

Dean Carroll

I hope to see you in
Amsterdam, Conn

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SIR HUMPHRY DAVY AND HIS SAFETY LAMP FOR COAL MINERS*

Thomas E. Keys, M.A., Mayo Clinic Library

YOUTH AND EARLY CAREER

Humphry Davy (Fig. 1) was born at Penzance in Cornwall, England,¹ on Dec. 17, 1778. He was the oldest of five children, including a brother, John, who became one of his biographers.

When Humphry was six, the Davy family moved two or three miles out from Penzance to their small estate on Mount's Bay, opposite St. Michael's Mount. To attend school, Humphry stayed on at Penzance and lived with Mr. Tonkin, an eminent surgeon; but he spent his holidays with his family. His favorite pastime was fishing; and later in life, scientists and other friends who enjoyed fly-fishing endeared themselves to him.

His first schoolmaster was so impressed with Humphry's ability that he persuaded the boy's father to send him to the more advanced Penzance grammar school. From this, Humphry was sent 25 miles to Truro in 1793 and finished his schooling there.

Humphry wanted to study medicine at Edinburgh; but his father died in 1794, leaving a depleted inheritance. Consequently, in 1795 Mrs. Davy apprenticed her son to Mr. John Borlase, a surgeon and apothecary in Penzance. In Mr. Borlase's dispensary, as an energetic 17-year-old, he met with chemistry and found it much to his liking. Since he could not continue in school, he was determined to educate himself; and he set a rigorous course of self-instruction in science and arts. When he came to concentrate on chemistry, in 1797, his texts were Lavoisier's *Elementary Treatise on Chemistry*[†] and *The Dictionary of Practical and Theoretical Chemistry* compiled by William Nicholson.

In the winter of that year Davy made two important friendships, those of Gregory Watt and Davies Giddy. Gregory Watt, the son of the famous engineer, James Watt, was a consumptive and had been sent to Penzance for the benefits of its climate by his physician, Thomas Beddoes,⁴ formerly a

*Presented at a quarterly meeting of the Mayo Foundation History of Medicine Society on July 10, 1968.

[†]According to Hartley^{3a} he read Lavoisier's *Traité Élémentaire* in French and not in the English translation.

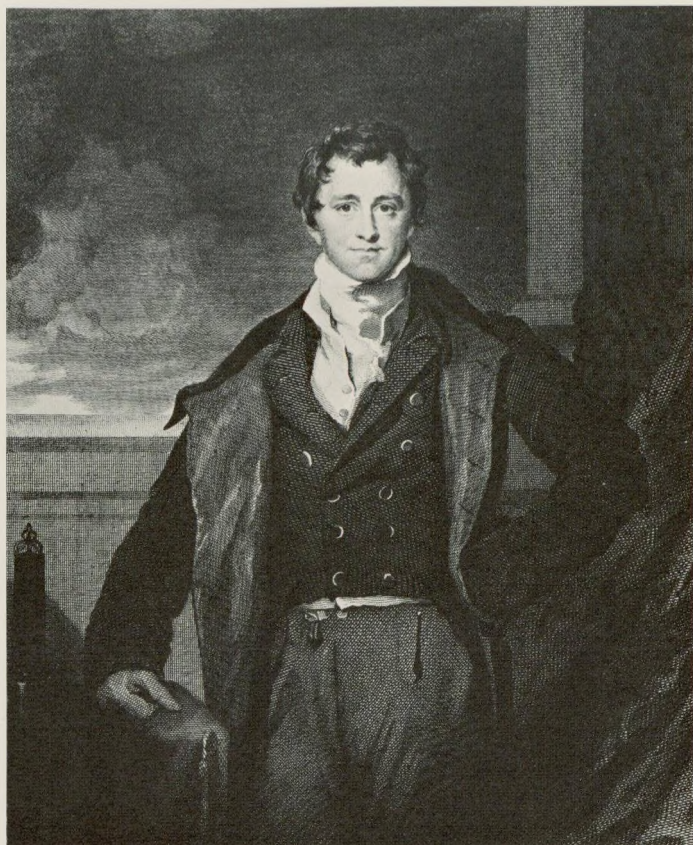


Fig. 1. Sir Humphry Davy, from engraving after painting by Sir Thomas Lawrence. Davy lamp is at his right. (From Paris.^{2a})

