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How Big is a Hole?: The Problems of the Practical Application of Science in the Invention of the Miners' Safety Lamp by Humphry Davy and George Stephenson in Late Regency England

by

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INTRODUCTION

> An instance for Bacons spirit to behold — Davys magic lantern — The Miners Davy &c Every philosopher must view it as a mark of subjection set by Science in the strongest holds of nature.[1]

These are the notes used by the 25-year-old laboratory assistant at the Royal Institution, Michael Faraday (1791–1867), for his lecture to the City Philosophical Society[2] on 16 July 1817 on carbon. They refer to the miners' safety lamp invented by Humphry Davy (1778–1829) towards the end of 1815. Since I first came across this passage, twenty years ago, I have always been fascinated by it. It can be subjected to multiple meanings and in the course of this paper I will tease some of them out. The quotation provides the text for the narrative that I want to explore in this paper, namely the link between science and technology. The idea that understanding the natural world through science gives humankind power to control the material world through technology goes back to Francis Bacon (1561–1626) in the late sixteenth century with his slogan 'knowledge itself is power'[3] and this, of course, is the first meaning that one can ascribe to Faraday's text.

Ever since Bacon there has been a significant strand in English thought of the benefits of applying science for practical purposes. Both the Royal Society founded in 1660 and the Royal Institution founded in 1799 were established with practical purposes in mind, at least at a rhetorical level, to encourage the support of science. The snag was that the contribution of scientific knowledge to developing and understanding engineering practice in the seventeenth and eighteenth centuries was limited. With a few obvious exceptions, such as the separate condenser of James Watt (1736–1819), where his knowledge of latent heat, a concept developed by Joseph Black (1728–1799), may have played some role,[4] it is hard to see where scientific knowledge was significant during the early stages of industrialisation. All those names familiar from the school history curriculum — Thomas Newcomen (1664–1729), Abraham Darby (1678–1717), James Brindley (1716–1772), Richard Arkwright

(1732–1792), Samuel Crompton (1753–1827) etc. — could as well have done their work without knowing the inverse square law of gravitation or that white light comprised seven colours. Other factors in industrialisation such as population growth and distribution infrastructure, the development of the banking system and so on had even less link to the gentlemanly concerns of the eighteenth-century Royal Society.[5]

Such lack of delivery of material benefits helps account for the size of, what can be termed anachronistically, the scientific community during the eighteenth century. One has to remember that even as late as 1864 the scientific community (as defined by membership of the main scientific societies in Britain) numbered only about 4000[6] of which those who were paid for doing science probably only just scraped into triple figures. Science was seen as branch of learning, with a theological tendency,[7] alongside other subjects such as ancient languages. By the end of the nineteenth century, however, science and technology had become fused together into a single continuous spectrum of practice, as evinced by the formation in 1907 of the Imperial College of Science and Technology. One of the icons of this process of coalescence, from the nineteenth century to the present, is Humphry Davy.

In this paper I will consider, in some detail, Davy's foray into engineering practice with his work on the miners' safety lamp in the mid 1810s. I will then discuss the precisely contemporary invention of a similar lamp by George Stephenson (1781–1848) and how the ensuing priority dispute was fought out both nationally and regionally. This will include examining the crucial role played in the controversy by business (the mine owners), the media (national and local papers as well as the scientific press) and by the arts. Finally, by way of conclusion, I will briefly examine the effectiveness of the lamp and compare the story of the lamp with Davy's development of the electro-chemical protection of the copper of the underside of ships just under a decade later.

SCIENCE AND EMPIRE

There was one place earlier than Davy where science was especially important practically and that was its political role in expanding and consolidating the Empire. Expeditions with an ostensibly scientific purpose were also used to make claims on additional territory.[8] For example between 1768 and 1771 James Cook (1728–1779) commanded HMS Endeavour on the voyage to observe the transit of Venus (itself useful for navigational purposes) from Tahiti on 3 June 1769. In the course of the voyage he claimed Australia for the British Empire. Accompanying Cook was the botanist Joseph Banks (1743–1820) who botanised in Botany Bay and named the Kangaroo. Following his return to England, he became enormously influential in government circles, suggesting that Australia would be good for sheep and criminals; it was also Banks who proposed that William Bligh (1754–1817) should command the Bounty expedition in 1787 and later (1805) that he should be governor of New South Wales. Banks, a follower of Bacon, sought to make science a safe and indeed useful activity in the eyes of the English governing elite, as opposed to the way it was used in France to support the overthrow of the *ancien régime*.[9] It is thus no coincidence that, as President of the Royal Society from 1778 to 1820, he was one of the key figures in founding the Royal Institution of Great Britain.[10] The Royal Institution had the explicit remit of using science for practical purposes, by providing expert advice, and by disseminating scientific knowledge through lectures. The early membership of the Royal Institution contained significant sections drawn from landowners and colonial officials[11] who, after six years of

world war with France, believed that science could be used to defend, consolidate and expand Britain's agricultural, industrial and imperial position.

DAVY — THE EARLY YEARS

In its early years, the Royal Institution, like the rest of the scientific community in the previous century, did not deliver on this and slowly the agricultural and imperial interests drifted away. Davy, appointed there in 1801, undertook a detailed study of tanning (for which he was awarded the Copley Medal of the Royal Society in 1805) which concluded that tanners 'appear to have arrived, in consequence of repeated practical experiments, at a degree of perfection which cannot be very far extended by means of any elucidations of theory that have as yet been made known'.[12] Confirming existing best practice was not the most effective way to retain interest in the practical side of the Royal Institution's work. The Royal Institution did become, however, the location for the provision of polite scientific entertainment that became very popular. It was for his lecturing qualities, rather than his scientific research, that Davy was appointed.[13] Because of the need to provide spectacular, not to say dangerous demonstrations of scientific experiments, the laboratory of the Royal Institution became so well equipped that Davy was able to use its facilities to carry out his fundamental electro-chemical researches including isolating sodium and potassium among other chemical elements. Thus scientific research, which was not intended by the founders as one of the functions of the Royal Institution, became, by default, one of its leading features, although this was not formally acknowledged until 1862.

Davy was born in Penzance in 1778 and in 1798 made his way to the Pneumatic Institution of the radical chemist Thomas Beddoes (1760–1808) in Bristol.[14] There he discovered the physiological effects of nitrous oxide (laughing gas) and became a friend of the poet and philosopher, Samuel Taylor Coleridge (1772–1834) at whose suggestion he edited the second edition of *Lyrical Ballads* by William Wordsworth (1770–1850) — that seminal text of English Romanticism — for Davy was also a more than competent poet. Following his appointment to the Royal Institution, Davy's rise in the London scientific world was meteoric. Under Banks's patronage he was elected a Fellow of the Royal Society in 1803, and became one of its Secretaries in 1807. That same year, despite the war, he was awarded the Napoleon Prize of 3000 Francs by the Académie des Sciences in Paris. So famous did Davy become that he was knighted by the Prince Regent (later George IV, 1762–1830) on 8 April 1812. Three days later he married a very wealthy widow, Jane Apreece (1780–1855). By this event, which recalls the contemporary novels of Jane Austen (1775–1817), Apreece gained a title (which she had missed with her first marriage) while her wealth allowed Davy to retire from his professorship at the age of 34. However, he did retain the unpaid position and title of Director of the Laboratory in the Royal Institution.

EUROPEAN TOUR

The following year he was permitted to visit France taking his new wife, her maid and Faraday as amanuensis, assistant and reluctant valet. To modern eyes it might seem strange that England's leading chemist should be allowed to travel to and through the country with which it had been at war more or less continuously for 20 years — the more so as the British army under Arthur Wellesley, Viscount Wellington (1769–1852), was about to invade

France from Spain. What this suggests is that chemistry, or at least the sort of chemistry that Davy did, was not seen by either of the conflicting powers as particularly important for the conduct of war and is added evidence for my contention that the influence of scientific knowledge on technology was minimal at this time.

The party travelled through France into the Italian states (where they heard of the abdication of Napoleon Bonaparte (1769–1821) as Emperor of France and the allied occupation of Paris), Switzerland, the South German states and back into Italy. At Naples on 7 March 1815 they heard that Napoleon had escaped from Elba[15] and Davy, at that point, decided to cut short the tour and rapidly returned to England arriving in mid April 1815. He did this probably because of the strained relations between Faraday and Lady Davy and used the renewal of the war as an excuse.

On their return Davy ensured that he was elected a Manager and Vice President of the Royal Institution and Faraday resumed his old role as assistant in the laboratory and lecture theatre. In the middle of July 1815, a month or so after the Battle of Waterloo, Davy went to Scotland to visit John Southey Somerville, 15th Baron Somerville (1765–1819), in Melrose for the shooting.[16] While there he received a letter from Robert Gray (1762–1834), Rector of Bishopwearmouth, County Durham, now part of Sunderland. Gray would later achieve a degree of notoriety when, as Bishop of Bristol, following his voting against the Reform Act in the House of Lords, his palace was burnt by an angry mob on 30 October 1831.[17] This fire did not destroy Gray's correspondence with Davy and others about the lamp, but even if it had John Ayrton Paris (1785–1856) had already published many of these letters that year in his biography of Davy.[18]

THE FIRE-DAMP PROBLEM

Gray, a paternalistic Tory, was concerned about the number of fatalities caused by explosions in coal mines and the consequent dire social effects. The explosions were caused by the ignition of fire-damp, now known as methane, CH_4, which was particularly prevalent in the coal mines of the North East. The North East coal field, located in County Durham and southern Northumberland (Figure 1), was a key area for coal production, accounting in 1815 for nearly of quarter of British output (Figure 28). Following a series of explosions in the North East coal field, it was estimated by the Sunderland physician William Reid Clanny (1776–1850) that more than 200 miners had been killed between 1805 and 1812[19] (see Figure 29), while the official history of the coal industry noted that 197 mine workers were killed in the North East during 1815 alone.[20] An explosion at Felling colliery, owned by the Brandling family, on 25 May 1812, which killed 92 people, together with the growing death rate in the coal mines, prompted the formation, in the autumn of 1813, of 'A Society for preventing Accidents in Coal-Mines', generally known as the Sunderland Society. The formation of this Society had been prompted by the Durham born London lawyer James John Wilkinson (1780–1858) who happened to be present at the time of the Felling explosion and had been appalled at the length of the funeral cortège.[21]

The Whig MP Ralph Milbanke (1747–1825) was President of the Society in which Gray played an active role. Its object to raise funds to provide premiums 'for the discovery of new methods of lighting and ventilating mines' was never realised.[22] However, in early 1814 the Society issued its first report which mainly comprised a letter from Unitarian, liberal and prominent mine viewer John Buddle (1773–1843) to Milbanke. This letter dealt largely with

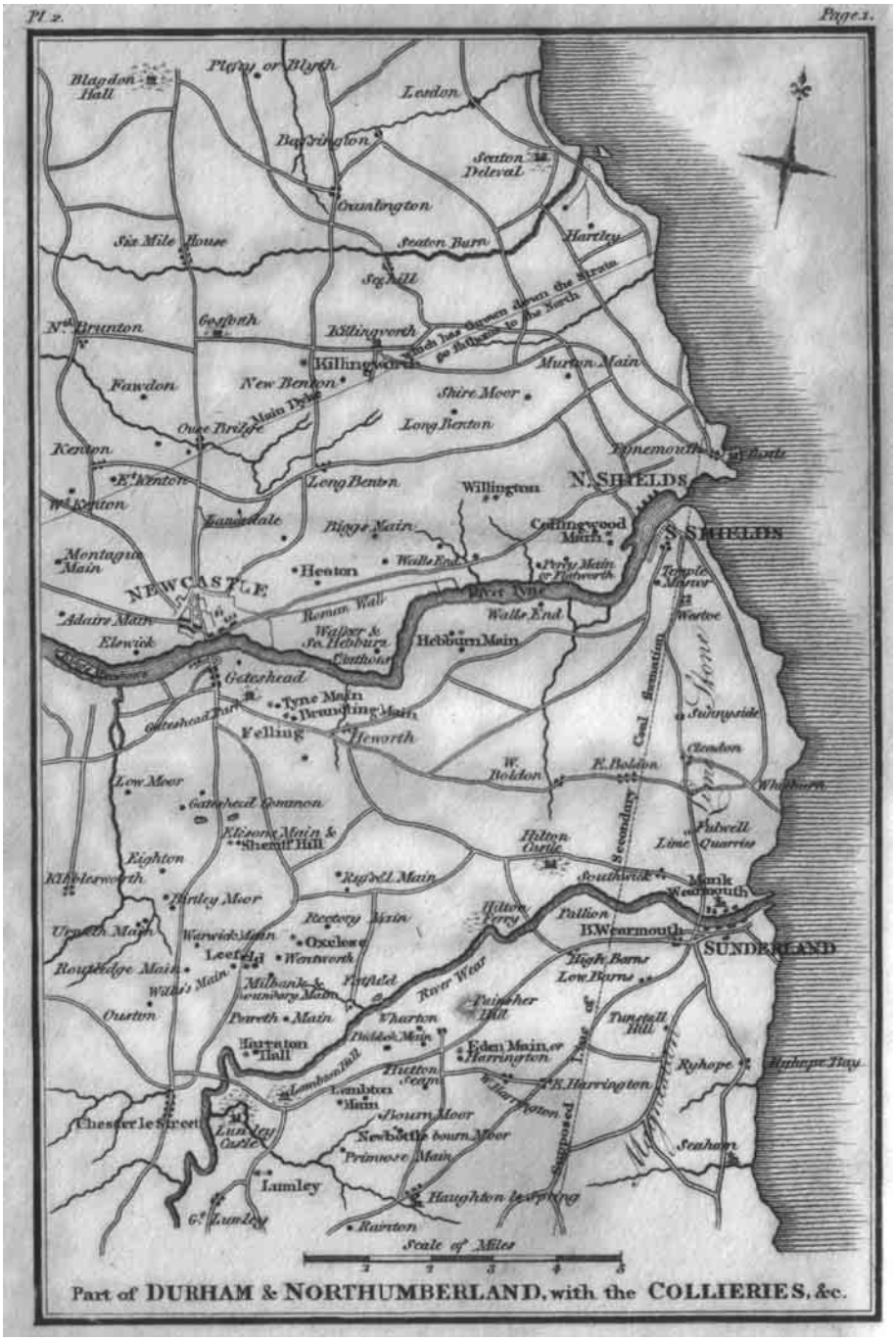


Fig. 1. Map of the North East coal field. From J.H.H. Holmes, *A treatise on the Coal Mines of Durham and Northumberland . . . containing accounts of the explosions from fire-damp which have occurred therein for the last twenty years* (London, 1816), opposite p. 1.

the ventilation of coal mines, but towards the end Buddle commented that one way to render fire-damp harmless might be by

> providing such a chemical change upon carburetted hydrogen gas, as to render it innoxious as fast as it is discharged, or as it approached the neighbourhood of lights.
>
> In this view of the subject, it is to scientific men only that we must look up for assistance in providing a cheap and effectual remedy.[23]

Doubtless with this injunction in mind, Wilkinson called on Davy at the Royal Institution to ask for his help, but found that he had gone to Paris. The letter he then wrote to Davy was returned as lacking sufficient postage.[24] However, at a meeting of the Sunderland Society on 4 July 1815, chaired by Gray, who appears to have been 'generally acquainted'[25] with Davy, it was resolved to approach him again about preventing explosions in mines.[26] Gray's letter has not been found, but judging by Davy's reply sent from Melrose on 3 August 1815, he had asked Davy if there were any chemical means of destroying fire-damp — that is the strategy proposed by Buddle. Davy commented that the

> difficulty is to ascertain when it is present without introducing lights which may inflame it. I have thought of two spe<cies> of light which have no power of inflaming the ga<s which is> the cause of the fire damp, but I have not here the means of ascertaining whether they will be sufficiently luminous to enable the workmen to carry on their business.[27]

Right from the start, therefore, Davy was thinking in terms of lamps that would not cause explosions. Furthermore, this letter introduced the humanitarian theme that became one of the main ideological threads running through most of the texts related to the invention of the safety lamp; it was 'an enquiry so interesting to humanity' as Davy put it. He added that he would visit the North East on his way South to acquire information about the gas. However, he was in no hurry to start work as he went off to the Highlands for more shooting,[28] writing the same day to Faraday asking him to send one of his guns to Selkirk.[29]

When he returned to Melrose he found a letter from Gray awaiting inviting him to visit Newcastle to meet Buddle, an invitation that Davy accepted.[30] He stayed at the Turk's Head in Newcastle and on 24 August was visited there by John Hodgson[31] (1779–1845), incumbent of Jarrow with Heworth, in which parish Felling colliery was located. Hodgson, like Buddle, was active in the Sunderland Society and he became one of Davy's main contacts in the North East and, with Buddle, his leading champion there. Together Davy and Hodgson went to Wallsend Colliery where they visited Buddle.[32] Buddle later recollected that he had a great deal of conversation with Davy explaining the nature of the problem and that as he was leaving Davy said 'Do not despair; I think I can do something for you in a very short time'.[33] Hodgson then took Davy to Coaly-hill Dike before going to Hebburn Hall, the seat of the moderate Tory MP for Newcastle Cuthbert Ellison (1783–1860), where they stayed overnight.[34]

The following morning, it would appear, Davy and Hodgson visited Hebburn Colliery, owned by Ellison and managed, on Buddle's behalf, by Matthias Dunn (1789–1869).[35] This was followed by a visit to Gray at Bishopwearmouth, where Davy stayed the night.[36] That day Davy also met Clanny who lent him overnight a lamp that he had invented[37] (Figure 2). This lamp involved passing air through a bellows into the lantern to create an enclosed combustion chamber which could not communicate flame to the surrounding atmosphere. In the late summer of 1812 this lamp had been demonstrated to the chemist and Secretary of the Royal Society William Hyde Wollaston (1766–1828) in the presence of the Swedish chemist Jöns Jacob Berzelius (1779–1848) and other English chemists[38] and it was published

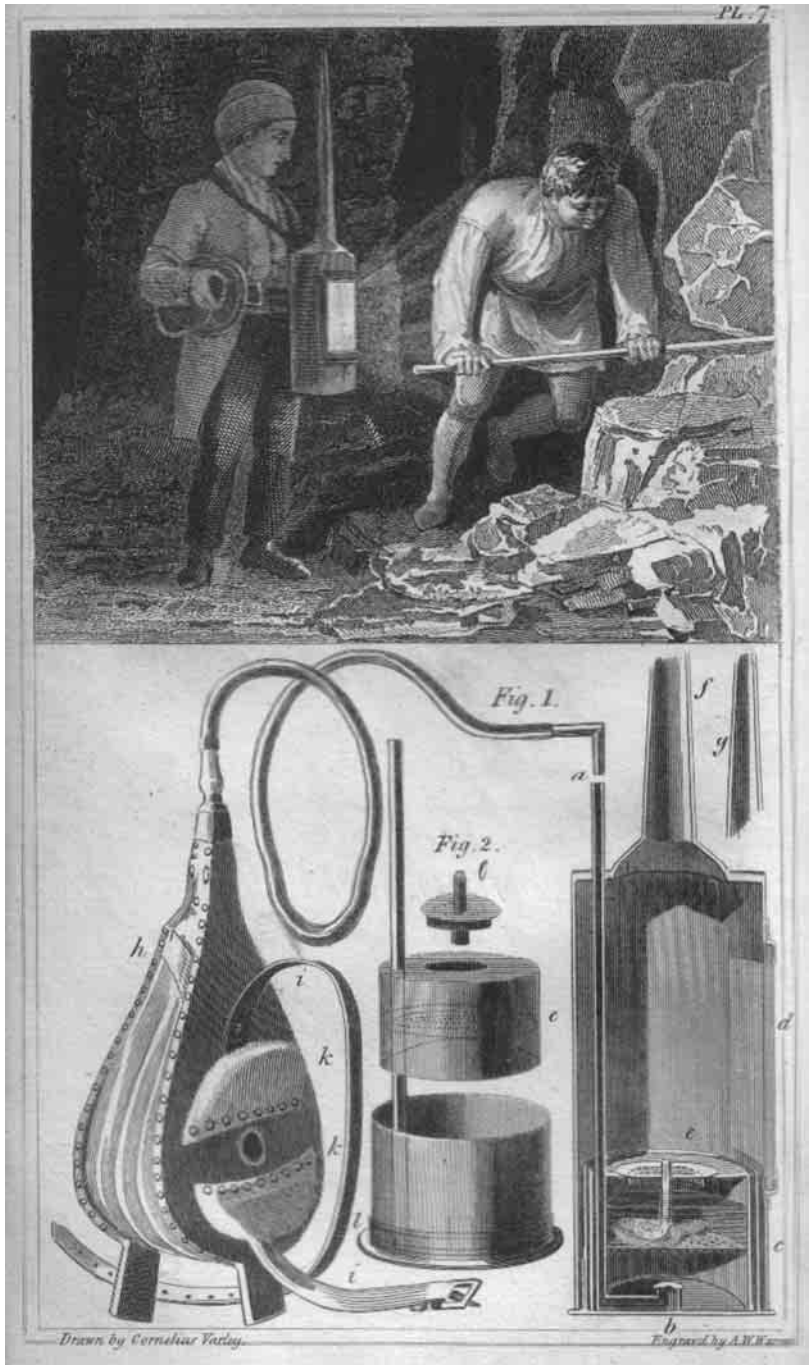


Fig. 2. Safety lamp invented by William Reid Clanny. From *Transactions of the Society of Arts*, 34 (1817), opposite p. 121.

