by the defenders: Mr. George Cottam, an engineer and iron founder of London; Edward Sang, formerly an engineer and machine maker, now a lecturer on mechanics and engineering in the new college in Manchester; and William Carpmael, a civil engineer of Old Square, Lincoln's Inn.[95] These witnesses all argued that Neilson's specification was inadequate in what it said about the heating vessel. Carpmael testified that he considered Neilson's specification to be directed not so much toward the heating of air but its expansion, which led him into a discussion of the elasticity of air, in which Carpmael seemed to lose himself and his audience.

Mr. Rutherfurd's concluding address to the jury dispensed first of all with the challenges to the originality of Neilson's hot blast. The witnesses to what had transpired in Wilkinson's Bradley Iron Works were unreliable, he argued. They were young at the time and not very knowledgeable. Whatever the experiment had been, it was a private one and was quickly abandoned. It made no impression on public knowledge. Neilson's invention was a surprise when it was made. Turning to the Househill apparatus and whether it was substantially the same as that in the Neilson specification, Rutherfurd pointed to the great variety of scientific and practical men who had answered that question in the affirmative. He accused defense witnesses Carpmael and Sang of sophistry in not speaking the plain meaning of the specification when they tackled that question. They were having "recourse to all sorts of Jesuitical and miserable shifts, and bringing abstruse science not to enlighten but to mystify, by applying to it cavils and paltry criticisms, and all in order to defeat an object set forth in plain and unambiguous terms."

In his summing up, the Lord Justice Clerk[96] quickly steered the question toward the question of the specification and whether it sought to secure a patent for an abstract principle:

> The Defenders . . . were very reluctant to state whether they actually raised that point or not. I think it is at the foundation of their whole case, and sure I am, that to enable you to discharge your duty, it is very necessary that I should not in any way avoid that question of law . . . [97]

It will be recalled that the Solicitor General, in his opening speech for the defenders, had mentioned the point that Neilson's patent was "an attempt to seize a principle," but he had introduced this right at the end of his speech and not developed it at all. He had devoted most of his statement to the insufficiency of the patent as a guide to constructing an apparatus. Most of the defenders' evidence from witnesses had been directed at that same point or to the claim that the hot blast was not novel. So, in bringing the central question back to the issue of the patenting of principle, the Lord Justice was shifting the ground on which the jury was being instructed to consider the case.

Accordingly, the Lord Justice rehearsed the law on the question: that an abstract philosophical principle cannot be patented, that the discovery of a principle is not an invention, and that a principle must be turned to a practical effect if a patent is to be granted for invention. He continued:

> The main merit—the most important part of the invention, may consist in the conception of the original idea—in the discovery of the principle in science, or of the law of nature stated in the patent, and little or no pains may have been taken in working out the best manner and mode of the application of the principle to the purpose set forth in the patent. But still, if the patent is stated to be applicable to any special purpose, so as to produce any result previously unknown, in the way and for the objects described, the patent is good. It is no longer an abstract principle. It comes to be a principle turned to account—to a practical object, and applied to a special result. It becomes then not an abstract principle, which means a principle considered *apart* from any special purpose or practical operation, but the discovery and statement of a principle

> for a special purpose—that is, a practical invention—a mode of carrying a principle into effect.[98]

Next, he noted that this interpretation of the law is well accepted in the case where someone takes a well-known principle and turns it to a new special purpose. It would be "strange and unjust" to refuse the same legal coverage "when the Inventor has the additional merit of discovering the principle as well as its application to a practical object." The implication was, of course, that this was precisely what Neilson had done.

There was one final, and crucial, point to be made on this legal question concerning the situation where the application of a principle to a special purpose, to a certain specified result, "includes every variety of mode of applying the principle according to the general statement of the object and benefit to be obtained." The Lord Justice here suggested that "the greater part of the Defenders' case is truly directed to this objection." He was in no doubt as to the answer in law:

> . . . I must tell you distinctly, that this generality of claim—that is for all modes of applying the principle to the purpose specified . . . —is no objection whatever to the patent. That the application or use of the agent for the purpose specified, may be carried out in a great variety of ways, only shews the beauty and simplicity and comprehensiveness of the invention.[99]

This was a powerful interpretation of law that steered the jury decisively toward a finding for Neilson and his partners.

The rest of the Lord Justice Clerk's summing up was no less destructive of the defenders' case. On the question of novelty and anticipation, he advised that it was not enough to show that in experiments or incidental trials, others had hit on the same idea. The principle must have been made public and applied to the same processes. Finally, he had his say about the evidence and here he was complicit in the character assassination of the defenders' witnesses begun by Rutherfurd in his concluding address. Carpmael was singled out. He was, the Lord Justice observed, presented by the defense as a "man of great science," but then he went on to say "various surprising things showing considerable ignorance," many of them in direct response to the Lord Justice's questions.

The jury found for the pursuers on all issues.[100] The case against Househill had certainly involved the appeal to utility (depicting Neilson as great benefactor to his country), as had the Harford case. However, the Househill trial had traded more on the credibility of witnesses than Harford did. For whatever reason, the "scientific" witnesses for the patentees in *Neilson v. Househill* were treated with great respect and deference, whereas the credibility of their opposite numbers was demolished, by the judge as much as anyone. The question of the patenting of principle put into effect emerged as important in Harford and became the focus of that first legal judgment. The defenders in the Househill case tried to shift the issue to one side, perhaps for that reason, but the Lord Justice returned it to center stage once again.

The challenge to Neilson by Househill had, of course, been engineered by the confederacy of iron manufacturers headed by the Bairds, one of many ways in which, since the early 1830s, the Bairds had avoided mounting a direct challenge. But even as the Househill case was being prosecuted, the ground was laid for direct confrontation in what was to become the third, largest, and most celebrated jury trial of the Neilson patent.

Neilson and Others v. W. Baird & Co.

The final jury trial of the Neilson patent began on 10 May 1843 and ended 10 days later (20 May). It was described by the Lord Justice-General[101] in his address to the jury as "an unparalleled trial—a trial which has in it a more extensive body of Evidence on both sides, and has occupied more of the attention of the Jury than any case with which I am at all acquainted in this country."[102] The examination and cross-examination of the witnesses occupied almost eight days. The counsel for Neilson were the Dean of the Faculty (Robertson), the Solicitor-General (Anderson), Andrew Rutherford (who had acted in the Househill case), and John Inglis. The Lord Advocate (Duncan McNeill) appeared for the defenders. The opening and closing addresses were of several hours' duration. The issues were broadly the same as in the earlier cases: that the Neilson patent was void because it was a patent of principle; that its specification was insufficient to allow one skilled in the art to construct the invention; and that the invention was not novel with Neilson, as it had been anticipated variously.

On this last point, a great deal of effort and numerous witnesses were directed to making and contesting the claim that the hot blast had been used at the Bradley Iron Works of John Wilkinson. This point had been pursued in the Househill trial, but here it was pushed even harder. The defenders called no fewer than 14 witnesses, all workmen at the Bradley works, to testify on this question and maintain that Wilkinson had used a cylinder to heat the blast long before it had been suggested by Neilson. The pursuers in cross-examination and in calling their own witnesses, who were partners in or managers of the Bradley Iron Works, argued that the defenders' witnesses were mistaken. The cylinder that had been installed at that time was intended for another purpose entirely, it being filled with charcoal that was supposed to be carried into the furnace by the blast to try to make iron of certain qualities. The experiment had failed and been quickly abandoned. This alternative explanation, together with contradictions between the defendants' witnesses about the year when this reputedly happened, capped off by the testimony of Wilkinson's close associates among the partners and management that he had never mentioned anything like the hot blast to them, tended to defuse this part of the case.