reader in chemistry at Oxford. Watt lodged and boarded with Davy's mother, and aided the youth in his study of chemistry. The other friend, Davies Giddy (who later changed his surname to Gilbert), was a former student of Beddoes and a person especially interested in the Pneumatic Institution which Beddoes was organizing in Bristol to study the medical effects of gases. Beddoes was looking for a superintendent to take charge of his newly founded hospital and laboratory; Giddy suggested Davy; and Davy was hired for this new position, assuming his duties in Bristol in October 1798.

At the Pneumatic Institution, Davy soon was experimenting with breathing of nitrous oxide, or "laughing gas" as it came to be called because of its sometimes amusing effects

upon those who inhaled it.⁴ These experiments, undertaken when Davy was only 20, were to have far-reaching consequences and were to be embodied in his book, *Researches, Chemical and Philosophical; Chiefly Concerning Nitrous Oxide, or Dephlogisticated Nitrous Air, and Its Respiration*.⁵ This work, published in 1800 when Davy was only 21, clearly indicates his genius. It included his explicit suggestion that the gas be used for surgical anesthesia, which unfortunately was not put to use by anyone until after discoveries much later.⁴

SUCCESS AT THE ROYAL INSTITUTION AND BEGINNING OF TRAVELS

Nevertheless, Davy's reports of his Bristol research on gases were early noticed by prominent men, including Benjamin Thompson, Count Rumford, the Massachusetts-born scientist, administrator, and philanthropist who, after careers both in England and in Bavaria, had founded the Royal Institution with Sir Joseph Banks and others and obtained a charter for it from George III in 1800.

Rumford's selection of Humphry Davy as assistant lecturer and director of the laboratory in 1801 was a fortunate choice, for the young chemist became the principal cause of the Institution's success.^{6a} Davy's lectures immediately won a large and appreciative audience. Also, because of his work on galvanism and tanning, he was elected a fellow of the Royal Society in 1803; and he won the Copley medal of the Royal Society in 1805 for his reports on analysis of minerals by use of boracic acid and other experiments. In 1806 Davy was investigating galvanism; and he soon applied the contributions of Volta to produce increasingly powerful voltaic batteries, with which he demonstrated the character of oxy-muriatic acid and isolated potassium, sodium, and chlorine.

In 1807 he was elected secretary of the Royal Society. His Bakerian lecture on his recent discoveries, delivered before the Royal Society in November, attracted the attention of many European scientists. Napoleon had offered through the Institute of France a prize of 3,000 francs (£120) "for the best experiment which shall be made in the course of each year, on the Galvanic fluid";^{2b} and the first award of the prize was made to Davy for the discoveries announced in this lecture.

Besides his usual lectures at the Royal Institution, Davy performed a series of investigations which culminated in the Bakerian lecture to the Royal Society in 1808. Here he discussed ammonia, phosphorus, sulfur, charcoal, and diamond.

As Bakerian lecturer in 1809, Davy considered the metallic bodies of alkalis and earths and combinations of hydrogen, and in 1810 some of the combinations of oxymuriatic gas and oxygen. In 1810, also, the Dublin Society requested lectures on his recent discoveries in electrochemical science, and the Farming Society of Ireland arranged for a series on the application of chemistry to agriculture. On his return to Dublin the next year, Trinity College conferred upon him an honorary LL.D. degree.