the following year in the Society's *Philosophical Transactions*.[39] However, the lamp was generally deemed impractical, although versions of it were used in a few mines.[40]

Buddle, who believed that Davy was going to serve the cause of humanity, agreed to provide him with samples of gas from the mines for Davy to examine. At this point Davy was thinking, as Gray had originally asked him, in terms of using another gas to neutralise the explosive nature of fire-damp.[41] Davy stayed in the Durham area for at least three weeks and possibly longer. He spent a few days with Shute Barrington (1734–1826), Bishop of Durham, at his palace at Bishop Auckland.[42] From the beginning of September he seems to have stayed with the army officer George Hutchinson (1767–1833) at Eggleston[43] before moving to Rokeby Park (both near Barnard Castle), the seat of the independent MP John Morritt (1771–1843). Writing from there to his early patron, Davies Gilbert (1767–1839), on 8 September, Davy commented that he had been conducting some experiments on explosions in coal mines and that he was 'not without hopes that means may be adopted to remedy this evil' but that he would continue them in London.[44] However, he was in no hurry to return to London and seems to have been continuing investigations on the spot since on 20 September he told Faraday that he would be back in London in about three weeks asking him to look out for the arrival of 'bottles of air' and not to open them should they arrive.[45] By the end of September Davy had commenced his leisurely journey back to London and was visiting Harewood House, the seat of Edward Lascelles, first Earl of Harewood (1740–1820), from whom Davy had leased his London house, 23 Lower Grosvenor Street, in June.[46] From Harewood on 27 September he wrote to Hodgson to specify his needs for five or six quart bottles of fire-damp to be collected by Dunn and to be sent to him.[47] At the beginning of October he wrote to Faraday asking him to order, from John Newman (1783–1860), the Royal Institution's instrument maker of Lisle Street, four thick glass tubes which must be able 'to stand an explosion'.[48] There is some evidence which suggests that Davy, around this time, decided to move more quickly. He seems to have been expected at Banks's Lincolnshire seat, Revesby Abbey, on his way south but hastened to London instead.[49] In his letter from Harewood he said that he was going expressly to London to undertake experiments on the subject and added 'I have thought a good deal on the prevention of explosions from the fire damp and I entertain strong hopes of being able to effect something satisfactory'.[50]

WORK ON A SAFETY LAMP

Davy returned to the Royal Institution at some point early in the week beginning 9 October 1815. In the following fortnight, he, with Faraday's assistance, analysed the gases and developed various types of safety lamp. Unfortunately, there are no references to his work on the lamp in the Royal Institution laboratory notebook. It seems to me that lacuna this may be a reason why, somewhat surprisingly, there has never been a detailed account of the manner in which Davy invented his lamps.[51] In turn this lack, it seems, has led to some quite spectacular misunderstandings in the literature. For example, A.R. Griffin in his slightly idiosyncratic 1978 Rolt Memorial lecture suggested that Davy's work on electro-chemistry was more important for human progress than the safety lamp.[52] In 1984 the official history of the coal industry stated that 'Davy's final version [of the lamp] was publicly described in London as early as 9 November [1815]',[53] while Henry Pohs in his massive tome on underground lighting was equally misled.[54] Such statements are all the more remarkable

since F.W. Hardwick and L.T. O'Shea had pointed out in 1916, using printed sources alone, that this could not possibly have happened.[55] Other commentators, such as Alan Smith and W.F. Watson, showed in 1998 that there was something seriously wrong with the standard accounts of the events surrounding the invention of the miners' lamp.[56] However, they were not quite able to understand why such a view had come to predominate in the historical literature. Such lack of understanding can be attributed partially to the rather tortuous, but rapid, path by which Davy invented his lamp. But, additionally, the historical misunderstandings could well be related to Davy making ambiguous, if not deliberately misleading, statements during 1816 and 1817 about his work on the lamp.

It is the path to Davy's lamp that we shall now retrace. We can do this, to a considerable extent, from Davy's letters, a preliminary 'sketch', four manuscript drafts of his first paper as well as his published papers (summarised in Figure 3). I will not be analysing the minutia of the textual differences between each draft, since I have found that to be only of limited value in reconstructing the course of events. What is significant, however, are the changing illustrations and their captions, the more so because Davy never properly tied them into any draft of the paper.

By the end of his first week in London, Davy wrote to Hodgson to thank him for the samples of gas, concluding 'My experiments are going on successfully, and I hope in a few days to send you an account of them. I am going to be fortunate far beyond my expectation'.[57] Davy did not tell Hodgson what he had accomplished by this point, but four days later on 19 October Davy informed him that gases undergoing combustion would not pass through small tubes.[58] At the end of the month, in his 'sketch', Davy confirmed that fire-damp was an hydro-carbon and had determined the circumstances under which it could be ignited noting that gas '*will not explode* in a *small* tube, the diameter of which is less than the 8[th] of an inch'.[59]

He used this principle to develop his first three lamps during the last two weeks of October. The first type of that lamp that Davy invented was what he named the Safe Lamp. In this a candle burnt the air necessary for combustion which was admitted by small tubes at the base and likewise the products of combustion were taken away in small tubes. The original of this remains in the Collections of the Royal Institution and a modified version was illustrated in Davy's published paper (Figure 4). In the other two types of lamp the small air inlet tubes were replaced a small pair of bellows or a piston to pass the air into the lamp. Within these lamps, in the presence of fire-damp, the flame would burn more quickly thus rapidly exhausting the oxygen which could not come in fast enough because of the constricted tubes and hence the flame would automatically extinguish itself.

So confident was he of the outcome of his work that during the last full week of October Davy announced his discoveries at a meeting of a rather obscure group called the London Chemical Club on 25 October.[60] Two days later, apparently, he told patron Banks what he had achieved.[61] Unfortunately, neither that letter, nor an account of the London Chemical Club meeting, have been found. However, Banks's reply of 30 October, congratulating Davy 'on defending Society from a Tremendous Scourge of humanity', does survive. Somewhat self-centredly Banks commented how Davy's work would boost the reputation of the Royal Society and that he would direct that Davy's paper should be read at the first meeting of the Society in the new season.[62]

The same day as Banks's letter, Davy wrote to Gray owing him 'the first notice of the progress of my experiments' which had been 'successful far beyond my expectations'.[63] What this meant was that although Davy had told already told Banks and others in

TEXT	WRITER	REFERENCE	FIGURE REFERENCE
Sketch	In Davy's hand In Faraday's hand	RI MS F8, tipped in between pp.313 and 313 NRO SANT/BEQ/18/11/13, pp.183-5	No figures
Draft 1	In Davy's hand	RI MS HD 11, pp.31-68	Five figures on pp.107-9
Draft 2	In Faraday's hand	RS MS PT 10.1bis	Five figures on pp.19-21 as in draft **1**
Draft 3	In Faraday's hand with substantial alterations by Davy	RI MS HD 11, pp.71-98	Five figures on pp.111-3 (1 and 2 significantly different from those in draft **2**)
Draft 4	In Faraday's hand	RS MS PT 10.1	Four figures in RS MS PT 73.57 engraved in RI MS HD 11, p.115
Published 1	Printed	*Philosophical Magazine*, 1815, **46**: 444-58.	Ten figures opposite p.456
Published 2	Printed	*Philosophical Transactions*, 1816, **106**: 1-22	Ten figures opposite p.22. Manuscripts of figure 1-8 in Faraday's hand in RS MS PT 73.55 and 9-10 in RS MS PT 73.56

Fig. 3. Sources, in chronological order, for tracing the development of Davy's first paper.

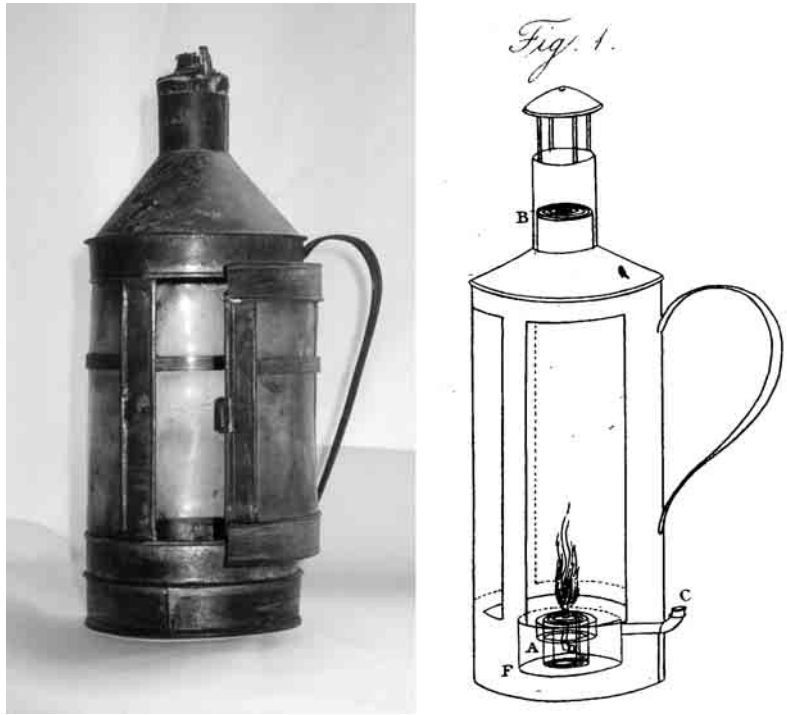


Fig. 4. (a) Davy's first Safe Lamp as retained in the Collections of the Royal Institution and (b) as illustrated in *Philosophical Transactions*, 106 (1816), opposite p. 22.

London, he enclosed to Gray a copy of the 'sketch' of his results[64] (which he had probably not sent to Banks) adding that he would shortly be sending his paper with the apparatus to the Sunderland Society. The same day he also sent another copy of the 'sketch', in Faraday's hand, to Hodgson.[65] Five days later Davy's discoveries were announced by the lawyer Charles Butler (1750–1832) at a ceremony laying the foundation stone of the London Institution in Finsbury Circus.[66]

Davy continued work on developing the lamp into November. But, as Banks had directed, a paper by him on this subject had been put down to be read at the Royal Society on 9 November. Thus Davy worked on developing the lamp whilst simultaneously writing his paper. The first draft of Davy's paper followed closely the structure of the 'sketch' he had sent to Gray and to Hodgson.

The first draft of the paper included drawings of the modifications of the lamp that Davy had made in early November following his initial 'sketch'. In the first type of lamp he changed the chimney into a bulb shaped aperture. Davy drew this lamp (Figure 5a) which is also retained in the Collections of the Royal Institution (Figure 5b) and Faraday prepared a neat drawing for publication (Figure 5c). It is evident here, and in later instances, that there are significant differences in detail between these drawings and the now existing object. Those differences between Davy's and Faraday's drawings can be ascribed to the different purposes for which they were made, to Faraday's more general neatness and to his having

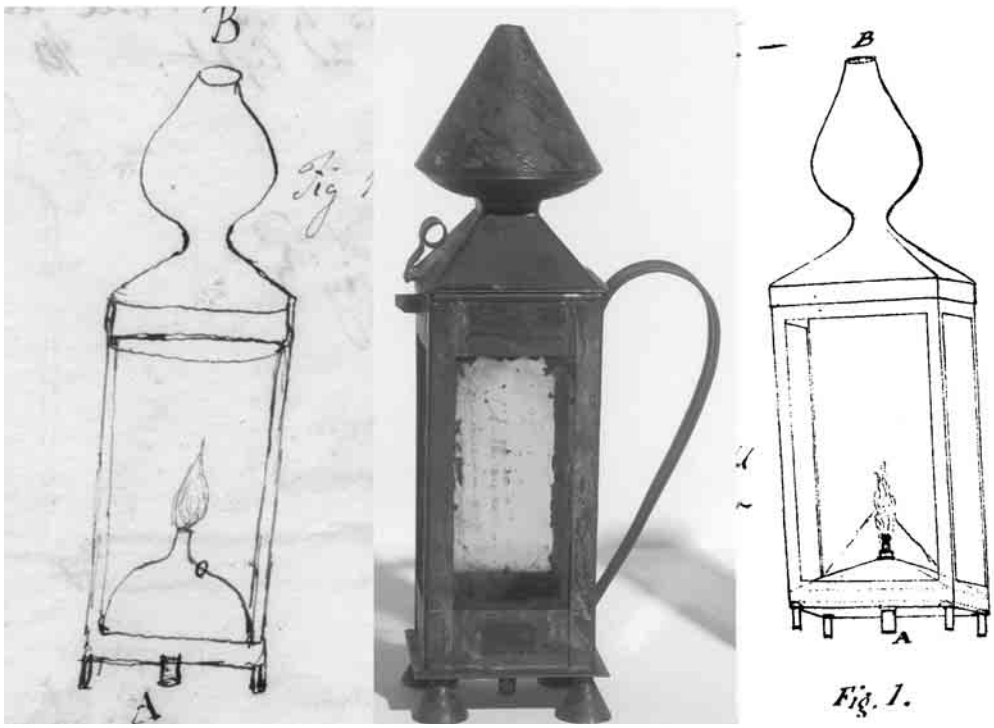


Fig. 5. (a) Davy's sketch of his second lamp (RI MS HD 11, p. 107), (b) as retained in the Collections of the Royal Institution and (c) as drawn by Faraday (RS MS PT 10.1bis, p. 19).

been taught to draw by the painter John James Masquierer (1778–1855). The differences between the drawings and the object suggest that when Davy was working with the lamps he would modify them, rather than make a new lamp from scratch.

In the first draft of his paper Davy introduced an ingenious idea, not in evidence in his 'sketch' at the end of October, to extinguish the flame. This was what he called his valve lamp which came in two forms. In the first the valve inside the chimney was located at the end of a bimetallic spring of steel and brass riveted together (Figure 6).[67] Unfortunately Davy did not say how many rivets were used, and as this part of the lamp has not survived, I have not been able to count them. When the inside of the lamp became too hot, the spring would expand thus moving the valve which closed the exhaust. In the second type of valve lamp the spring when it expanded in the chimney pulled a wire which closed a valve in the air intake (Figure 7); in both cases the flame would be quickly extinguished. The other two lamps that Davy proposed in this draft of the paper were new modifications of the bellows (Figure 8) and piston (Figure 9) lamps both having a novel metal 'S' shaped chimney (Figure 10). None of these designs were ever published, but they were probably the lamps that were described and displayed at the Royal Society in Somerset House when his paper was read on 9 November 1815[68] and shown in Banks's library in Soho Square in mid November;[69] some were, however, described briefly in an appendix to the published paper.[70]

The third draft of the paper, again in Faraday's hand, but with substantial alterations by Davy was presumably written after 9 November. Like the second draft, read to the Royal Society, this contained five illustrations of which the final three were virtually identical with the second draft (Figure 11). However, the first two figures (of the original safety lamp and the first form of the valve lamp (Figure 12)) were significantly different from the earlier versions in three main respects. First instead of the single air inlet there were now six, each a minimum of 1½ inches in length.[71] Second, the oil lamp was attached by a sling to the chimney so that when the lamp was opened by lifting the chimney up, it would be easy to refuel and also replace the wick. Finally there was a liquid seal at the top to make the lamp completely air tight apart from the air inlets and the chimney. The bottom part of this lamp is still in the Collections of the Royal Institution, although I am sorry to say that until early 2004 it was displayed upside-down!

FROM PROTOTYPE TO PRACTICAL LAMP

Davy's immediate problem was now concerned with turning his prototype lamps into something that could be used and tested practically in a coal mine. He complained to Gray that it is 'impossible to conceive the difficulty of getting any thing made in London which is not in the common routine of business',[72] a comment which presumably referred to Newman. However, it was really Davy who was delaying implementation since before the paper was sent off, he had a complete rethink about what he was going to describe. Out from the third draft went the descriptions and illustrations of all but the first lamp. The other lamps were described briefly in an appendix with a note on the circumstances in which it might be necessary to use the valve lamp.[73] Instead he described only the Safe Lantern and got Faraday to draw it in its component parts which was much the same as the first drawing in the third draft (Figure 13). These illustrations were engraved as a plate (Figure 14) which is pretty good evidence that the Royal Society believed that the publication process was nearing completion.

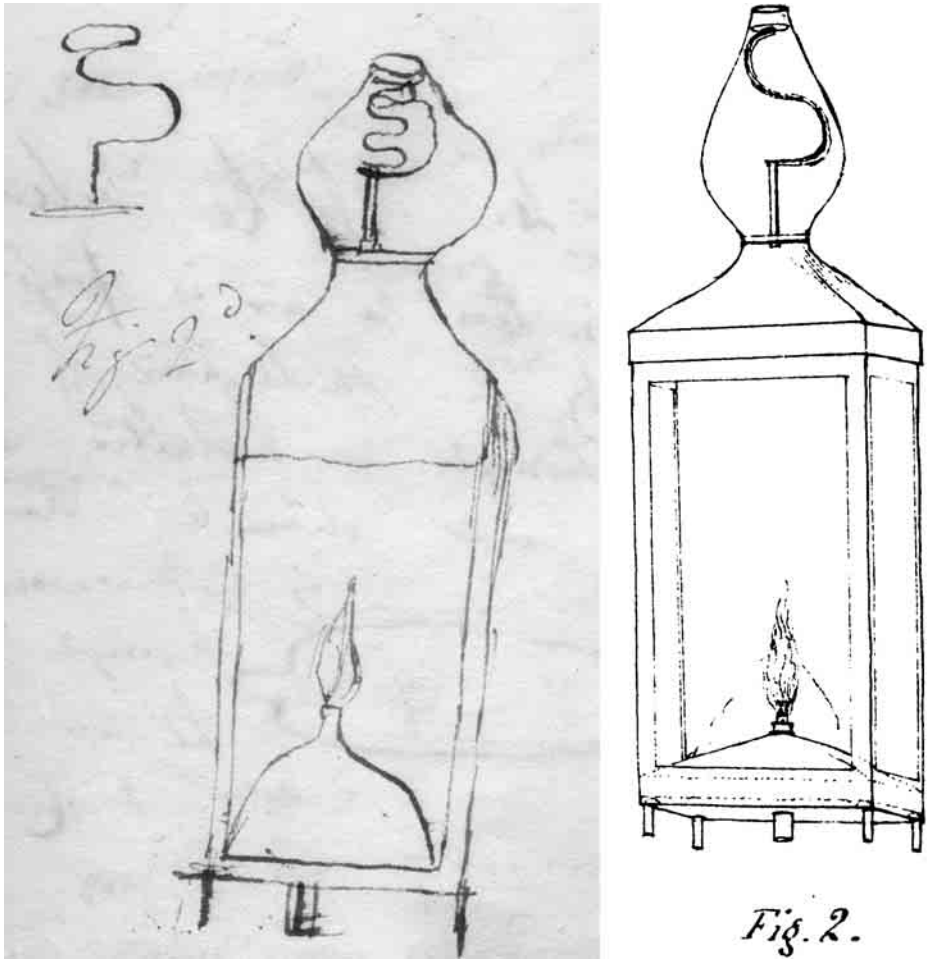


Fig. 6. Davy's lamp with the valve at the top. (a) Davy's sketch (RI MS HD 11, p. 107) and (b) as drawn by Faraday (RS MS PT 10.1bis, p. 19).