The defenders also pursued the argument that Neilson's invention had been anticipated in various smiths' forges, notably in a forge at Irvine and another in Port Glasgow, a line of argument and evidence that had been cut short by the judge's intervention in the Househill trial. In this case, however, it was allowed, and the defenders called a number of smiths to make the case. The pursuers called several smiths of their own to testify to the contrary and argue that the tube supposed to carry a hot blast to those forges was merely designed to relocate the blast when working on articles whose shape and size did not allow normal working.

The sufficiency or otherwise of the patent specification and the closely related issue of the patenting of principle were argued out much as in the earlier trials. The pursuers relied as before on a strong cast of scientific witnesses (including Forbes, Fyffe, and Mushet) and ironmasters to testify to the sufficiency of the specification. The defenders opted for the contrary testimony of those closer to the workface. Rutherfurd maintained the simple interpretation of the specification as genuinely putting a principle into effect by its basic account of the interposition of a heating vessel between the blowing apparatus and the furnace. McNeill argued that this amounted to no description at all of how the hot blast was to be put into effect. That key word "effect" was again much negotiated, with McNeill contending that reference to the immateriality of the shape and size of the vessel to the production of the effect was clearly in error, and that "effect" in his view obviously referring to the effect of heating the blast. From this perspective, the specification was more than inadequate—it misled. Rutherfurd argued once again the position that "effect" referred to the effect of improving the operation of the furnace to which the *extent* of the heating of the interposed vessel and hence that vessel's form and shape was indeed immaterial, as the patent claimed, in the sense that any vessel and any heating would produce some effect.

Apart from the contest over lack of novelty, which was pursued with vigor by the defenders, the main focus of the defenders' counsel was on the level of damages claimed from their clients. It was almost as if the arguments regarding patenting of principle and patent sufficiency had been ceded. There were a number of references to their having been decided in Neilson's favor in earlier trials. The question of damages was very complex, and raised the issue of just how effective and profitable the hot blast was. A sub-theme that grew out of this was the quality of the hot-blast iron. There was significant suspicion of "Scotch iron," as the hot-blast iron was often designated, which was believed to be of inferior quality and strength to the cold-blast product. Some engineers and contractors refused to use it.[103] The defenders used this controversy, as well as claims that the market price of hot-blast iron reflected these concerns, to argue that damages were being set too high. They also used this evidence to cast at least a partial cloud over the overall utility of the hot blast, which they had previously treated as indubitable. The defendants' counsel went so far as to point out that some people thought "that this hot-blast is undermining the character of the trade in this country, and is laying the foundation of a very sad and serious reduction."[104] Neilson's counsel in response relied heavily on scientific experiments done by Eaton Hodgkinson and William Fairbairn under the auspices of the British Association for the Advancement of Science, which showed that the two forms of iron were of roughly equal quality when other variables such as the nature of feedstocks were controlled for. The pursuers noted with evident glee that Hodgkinson had received the Gold Medal of the Royal Society of London for that work, which had been done for scientific purposes and had exploded the prejudice that existed in some quarters regarding the hot-blast product. Fairbairn was called to give evidence about this work.[105]

In his summing up,[106] the Lord Justice-General sided with the Neilson camp on all matters of law, including his statement that the patent was not merely for an abstract principle "because it combines a principle, with the special purpose, and important result of having atmospheric air heated in a vessel or receptacle between the blowing apparatus and fires, forges and furnaces . . . . " Dealing with the evidence and witnesses, he drew a stark contrast between the learned and scientific persons who had appeared for the pursuers and those for the defendants. Among the latter, Carpmael once again was treated with disdain, being admonished to consider carefully Lord Tenterden's remarks about there being "a great deal too much critical acumen" applied to criticizing patents.[107] In this connection, the Lord Justice referred, as had Baron Parke, to recent trends in the law:

> . . . the feeling which formerly seems to have pervaded the Courts of Law to detect frauds in patents, and set them aside as fast as

> possible, is very much of late exploded; and . . . a patent, like every other solemn contract and written document, ought to get a fair and deliberate, and impartial consideration of the just and true construction that is to be put upon it.[108]

The jury found for the pursuers on all counts. Importantly, Rutherfurd had asked the judge that the additional question of the proper meaning of the term "effect" in the specification be put to the jury. The judge finally agreed to this amid protests from the defenders' counsel. The jury found that "by the use of the term effect the patent does not state that the form and shape of the air vessel or vessels were immaterial for the purpose of heating the air in such air vessel or vessels." This denial of the defenders' interpretation of the term arrived at by the jury established the Neilson camp's interpretation of the meaning of "effect" as a matter of fact immune to further legal argument. It ensured that Neilson had the right to the effect understood as the "principle of the hot blast turned to effect."

Conclusions

In conclusion, I do two things. First, I summarize what this detailed case study has revealed about the relationship between patent right claims, the successful construction of narratives of heroic invention, and what we might hazard to be the complex collective processes that realize invention. Second, I move to broader, but related, considerations sparked by a recent revisionist account of the history of the British patent system during the industrial revolution.

The trials of the hot-blast patent are remembered in the legal world as producing a precedent concerning the patentability of subject matter. As we noted in the case of Samuel Morse's telegraph patent, the hot-blast trial judgments were referred to as legitimizing the patenting of a principle as patentees sought to push the scope of their claims further and further. Neilson crops up in this connection in modern debates about software patenting in particular.

In examining the entire proceedings, and to some extent the context, of the trials and not just the judgments, we have seen that the excavation of the difference between a patent of a "principle" and a patent on a "principle turned to effect" was extensive and thorough. But the distinctions that each side developed were fine and unstable ones. Elisions between one and the other were readily made, and Morse's lawyers tried later to trade on this. Neilson himself appeared to make such a slip during his participation in a discussion of the history of the hot blast in 1859. Having commented on the historical account just given by Henry Marten at a meeting of the Institution of Mechanical Engineers, Neilson reportedly concluded as follows:

> The invention of the hot blast consisted solely in the principle of heating the blast between the engine and the furnace, and was not associated with any particular construction of the intermediate heating apparatus; this was the cause of the success that had attended the invention, and in this respect the case had much similarity to that of his countryman James Watt, who in connexion with the steam engine invented the plan of condensing the steam in a separate vessel, and was successful in maintaining his invention by not limiting it to any particular construction of condenser.[109]

To identify the invention solely as a principle as Neilson did here was to mischaracterize what he had been allowed to patent. That Neilson could do this before such an audience is a sign of how "unstable" the judgments in his favor were and how easily they were misconstrued or misrepresented. Put more precisely, this misconstrual shows that the judgments of similarity and difference between a "principle" and a "principle put into effect" were very fine, and contingent, ones.