April of 1812 was another turning point in Davy's career. On the 8th, he was knighted by the prince regent; and on the 11th, he married a wealthy widow, Mrs. Jane Apreece. In June of 1812 appeared Davy's book, *Elements of Chemical Philosophy*, dedicated to Lady Davy "as a pledge that he shall continue to pursue science with unabated ardour."^{2c}

But in April of 1813 he resigned from his professorship at the Royal Institution, whose board then elected him honorary professor of chemistry. From this time, he traveled a great deal. He took scientific apparatus with him, visited many prominent scientists at their laboratories, and worked with much success, sending back seven papers to the Royal Society from a Continental tour of 19 months, ending in April 1815.¹

The trip to the Continent, and especially France, was bitterly attacked by the newspaper reporters because it had required an application to Napoleon for a safe-conduct during the wartime so that Davy could study the extinct volcanoes in the Auvergne. The *London Times* remarked:

We cannot help thinking, that while so large a portion of the Continent (Spain included) is, either through our bravery or that of our Allies, open to the researches of science, Sir Humphry might have spared himself the trouble of accepting any favor from the enemy of his country, by visiting France first.⁷

Nor did Lady Davy escape the barbed pen. Sir Humphry, one writer remarked (in 1824),

thinks it quite fashionable to act indifference to his wife. . . . They never, by any chance, interchange a word, but if they happen to get together into the same circles, at dinner, for example, they are continually talking *at* one another. Whatever position her ladyship lays down, her knightly helpmate is surely a side wind to contradict it.⁸

One may bear in mind that the journalism of the day customarily was captious and sensational.

Upon his return to London in April 1815, Davy appeared to be at the height of his career. As detailed by Bence Jones,^{6b}

When he returned he probably intended to make greater discoveries in chemistry during the following ten years than he had made during the fifteen years that he had been at the Institution. He was in the prime of life. He had won the greatest rank as an original inquirer.



Fig. 2. Early miner's lamp, lower right corner. (From Agricola, G.: *De Re Metallica*. [Translated by H. C. Hoover and L. H. Hoover.] New York, Dover Publications, Inc., 1950, p. 120. By permission.)

He had a love of research which, in spite of his marriage, his wealth, and ultimately his ill health, never ceased until his early death. He had Faraday as his assistant, and he soon found a subject more fruitful than the composition of nitrogen, which had long baffled his genius.

THE MINE SAFETY LAMP

Background and Preliminary Ideas.—This subject was the mine safety lamp, an invention demanded by the times. Coal had been mined in England as early as the twelfth century.^{9a} At first it was obtained from outcroppings and mining was done by daylight; but as the miners advanced farther into the beds, some kind of artificial light must have been used. Agricola's¹⁰ comprehensive work on metals and their mining, published in 1556, includes a picture of a miner in a tunnel carrying a wick lamp (Fig. 2); and presumably such lamps were employed by coal miners also at that time.

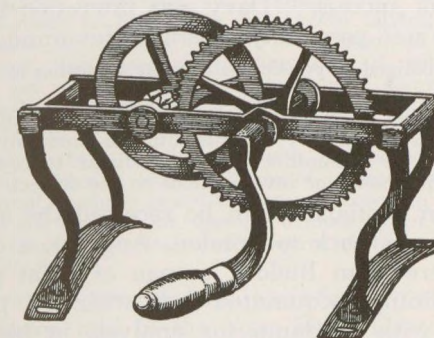
Coal, however, gives off the gas which, mixed with air, has long been called "firedamp"; and in deep mines it tends to accumulate. In certain proportions with air, it will burn;^{11a}



Fig. 3. Fireman igniting firedamp. (From Singer, C. J., Holmyard, E. J., Hall, A. R., and Williams, T. I.: *A History of Technology*. Oxford, The Clarendon Press, 1958, vol. 4, p. 92. By permission.)