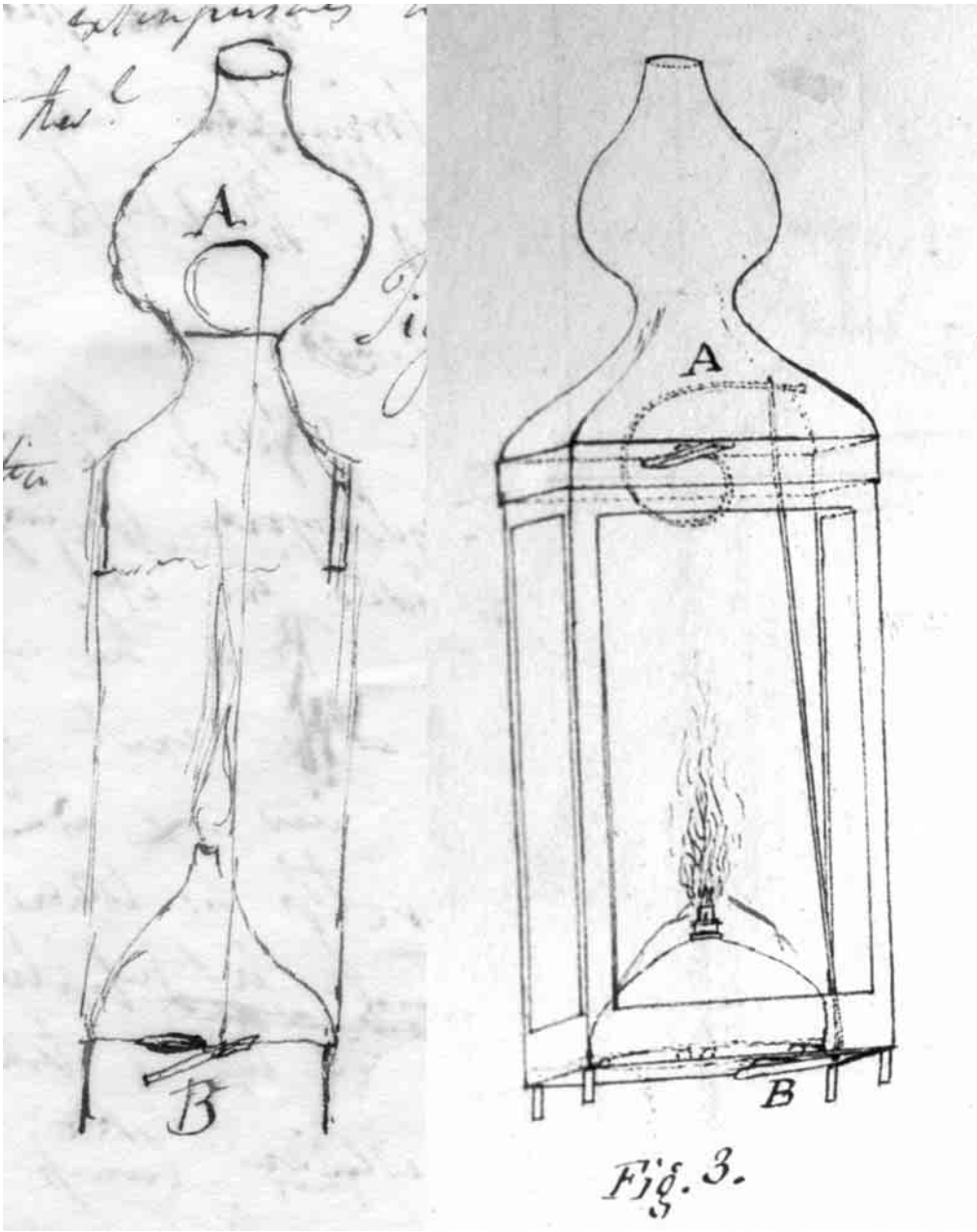


Fig. 7. Davy's lamp with the valve at the bottom. (a) Davy's sketch (RI MS HD 11, p.108) and (b) as drawn by Faraday (RS MS PT 10.1bis, p. 20).

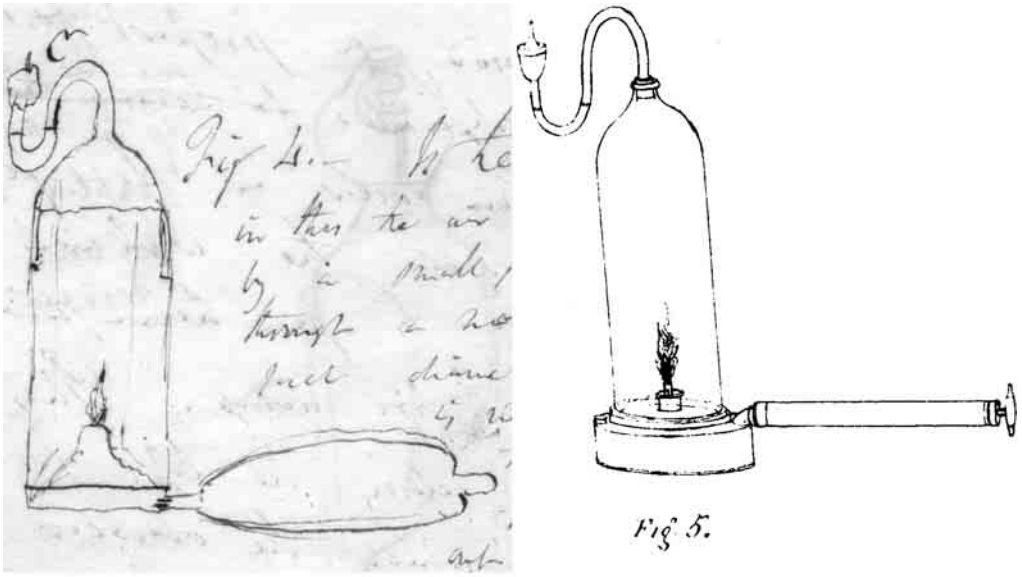


Fig. 8. Davy's bellows lamp. (a) Davy's sketch (RI MS HD 11, p. 108) and (b) as drawn by Faraday (RS MS PT 10.1bis, p. 20).

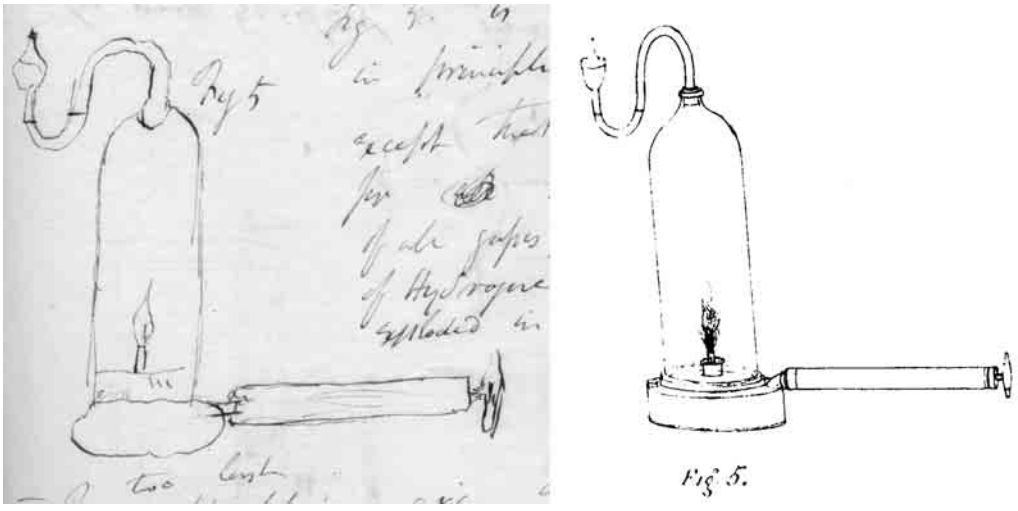


Fig. 9. Davy's piston lamp. (a) Davy's sketch (RI MS HD 11, p. 109) and (b) as drawn by Faraday (RS MS PT 10.1bis, p. 21).

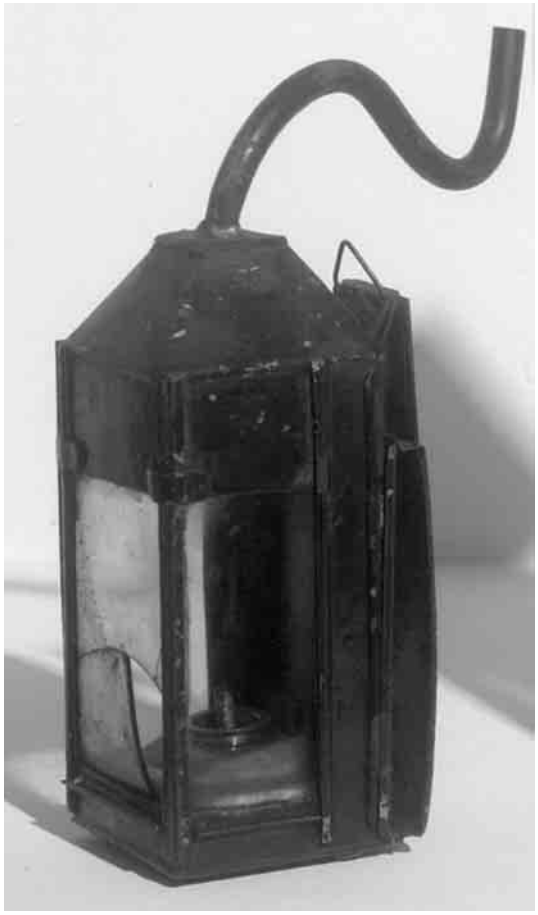


Fig. 10. Davy's lamp with 'S' shaped chimney in the Collections of the Royal Institution.

However, they were wrong. Davy, in the course of his continuing work, had had an even more fundamental rethink about the lamp which he probably completed around the middle of December and this whole plate was pulled. Instead of narrow bore pipes to admit air and carry away the products of combustion, Davy had found that concentric or rectangular canals made of metal, which he called fire sieves (Figure 15) would have the same effect. He illustrated all of this in considerable detail, Faraday, once again, doing the drawing.[74] Using this sieve, Davy showed it they could be used to make a glass chimney safe (Figure 16). Most significant, however, was his making an Argand lamp safe by having the concentric metallic sieves at the bottom, but placing on top a tin chimney with a metallic gauze insert to prevent the passage of flame (Figure 17). In this rather unceremonious manner, Davy introduced the use of gauze into safety lamps. Quite how he discovered that he could use gauze in this way is not known, but he soon began to exploit it. He realised that gauze could be used for the inlet as well as for chimney of a lamp and he also showed how a candle lamp could be protected by gauze (Figure 18). (Although with the wax dripping onto the gauze below, I am not sure how practical this would have been.) In the appendix to his published paper, entirely rewritten from the fourth draft, and much shorter, Davy

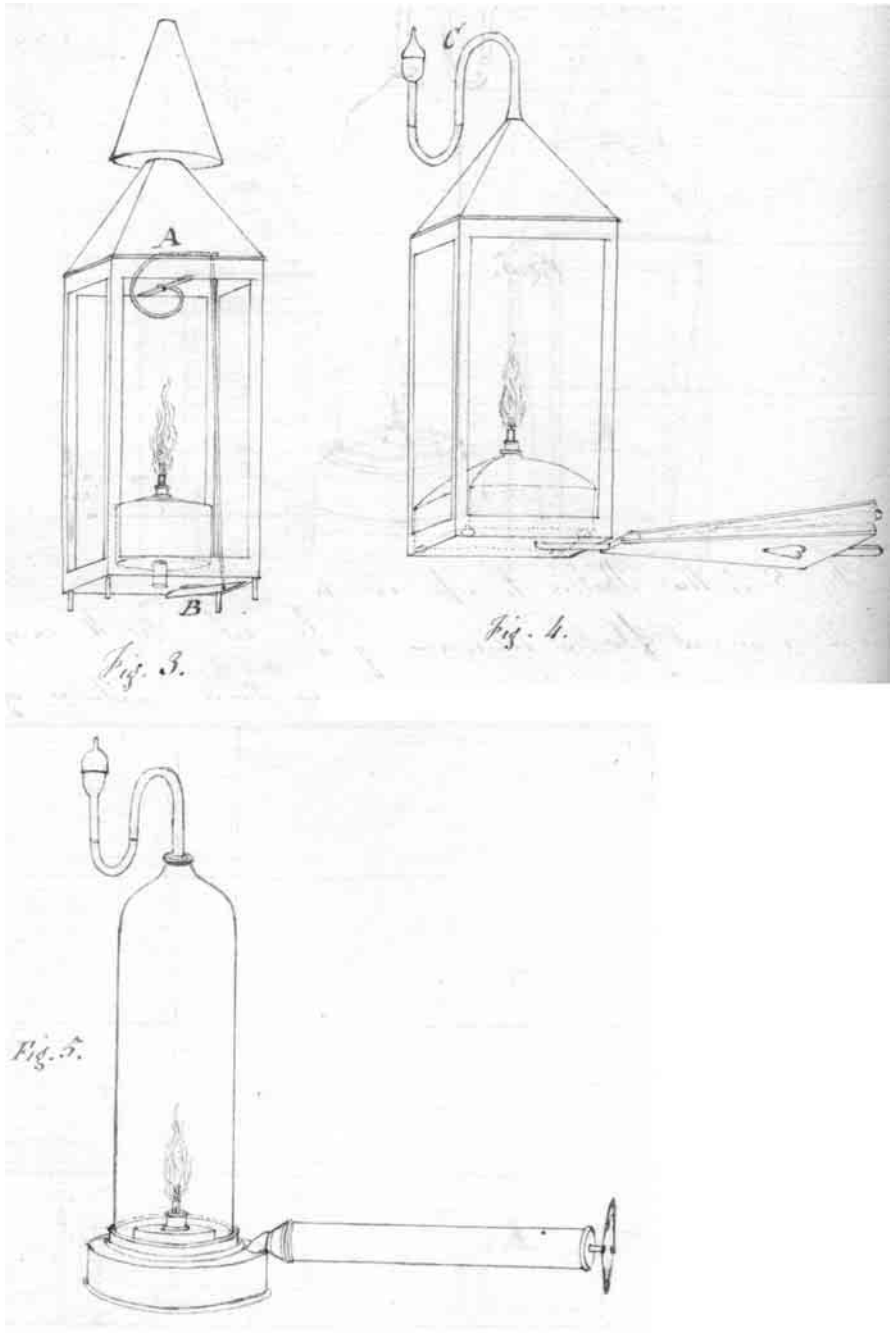


Fig. 11. Drawings by Faraday of Davy's lamps from the third draft of his paper (RI MS HD 11, pp. 112, 112, 113). Note similarities with figures 7, 8 and 9.

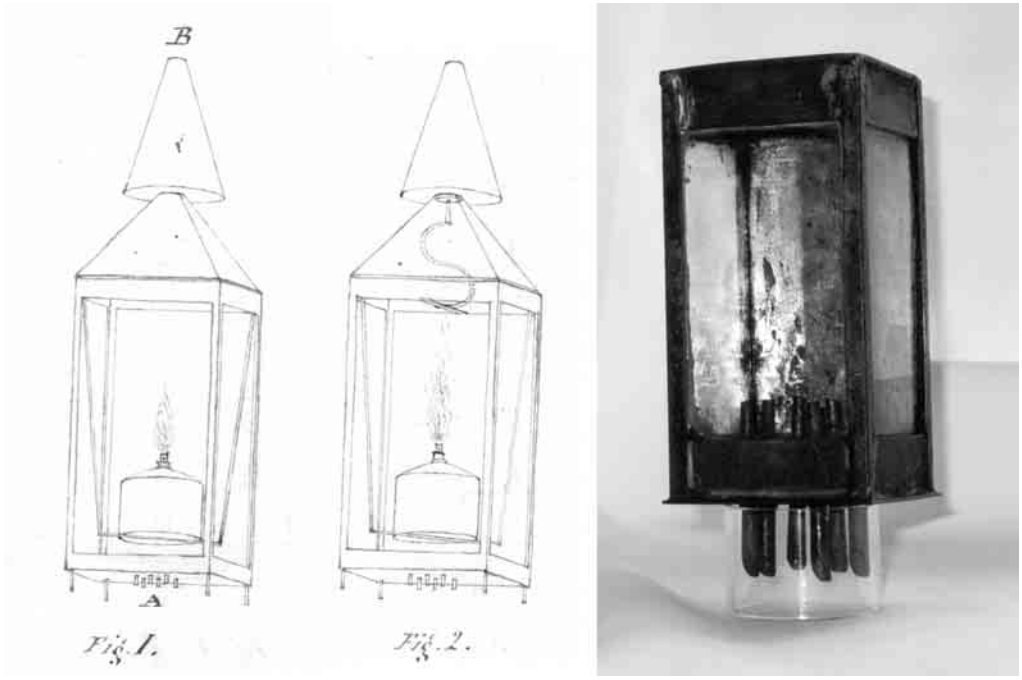


Fig. 12. Davy's lamps with 1½ inch intakes. (a) the Safe Lamp, (b) the valve lamp (both drawn by Faraday in RI MS HD 11, p. 111) and (c) the bottom half of the lamp in the Collections of the Royal Institution.

commented that 'I have little doubt but that windows of fine metallic gauze may be used for giving light in lanterns, with perfect security'.[75] Davy had thus invented devices which had the dual function of both providing light and detecting the presence of fire-damp.