The status of Neilson as *the* individual inventor of the hot blast and the sufficiency of his patent specification were established as the two sides of a coin. The judgment was made that key features of the hot-blast technology incorporated as it matured in the 1830s (i.e., the new forms of heating vessel, including the tubular oven apparatus, the use of raw coal rather than coke, and the incorporation of the water-cooled twire) were not part of the invention but rather belonged to its subsequent development. What we might otherwise see (correctly I think) as an extended process of invention,[110] in which Neilson, Dixon, the Bairds, John Condie, and others participated, is thereby reduced to an individual act to which others provided a series of interesting footnotes.

From what we have seen, it would have been quite easy for the result to have turned out differently. The swing of public and judicial opinion in favor of the patentee in the 1830s and 1840s was a key element of the story. Of course, not all welcomed that shift. The Bairds considered that they were the victims of an Edinburgh-based, Whig political and judicial pro-patent elite that had lined up against them.[111] Certainly there are signs of this, including Brougham's backing of Neilson and his case, as well as the existence (for the most part) of a Whig/Tory split amongst the counsel on the opposing sides. The high tide of patent abolitionism lay a little in the future, but such sentiments likely drove some of the ironmasters who combined against Neilson. The creation of Neilson as a heroic figure of invention was to feed, in the way that Christine MacLeod has shown, into the defense of the patent system against the abolitionists in the later nineteenth century.[112]

Also notable is the protagonists' engagement in an ongoing struggle in which the trials were culminating events. Corrins has shown how the Bairds were behind virtually all of the legal struggles over Neilson's patent. They decided early to challenge the patent and when stymied settled in for the long haul, building allies in the cause and orchestrating a campaign. But I have shown that the conspiracy of capital against intellect, if such it was, was matched by its obverse as Neilson and his partners sought to mobilize their friends and associates in the scientific, technical, and legal arenas. Watt Jr. and others were involved in the drawing up of the patent in a form that appears in retrospect to have been very astute, a form that gained maximum advantage from what John Percy described as a "lucky hit" on Neilson's part.[113] We have strong indications that Neilson, Dunlop, and allies such as Thomas Clark made use of scientific forums such as the British Association for the Advancement of Science, the Royal Society of Edinburgh, and the Institution of Civil Engineers to recount the story of the hot blast in a way that enshrined Neilson's achievements not as a "lucky hit" but as more systematic and "scientific," and leaving the contributions of others very much in the background. The trials (by granting Neilson the rights to the invention of the "principle turned to effect"), the Royal Society of London (by subsequently electing him to its number as the "discoverer of the hot blast"), and Samuel Smiles (by broadcasting his story) all enshrined the legend.

Ultimately, it was probably the utility of the hot blast that swung the decision in Neilson's favor. Neilson constructed as the individual inventor was also, and because of that, portrayed as an individual benefactor to the industry and the nation on an enormous scale. Technically speaking, there was no disagreement about the utility of the hot blast, yet the plaintiffs in the trials repeatedly brought out the utility of the invention even as the defendants' counsel vehemently objected that this was not at issue. The plaintiffs displayed evidence of licensees contentedly signing up to pay their fees because of the invention's utility for them, and the defendants strenuously objected that the acquiescence of others meant nothing to the present case. Even as the defendants denied that utility was an issue, they entered on the question themselves by trying to sow seeds of doubt about the quality of the hot-blast iron and its long-term future. The plaintiffs claimed that the highest scientific authority exposed such doubts as mere prejudice concerning a transformative invention. These "irrelevancies" were, I think, crucially important in creating a judgmental context in which similarities and differences between the invention as specified and beneficially employed were approached with an inclination that favored Neilson. They played their part with judge and jury in producing decisions that perpetuated the dance of individualistic accounts of discovery and invention with the limited monopoly provided by the patent system. Moreover, patents of broad scope that narrowly escape being declared void as patents of principle are likely, by usurping so much of the collective process, to generate inventors of heroic proportions in the public sphere. As the toasts rang in his ears on that February night in the Tontine Hotel, with the trials of his patent over, James Beaumont Neilson was on the cusp of that sort of immortality.

I turn now to the broader relevance of my account of this case to histories of the British patent system and its operation. The issue at stake here has been brought into focus by Sean Bottomley's important recent work.[114] Bottomley challenges a particular historical view of the development of the British patent system. Although much of what Bottomley claims about the evolving *structure* of the patent system might be granted, the presumed implications of this for its operation do not necessarily follow. My case reveals a contrast between idealized structure and actual operation. Furthermore, theoretical considerations suggest, to me at least, that the contrast between structure and operation was likely to have been present more generally.

Bottomley reads the historiography of the patent system in terms of views about its effectiveness as a system. So far as the large transformation of the system from one of privilege to one of property rights is concerned, Bottomley suggests that this was well underway much earlier than previously thought. By unearthing substantial eighteenth-century patent litigation in the Court of Chancery in the eighteenth century, Bottomley shows the early shift of patent affairs from matters of Royal privilege, as arbitrated by the Privy Council, to matters of equity. So far as the nineteenth-century patent system is concerned, Bottomley argues against those historians, notably Dutton and MacLeod, who have sided with the mid-nineteenth century patent reformists' perception that the system was deficient in various ways in protecting the interests of the inventor class until well into the nineteenth century, indeed until the reforms beginning in mid century. On the contrary, Bottomley argues, the patent system was already working quite effectively in the service of that interest in the early nineteenth century. On the one hand, he claims, there was already a much more substantial body of case law built up, especially relating to the question of the specification, than has previously been acknowledged. On the other hand, Bottomley shows that the statistics used by Dutton to argue that patentees were not well served by judicial decisions are misleading. His own statistics, drawing on an expanded range of cases, show, at the very least, that previous perceptions of a major shift in judicial attitudes in favor of patentees in the 1840s are less well grounded than we thought. As a corrective account of the evolution of the structures of patent law, Bottomley's work has many strengths. But it is important not to extrapolate too readily from structure to operation.

It would be unfortunate if Bottomley's perspective were taken to mean that the broader social and political contexts that the traditional historiography has seen as relevant to the operation of patent law should be treated as extraneous to that operation. Indeed, it is not entirely clear that Bottomley thinks they should be, since he does acknowledge, for example, that judicial decisions may well have been influenced by cultural trends in perceptions of the inventor class.[115] But overall, it would be easy for the reader to conclude that Bottomley believes that the more substantial and sophisticated legal structures and case law, concerning specification in particular, that he reveals left less room for such "extra-legal" considerations to shape judicial decisions. Following Bottomley, crucial issues of judicial interpretation might be seen as dealt with adequately *within* the system because they were reasonably resolvable within the rule structures of the much more substantial body of early nineteenth-century patent law that he unearths.

For what it is worth, the present case study appears to support the traditional historiography on this question in that it shows that the actors concerned in an important mid-century case invested enormous energy into marshaling "extra-legal" resources to favor their case. Furthermore, judicial interpretation, so far as we can access it, appears to have been profoundly shaped by the judges' estimations of matters such as scientific credibility of witnesses and the policy implications of declaring the patent valid or not. Although Bottomley convincingly redraws the historical timeline of the legal structure of patent regimes, the idea that considerations of the public utility of an invention in adjudicating a patent were left behind because it was tied to the structure of the Privy Council jurisdiction is mistaken. We have seen in our case that the arguments mounted in this nineteenth-century patent contest often gravitated back to such issues, in a recapitulative fashion, in attempts to break otherwise circular arguments about the adequacy of the specification.