Judging by Davy's track record over the reworking of his paper, there seems to me every reason to think that he would have wanted to continue work on the line of enquiry promised by the use of gauze and to add those results to his paper. However, then, as now, publishers of journals like deadlines to be met and the copy date was now at hand. Davy's paper was finally published in the December issue of the *Philosophical Magazine*, edited by Alexander Tilloch (1759–1825) who also edited the London evening paper *The Star*. Davy's paper in the *Philosophical Magazine* included a note that the Royal Society had waived its usual restriction that papers for the *Philosophical Transactions* could not be published earlier elsewhere.[76] The *Philosophical Magazine* was published at the end of each month and it is for this reason that I have dated the completion of this last spurt of Davy's work on the lamp to mid December. There is, however, some evidence that the last two illustrations (Figure 18) were added slightly afterwards, since the original drawings, in Faraday's hand, are on a separate piece of paper from the others and that sheet also contains the captions in a mixture of Davy's and Faraday's hands[77] which the other sheet does not.[78]

Davy continued to work on the implications of using wire gauze during the last two weeks of December. At the beginning of this period he told Hodgson that '*Fine Wire Gauze* forms an explosion sieve & separates flame from air; & yet emits more light than horn'.[79] This passage suggests that Davy had gone beyond what was about to be published in the

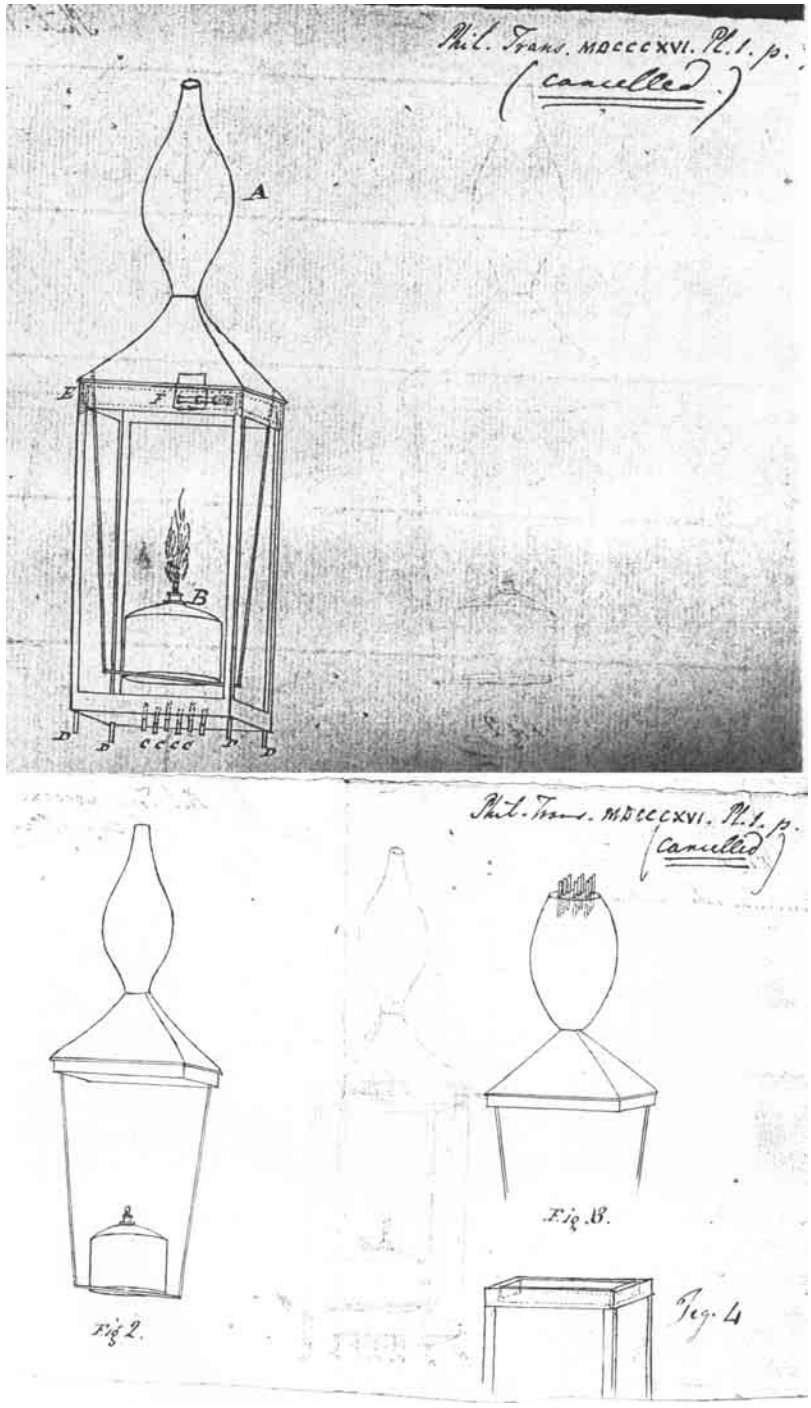


Fig. 13. Faraday's drawings for the fourth draft of Davy's paper. (RS MS PT 73.57). Note the word 'cancelled' on both drawings.

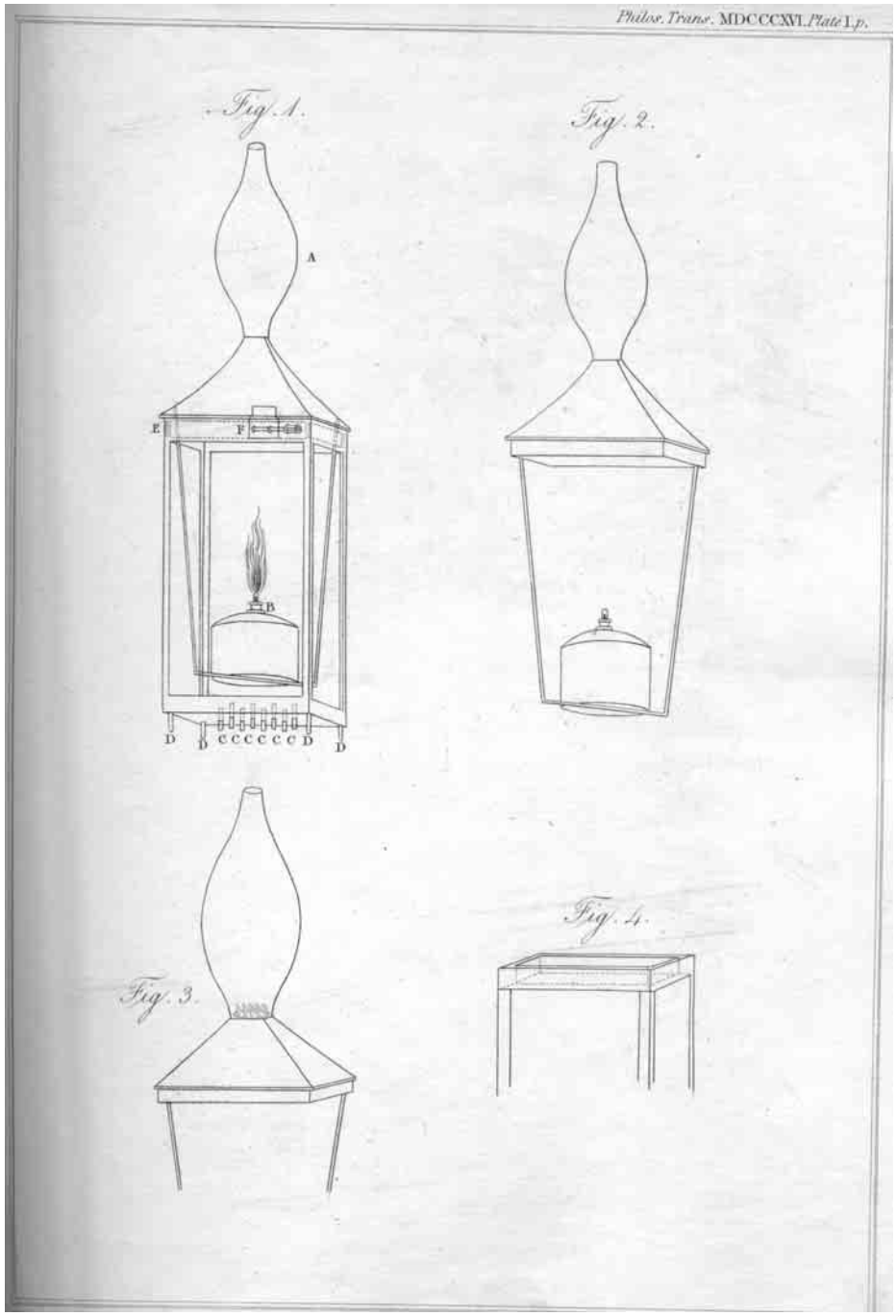


Fig. 14. First engraved plate for Davy's paper. This is in RI MS HD 11, p. 115 and is the only copy so far located.

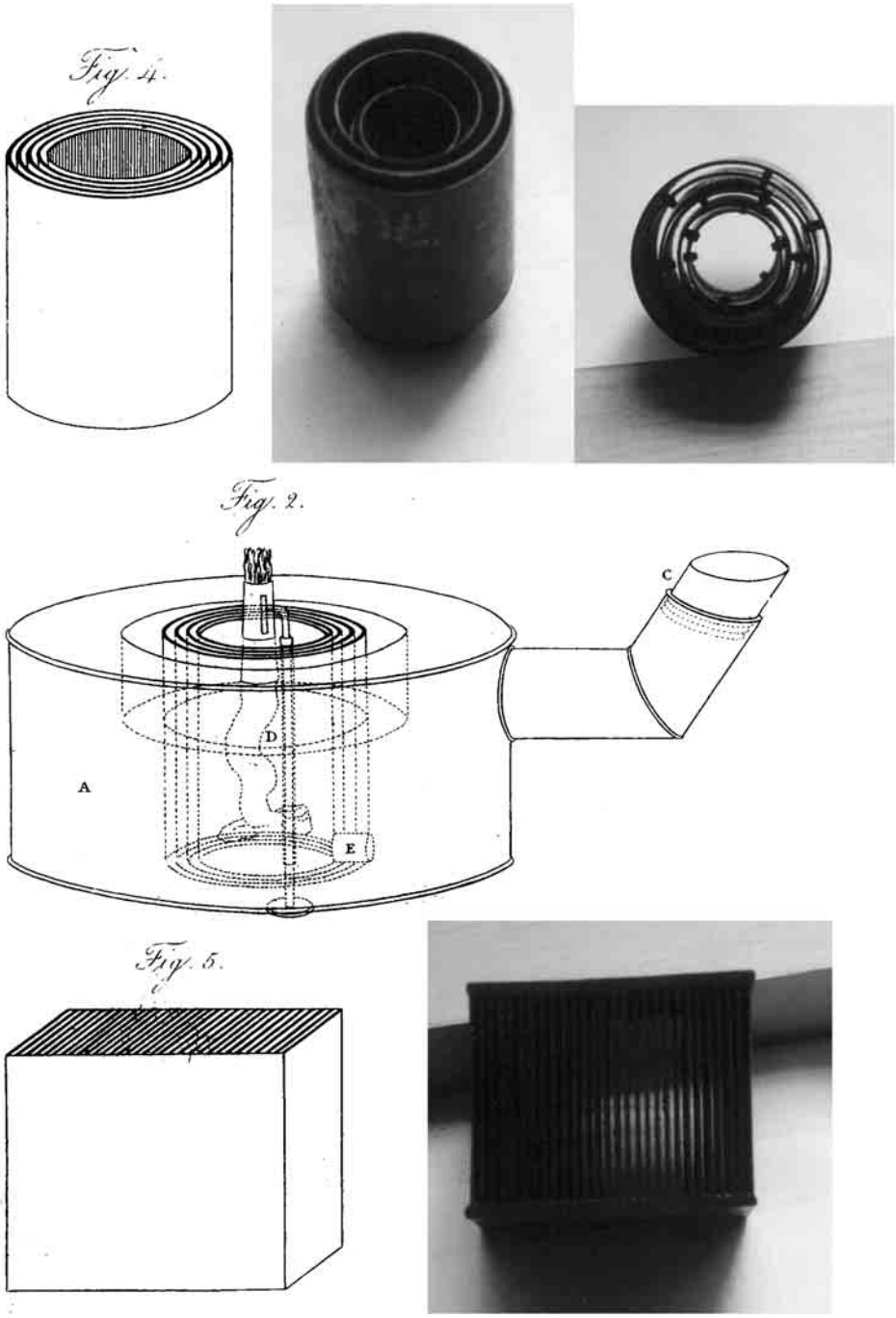
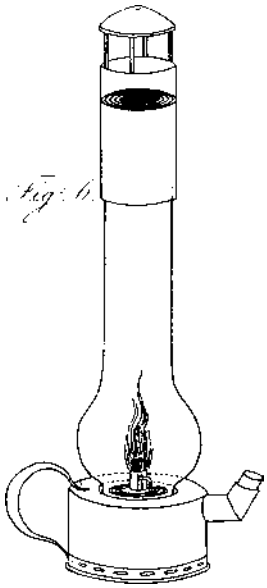


Fig. 15. (a) Drawing of Davy's circular fire sieve, (b, c) photographs of surviving example, (d) how the sieve was inserted in the base of a lamp (see also Figure 3b), (e) Davy's rectangular fire sieve, (f) photograph of surviving example. All illustrations from *Philosophical Transactions*, 106 (1816), opposite p. 22 and objects from the Collections of the Royal Institution.



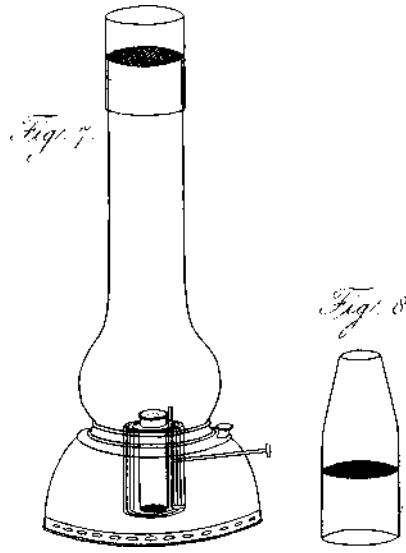


Fig. 16 (above left). Glass lamp rendered safe by use of a concentric fire sieve in chimney. From *Philosophical Transactions*, 106(1816), opposite p. 22.

Fig. 17 (above right). Davy's method of protecting an Argand Lamp by using a chimney with a metallic gauze insert (detail). From *Philosophical Transactions*, 106 (1816), opposite p. 22.

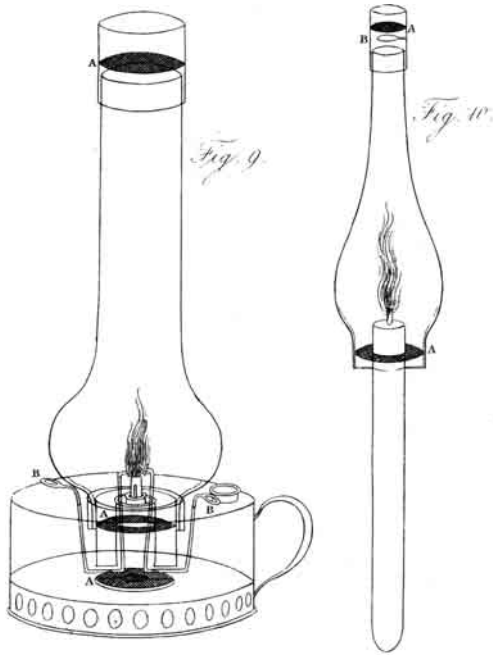


Fig. 18. Davy's method of using gauze to protect (a) an ordinary lamp and (b) a candle lamp. From *Philosophical Transactions*, 106 (1816), opposite p. 22.

Philosophical Magazine, but it is not clear how far beyond. Two days later, however, it is clear that had gone a bit further when he ensured that his work was reported in Tilloch's *Star*: 'He is able in consequence of this discovery to make all common lamps or lanterns safe for the miners by covering their *air apertures* with *metallic gauze*'.[80] By 29 December, when he again wrote to Hodgson, Davy had realised that all one needed was the gauze: 'When a candle or lamp is enclosed in a wire gauze cylinder & introduced into an explosive mixture the flame of the wick is extinguished but the mixed gas burns steadily within the wire gauze vessel. [. . .] I can confine this destructive element flame like a bird in a cage'.[81] At the bottom of the page Davy sketched the earliest existing image of what we now know as a Davy lamp (Figure 19). Three days later he told Gray that he had 'made very simple and economical lanterns, and candle guards, which are not only absolutely safe, but which give light by means of the fire damp'.[82]

In a two page paper read to the Royal Society on 11 January 1816 (its first meeting since 21 December 1815), Davy announced that just by surrounding the flame with wire gauze he had invented an effective safety lamp.[83] The illustration (Figure 20) of this was added to the plate for his first paper in *Philosophical Transactions*; it was not in the *Philosophical Magazine* plate. It was clearly too late to revise the first paper and one assumes that the Royal Society would have been unhappy with altering a text of a paper which had already been published earlier with permission. However, this second paper was published in *Philosophical Transactions* immediately after the first. Furthermore, Davy was permitted by the Royal Society to also publish his first paper as a pamphlet,[84] dedicated to the Bishop of Durham, at the front of which was what he called an 'Advertisement' which contained a description of the gauze lamp. The plate that was published in this pamphlet was identical to that which would be published in the *Philosophical Transactions*. Davy dated this 'Advertisement' 31 December 1815 and it was published during January 1816 as it was noticed in that month's *Philosophical Magazine*[85] and reviewed in the February issue of the *Edinburgh Review* as an example of Baconian science.[86]

ON-SITE TESTING

At the beginning of 1816 Davy sent five lamps, his original safe lamp, three of his gauze lamps and a gauze cylinder to surround a miner's candle, for testing in the North East.[87] Two of the gauze lamps, looking suitably battered from use, are now in the National Museum of Science and Industry (Figure 21).[88] On 9 January, with these lamps in hand, Hodgson descended into Hebburn Colliery aided by Dunn, who drew one of them (Figure 22), and other workers to test them.[89] Hodgson repeated the process on 17 January with Buddle and Dunn and wrote Davy an account of the success of these tests which was published in the first issue of the new *Journal of Science and the Arts*, edited by Davy's successor as Professor of Chemistry at the Royal Institution, William Thomas Brande (1788–1866).[90]

On 25 January 1816, a third paper by Davy was read to the Royal Society in which he reported, presumably using Hodgson's letter, that his lamps had been tried with success in two coal mines near Newcastle.[91] This success was reported in the short account of the meeting published in the January issue of the *Philosophical Magazine*.[92] Buddle was clearly enormously impressed with the lamps and in the ensuing months introduced them into use in the collieries for which he was responsible and, as he told Davy at the beginning of June, 'they have answered to my entire satisfaction'.[93]

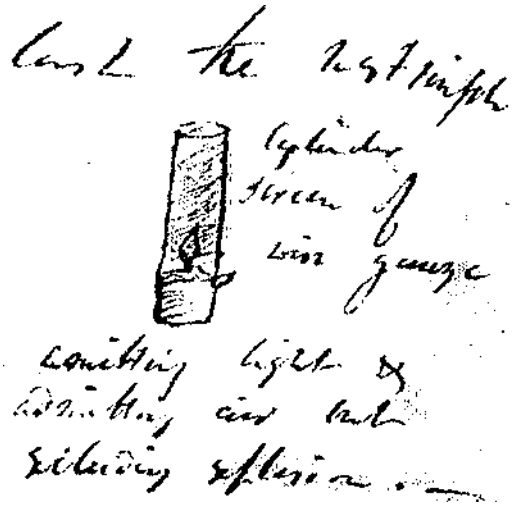


Fig. 19. Earliest known sketch by Davy of a gauze lamp. From NRO SANT/BEQ/18/11/13, p. 265.

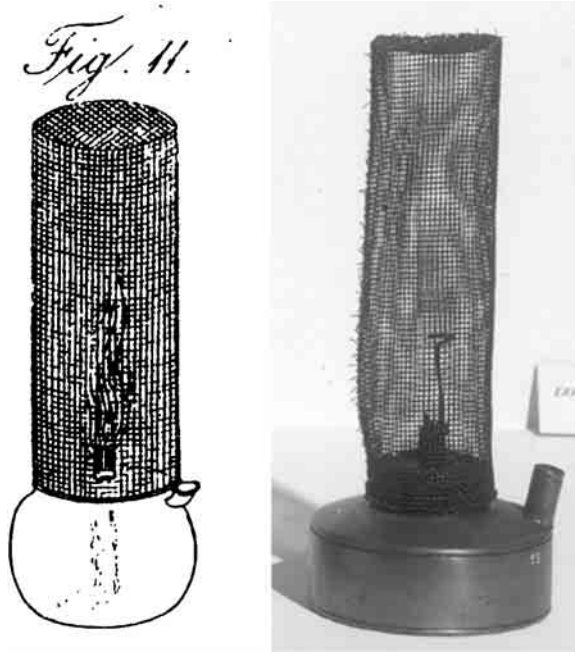


Fig. 20. Illustration of Davy's gauze lamp (from *Philosophical Transactions*, 106 (1816), opposite p. 22) and the original lamp (from the Collections of the Royal Institution).

Fig. 21. Davy's gauze lamps tested in Hebburn Colliery on 9 January 1816. (NMSI Inv 1857–208).

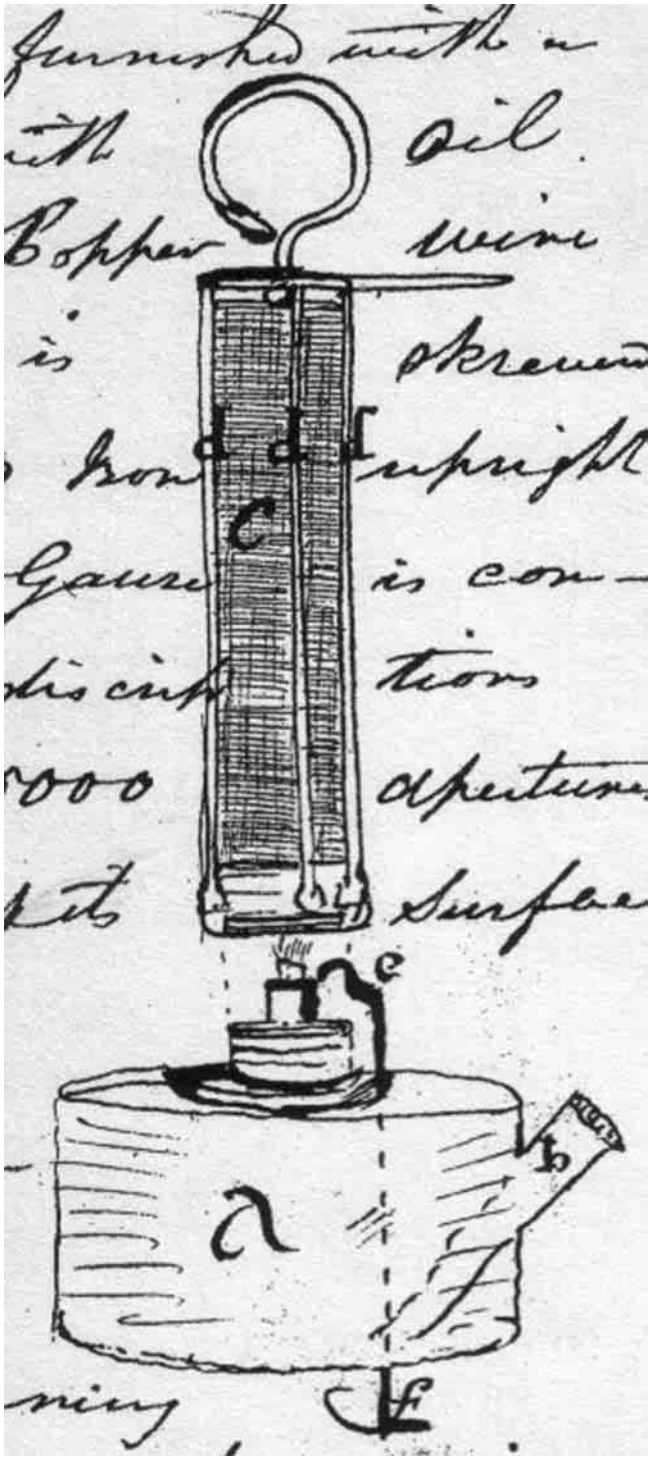


Fig. 22. Matthias Dunn's drawing of a Davy gauze lamp tested at Hebburn Colliery on 9 January 1816. (From NEOAMB MS 1997–202, p. 24).

WAS IT SCIENCE?

Davy had thus provided a workable solution to a serious practical problem. In what sense does this story bear out Faraday's assertion that this was an instance for Bacon's spirit to behold? To what extent was this discovery made according to Baconian methodological precepts, or indeed, more problematically, in what sense was it made in a scientific manner at all? So far as the former is concerned, there is no evidence that Davy went around collecting large numbers of observations and then somehow induced the lamp from them, although he later claimed that this is precisely what he did;[94] although to a different audience he ascribed it, in the only theological reference I have found in this episode, to 'Providence to make me an instrument for preserving the lives of some of my fellow-creatures'.[95]

From the account I have given here, Davy's work on the lamp was an evolutionary process which went through several identifiable stages in the laboratory once he had discovered the explosive property of the gas in narrow tubes. We should not be too surprised by Davy's non-Baconian approach, since very few, if any, discoveries, have been made in such a way although they were often presented as if they had been, as both Davy and Faraday tried to do in this instance. More interesting, to paraphrase J.V. Field's famous question, is what was scientific about the Davy lamp?[96] Aside from his understanding of the explosive properties of gas, what Davy did was to develop a technology which does not seem to have called for much scientific knowledge and in which the instrument maker Newman clearly played a key role. However, Davy's approach is an illustration of the playful, exploratory, way in which knowledge is constructed in the laboratory, as David Gooding has identified in the later electrical work of Faraday.[97] Finally, we need to remember that from this work Davy undertook a significant investigation into the nature of flame[98] including the first study of what Berzelius would later term the catalytic effect of heated platinum,[99] which illustrates, in this case, that science emerged from technology.

To investigate what, if anything, was scientific about the Davy lamp, we must now rewind the clock and look at the reaction to Davy's work. This will also cast light on both the pulling of the plate and the prior publication of Davy's paper in the *Philosophical Magazine* both of which were unusual events to say the least, the former having cost implications. Furthermore, examining the response to Davy's work will help to understand the structure and content of the paper as it was finally published. All this seems to reflect two things. First Davy's continuing active development of the lamp, as we have seen, and, second, the thorny issue of his priority in the invention.

This latter had arisen because, although Davy had explicitly told Gray that his letter of 30 October 1815 to him was a '*private* communication',[100] he had not mentioned this in his letter to Hodgson.[101] Thus Hodgson made copies of the 'sketch' for Buddle, Dunn and other professional men about 2 November.[102] This was given to them at a committee of the coal trade either that day or the following[103] and was read to a general meeting of the coal trade held on 10 November.[104] Davy, who was happy to announce his work in London to at least twenty gentlemen between 12 and 30 October 1815 as he later recollected,[105] seems, oddly one would think, to have been concerned about its public announcement in the North East and not in accord with Bacon's notion of collaborative research. By way of explanation Davy wrote that 'my only reason for wishing to keep back my results from the public eye was the conviction that they might be rendered more perfect, and this I have now fully proved'.[106] He heard about the November meeting in Newcastle quite quickly and received a letter from Hodgson apologising that his copy of the 'sketch' had been read. However, he

added that prior to the reading he had already seen a notice of Davy's work in a newspaper,[107] presumably an account of Butler's address at the London Institution, reports of which were already circulating in the North East.[108]

THE STEPHENSON LAMP

At the meeting of the committee of the coal trade held on 2 or 3 November, Richard Lambert, the chief agent for the Killingworth Colliery owned by the Brandlings, mentioned that George Stephenson, the engineer for that colliery, had already been using a lamp there for the same purpose as Davy's lamp.[109] Stephenson, working closely with the 20-year-old Nicholas Wood (1795–1865)[110] with whom he shared the expense,[111] had, as early as August 1815, been investigating ways of lighting mines safely.[112] He had developed an idea for a lamp during September and ordered it to be constructed by M.W. Hogg, a tinman of the Side, Newcastle. According to Stephenson it took Hogg took several weeks to execute the order,[113] while Hogg said 'it was at least a fortnight'.[114] However, the lamp was delivered on 21 October and tested the same day in Killingworth.[115] It is worth noting that this was the tenth anniversary of the Battle of Trafalgar, which presumably accounts for the precision with which the date of this first test was recollected. There might also have been some idea about conquering nature that day; one of his colleagues later reported of that day that 'Stephenson would try the lamp *confiding* in its safety'[116] which was the word that Horatio, Viscount Nelson (1758–1805), had originally used in his famous signal.

As with Davy's lamps, Stephenson's underwent an evolutionary process, but in the mine. In Stephenson's first conical lamp a glass cone was placed in a tin casing, with a flap that could be opened or closed to control the light (Figure 23).[117] (There is a problem of representation here, namely that this lamp, as with Stephenson's first, was initially conical in form but he later illustrated it as cylindrical.) The products of combustion were exhausted through small apertures at the top of the casing, while a central tube at the bottom, surrounded by a concentric ring for the wick, allowed air in. The control for the air inlet was a slider in the base. The test in Killingworth colliery was reasonably successful, in that there was no explosion, but it was found that the lamp went out if it was moved too quickly.[118] By varying the size of the aperture using the slider Stephenson found, as did Davy, that flame would not pass through narrow tubes. This gave Stephenson the idea for his second lamp where the single air inlet was replaced with three narrow tubes (Figure 24). This was constructed by another Newcastle tinman, David Matthews of Middle Street,[119] and tested successfully on 4 November.[120] It was shown to Lambert on the 17th[121] and to Robert William Brandling (c. 1774–1848) on the 24th.[122] On the basis of the successful trial, Stephenson ordered, around 19 or 20 November, a third lamp from the Newcastle plumber Robert Watson of High Bridge,[123] which was tested on 30 November (Figure 25).[124] Surrounding the glass was a tin case with small apertures at the top and bottom to allow the intake of air and the emission of exhaust. Larger holes on the sides permitted the light to pass.

CLAIM AND COUNTER CLAIM

On 10 December 1815, just over a month after Davy's paper had been read to the Royal Society, the Newcastle botanist Nathaniel John Winch (1768–1838) signing himself 'N',[125] wrote to the *Philosophical Magazine* reporting on developments in the North East. He

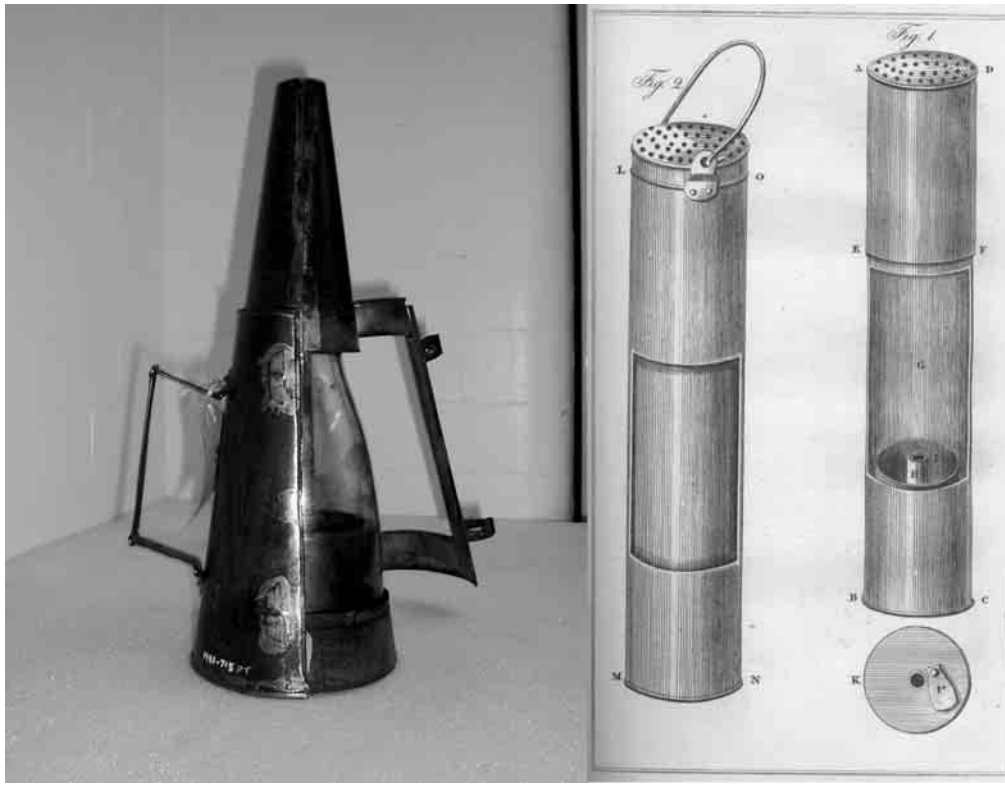


Fig. 23. Stephenson's first lamp (a) in the Collections of the Royal Institution and (b) as illustrated in *Report upon the Claims of Mr. George Stephenson, relative to the Invention of His Safety Lamp* (Newcastle, 1817), opposite p. 26.

began with an account of the 5 December meeting of the Newcastle Literary and Philosophical Society. There a paper by John Murray (c. 1785–1851) on the safe lamp had been read, Clanny had shown his lamp as had R.W. Brandling and, lastly, the final version of Stephenson's lamp had been displayed and tested (Figure 26).[126] Winch described this latter in some detail. It was essentially a modification of Stephenson's third lamp and its shape no doubt prompted *The Newcastle Chronicle* to describe it as resembling a wine decanter.[127] Winch sent a drawing of the lamp to the *Philosophical Magazine* which was included on the same plate as Davy's illustrations (Figure 27). Winch was at pains to say that though this lamp was similar to Davy's, it had not been 'pirated' from him. He added 'Davy's discovery flowed from science judiciously applied, Stephenson's discovery appears to have resulted from trials made below ground; for, though an excellent mechanic and acute man, he is unacquainted with the science of chemistry'.[128] Thus was set up, from the beginning, the dynamic for a priority dispute between knight and worker, chemist and engineer, savant and artisan, theory and practice, metropolis and province, although, as we shall, see there was a deep intra-regional dimension to the dispute.

As news of Davy's Royal Society paper circulated in the North East at the end of November and beginning of December, the press began to take a strong interest. The *Tyne*

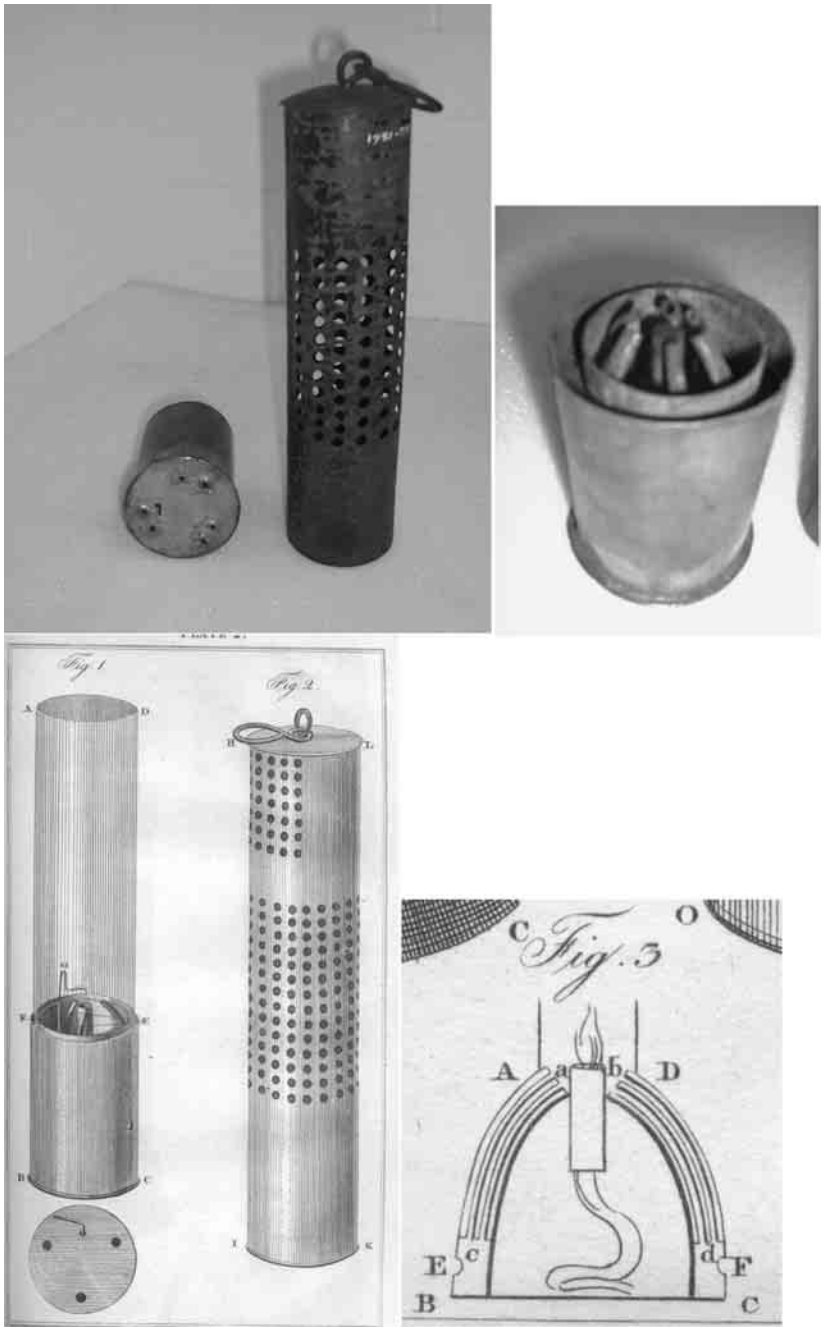


Fig. 24. Stephenson's second lamp (a) with detail (b) of inlet tubes in the Collections of the Royal Institution and (c, d) as illustrated in *Report upon the Claims of Mr. George Stephenson, relative to the Invention of His Safety Lamp* (Newcastle, 1817), opposite pp. [27] and [28] respectively.

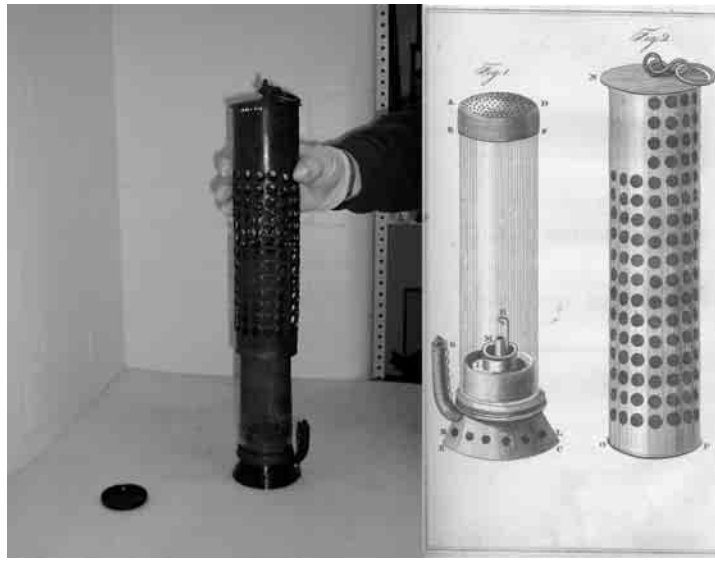


Fig. 25. Stephenson's third lamp (a) in the Collections of the Royal Institution and (b) as illustrated in *Report upon the Claims of Mr. George Stephenson, relative to the Invention of His Safety Lamp* (Newcastle, 1817), opposite p. [28].

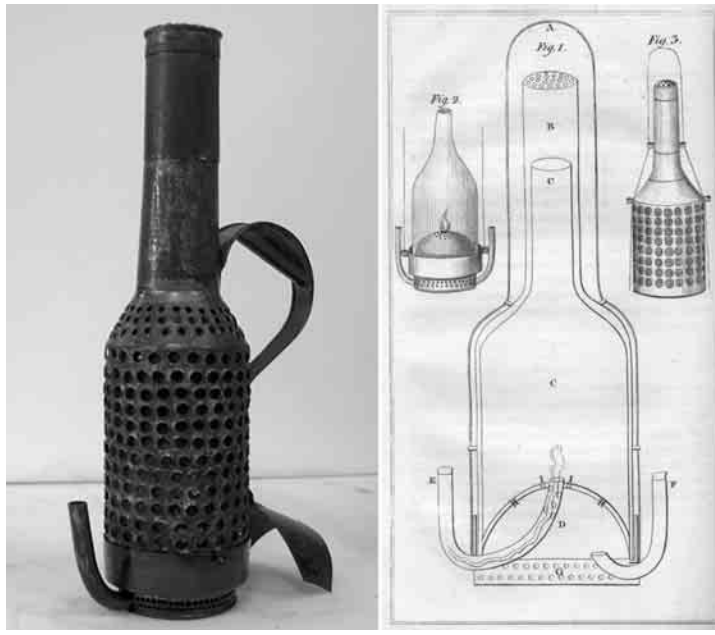


Fig. 26. Stephenson's fourth lamp (a) in the Collections of the Royal Institution and (b) as illustrated in *Report upon the Claims of Mr. George Stephenson, relative to the Invention of His Safety Lamp* (Newcastle, 1817), opposite p. 25.