So any claim that in mid-nineteenth century British patent law the interpretation of specifications was already a legally routinized matter is dubious. If this had been so, then one would not expect such extensive and protracted contest over the Neilson patent. The protagonists' debate of issues of scientific credibility and public utility in trying to resolve the case, and the judges interpretation of such questions, would, if Bottomley was right, be of little concern to them or us. However, my account strongly suggests that such debate was crucial and central, and also that the debate was resolved not by straightforward application of an already mature legal regime but, significantly, by appeal to broader matters of credibility and utility. I concede that one should not give too much significance to conclusions drawn from one case. Nevertheless, the prominence of the Neilson case at that time gives it more than passing interest.

In my view, there are, however, broader issues of an ultimately philosophical nature that are at stake here and that inform the historical debate. These issues concern the nature of rules, whether those rules are rules of technical specification or rules of legal interpretation. Any attempt to use Bottomley's work to argue from structure to operation of legal systems must rest ultimately on a belief that it was possible to create a system of legal interpretation in which rules about matters such as the scope of an invention, and whether or not it is a "principle" or a "principle put into practice," can be straightforwardly developed and applied. In my mind, belief in such a system is not warranted either in legal or scientific and technical realms. The necessarily contextual and contingent character of rule specification and interpretation as expressed by Wittgenstein and scholars within the sociology of scientific knowledge tradition is, I believe, decisive.[116] If, as I am persuaded, the most esoteric and technical evidential questions concerning scientific knowledge and concerning successful technological manipulation are themselves best seen as contingent on specific context and circumstance, then we can have little ground for believing that the interpretation of matters of legal principle will be any different. Of course, it is true that in science, in the law, as indeed in everyday life, rules are not always problematized. Tacit understandings, shared within communities, do allow for routinized judgment. But such routines, even when established, are not unchallengeable in principle. If the stakes are high enough, if there is enough incentive for contest over rule interpretation, then that contest can and will occur. Such contest will not be resolvable by appeal to the rules whose application is under challenge. At the very least, we should remain constantly aware that ultimately such epistemological questions underlie historical interpretations of inventions and the patent systems with which they are so thoroughly entangled in modern societies.

Endnotes

1. The following account of this occasion draws on "Dinner to James Beaumont Neilson Esq.," *Glasgow Herald*, 3 February 1845, 2.

2. This text was enclosed in Muirhead to Watt Jr., 2 February 1845, Muirhead Papers, Special Collections, University of Glasgow Library, MS GEN 1354/775. Muirhead informed Watt Jr. of the "rapturous applause" greeting every reference to his father's discoveries. See David Philip Miller, *Discovering Water: James Watt, Henry Cavendish and the Nineteenth-Century "Water Controversy"* (Aldershot: Ashgate, 2004), 185–6.

3. On Morse and his eighth claim, see Maurice M. Klee, "The Inventor Who Claimed Too Much," *IEEE Engineering in Medicine and Biology* 14 (1995): 451, and Kenneth Silverman, *Lightning Man: The Accursed Life of Samuel F. B. Morse* (New York: A. A. Knopf, 2003), 297–324.

4. See David Philip Miller, "Intellectual Property and Narratives of Discovery/ Invention: The League of Nations Draft Convention on Scientific Property and its Fate," *History of Science* 46 (2008): 299–342; Abraham S. Greenberg, "Quasi-Patent Rights: A Proposal for the Future," *Journal of the Patent Office Society* 12 (1930): 13–127, at 25–9. Richard H. Stern, *Cases and Materials for Computer Law 484 at George Washington University Law School*, Chapter 7, at http://docs.law.gwu.edu/facweb/claw/ch7.htm#Neilson; Jeffrey A. Lefstin, "Inventive Application: A History," *Florida Law Review* 67 (2015): 565–648, especially 577–92, which provides a fine legal overview of the hot-blast trials and their ongoing importance.

5. Among a very extensive literature, see the essays edited by Myles W. Jackson in *Perspectives on Science* 23, no. 1 (2015).

6. Most prominently Christine MacLeod, *Heroes of Invention: Technology, Liberalism and British Identity 1750-1914* (Cambridge: Cambridge University Press, 2007), and also MacLeod, "Concepts of Invention and the Patent Controversy in Victorian Britain," in *Technological Change: Methods and Themes in the History of Technology*, ed. Robert Fox, 137–54 (Amsterdam: Harwood Academic Publishers, 1996). Also Stathis Arapostathis and Graeme Gooday, *Patently Contestable: Electrical Technologies and Inventor Identities on Trial in Britain* (Cambridge, M.A.: The MIT Press, 2013); Christopher Beauchamp, *Invented by Law. Alexander Graham Bell and the Patent that Changed America* (Cambridge, M.A.: Harvard University Press, 2014); Christopher Beauchamp, "Who Invented the Telephone? Lawyers, Patents and the Judgments of History," *Technology & Culture* 51 (2010): 854–78. For the use of historical claims on these issues in ideologically charged contemporary legal debate, see Mark A. Lemley, "The Myth of the Sole Inventor," *Michigan Law Review* 110 (2012): 709–60, and John Howells and Ron D. Katznelson, "A Critique of Mark Lemley's 'The Myth of the Sole Inventor,'" available at http://bitly.com/Lemley-Critique

7. Paul Belford, "Hot Blast Iron Smelting in the Early 19th Century: A Reappraisal," *Historical Metallurgy* 46 (2012): 32–44.

8. The chief sources on Neilson's life are: T. B. Mackenzie, *The Life of J. B. Neilson, F.R.S.: Inventor of the Hot Blast* (Glasgow: West of Scotland Iron and Steel Institute, 1928); Samuel Smiles, *Industrial Biography: Iron-Workers and Tool-Makers* (London: Murray, 1863), 189–203; Francis Espinasse, "Neilson, James Beaumont (1792-1865)," rev. Ian Donnachie, *ODNB,* Oxford University Press, 2004, online edition May 2009 [http://www.oxforddnb.com/view/article/19866]; Tom Swailes, "Neilson, James Beaumont," in *Dictionary of Civil Engineers in Great Britain and Ireland. Volume 2: 1830–1890*, ed. P. S. M. Cross-Rudkin and M. Chrimes (London: Thomas Telford Ltd, 2008), 571–3. On his being known as "Beaumont,"

see, "Obituary. James Beaumont Neilson, 1792–1865," *Minutes of the Proceedings of the Institution of Civil Engineers* 30 (1870): 451–3.

9. R. D. Corrins, "The Great Hot-Blast Affair," *Industrial Archaeology* 7 (1970): 233–63, provides an excellent guide to the pattern of legal contest over the hot blast but is little concerned with its content.

10. James Cleland, *Enumeration of the Inhabitants of the City of Glasgow and County of Lanark, for the Government Census of 1831: With Population and Statistical Tables Relative to England and Scotland* (Glasgow: John Smith & Son, 1832), 140–2. A substantially similar version was published in *The New Statistical Account of Scotland No. VII Containing Part of the County of Lanark* (Edinburgh: William Blackwood and Sons, 1835), 159–62.

11. J. B. Neilson, "On the Hot Air Blast," *Transactions of the Institution of Civil Engineers* 1 (1836): 81–3. Neilson had been elected a member of the Institution in 1832.

12. See "James Beaumont Neilson, C.E., F.R.S., Inventor of the Hot Blast," *The British Controversialist and Literary Magazine* (1865): 292–6, 449–55 at 453.

13. The certificate (EC/1846/01) can be accessed on the Royal Society's website via http://royalsociety.org/library/collections/biographical-records/. It is, I think, significant that Neilson's nomination describes him as "discoverer" rather than inventor, let alone patentee, of the hot blast. On negative attitudes within the Royal Society from the late-eighteenth century to the potential commercial exploitation of the Fellowship, see David Philip Miller, "The Usefulness of Natural Philosophy: The Royal Society of London and the Culture of Practical Utility in the later Eighteenth Century," *The British Journal for the History of Science* 32 (1997): 185–201. Such attitudes were still prevalent in the 1840s and beyond. See my unpublished paper "Connecting Engineering and Natural Knowledge at the Royal Society in the Late Eighteenth and Nineteenth Centuries," presented at joint BSHS/HSS/CHSS Conference, Keble College Oxford, 2008, and also the important recent paper Christine MacLeod, "Reluctant Entrepreneurs: Patents and State Patronage in New Technosciences, circa 1870-1930," *Isis* 103 (2012): 328–39.

14. "The Scottish Iron Manufacture," *The North British Review* 4 (November 1845): 126–48 at 142.

15. Smiles, *Industrial Biography*, Chapter 9. The piece on Neilson in *The British Controversialist* (see note 12) was in a series titled "Toiling Upward: Lessons in Life, Progress and Improvement."

16. See, for example, the depiction of Neilson as inventor that emerges from the address given by Sir John Campbell, Attorney General, representing the defendants in *Neilson et al. v. Harford*, recorded in *Trial Before Mr. Baron Parke and a Special Jury in the Case of* Neilson and Others v. Harford, *For Infringement of Patent . . . From Notes Taken by Mr. G.B. Snell* (Edinburgh: Printed by Thomas Constable, 1841) [Hereafter referred to as *Trial (Harford)*], 141–70. This depiction of Neilson is further discussed below.

17. Neilson, "On the Hot Air Blast," 82.

18. Ibid., 82.

19. The regulator was a device that equalized the blast sent into the furnace. The story about painting the regulator white may derive from David Mushet, who testified in *Neilson et al. v. Harford* that he had done this. See *Trial (Harford)*, 69.

20. "Iron and Steel," *The Quarterly Review* 119 (July 1866): 34–56 at 44; "The Scottish Iron Manufacture," *The North British Review* 4 (November 1845): 126–48 at p. 134.

21. Of these gentlemen, Macintosh (1766–1843) is probably the best known as the inventor of the rubberized textile that led to a waterproof raincoat being named after him. He had studied chemistry under Dr. William Irvine at Glasgow University and Joseph Black at Edinburgh and applied his extensive knowledge in the industrial and commercial businesses pioneered by his father, as well as in ventures of his own. See D. W. F. Hardie, "The Macintoshes and the Origins of the Chemical Industry," in A. E. Musson, ed., *Science, Technology, and Economic Growth in the Eighteenth Century* (London: Methuen, 1972), 168–94, and George Macintosh, *Biographical Memoir of the late Charles Macintosh, F.R.S. of Campsie and Dunchattan* (Glasgow: W. G. Blackie & Co., 1847). Colin Dunlop (1775–1837) had purchased Clyde Iron Works in 1810. He had trained for the law and been an admitted advocate but never practiced. He was a Whig and leader of the Reform party in Glasgow, and was elected a Member of Parliament (MP) for that City in 1835. John Wilson (1787–1851) came from a farming family and was appointed by Dunlop as a colliery manager and then manager of the Clyde Iron Works. It was in the latter capacity that he collaborated with Neilson's experiments on the hot blast. Wilson and Dunlop were partners in the Dundyvan Iron Works, and Wilson became sole proprietor on Dunlop's death.

22. Papers of Bannatyne, Kirkwood, France & Co., The Mitchell Library, Glasgow, File T-BK 163/30. The file is annotated in pencil "J.B. Neilson's specification 1829." It contains 12 documents, all relating in various ways to the process of drawing up Neilson's Scottish and English patents and specifications.

23. Macintosh had been granted a patent in 1823 (No. 4804) for a process and manufacture in which two layers of textile were cemented together by a solution of rubber in naptha to produce the waterproof material with which his name became synonymous. In an area closer to Neilson's interests, Macintosh had taken out a patent in 1825 (No. 5173) for converting malleable iron into steel, but the process never proved viable. Macintosh, of course, also had long experience as a chemical manufacturer. See Archibald Clow and Nan L. Clow, *The Chemical Revolution. A Contribution to Social Technology* (London: Batchworth Press, 1952), 254–5.

24. I have previously noted the involvement of "team Watt"—that is, the group of individuals centered on Watt Jr., and including Henry Brougham, who were the rather fervid guardians of the reputation of Watt Sr. in the decades after his death—with the Neilson patent affair. This document, however, makes it clear that they were involved in drawing up the patent specification as well as in its subsequent defense. Participants in the trial, and many subsequent commentators, noted the clear parallels between the character of Watt's specification of his 1769 patent and Neilson's specification. See Miller, *Discovering Water*, 185–6.

25. Charles Carpenter Bompas (1791–1844) was from a Baptist family in Bristol. He was called to the Bar at Inner Temple in 1815 and became Serjeant at Law in 1827 when he moved to London. He was a leader on the Western Circuit and a Dissenting Deputy. In 1817, he published a book (under the name Charles Bompass), *On the Nature of Heat, Light and Electricity*. [See "The Bumpus Biographies," at http://www.armadale.org.uk/wellsgenealogy/bumpas/bumpusbiographies.htm, and Geof-

frey Cantor, *Optics after Newton: Theories of Light in Britain and Ireland, 1704–1840* (Manchester: Manchester University Press, 1983), 112–3].

26. My chief source for this section is Henry Marten, "On the Construction of Hot Blast Ovens for Iron Furnaces," *Proceedings of the Institution of Mechanical Engineers* 10 (1859): 62–91, 97–108, which recounts the range of designs in the previous 30 years. Marten, however, repeatedly thanked Neilson for information, and Neilson participated in the discussion of Marten's paper, so that the information is presented very much as a celebration of Neilson's accomplishments. To that extent, caution is warranted.

27. Marten, "Hot Blast Ovens," 67. A "twire" is a nozzle through which a blast of air is directed into the furnace. There is luxuriant variation in the term "twire," including "twyer," "twyre," "tweer," and the French "tuyère." I have adopted "twire" as my standard usage and used other forms only in direct quotation. A modified "twire" was developed that was cooled by water. This was often referred to as the "water twire." For this, I have adopted the term "water-cooled twire" throughout.

28. Marten, "Hot Blast Ovens," 66.

29. Corrins, "Hot-Blast Affair," 240.

30. Smiles, *Industrial Biography*, 101, n. 119; *Mechanics' Magazine* 24, no. 644 (12 December 1835): 211–5, at 215. On the Wilsontown works, founded by the Wilson family but purchased by Dixon in 1821, see I. Donnachie and J. Butt, "The Wilsons of Wilsontown Ironworks: A Study in Entrepreneurial Failure," *Explorations in Entrepreneurial History*, 2nd series (1967): 150–68.

31. *Trial (Baird)*, 351–5.

32. *Trial (Baird)*, 354.