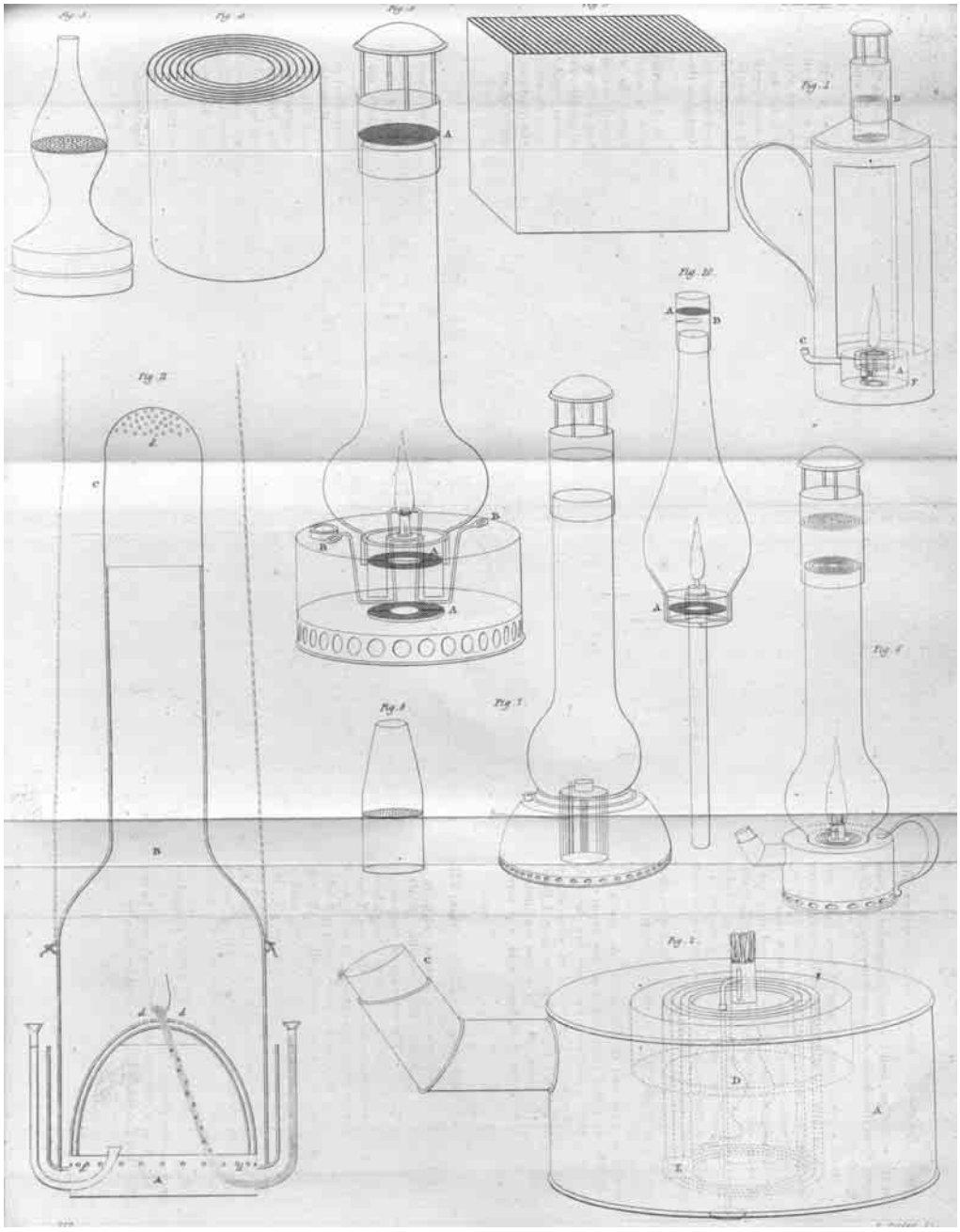


Fig. 27. Plate from *Philosophical Magazine*, 46 (1815), opposite p. 456 showing Stephenson's fourth lamp (bottom left) with the illustrations for Davy's paper.

Mercury mentioned Clanny's lamp[129] while the *Newcastle Chronicle* referred to the lamp used in Killingworth Colliery, but did not mention Stephenson by name.[130] It was not Stephenson, however, but Clanny who caused Davy's first problems. The *Tyne Mercury* of 5 December 1815 carried a letter from the London based lawyer Joseph H.H. Holmes (d. 1831) who had family near Sunderland. This letter noted that when Davy had visited Sunderland, Clanny had lent him one of his lamps for the whole day, and, furthermore, that Davy had not mentioned Clanny in his paper and that he, Holmes, wished, 'to publish to the world the unexpected and unhandsome manner in which Sir H. Davy has attempted to snatch the honor from Dr. Clanny'.[131] The reports of Davy's work that had been published by the end of November did not, indeed, refer to Clanny.[132] Davy, writing to Gray on 13 December, was highly indignant about this libel as he put it. He wrote that he had mentioned Clanny's lamp in his paper, indeed since it was published in the *Philosophical Transactions*[133] it would have been hard for him not to have done so. Davy asserted to Gray that his lamp had 'no one principle in common with that of Dr. Clanny. He forces in his air through water by bellows'.[134] Davy's bellows lamp, which he had mentioned in his 'sketch' (of which Clanny was presumably aware) did have much in common with Clanny's lamp. This may possibly account for Davy dropping all reference to his bellows lamp (and indeed the piston lamp) in the published text of his paper. Furthermore, the mid December date for this letter meshes well with what can be deduced about the development of Davy's work on the lamp. Davy was further annoyed when on 31 May 1816 the Society of Arts awarded Clanny a silver medal for his safety lamp.[135] Davy severely criticised this award contemptuously referring to the Society as 'the Committee of Tradesmen from the Strand'.[136]

Since the Sunderland Society had highlighted the issue as to how mines could be safely illuminated, it should not come as too much of a surprise that there were quite a number of proposals made at roughly the same time, from a variety of sources, as to designs for safe lamps. The priority controversy covered both the function of the lamps and the methods by which they carried out that function. Clanny and Stephenson, for example, undoubtedly developed lamps which were in many respects similar to Davy's earlier designs and would have performed the same function satisfactorily. Davy's gauze lamp was original to him, there being no evidence so far produced that anyone else had proposed the use of gauze and Davy and his supporters concentrated on this aspect of his design. Stephenson on the other hand thought that the 'use of the wire gauze is certainly a happy application of a beautiful manufacture to a very useful purpose, but I confess I cannot consider it in any other light than as a variation in construction'[137] — in other words the dispute centred on the question of how big was a hole. Thus, as so often when studying priority disputes, the issues that are involved centre on the selection of the parameters to be discussed, but with neither side accepting the validity of the other's selection.

However, some contemporaries did recognise a difference. Winch, still pseudonymously signing himself 'N', who had earlier pointed out the work of Stephenson, wrote again to the *Philosophical Magazine* in mid February to comment on the Davy gauze lamps that had been used at Wallsend and Hebburn collieries and which had been put on display at a meeting of the Newcastle Literary and Philosophical Society on 6 February 1816. Winch commented that the merits of the Davy lamps 'appear to be still greater than those of Mr. Stephenson'.[138]

Throughout 1816 Davy received congratulations and support for his work. In March he visited Newcastle, where, on the 18th, he was formally thanked for his invention by some

of the mine owners.[139] At the same meeting the coal trade awarded Stephenson a hundred guineas 'for your ingenuity in the invention of a safe lamp' as Buddle put it.[140] These respective methods of gratitude doubtless reflected the coal owners' perception of the class differences between the knighted savant Davy and the practical engineer Stephenson, although the *Newcastle Courant* did hope that some mark of national distinction would be conferred on Davy.[141] In April Murray tested Davy's gauze lamp and wrote to the *Philosophical Magazine* 'I am happy in adding my complete conviction of the perfect safety of this invaluable discovery'.[142] In August and September Davy was again in the North East, primarily for the shooting it would seem,[143] but he did go down the Wallsend mine to see his lamp at work.[144]

Davy's triumph, as he explicitly saw it,[145] was bound to incur the displeasure of those who supported Stephenson's claims, especially as a general vend (a collection of money from coal production) for a presentation of a service of plate to Davy was being proposed at the same time as he was in the area. R.W. Brandling wrote to the Secretary of the mine owners on 22 August to say that he thought Stephenson was the inventor of the safety lamp and enclosing a chronology of Stephenson's work. He added that he wanted to establish who had made the discovery,[146] but this intervention did not prevent the mine owners agreeing at the end of the month to raise the necessary funds for Davy.[147] Nevertheless, at a meeting of the mine owners on 11 October, Brandling proposed that an investigation should be made as to whether Davy or Stephenson had invented the safety lamp. This motion was defeated.[148] The following week the *Durham County Advertiser* carried a letter from Stephenson denying that he had had any knowledge of Davy's work while he was doing his own and enclosing Brandling's August letter and his own chronology.[149] This was sufficient to derail the vend and Buddle proposed instead, explicitly because of Brandling's 'unpleasantness', that it should be a voluntary subscription instead which, by the end of October, had raised £971. 5*s*.[150]

Davy was staying at Bath at this time and his response was to engage the support of one of the major mine owners of the North East, the 24-year-old John George Lambton (1792–1840). A radical Whig, Lambton was later First Earl of Durham and a disastrous Governor General of Canada. He had known Davy since he was a boy of six when he was a pupil of Beddoes's in Bristol — he had been sent there by his mother following the death of his father.[151] In 1812 the annual income that Lambton derived from his mines was nearly £80,000;[152] to put that into context the Royal Institution building in Mayfair cost £4850 in 1799.[153] At the end of October Davy wrote to Lambton to say that he had never heard of Stephenson's work until six weeks after his paper had been published.[154] The most charitable interpretation of this ambiguous statement is that by publication Davy meant the reading of his paper to the Royal Society on 9 November 1815 which, as we have seen, did not include his gauze lamp. If this was what Davy intended to convey, then it means that he was willing to admit that he had heard about Stephenson's work on or about 21 December 1815, in other words just after he had found the properties of gauze. However, on 18 December 1815, Tilloch in *The Star* had published an account of Stephenson's lamp taken from a Newcastle paper, presumably the 9 December 1815 report of *The Newcastle Chronicle*. Tilloch must have told Davy of this since it is in the same article that the announcement of Davy's gauze lamp was first made, for which there could have been no source other than Davy.[155]

Davy must have been alarmed at the reports of Stephenson's lamp, which would almost certainly have also included Winch's detailed description of 10 December 1815 sent to

Tilloch for the *Philosophical Magazine*.[156] Whatever differences and similarities that might or might not be claimed in the details of the design between the lamps, it would be very hard to deny convincingly that Stephenson's lamps were very similar in operation to the earlier versions of Davy's lamp and, of course, the function was identical. Davy would have had no idea how far Stephenson might go before publication of his most recent discovery of fire resistant properties of gauze and therefore he had to act to establish his priority. If, and it is only an if, Davy thought in this way, it would explain his publication strategy from mid December 1815 as well as the structure and content of his paper as published. It would account for his obtaining permission from the Royal Society to publish the final text of his paper in the *Philosophical Magazine* immediately rather than to wait until March, at the earliest, before *Philosophical Transactions* was published.[157] It would explain his pulling the plate, since the paper would now emphasise the results of his most recent work up until mid December rather than concentrate on the lamps described at the Royal Society on 9 November 1815, which had the most similarities with Stephenson's lamps. But Davy did retain an account (and illustration, Figure 4b) in his paper of his first safe lamp since this could potentially be used to help establish his priority as to the scientific principle involved. Finally, such a defensive strategy would also explain why, after he had invented the gauze lamp, he also re-published his paper as a pamphlet, complete with illustration, with the 'Advertisement' describing his new lamp. The gauze lamp was clearly too late for inclusion in the *Philosophical Magazine*, but the pamphlet would ensure his priority for that lamp while the earliest priority he could claim would be guaranteed by the 18 December 1815 announcement in *The Star*, even though it was not noted as primary place for scientific publication.

Davy was clearly in a quandary about how best to deal with Stephenson and concluded his letter to Lambton by writing 'I hope you will not blame me for not taking any notice of the attacks of my enemies in the North. I have no desire to go out of my way to crush gnats that buzz at a distance, and do not bite me, or to quarrel with persons who shoot arrows at the moon'.[158] To have taken public notice of Stephenson would have invited comment on Davy's work; much better to remain silent in public and abuse him in private.

The decision, despite Brandling's views, to collect for a presentation of plate to Davy, ignited a furious controversy in the Newcastle press and elsewhere as well as causing the publication of a number of pro-Stephenson pamphlets. These included Stephenson's own account of his work on the lamp published in January 1817,[159] which led Davy to refer to his 'piracy' and to express irritation at Brandling's support.[160] Tilloch picked up the charge of piracy in the February 1817 issue of the *Philosophical Magazine* when he inserted a short, unsigned, article alleging that Stephenson had 'borrowed from what he had heard of Sir Humphry Davy's researches'.[161] This drew a denial from Stephenson published the following month stating briefly his position and hoping that Tilloch would acknowledge that he had 'hastily committed an act of great injustice'. However, Tilloch added a note after the letter outlining the chronology of events as he saw them and restating his view as to the independence or otherwise of Stephenson's work.[162] Many of the newspaper letters published between August 1816 and March 1817 were collected and published in a pro-Stephenson pamphlet.[163] This included a number of pseudonymous letters by authors signing themselves with names such as 'Aladdin'[164] — hence the reference to 'Davys magic lantern' in Faraday's lecture notes where he referred to the controversy as a 'disgraceful subject'.[165] At the same time in early 1817 the charge of piracy went the other way and the publication of Stephenson's pamphlet led to suggestions that Davy had heard of

Stephenson's work before his own. In mid January Buddle publicly denied that he had told Davy clandestinely about Stephenson's work.[166] Davy was put on the defensive and although I have found no direct evidence that he was aware of Stephenson's work before 18 December 1815, in a mid February 1817 letter to Hodgson Davy felt the need to deny strongly any prior knowledge. He provided Hodgson with details of his movements during September 1815 to show that though close to Durham, he was out of the coal district during that month. He added that for him to know of Stephenson's work 'there must have been a conspiracy between the Bishop of Durham, the High Sheriff, Mr Morritt & Mr Headlam to give me Mr G. Stevenson's discovery & deprive this poor man of his right'.[167] This controversy may explain why, uniquely for a major piece of work by Davy, there is hardly any documentation in his papers on the lamp. He (or his literary executors) may have had strong motives to ensure that there existed no documents which might cast doubt on Davy's version of events. What documents that have survived relating to Davy's work on the lamp did so because from an early point they were already in the possession of others — Hodgson, Faraday and the Royal Society.[168]

It is clear that there were two major factions among the North East mine owners, pro- and anti-Davy, which in large part, though not entirely, divided along Whig–Tory lines — or at least pro- and anti-Lambton. The Whigs following Lambton tended to support Davy while the Tories, following the Brandlings supported Stephenson. The strength of Davy's support is illustrated that by mid January 1817 the collection for his plate had risen to £1500,[169] and by mid March to £1600.[170] By the time the plate[171] was presented by Lambton to Davy at a dinner at the Queen's Head Newcastle on 11 October 1817,[172] a total of £2500 had been raised.[173] In his presentation speech Lambton referred to the service to humanity that Davy had performed adding that in the nearly two years of operation not a single failure had occurred. Furthermore, Lambton referred to the way in which the lamp had 'increased the value of an important branch of productive industry'.[174] In his response to the toast, Davy concentrated on the industrialisation of England and what he saw as the role of scientific invention referring explicitly to pottery, the steam engine and gas light. Echoing and extending the Banksian vision of the role of science in English society, Davy asserted that 'Science, Gentlemen, is of infinitely more importance to a state than may at first sight appear possible'.[175] He then proceeded, despite his earlier self-denying ordinance, to criticise those who had made 'mean attempts to impeach the originality of a discovery, given to them in the most disinterested manner' but he hoped that their motives 'had been prompted by ignorance rather than by malevolence, by misapprehension rather than by ingratitude'.[176] This attitude of Davy's fully accords with the view of his character expressed by Harriet Martineau (1802–1876), although they almost certainly never met. In her history of the 30 years' peace she wrote of Davy: 'Besides the degree of wildness which appears in all the evidence of his life and writings, there was an excessive egotism, a lack of magnanimity, an insufferable pride and vanity unlimited, which destroyed all pleasure on both sides in his intercourses with others than his flatterers'.[177]

Davy's non-too-subtle attack on the nameless Stephenson invited response. At a meeting held on 1 November chaired by the brother of R.W. Brandling, the former Tory MP for Newcastle Charles John Brandling (1769–1853), another group of mine owners acclaimed Stephenson as the inventor of the lamp.[178] They raised about 600 guineas for him[179] and appointed a committee to continue the collection. Shortly after the meeting Lambton wrote personally to R.W. Brandling to affirm his opinion that Davy was the inventor of the

lamp.[180] Buddle sent Davy the resolution by 5 November on which day Davy told him that it was not unexpected but still unpleasant. He added that he would consult with Banks and his friends at the Royal Institution and the Royal Society (who for his work on the lamp had awarded him the previous November its Rumford Medal for new discoveries on heat and light) before deciding what to do.[181] Davy seems to have gone into a towering rage, since, despite telling Lambton that he would not take any immediate action as he would observe the state of mourning due to the death on 6 November of the heir to the throne, Princess Charlotte (1796–1817),[182] he wrote to at least two of Stephenson's supporters, the Newcastle lawyer and Whig James Losh (1763–1833), whom Davy had known from his days in Bristol,[183] and John Bowes, 8th Earl of Strathmore (1769–1820). These letters were intemperate, unwise, unmeasured and unguarded, nicely illustrating Martineau's assessment of Davy's character. To Losh he wrote that he wished 'to know my enemies on this occasion, not from any feeling of fear, but because I would not connect the names of honourable men with those other persons whose conduct with respect to my exertions in their cause, will I think awake public indignation'.[184] Losh's restrained response was nevertheless to the point, replying that Davy's letter was 'written in a style of authority, to say the least of it, very unusual in the correspondence of gentlemen'.[185] The style and content of the correspondence with Strathmore was similar.[186]

Following these exchanges Davy and his mine owner supporters decided to take action. Davy persuaded the metropolitan elite of science to support his position against Stephenson. A formal document asserting Davy's position was issued from Banks's house on 20 November 1817, the day after the burial of Princess Charlotte. It was signed by Banks, by Thomas Young (1773–1829), Foreign Secretary of the Royal Society, by Brande, Secretary of the Royal Society, and by Davy's personal friends the chemists Wollaston and Charles Hatchett (1765–1847). The following day Davy sent this document to Lambton,[187] together with an exposé in which he rebutted in detail Stephenson's claims to priority. This was published in the *Tyne Mercury*[188] and *Newcastle Courant*.[189] On 26 November his faction of the mine owners, chaired by Lambton, met at the assembly rooms in Newcastle to again express their collective support for Davy.[190]

The response of Stephenson's supporters was to examine him under oath. This was the explicit response of the Stephenson Committee to the Royal Society resolution. They gathered evidence from Stephenson and others involved about his work on the lamp which was published as a report in late 1817.[191] Buddle told Lambton that Stephenson had apparently produced some new facts but as he put it 'Fortunately for the cause of truth Stephenson's *old facts* have been too long before the public, to allow *new ones* to take deep root'.[192] However, the opposition kept going and on 12 January 1818, a dinner for Stephenson, chaired by C.J. Brandling, was held in the Assembly Rooms. There Stephenson was presented with an appropriately engraved silver tankard (now in the Institution of Mechanical Engineers) which had been purchased out of the £1000 pounds raised for him together with the remaining sum.[193] Such a deep split in the views of the mine owners meant that the Newcastle Literary and Philosophical Society had to be seen to be even handed and this doubtless explains why the Society decided that both Davy and Stephenson should be nominated for election as Honorary Members simultaneously on 4 November and they were both duly elected on 2 December 1817.[194]