33. *Trial (Baird)*, 354–5. At the 1843 trial, Condie denied saying this in an affidavit even though a document to that effect was tendered in evidence.

34. Corrins, "Hot-Blast Affair," 239.

35. Corrins, "Hot-Blast Affair," 247. James Baird's detailed account of these developments is in *The Bairds of Gartsherrie. Some Notices of Their Origin and History* (Glasgow: Privately Printed, 1875), 56–61. It is clear from this account that from the beginning, James was the brother who took on the technical side of the business. He presents himself as becoming a largely self-taught, but superior, jack-of-all-trades in the iron business, able to outperform even skilled workmen of various sorts. He also saw himself as an inventor, moreover one whose inventions, unlike Neilson's, survived intact without any need for further development.

36. Marten, "Hot Blast Ovens." See Figs. 6 and 7 in Figure B. Note that Marten calls this Neilson's first hot-blast *oven*. Earlier hot-blast designs are characterized as "arrangements" or "vessels." For a description of the Baird apparatus as given in the trials, see below.

37. Ours-Pierre-Armand Petit-Dufrénoy, *On the Use of Hot Air in the Iron Works of England and Scotland. Translated from a Report made to the Director General of Mines in France by M. Dufrenoy, in 1834* (London: John Murray, 1836). The work was translated, and plates drawn, by Lady Charlotte Guest, wife of Sir John Guest, one of the proprietors of the Dowlais Ironworks. Dufrénoy (1792–1857), was pro-

fessor of mineralogy and later director of the Ecole des Mines, and is best known as producer, with Elie de Beaumont, of a great geological map of France in 1841.

38. It is possible, of course, that Neilson and partners would lay claim to what was going on at Calder, since they perhaps considered Dixon, and Condie, as doing their bidding there.

39. *Report of the Fourth Meeting of the British Association for the Advancement of Science held at Edinburgh in 1834* (London: John Murray, 1835), 578–9.

40. Thomas Clark, "On the Application of the Hot Blast in the Manufacture of Cast-Iron," *Transactions of the Royal Society of Edinburgh* 13 (1836): 373–82.

41. Clark, "The Hot Blast," 376–7. My italics.

42. Robert A. Chalmers, "'Hot-Blast' Clark: Thomas Clark, Professor of Chemistry, Marischal College, 1833-1860," *Analytical Proceedings (of the Royal Society of Chemistry)* 17 (1980): 463–6.

43. The defendants named in the case against the Harford Company were William Thompson [1792–1854] and Thomas Seaton Forman [1791–1850]. Both were well-known, important figures. Thompson was a financier, ship-owner, and iron-master. He was a Member of Parliament for various constituencies between 1820 and 1854, Lord Mayor of London (1828–9), a Director of the Bank of England, and a Chairman of Lloyd's, whose wealth at death was £900,000. Forman's family was involved in the Welsh iron industry, and he was Conservative MP for Bridgwater (1841–7). On Thompson, see *The History of Parliament: The House of Commons 1820–1832*, ed. D. R. Fisher (Cambridge: Cambridge University Press, 2009), and Anthony Howe, "From 'Old Corruption' to 'New Probity': The Bank of England and its Directors in the Age of Reform," *Financial History Review* 1 (1994): 23–41, at 33. On Forman, see Laurence Ince, "The Forman Family (per. 1784–c. 1870)," *Oxford Dictionary Of National Biography*, Oxford University Press, 2004, http://www.oxforddnb.com/view/article/56536

44. To be more precise, Baron Parke found in favor of the plaintiffs on four of five counts, the fifth being further considered and eventually decided in the plaintiffs favor.

45. William Webb Follett (1796–1845) was educated at Trinity College Cambridge, joined Inner Temple in 1814, and subsequently built a substantial practice. In 1834, he became Solicitor-General in Peel's first administration at the same time he was appointed KC and knighted. In 1835, he was elected MP for Exeter and served again as Solicitor-General in Peel's second administration. In April 1844, Follett succeeded Sir Frederick Pollock as Attorney-General. On his early death, Follett reportedly "left behind him the reputation of having been the greatest advocate of his generation." [J. A. Hamilton, "Follett, Sir William Webb (1796-1845)" rev. David Pugsley, *Oxford Dictionary of National Biography*, 2004, http://www.oxforddnb.com/view/article/9796. See also David Pugsley, *Follett, Our Great Lawyer* (Exeter: Law Faculty, University of Exeter, 1991)].

46. The initial declaration and pleadings are recorded in Thomas Webster, *Reports and Notes of Cases on Letters Patent for Inventions* (London: Thomas Blenkarn, 1844), 295–8.

47. Webster, *Reports*, 296.

48. Webster, *Reports*, 296–7.

49. *Trial (Harford)*, 5.

50. *Trial (Harford)*, 10–1.

51. *Trial (Harford),* 10.

52. David Philip Miller, "Watt in Court: Specifying Steam Engines and Classifying Engineers in the Patent Trials of the 1790s," *History of Technology* 27 (2006): 43–76.

53. *Trial (Harford)*, 17–8.

54. John Scott Russell (1808–82), engineer and naval architect, was a graduate of Glasgow University and pursued a varied career as a designer of vessels (from canal barges to the *Great Eastern*); manager of Caird's engine works in Greenock (1838); and Secretary of the Royal Society of Arts (1845), in which position he had much to do with inauguration of the Great Exhibition of 1851. He is perhaps best remembered for his sustained investigations into what he called the "wave of translation" and also his shipbuilding work with Brunel in the 1850s. He was elected FRS in 1849. See David K. Brown, "Russell, John Scott (1808-1882)," *Oxford Dictionary of National Biography*, Oxford University Press, 2004, http://www.oxforddnb.com/view/article/24328; George S. Emmerson, *John Scott Russell: A Great Victorian Engineer and Naval Architect* (London: John Murray, 1977); Olivier Darrigol, "The Spirited Horse, the Engineer, and the Mathematician: Water Waves in Nineteenth-Century Hydrodynamics," *Arch. Hist. Exact Sci.* 58 (2003): 21–95.

55. *Trial (Harford)*, 23.

56. This William Jessop was the son of the well-known engineer William Jessop (1745–1814), pupil and assistant of John Smeaton and known for his work on canals, harbors, and early railways. With Benjamin Outram and others, Jessop Sr. had founded the Butterley Iron Company in 1790. The younger William took over the Company in 1805.

57. Clow and Clow, *Chemical Revolution*, 355.

58. Mushet (1772-1847) was the son of a foundry owner in Dalkeith. In 1792, he had become accountant at the Clyde Iron Works, where he began what were to be lifelong scientific investigations into the smelting of iron ores. He was a partner in a variety of iron works and discovered black band ironstone near Coatbridge, Lanarkshire, in 1801. The hot-blast process assisted greatly in the exploitation of this resource. He contributed the article "Iron" that was published in the 1824 Supplement to the *Encycopaedia Britannica*, and the articles "Blast-furnace" and "Blowing machine" in Rees' *Cyclopaedia* (1819). He held patents on direct steel making in crucibles and on improvements to the puddling process. In 1840, his many communications to *Philosophical Magazine* were collected in the volume *Papers on Iron and Steel, Practical and Experimental* (J. Weale, 1840). [See Ian J. Standing, "Mushet, David (1772-1847)," *Oxford DNB*, 2004, http://www.oxforddnb.com/view/article/19670]

59. Penrice (1804-1865) is a shadowy figure but was, from 1840, colliery agent of the Workington Colliery. (See "The Workington Colliery," *Whitehaven Herald*, 28 March 1846, as transcribed at Durham Mining Museum, http://www.dmm.org.uk/news18/846032a.htm.)

60. On Farey, see A.P. Woolrich, “John Farey Jr. (1791-1851), Engineer and Polymath,” *History of Technology* 19 (1997): 112–42. Farey worked as a consulting engineer, was a prolific engineering journalist, and acted as a witness to a number of Parliamentary inquiries, inquests, and court cases. He is best known as author of *A Treatise on the Steam Engine* (London: Longman, Rees, Orme, Brown and Green, 1827).

61. On the classification and hierarchy of engineers in the late eighteenth and early nineteenth centuries, see Peter M. Jones, “Becoming an Engineer in Industrialising Great Britain *circa* 1760,” *Engineering Studies* 3 (2011): 215–32, and also Miller, “Watt in Court,” 50–1, 63.

62. *Trial (Harford)*, 102.

63. This was Professor John Frederic Daniell (1790–1845), Professor of Chemistry at King’s College London from 1831. He was FRS in 1813 and Foreign Secretary of the Society from 1839.

64. Professor Thomas Graham (1805–69) was a student of Thomas Thomson in Glasgow and left a professorship at the Andersonian Institution in 1837 to become Professor of Chemistry at University College London. At about the time he gave his testimony in this trial, he became the first President of the Chemical Society of London. See George B. Kauffman, “Thomas Graham: Father of Colloid Chemistry,” *The Chemical Educator* 10 (2005): 457–62.

65. *Trial (Harford)*, 139

66. Ibid.

67. *Trial (Harford)*, 141.

68. See note 6.

69. *Trial (Harford),* 144.

70. *Trial (Harford)*, 144.

71. Quoted in *Trial (Harford)*, 148.

72. *Trial (Harford)*, 150.

73. *Trial (Harford),* 150. Although the Attorney General chose to ignore them, there were significant doubts about Watt’s patent specification both at the time his patent was litigated and in the early nineteenth century. Those doubts stemmed precisely from the perception that the specification was too broad and trying to claim too much. John Farey had been among those who expressed that view. See Miller, “Watt in Court,” 68–9.

74. As we will see later in our story, much was to turn on establishing the referent of the word “effect.” The defendants were to maintain that it referred to the heating of the air so that the specification was making a statement that the form or shape of the intermediate heating vessel was immaterial to the degree to which the air could be heated. This statement was demonstrably untrue and might be regarded as rendering the patent void altogether. The plaintiffs maintained that the word “effect” referred to the effect of improving the operation of the blast furnace so that the shape or form of the heating vessel was immaterial to that in the sense

that any intermediate vessel achieving any increase in the temperature of the blast would improve the performance of the furnace.

75. *Trial (Harford)*, 158.

76. *Trial (Harford)*, 161.

77. *Trial (Harford)*, 162. Each side in the affair was anxious to have the legendary Watt on their side. Although the defendants' counsel relied on this imaginative reconstruction of Watt's reaction to the specification and also on an assumed *contrast* between Watt's successfully defended patent and Neilson's, the plaintiffs relied on what they saw as the deep *similarities* between the two patents and their specifications. See *Trial (Harford),* 150.

78. *Trial (Harford)*, 168.

79. *Trial (Harford)*, 177. Dutton confirmed this perception with his finding that whereas in the late eighteenth and early nineteenth centuries less than 40% of patent cases at common law were decided in favor of the plaintiffs, in the 1830s and 1840s 76% were so decided. See Harold I. Dutton, *The Patent System and Inventive Activity During the Industrial Revolution 1750-1852* (Manchester: Manchester University Press, 1984), 78–9. Dutton's statistics have, however, been challenged recently by Bottomley (see note 114).

80. *Trial (Harford)*, 178.

81. *Trial (Harford)*, 181. Why Parke did this is not clear. Perhaps he reasoned that if, as was routinely accepted, a person skilled in the art can supply an absence in a specification, then they might just as legitimately correct an error.

82. In the following paragraphs, I summarize the extensive deliberations and arguments of Follett and Campbell before the Lord Chief Baron, Baron Parke, Baron Alderson, and Baron Rolfe as recounted in *Trial (Hanford)*, 213–376.

83. It is interesting that this view of things sits perfectly with the commemorative idea put forward by the writer in *The North British Review* in 1845 that Neilson would best be remembered by an image or statue that had him standing between a blowing apparatus and a blast furnace. That suggestion was probably made in the knowledge that such iconography would indeed reflect the central legal judgment that had awarded the invention to Neilson. See "The Scottish Iron Manufacture," 142.

84. The modern example of the legal disputes over breast cancer genes appears to be a case in point.

85. Details of the trial come from *The Trial Before the Lord-Justice Clerk, and a Special Jury, of the Issues in the Action of Count, Reckoning, Payment and Damages, at the Instance of James Beaumont Neilson of Glasgow, Engineer, and Others, Against the Househill Coal and Iron Company (Infringement of Patent Right)…. taken in shorthand by Mr. David Buchanan, June* (Edinburgh: Alexander Laurie & Co, 1842). Hereafter referred to as *Trial (Househill).*

86. Rutherfurd (1791–1854) was born Andrew Greenfield but changed his name to reflect his mother's ancestry. Educated at Edinburgh University, he became an advocate in 1812 and built a substantial practice. He was associated with the Whig party. In 1837, he was appointed Solicitor-General for Scotland in the Melbourne administration, and in 1839, he became Lord Advocate and MP for the

Leith Burghs. He left office during the Peel administrations. In 1851, he was appointed ordinary lord of session with the title Lord Rutherfurd.

87. *Trial (Househill)*, 3.

88. *Trial (Househill)*, 9

89. *Trial (Househill)*, 17.

90. Forbes (1809–68) was a very well-known figure in nineteenth-century physics and geology and a close associate of the Cambridge Network in the affairs of the British Association (see Frank F. Cunningham, *James David Forbes: Pioneer Scottish Glaciologist* [Scottish Academic Press, 1990], and J. C. Shairp, P. G. Tait, and A. Adams-Reilly, *Life and Letters of James David Forbes* [London: Macmillan and Co., 1874]). William Gregory (1803–58) had studied with T. C. Hope at Edinburgh and Justus Liebig in Giessen. He spent much of the 1830s as a chemistry lecturer in Edinburgh before succeeding Thomas Graham as Professor at the Andersonian Institution. In 1839, he was appointed Professor of Medicine at King's College, Aberdeen, where he also taught chemistry. He became Professor of Chemistry at Edinburgh University in 1844 (see Alexander Findlay, *The Teaching of Chemistry at the Universities of Aberdeen* [Aberdeen: The University Press, 1935], 49–57). Andrew Fyffe (or Fyfe) (1792–1861) graduated in medicine from Edinburgh University in 1814 but earned his living primarily as a teacher of chemistry in Edinburgh. In 1844, he became Professor of Chemistry at Aberdeen.

91. See J. D. Forbes to George Dunlop, 15 June 1841, J. D. Forbes Papers, Special Collections, University of St. Andrews, msdep7, Letterbook III, 183; Forbes to Dunlop, 23 February 1842, Letterbook III, 346.