It is clear from all of this that Davy must have felt seriously concerned by the persistent claims of Stephenson and his supporters. In a letter to Paris, written when he was collecting

material for his biography, Buddle recalled a conversation he had with Davy probably in September 1816. Buddle had then suggested that Davy should have secured his invention with a patent. Davy reportedly replied 'I never thought of such a thing; my sole object was to serve the cause of humanity'.[195] In January 1817 Davy told Buddle that he had considered patenting one of the developments of his lamp 'not for the sake of gain but to prevent Persons guilty of such conduct as Mr Brandling from profiting by my labours without a fine which I would give to the poor. But I have resolved that their illiberality shall not alter my conduct'.[196] Less charitably, in both instances, one might suggest that with the claims of Stephenson and others being vocally aired, Davy might not have secured any patent which would have put an end to his claims. His reaction, perhaps even overreaction in case of the memorandum signed by Banks, Young, Brande, Hatchett and Wollaston, to the continuing claims does suggest a degree of uncertainty on Davy's part about his own claim to the invention. Much better not to put it to a legal test, but to claim the moral high ground of benefiting humanity.[197]

THE DAVY LAMP APPRAISED

The Davy lamp seems to have quite quickly penetrated into the collieries. In 1835 Buddle estimated that there were between 1000 and 1500 lamps in use in the North East mines with which he was involved.[198] Although priority disputes have unedifying aspects to them and are probably unpleasant and unenjoyable to those involved at the time, they do serve, as I have commented elsewhere,[199] to publicise very effectively new developments in science and technology. It was thus not only in England where the lamps penetrated quickly but also elsewhere in Europe; Davy gave advice to the miners in Flanders[200] while Czar Alexander I (1775–1825) presented him with a silver cup in recognition of his work which is still in the Collections of the Royal Institution.[201]

But did the lamp benefit humanity in the sort of way Davy and others hoped? Particularly posed by labour historians, this was a recurrent question in discussions of mining safety. Faulty lamps or faulty usage of lamps by the mineworkers were blamed for explosions including that at Haswell colliery, County Durham, which killed 95 men and boys in 1844 and for which Faraday and the geologist Charles Lyell (1797–1875) conducted the enquiry for the Home Office.[202] In 1873 Richard Fynes described the Davy lamp as 'the most deadly instrument ever devised in mining operations',[203] while in the early twentieth century Lawrence Hammond (1872–1949) and Barbara Hammond (1873–1961) were emphatic that 'the alleviations of science were turned to the miner's disadvantage'.[204]

The key point made by Lambton in his speech presenting Davy with his plate was that it allowed deep coal seams to be worked, which without the lamp 'never could have seen the light of day' as Buddle put it.[205] This point is borne out by the statistics for the expansion of coal production both in Britain and the North East. Although the proportion of British coal produced there gradually decreased, it was still over a fifth by mid century (Figure 28). Once the lamp had been introduced average annual deaths fell markedly, a trend which is best seen if the figures are averaged over five-year periods (Figure 29). The increase in the first half of the 1840s was probably due to ever deeper mining and, of course, included the Haswell explosion. When the data is calculated in terms of average annual deaths per million tons of coal produced (Figure 30), there was a steady long term decline from the 1820s onwards apart from the first half of the 1840s.[206] It should be pointed out that other

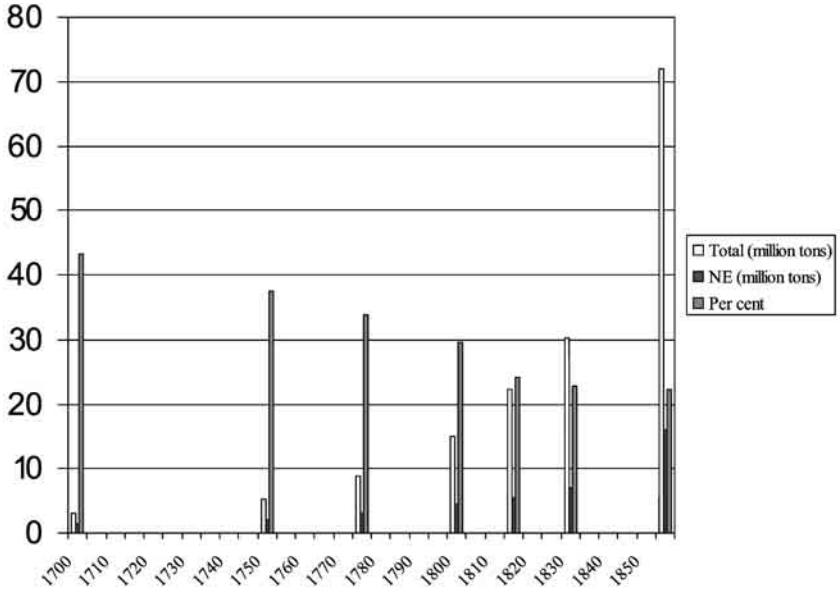


Fig. 28. British and North East Coal Production, 1700–1855. Sources: Michael W. Flinn and David Stoker, *The History of the British Coal Industry, Volume 2. 1700–1830: The Industrial Revolution* (Oxford, 1984), p. 26. Carol Jones, 'Coal, gas, and electricity', in *Atlas of British Social and Economic History since c. 1799*, ed. Rex Pope (London, 1989), pp. 68–95 (p. 71).

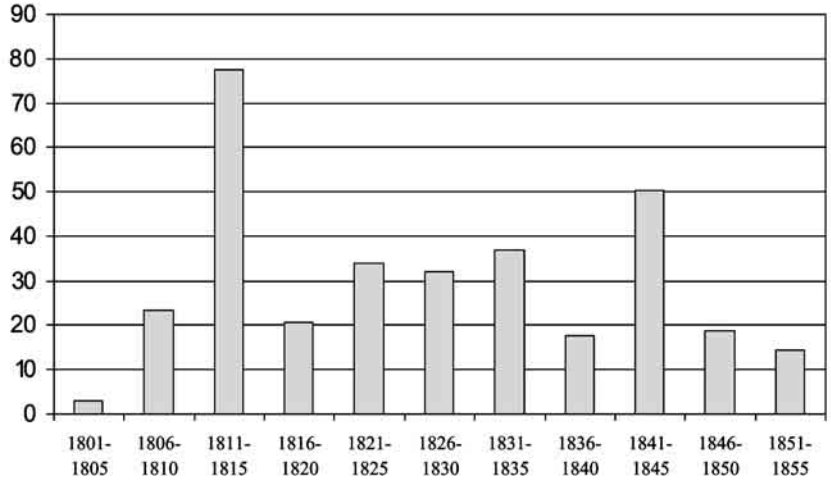


Fig. 29. Annual fatalities (from explosions only) in the North East averaged over five-year periods. Sources: John Sykes, *Local Records; or historical register of remarkable events which have occurred exclusively in the counties of Durham and Northumberland*, 2 vols (Newcastle, 1866). TWAS S.PAM/1/195–200. Buddle's evidence in 'Report from Select Committee on Accidents in Mines', *Parlimentary Papers*, 1835 (603), V, question 3003. NB. It is more than likely that there was some under-reporting in the first decade of the nineteenth century.

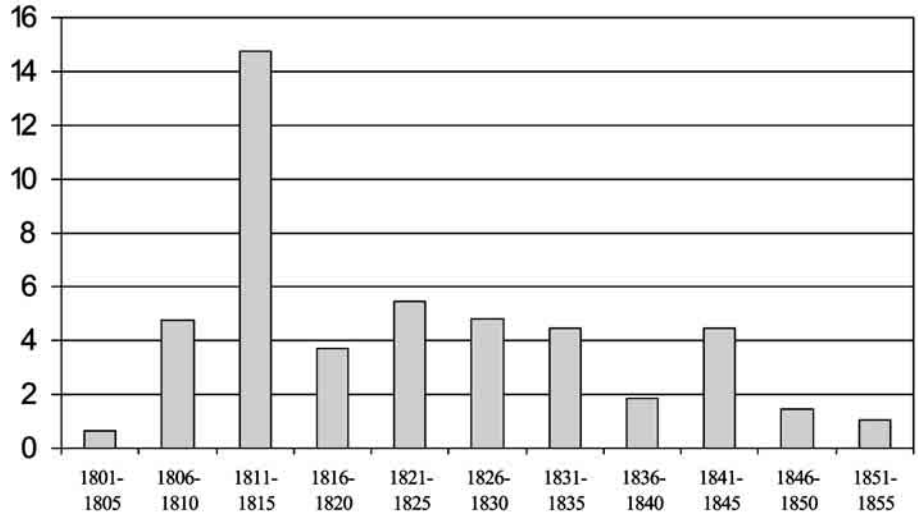


Fig. 30. Annual facilities in the North East Coal Field Period per Million Tons of Coal Produced averaged over five-year periods. Source: Combining interpolated data in Fig. 28 with data in Fig. 29.

factors, such as better ventilation, were probably also at play in producing this trend. The need for ventilation, which had been a concern of Faraday's for some time,[207] was a major issue in his and Lyell's report on the 1844 Haswell explosion[208] as was Faraday's discovery that coal dust was an explosive agent.[209] However, in the mid 1830s it was not clear that fatalities in mining explosions were decreasing and in 1835 the House of Commons established a Select Committee on Accidents in Mines. The Committee found that more people had been killed in North East mines in the years after 1815 than before, but ascribed the cause of this (without statistical analysis) to the increase of production.[210]

DAVY'S REWARD

Despite continuing claims for Stephenson's lamp, Davy emerged, with some exceptions, with virtually the entire credit for the invention of the miners' safety lamp. He was raised to the Baronetcy in 1818 as a result — as David Knight commented an empty honour for someone with no children.[211] The origins of the bias towards Davy can be found in nineteenth-century accounts of the lamp. The 1835 Select Committee discussed the claims of Clanny, Stephenson and Davy, but generally supported Davy's.[212] The Scottish natural philosopher James Forbes (1809–1868) in the 8th edition of the *Encyclopaedia Britannica* published in the 1850s gave most of the credit to Davy whilst being somewhat dismissive of Stephenson's claims[213] which drew a complaint from Robert Stephenson (1803–1859).[214] Fynes referred only to the Davy lamp,[215] while Robert Galloway in his 1898 *Annals of Coal Mining* regarded Stephenson's claims as 'altogether preposterous'.[216] As these examples suggest, most sources when discussing Davy and the lamp did and continue to mention Stephenson's work to some extent, but only very rarely is he given the whole credit.[217] The exceptions to the general praise of Davy are found in biographies of Stephenson, starting

with Samuel Smiles (1812–1904), where he is seen as a practical provincial man triumphing over the metropolitan elite.[218] However, there is a tendency in these texts to ignore the issue that Davy had very strong support in the North East and to portray the controversy simplistically as metropolis versus province.

Although Davy and Stephenson had based their development of the lamp by making precisely the same scientific discovery (albeit in the very different contexts of the laboratory and the mine) that flame will not pass through narrow tubes, the difference between them was that Davy was able to dress up his work in the rhetoric of Baconian philosophy, an option that was not available to Stephenson and his supporters. Baconian rhetorical strategies had been deployed successfully by Banks during his career in his efforts to show the English governing elite that science was a safe and useful subject. Davy was able to draw on Banks's success to demonstrate how science could be used practically by natural philosophers to control nature — a point made explicitly by Faraday in his lecture to the City Philosophical Society. Thus Davy, in addition to his personal powers of persuasion and networking, was also able to secure the support of the elite scientific community by making common ideological cause with the Banksian programme with his view of the scientific status of the lamp. Not only did this mean that Stephenson and his lamp were ignored, or in some cases vilified, by most commentators, it also meant that Davy was put in an extraordinary powerful position within the English scientific community by being seen as having made such a major discovery in a key industry. This doubtless contributed to his election as President of the Royal Society in November 1820 after a brief interregnum period when Wollaston held the office immediately following Banks's death.

Hence the miners' lamp and in particular Davy's quickly became and indeed remains, rightly or wrongly, a potent symbol of how scientific knowledge can be applied practically.[219] For instance the 20th International Congress of the History of Science held in Liège in 1997 used a later version of the lamp as its logo. The symbolism of the lamp has been used to support the link between science and technology in many contexts. This had its origin in the nineteenth century expressed through history (as we have seen), literature and art. The erstwhile son in law of the President of the Sunderland Society, George Gordon, 6th Lord Byron (1788–1824) referred to Davy and the lamp in the first canto of *Don Juan* published in 1819:

> This is the patent-age of new inventions
> For killing bodies, and for saving souls,
> All propagated with the best intentions;
> Sir Humphrey Davy's lantern, by which coals
> Are safely mined for in the mode he mentions,
> Tombuctoo travels, voyages to the Poles,
> Are ways to benefit mankind, as true,
> Perhaps, as shooting them at Waterloo.[220]

And, perhaps, the best known portrait of Davy painted by Thomas Lawrence (1769–1830) in 1821 shows him, as President of the Royal Society, alongside one of his lamps.[221] The statue of him placed on top of Burlington House in 1870 and that erected to him in his place of birth, Penzance, two years later, both portrayed him with the lamp.[222] The same sort of iconographical tradition did occur also with Stephenson. He was posthumously painted in 1857 explaining the lamp to his family and four years later one of the supporting figures to his statue in Newcastle was depicted holding his lamp.[223] But the iconography of Stephenson did not have the same general impact that Davy's enjoyed.

COPPER PROTECTION

The perception of Davy's enormous success with the lamp, especially in such a key industry, led to his being involved in a number of other projects where it was attempted to apply science for practical purposes. Following his election to the Presidency of the Royal Society Davy automatically became chair of the Board of Longitude. In this capacity he oversaw the unsuccessful programme to improve optical glass which involved Faraday in a considerable amount of unrewarding activity in the second half of the 1820s.[224] However, I want to conclude this paper by discussing Davy's development and application of an electro-chemical method to protect the copper bottoms of naval vessels from corrosion. As I have discussed this episode at length elsewhere,[225] I will only outline it briefly here to emphasise the structural similarities and dissimilarities between this project and the safety lamp. The comparison between Davy's work on copper and on the miners' safety lamp is instructive, not only by emphasising how difficult it was to apply scientific knowledge for practical purposes, but also by raising the question whether this happened in any meaningful way in either example. Furthermore, the comparison helps to emphasise the role played by other areas of society (business, the military, government, the media etc.) in shaping perceptions as to how knowledge generated in the laboratory was put into practice in the uncontrolled environment of what might be termed the real world.

In early 1823 Davy was asked by the Navy Board to find a way of preventing the corrosion of the copper bottoms of naval vessels.[226] This was an important issue since if the life of the copper could be extended then ships would have to be put in dry dock less frequently which would save cost, a very important consideration to the Admiralty at the time when post war retrenchment meant that its budget was being cut severely. Davy displayed the same lack of haste with this request as he had shown when Gray had invited him to see if anything could be done about preventing explosions in mines. Sporting activities took priority; he spent the summer of 1823 fishing in Ireland and Scotland.[227] There are thus two similarities, even at the very early stages of both projects, between the safety lamp and the protection of the copper sheeting. First, Davy was asked by an outside body to apply science to a practical problem and second that he initially displayed no especial sense of urgency.

As with his development of the lamp in the two months following his return to London in October 1815, Davy in October 1823 quickly set about investigating the problem of copper corrosion, research that continued into January 1824 by which time he had arrived at his electro-chemical solution. The entries in the Royal Institution laboratory notebooks on this work contain the only extended accounts of experimentation in his hand for this period of his life.[228] From these two examples one has to infer that Davy's pattern of work was after a period of thinking at leisure about a problem, to work it out really quite quickly in the laboratory.

Davy found experimentally in the laboratory, that if the electro-chemical polarity of the copper and sea-water was reversed by soldering zinc or cast iron on the copper, then it would stop corroding in sea water. This basic idea remained unchanged throughout the testing and deployment of the technology which contrasts with the lamp where there were significant changes of design in the laboratory, before it was tested in the mines. Davy protectors, as they were called, were tested for two months on some ships in Portsmouth Harbour and its apparent success there led it to being generally deployed. However, one effect of preventing corrosion was that barnacles, seaweed etc. could attach themselves to

the copper which thus reduced the steerage of the ships with the consequent disabling much of the Royal Navy during 1825. Thus Davy had failed disastrously to apply practically the cutting edge science of electro-chemistry, a science in which he had played such a major role in developing.

Unlike with the lamp, Davy did not make any preliminary announcements about the copper and indeed did not discuss his work anywhere else until his paper to the Royal Society was read on 22 January 1824.[229] Although, he did tell the Admiralty that he had solved the problem, he even kept them in the dark as to details.[230] He may have learnt from his experience with the lamp about the problems created by premature announcements, but it did not prevent his having, once again, to contend with the claims of a practical man. In this case the melter and refiner at the Royal Mint Robert Mushet (1782–1828), claimed to have invented, and indeed patented, a similar system of protection, although without any theoretical underpinning.[231] The Admiralty ignored Mushet in favour of Davy and from the start Mushet used the press to forward his method,[232] causing Faraday to refer to him scathingly as 'our friend of Fleet Street'.[233] The spectacular failure of electro-chemical protection doubtless rendered pointless any continuing controversy.

CONCLUSIONS

Despite the striking structural similarities that I have stressed about the way in which Davy approached the lamp and protecting copper, there is considerable irony in his work on applying science for practical purposes. Where little scientific knowledge was actually used, he scored a major technological success, in effect by a process of evolutionary design. Where novel scientific knowledge was a major component indeed the driving force behind the technology, the practical application was failure on a grand scale. It seems to me that the key issue in both the lamp and in electro-chemical protection was the matter of practical testing. Neither of the technologies were tested with anything approaching the rigour which later became commonplace. Indeed, it was worse than that. Because of the success of the lamp, Davy lured himself and others, especially the Admiralty, into believing the idea of the uniformity of nature. That is because a method, in this case the lamp, worked both in the laboratory and practically, it was taken for granted that in other cases where a method worked in the laboratory it too could be applied practically. The logic of this was that there was therefore little need for major on site testing of the electro-chemical protectors before full implementation.

Faraday was a participant in and a witness to both of these episodes and seems to have learnt from them, especially the latter. All the scientific advice that Faraday later provided was given at much greater length than anything Davy ever offered. Furthermore, in his advice Faraday was always at pains to stress the need for proper practical testing of science based technologies, especially those stemming from electricity, even if it took many years. It thus fell to Faraday to pick up the pieces left by Davy. Through his work for the Ordnance Office, Home Office, Trinity House, Admiralty and so on,[234] Faraday was able to contribute significantly to making apparent Davy's rhetoric in his Newcastle speech that science was indeed of infinite importance to the state. Faraday helped finally to realise the Baconian dream that 'knowledge itself is power' in a way that Davy did not quite achieve either at sea or in the mines.

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29. Davy to Faraday, 3 August 1815, James, op. cit. (16), letter 56.
30. Davy to Gray, 18 August 1815, Paris, op. cit. (18), pp. 309–10. For Gray's invitation see Gray to Buddle, 21 August 1815, DCRO NCB I/JB 577.
31. This meeting had also been arranged by Gray. See Gray to Hodgson, 21 August 1815, NRO SANT/BEQ/18/11/13, pp. 147–50.
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72. Davy to Gray, 14 November? 1815, Paris, op. cit. (18), pp. 314–15. Paris dated this letter, probably because of Davy's poor handwriting, as 14 December 1815, but the context and content suggests that it was written a month earlier.
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89. Dunn's report, dated that day, is in NEOAMB MS 1997–202, pp. 22–24; there is a copy in NRO 3410 FOR/1/13, pp. 72–73. See also Davy to Hodgson, 15 January 1816, NRO SANT/BEQ/18/11/13, pp. 291–94. Matthias Dunn, *An Historical, Geological, and Descriptive View of the Coal Trade of the North of England* (Newcastle, 1844), p. 30 incorrectly recollected that this happened on 1 January 1816 and Dunn, op. cit. (33), p. 187 repeated the error.