92. J. D. Forbes to Adam Anderson, 12 and 13 December 1840, Forbes Papers, msdep7, Letterbook III, 156–7 and 158–9.

93. *Trial (Househill)*, 37–41. At this point, the Lord Justice Clerk chimed in: "Well, this only shews how knowledge is required to understand a thing." The Lord Justice had earlier remarked, when Forbes acknowledged that he could not speak about the reception of Neilson's invention from recollection at the time but only from his reading, that counsel (Mr. Robertson) should remember that "professor Forbes, though an old professor, is still a very young man." Such commentary gave judicial endorsement to Forbes' status as a witness.

94. This was Duncan McNeill, 1st Baron Colonsay (1793–1874), Scottish advocate, judge, and Tory politician. He graduated MD from St. Andrew's University and LLD from Edinburgh University, held various offices including Solicitor-General under the Peel administrations, and sat as MP for Argyllshire from 1843 to 1851. In that year, he became a Lord of Session as Lord Colonsay and was raised to the peerage as Baron Colonsay in 1867.

95. Cottam (fl. 1818–57) was a partner in an iron foundry in Southwark, which produced decorative and structural ironwork. He was active in the Institution of Civil Engineers (see A. W. Skempton, *A Biographical Dictionary of Civil Engineers in Great Britain and Ireland* [London: Thomas Telford, 2002], 150). Edward Sang was a mathematician, mathematical table-maker, and engineer, educated at Edinburgh University who was lecturing at Manchester New College in 1841–3. Carpmael (1804–67) was a civil engineer who had read for the Bar and from about 1835 became a patent agent and consulting engineer. He was later known for his *Law*

Reports of Patent Cases, 2 vols. (London: A. Macintosh, 1843). (See his obituary in *Minutes and Proceedings of the Institution of Civil Engineers* 30 [1870]: 430.)

96. The Lord Justice Clerk was John Hope (1794–1858), who held the office from 1841 until his death. A man of Tory connections who took a controversial part in the affairs of the Church in Scotland, Hope was regarded as having contempt for public opinion and was known for speaking his mind. Although his politics might not naturally cause him to side with Neilson, his outspokenness is certainly evident in his summing up. So too is his love of precedent. (See Gordon F. Miller, "Hope, John [1794–1858]," *Oxford Dictionary of National Biography*, Oxford University Press, 2004, http://www.oxforddnb.com/view/article/13733.)

97. *Trial (Househill)*, 165–6.

98. *Trial (Househill)*, 166.

99. *Trial (Househill)*, 166–7.

100. Damages of £3060 were awarded to Neilson and his partners. See "Important Jury Trial," *Caledonian Mercury* 11 April 1842, 3. Although damages in all the trials were significant, much more significant were the license fees that consequently had to be paid.

101. David Boyle, Lord Boyle (1772–1853), held the office of Lord Justice General from 1841 to 1852.

102. *The Trial before the Lord Justice-General and a Special Jury of the Issues in the Action of Count, Reckoning, Payment and Damages, at the Instance of James Beaumont Neilson of Glasgow, Engineer and Others, against Messrs W. Baird & Co. of the Gartsherry Iron-Works* . . . . (Edinburgh: Printed by W. Burness, 1843). Hereafter referred to as *Trial (Baird)*.

103. The scientific debate was more temperate than some of the discussion in the press in which critics of hot-blast iron did not hesitate to attribute disasters and accidents to its use. See, for example, the attribution of a terrible accident at a mill in Oldham to the use of "Scotch iron" in its girders, *The Times*, 8 November 1844, 5.

104. *Trial (Baird)*, 187. As was pointed out, the use of this warning by Bairds' counsel when Bairds were among the leading hot-blast producers was rather odd.

105. *Trial (Baird),* 187, 206–7, 384–5. On Hodgkinson and Fairbairn's work and reports to the British Association, see Jack B. Morrell and Arnold Thackray, *Gentlemen of Science: Early Years of the British Association for the Advancement of Science* (Oxford: Clarendon Press, 1981), 497–8. Hodgkinson received the Royal Medal of the Royal Society in 1841 for his paper titled "Experimental Researches on the Strength of Pillars of Cast Iron and Other Materials," published in the *Philosophical Transactions* in 1840.

106. *Trial (Baird),* 391–420.

107. *Trial (Baird),* 395, 398.

108. *Trial (Baird),* 395.

109. From the discussion consequent on Marten, "Hot Blast Ovens," at 98–100.

110. I think that the term "collective invention" would be a useful descriptor of such extended inventive processes as distinct from individual acts. However, the term has already been appropriated, very usefully, to describe an explicit co-operative arrangement. See Robert C. Allen, "Collective Invention," *Journal of Economic Behavior and Organization* 4 (1983): 1–24, and Alessandro Nuvolari, "Collective Invention during the British Industrial Revolution: The Case of the Cornish Pumping Engine," *Cambridge Journal of Economics* 28 (2004): 347–63. Whether those opposing Neilson and his partners might be seen as constituting a "collective invention setting" in the west of Scotland iron industry is an interesting question worth further research and consideration. My claim is the more straightforward one that the hot-blast invention ought to be seen as including a sequence of contributions of which Neilson's was one.

111. Corrins, "Hot-Blast Affair," 250. James Baird recalled that David Boyle, the Lord Justice-General who presided over the 1843 trial which found against the Bairds, had some years earlier advised the Baird family that their hot-blast apparatus did not encroach on Neilson's patent. See *The Bairds of Gartsherrie*, 62.

112. MacLeod, *Heroes of Invention*, 265–71. MacLeod does not discuss Neilson specifically. See also Moureen Coulter, *Property in Ideas: The Patent Question in mid-Victorian Britain* (Kirksville, M.O.: Thomas Jefferson Press, 1992).

113. John Percy, *Metallurgy: The Art of Extracting Metals from their Ores, and Adapting Them to Various Purposes of Manufacture. Iron and Steel.* (London: John Murray, 1864), acknowledged that the hot blast was "one of the most important improvements ever made in metallurgy" but argued that it could not be termed a great invention. He did not see any "elaborate working out of a process or machine." Without wanting to detract from Neilson's just entitlements, Percy was of the view that "the hot-blast was a lucky hit rather than an invention properly so called." It has been suggested to me that the language of the "lucky hit" was often used by patent abolitionists as a way of devaluing the contribution of the individual inventor and hence supporting the abolitionist case against the need for patents. However, I have no direct evidence that Percy was an abolitionist.

114. Sean Bottomley, *The British Patent System during the Industrial Revolution 1700–1852: From Privilege to Property* (Cambridge: Cambridge University Press, 2014). I am grateful to the referees for urging me to deal explicitly with Bottomley's revisionist challenge.

115. Bottomley, *The British Patent System*, p. 161.

116. See David Bloor, *Wittgenstein: A Social Theory of Knowledge* (Macmillan, 1983) and *Wittgenstein: Rules and Institutions* (Routledge, 1997). Harry Collins, *Changing Order. Replication and Induction in Scientific Practice*, 2nd edition (Chicago: The University of Chicago Press, 1992) applies these insights to processes of scientific experiment via the notion of the "experimenters' regress." As previously noted, in Miller, "Watt in Court," inspired by Collins, I suggested that in legal contests over patents there is similarly a "patent specifier's regress."