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101. Davy to Hodgson, 30 October 1815, NRO SANT/BEQ/18/11/13, p. 181.
102. He noted doing this on his copy of Davy to Hodgson, 30 October 1815, NRO SANT/BEQ/18/11/13, p. 193.
103. [Nathaniel Winch], 'On Safe-Lamps for Coal Mines; with a Description of the one invented by Mr. Stephenson, of Killingworth Colliery', *Philosophical Magazine*, vol. 46 (1815), pp. 458–60 (p. 459) gave 3 November 1815. Hodgson to Editor, 21 October 1816, *Newcastle Courant*, 26 October 1816, [p. 2a], wrote that his copy was read but on 2 November 1815.
104. Hodgson's annotations on the copy of Davy to Hodgson, 30 October 1815, NRO SANT/BEQ/18/11/13, p. 193. Hodgson to Editor, 21 October 1816, *Newcastle Courant*, 26 October 1816, [p. 2a] gave 6 November 1815. This was acknowledged to be an error and changed to 10 November 1815 in Hodgson to Editor, 28 January 1817, *Newcastle Courant*, 1 February 1817, [p. 2a–b].
105. Davy to Hodgson, 4 March 1817, NRO SANT/BEQ/18/11/13, p. 567.
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107. This letter, which has not been found, was alluded to in Davy to Gray, 14 November? 1815, Paris, op. cit. (18), pp. 314–15. However, Paris inserted an ellipsis where Hodgson's name was; that identification is confirmed by the catalogue entry when this letter was auctioned by Phillips on 11 June 1992, lot 57.
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109. [Winch], op. cit. (103), p. 459.
110. Nicholas Wood, 'Address on the two late eminent engineers, the Messrs. Stephenson, father and son', *Transactions of the North of England Institute of Mining Engineers*, vol. 8 (1860), pp. 33–84 (pp. 43–47). For Wood's contemporary notes on his tests see NRO 610, f.30–31.
111. Stephenson to Brandling, 23 December 1816, IME IMS 129/5.
112. Stephenson's evidence in *Report upon the Claims of Mr. George Stephenson, relative to the Invention of His Safety Lamp* (Newcastle, 1817), p. 14.
113. Stephenson to Brandling, 23 December 1816, IME IMS 129/5.
114. Hogg's evidence in *Report*, op. cit. (112), p. 21.
115. Stephenson's evidence in *Report*, op. cit. (112), p. 15. John Moody certificate, 23 December 1816, IME IMS 129/3. Stephenson's evidence in 'Report from Select Committee on Accidents in Mines', *Parliamentary Papers*, 1835 (603) V, question 1537. This and the other lamps by Stephenson are now in the possession of the Royal Institution. Quite how all of them came to be so, is not clear. Davy had been sent the Stephenson lamp that had been taken down Hebburn

Colliery on 9 January 1816 with his lamps (Dunn report, NEOAMB MS 1997–202, pp. 22–24 which he drew on p. 23) and had inspected it when he was in the North East in March 1816. By early 1817 it was in his possession in London and described it as 'not a safe lamp', Davy to Buddle, 23 January 1817, BL MS add 33963, f.114. He received another lamp by early 1818 which he said was 'altogether unsafe'. Davy to Hodgson, 17 January 1818, NRO SANT/BEQ/18/11/13, pp. 519–26.

116. Moody's evidence in *Report*, op. cit. (112), p. 18. My emphasis.
117. Stephenson's evidence in *Report*, op. cit. (112), p. 14.
118. Stephenson's evidence in *Report*, op. cit. (112), pp. 15, 17.
119. Stephenson to Brandling, 23 December 1816, IME IMS 129/5.
120. Stephenson's evidence in *Report*, op. cit. (112), p. 16. Stephenson's evidence in 'Report from Select Committee on Accidents in Mines', *Parliamentary Papers*, 1835 (603) V, question 1538. This demonstration is referred to in Wood's contemporary notes on his tests see NRO 610, f.30. Stephenson to Brandling, 23 December 1816, IME IMS 129/5 does not mention the precise date.
121. Wood's contemporary notes in NRO 610, f.31 mention this demonstration.
122. George Stephenson, *A description of the safety lamp, invented by George Stephenson, and now in use in the Killingworth Colliery. To which is added, an account of the lamp constructed by Sir Humphrey Davy* (London, 1817), p. 10. This demonstration is referred to in Wood's contemporary notes on his tests see NRO 610, f.30.
123. Smith's evidence in *Report*, op. cit. (112), p. 24. The details are not mentioned in Stephenson to Brandling, 23 December 1816, IME IMS 129/5.
124. Stephenson, op. cit. (122), p. 10.
125. The identification is made due to a marginal annotation to volume 6 of 'Reports, Papers & Catalogues of the Lit & Phil Society of Newcastle-upon-Tyne, 1814–16', NLPS MS.
126. [Winch], op. cit. (103). A more detailed account is in 'Lighting of Coal Mines', *The Newcastle Chronicle*, 9 December 1815, p. 2d–e. NLPS MS Minutes of Meeting, 1806–1818, 5 December 1815 (not paginated). Edmondston's, Atkinson's and Clapham's evidence in *Report*, op. cit. (112), pp. 22–24. Atkinson noted that the meeting was attended by between 80 and 100 people. See also Stephenson, op. cit. (122), p. 10.
127. 'Lighting of Coal Mines', *The Newcastle Chronicle*, 9 December 1815, p. 2d–e.
128. [Winch], op. cit. (103), p. 460.
129. *Tyne Mercury*, 28 November 1815, [p. 2e].
130. *The Newcastle Chronicle*, 2 December 1815, [p. 2e].
131. Holmes to Editor, 3 December 1815, *Tyne Mercury*, 5 December 1815, p. 3c. The following year Holmes, op. cit. (22), pp. 105–45, 173–211 defended Clanny's claims at length.
132. Including the report of the 9 and 16 November 1815 meetings of the Royal Society in *Philosophical Magazine*, vol. 46 (1815), pp. 387–89.
133. Clanny, op. cit. (19).
134. Davy to Gray, 13 December 1815, Paris, op. cit. (18), p. 320.
135. *Transactions of the Society of Arts*, vol. 34 (1817), pp. 28, 121–27.
136. Davy to Hodgson, 12 July 1816, NRO SANT/BEQ/18/11/13, pp. 391–98.
137. Stephenson, op. cit. (122), p. 6.
138. [Nathaniel Winch], 'On Safe-Lamps for Mines', *Philosophical Magazine*, vol. 47 (1816), pp. 117–18 (p. 118).
139. Waldie to Davy, 25 March 1816, Paris, op. cit. (18), pp. 329–30; 'Communications Respecting Sir H. Davy's Safe-lamp', *Philosophical Magazine*, vol. 47 (1816), pp. 312–14; *The Newcastle Chronicle*, 30 March 1816, p. 2e; *Newcastle Courant*, 30 March 1816, [p. 4b].
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141. *Newcastle Courant*, 30 March 1816, [p. 4b].

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143. Davy to Children, 30 August 1816, BL MS add 38625, f. 40–41.
144. Buddle to Gray, 7 September 1816, Paris, op. cit. (18), pp. 330–31. Buddle's evidence in 'Report from Select Committee on Accidents in Mines', *Parliamentary Papers*, 1835 (603) V, questions 2226 and 2227.
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146. Brandling to the Secretary of the General Meeting of the Coal Trade, 22 August 1816, *Durham County Advertiser*, 19 October 1816, p. 3c.
147. 'Resolution of meeting of coal owners', 31 August 1816, NRO SANT/BEQ/18/11/13, p. 406.
148. 'Resolution of meeting of coal owners', 11 October 1816, NRO SANT/BEQ/18/11/13, pp. 457–60. For a detailed account of this highly embarrassing meeting see Buddle to Davy, 16 October 1816 (copy), NRO 3410/ZC/4/17 and also in Buddle's 'Colliery Memoranda', NRO 3410/BUD/30/45, p. 45.
149. Stephenson to Editor, *Durham County Advertiser*, 19 October 1816, p. 3c.
150. Buddle to Lambton, 27 October 1816, Lambton MS DP55, no. 2/11.
151. Stuart J. Reid, *Life and Letters of the First Earl of Durham, 1792–1840*, 2 vols (London, 1906), vol. 1, pp. 42–43.
152. Leonard Cooper, *Radical Jack: The Life of John George Lambton* (London, 1959), p. 39.
153. Berman, op. cit. (11), p. 16.
154. Davy to Lambton, 29 October 1816, Lambton MS DP55, no 2/2.
155. 'Accidents in Coal Mines', *The Star*, 18 December 1815, [p. 4b]. Both this report and *The Newcastle Chronicle*, 9 December 1815, [p. 2d–e] described Stephenson as an ingenious but illiterate mechanic.
156. [Winch], op. cit. (103).
157. The final paper in that issue of *Philosophical Transactions* was not read until 29 February 1816, p. 156.
158. Davy to Lambton, 29 October 1816, Lambton MS DP55, no2/2.
159. Stephenson, op. cit. (122). The manuscript of the first part of this is in IME IMS 129/1.
160. Davy to Hodgson, 8 February 1817 [misdated 1816], NRO SANT/BEQ/18/11/13, p. 301–14. Davy to Buddle, 8 February 1817, in A.M. Broadley, *Chats on Autographs* (London, 1910), pp. 97–98. Davy to Buddle, 13 February 1817, in S. Weil, 'An Unpublished Letter by on the Safety-lamp', *Annals of Science*, vol. 6 (1950), pp. 306–07 (p. 306). Davy to Murray?, 14 February 1817, BL RP 1159.
161. 'Safety-lamps', *Philosophical Magazine*, vol. 49 (1817), p. 152.
162. 'Letter from Mr. G. Stephenson of the Killingworth Colliery: with a few Remarks on his Claim to Priority in the Invention of the Safe-Lamp, by the Editor', *Philosophical Magazine*, vol. 49 (1817), pp. 204–06.
163. *A Collection of all the letters which have appeared in the Newcastle papers, with other documents relating to the safety lamps* (London, 1817).
164. Aladdin to Editor, *Newcastle Courant*, 1 February 1817, [p. 1e].
165. Faraday's lecture notes, IEE MS SC 2/1/3, p. 359.
166. Buddle to Editor, 13 January 1817, *Newcastle Courant*, 25 January 1817, [p. 2b].
167. Davy to Hodgson, mid February 1817, NRO SANT/BEQ/18/11/13, pp. 545–48. Hodgson duly reported Davy's movements in the *Newcastle Courant*, 22 February 1817, [p. 1a], but without Davy's gloss.
168. RI MS HD 11 is a bound volume of Davy manuscripts collected by Faraday which, for archival convenience, has been catalogued as being in the Davy papers.
169. Buddle to Gray, 11 January 1817, Paris, op. cit. (18), p. 334.
170. Clayton to Davy, 13 March 1817, copy in Lambton MS DP55, no2.

171. Later this plate was used to establish the Davy medal of the Royal Society in 1877. *The Record of the Royal Society of London*, 4th edn (London, 1940), p. 114.
172. For accounts of the dinner see 'Presentation of Plate to Sir Humphrey Davy', *Newcastle Courant*, 18 October 1817, [p. 4a–b] and 'Triumph of Science', *The Star*, 17 October 1817 [p. 3a–b]. Paris, op. cit. (18), p. 337 gives the date of the dinner as 25 September 1817 while John Davy, *Memoirs of the Life of Sir Humphry Davy*, 2 vols (London, 1836), vol. 2, p. 44 gives the correct date. A copy of the printed invitation, signed by Buddle and dated 2 October 1817, is in NRO 3410/WAT/1/26/10.
173. Buddle's evidence in 'Report from Select Committee on Accidents in Mines', *Parliamentary Papers*, 1835 (603) V, question 2418.
174. Lambton, 'Speech of 11 October 1817, delivered at the Queen's Head, Newcastle', Paris, op. cit. (18), p. 337.
175. Davy, 'Speech of 11 October 1817, delivered at the Queen's Head, Newcastle', Paris, op. cit. (18), p. 339.
176. Ibid., 340.
177. Harriet Martineau, *The History of England During the Thirty Years' Peace: 1816–1846*, 2 vols (London, 1849–50), vol. 1, p. 595.
178. See printed copy of resolution in NRO 3410/WAT/1/26/10.
179. Buddle to Lambton, 1 November 1817, Lambton MS DP55, no2/13.
180. Lambton to Brandling, 3 November 1817, copy in Lambton MS DP 55, no2.
181. Davy to Buddle, 5 November 1817, Lambton MS DP55, no2.
182. Davy to Lambton, 10 November 1817, Lambton MS DP55, no2/4.
183. Richard Welford, *Men of Mark 'twixt Tyne and Tweed*, 3 vols (London, 1895), vol. 3, pp. 82–88.
184. Davy to Losh, 11 November 1817, IME IMS 129/8 and 9.
185. Losh to Davy, 13 November 1817, IME IMS 129/8 and 9.
186. Davy to Strathmore, 10 November 1817, IME IMS 129/9; Strathmore to Davy, 14 November 1817, IME IMS 129/9. It was presumably at this time that he Davy wrote his undated letter on the same subject to M.W. Ridley, Lambton MS DP55, no2.
187. Davy to Lambton, 21 November 1817, Lambton MS DP55, no2/6.
188. *Tyne Mercury*, 25 November 1817 [p. 3b–c].
189. *Newcastle Courant*, 29 November 1817 [p. 1d–e].
190. *Newcastle Courant*, 6 December 1817 [p. 2e].
191. *Report*, op. cit. (112). See p. 1 for the origin of the *Report.*
192. Buddle to Lambton, 29 November 1817, Lambton MS DP55, no2/18.
193. For an account of the dinner see *Newcastle Courant*, 17 January 1818 [p. 4c–e]. See also Samuel Smiles, *The Life of George Stephenson, Railway Engineer* (London, 1857), pp. 127–28. There is a printed invitation dated 2 January 1818 signed by R.W. Brandling in TWAS S.PAM/1/187.
194. Minutes of Newcastle Literary and Philosophical Society meetings, 1806–1818, not paginated, NLPS MS.
195. Buddle to Paris, August 1830, Paris, op. cit. (18), pp. 343–44.
196. Davy to Buddle, 23 January [1817], BL MS add 33963, f.114. It appears that the first safety lamp to receive a patent was Thomas Bonner, 'Improvements on safety lamps', Patent 5571, dated 4 December 1827.
197. For a different interpretation of the patent episode see Knight, op. cit. (14), p. 115. Note also that Davy criticised Wollaston for becoming wealthy by his platinum work, see Davy, op. cit. (172), vol. 1, p. 258.
198. Buddle's evidence in 'Report from Select Committee on Accidents in Mines', *Parliamentary Papers*, 1835 (603) V, questions 2223 and 2233.
199. Frank A.J.L. James, 'The Creation of a Victorian Myth: The Historiography of Spectroscopy', *History of Science*, vol. 23 (1985), pp. 1–24.

200. Davy to Faraday, 5 June 1818, James, op. cit. (16), letter 83. Davy to Grace Davy, 26 June 1818, SM MS 333/32.
201. Smirnove to Paris, 29 May 1830, Paris, op. cit. (18), pp. 346–47.
202. Frank A.J.L. James and Margaret Ray, 'Science in the Pits: Michael Faraday, Charles Lyell and the Home Office Enquiry into the Explosion at Haswell Colliery, County Durham, in 1844', *History and Technology*, vol. 15 (1999), pp. 213–31.
203. Richard Fynes, *The Miners of Northumberland and Durham. A History of their Social and Political Progress* (Blyth, 1873), p. 147.
204. J.L. Hammond and L.B. Hammond, *The Town Labourer 1760–1832: The New Civilisation* (London, 1917), p. 25.
205. Buddle to Davy, 1 January 1824, quoted in Flinn and Stoker, op. cit. (20), p. 144. NRO 510, the volume of manuscripts in which this letter was located, has been mislaid.
206. This also accords with the findings of P.E.H. Hair, 'Mortality from Violence in British Coal Mines, 1800–1850', *Economic History Review*, vol. 21 (1968), pp. 545–61.
207. Clarges to Buddle, 10 July 1827, DCRO NCB I/JB 304.
208. James and Ray, op. cit. (202), pp. 224–25.
209. James McQuaid, 'Safety's debt to Davy and Faraday', *Proceedings of the Royal Institution*, vol. 68 (1997), pp. 177–208, pp. 200–06.
210. 'Report from Select Committee on Accidents in Mines', *Parliamentary Papers*, 1835 (603) V, p. iv.
211. Knight, op. cit. (14), p. 112.
212. 'Report from Select Committee on Accidents in Mines', *Parliamentary Papers*, 1835 (603) V, p. vii.
213. James David Forbes, 'Dissertation sixth: exhibiting a general view of the progress of mathematical and physical science, principally from 1775 to 1850', *Encyclopaedia Britannica*, 8th edn (London, 1857), vol. 1, pp. 794–996, pp. 969–71 on Davy, p. 883 on Stephenson.
214. Stephenson to Forbes, 1 February 1856, St Andrews University MS J.D. Forbes papers 1856/16. I am grateful to Michael Bailey for this reference.
215. Fynes, op. cit. (203), pp. 146–47.
216. Robert L. Galloway, *Annals of Coal Mining and the Coal Trade*, 2 vols (London, 1898–1904), vol. 1, p. 434.
217. A recent instance of this is Oliver Garnett, 'How the Geordies got their name', *National Trust Magazine*, no. 102 (Summer 2004), p. 84. Garnett wrote that Stephenson's lamp gave its name to Tynesiders. However, it would appear that the term Geordie refers to Newcastle declaring for George I during the Jacobite rebellion of 1715.
218. Smiles, op. cit. (193) pp. 94–133. J.C. Jeaffreson, *The Life of Robert Stephenson*, 2 vols (London, 1864), vol. 1, pp. 37–41. L.T.C. Rolt, *George and Robert Stephenson: The Railway Revolution* (London, 1960), pp. 24–34. W.O. Skeat, *George Stephenson: The Engineer and His Letter*s (London, 1973), pp. 25–29. Hunter Davies, *A Biographical Study of the Father of Railways: George Stephenson* (London, 1975), pp. 19–32.
219. See, for example, McQuaid, op. cit. (209).
220. [George Gordon, Lord Byron], *Don Juan* (London, 1819), canto 1, verse 132. For another reference to the lamp see Byron to Murray, 8 May 1820, Leslie A. Marchand, *Byron's Letters and Journals, Volume 7: 1820* (London, 1977), pp. 96–99.
221. Richard Walker, *Regency Portraits*, 2 vols (London, 1985), vol. 1, pp. 148–49.
222. Ibid., p. 150.
223. Ibid., p. 480.
224. Frank A.J.L. James, 'Michael Faraday's Work on Optical Glass', *Physics Education*, vol. 26 (1991), pp. 296–300.
225. Frank A.J.L. James, 'Davy in the Dockyard: Humphry Davy, the Royal Society and the Electro-chemical Protection of the Copper Sheeting of His Majesty's Ships in the mid 1820s', *Physis*, vol. 29 (1992), pp. 205–25.

226. Navy Board to Davy, 21 January 1823, RS MS DM 3.7.
227. Davy, op. cit. (172), vol. 2, p. 165.
228. Royal Institution Laboratory Notebook RI MS HD 8a, f.44–47(2).
229. Humphry Davy, 'On the corrosion of copper sheeting by sea water, and on methods of preventing this effect; and on their application to ships of war and other ships', *Philosophical Transactions*, vol. 114 (1824), pp. 151–58.
230. Davy to Croker, 18 January 1824, TNA ADM1 / 4534, f.15.
231. R. Mushet, 'Process for improving the quality of copper, and of alloyed copper, applicable to the sheathing of ships, and to other purposes', Patent 4802, dated 14 June 1823.
232. *Times*, 3 February 1824, p. 2c.
233. Faraday to Pollock, 19 March 1824, James, op. cit. (16), letter 228.
234. For a very brief summary of Faraday's work for these and other agencies see Geoffrey Cantor, David Gooding and Frank A.J.L. James, *Michael Faraday* (Atlantic Highlands, 1996), pp. 39–42.