and a flame or sometimes even a spark can set it off.^{11b} Apparently the earliest record of a fatality from flaming or explosion of firedamp in coal mining in Great Britain is contained in the register of St. Mary's Church, Gateshead-on-Tyne. Forester^{11b} has mentioned the entry, dated Oct. 14, 1621, recording the death of Richard Backas, who was "burn'd in a pit." From this time on there were more and more explosions in the mines. A common and dangerous practice in the eighteenth century was to get rid of the "coal gas" by firing it. A "fireman" (Fig. 3) dressed in a water-dampened suit would light the gas (which is lighter than air) above him. If he survived he would withdraw to fresh air after the flame had passed over him.^{12a} There were also lamps kept burning continuously whose purpose was to consume the gas as it accumulated, and extensive and complicated measures were employed to improve mine ventilation so as to carry the gas away.

About 1750 Carlisle Spedding, a young miner from Cumberland, invented the "steel mill" for giving light. This mill (Fig. 4) consisted of a thin disk of steel so mounted that it could be rotated rapidly by means of gears and a hand crank. A piece of flint pressed against the rim of the disk produced a continuous shower of sparks, which gave a little light. The sparks were supposed not to be hot enough to ignite firedamp;



Flint-and-steel mill, c 1813.

Fig. 4. Carlisle Spedding's flint-and-steel mill. (From Singer, C. J., Holmyard, E. J., Hall, A. R., and Williams, T. I.: *A History of Technology*. Oxford, The Clarendon Press, 1958, vol. 4, p. 94. By permission.)

but unfortunately, they occasionally did ignite it. In 1755 Spedding himself was killed by an explosion of gas in Whitehaven Collieries.^{11b,12b}

The expansion of coal mining in England during the eighteenth century was accompanied by an increase of mine fatalities. One of the many persons concerned about this was a physician of Bishop Wearmouth (now part of Sunderland), Dr. William Reid Clanny. In a communication to the Royal Society in May 1813, he counted up 200 miners killed by 6 large explosions in his district during the previous 8 years, not including those disabled and otherwise injured. The greatest of these disasters, which killed 92 men and left 41 widows and 133 orphans in May of 1812,¹³ led to the formation in Bishop Wearmouth on Oct. 1, 1813, of the Society for Preventing Accidents in Coal-Mines. The society was sponsored by the Bishop of Durham and the Duke of Northumberland and included a number of mine owners. Also among its members was Dr. Clanny, who had already devised a kind of safety lamp.

But though many ideas for safer lamps, improved mine ventilation, and even neutralization of the gas were urged upon the society, it found no ready practical plan for accomplishing its purpose. Consequently, in 1815 the chairman of its committee, who was the Reverend Dr. Robert Gray, Rector of Bishop Wearmouth (and later Bishop of Bristol), asked the help of Sir Humphry Davy, as the scientist most likely

to be capable of success.^{2d} Davy was interested immediately, and more than one possibility sprang to his mind:

... I am much obliged to you for calling my attention to so important a subject.

It will give me great satisfaction if my chemical knowledge can be of any use in an enquiry so interesting to humanity, and I beg you will assure the Committee of my readiness to co-operate with them in any experiments or investigations on the subject. . . .

Having been in Scotland when he received the appeal, Davy visited on his way back to London, Aug. 24, a colliery near Newcastle where John Buddle, a man of great practical experience in mining, acquainted him with the problem and provided him with firedamp for analysis in his laboratory.

Buddle reported to the committee chairman:

... he has given me reason to expect that a substitute may be found for the steel mill, which will not fire the gas. He seems also to think it possible to generate a gas, at a moderate expense, which, by mixing with the atmospheric current, will so far neutralize the inflammable air, as to prevent it firing at the candles of the workmen.^{2e}

Rational Research.—Davy went about his research in a way that attracted the admiration of scientists not only of his time but also up to the present era.¹⁴ To begin with, he tried out some sources of light without flame—apparently the possibilities mentioned in his early letter.

Having learnt from Mr. Buddle the degree of light required for the common operations of the workmen, I made several experiments with the hope of obtaining such a light without active inflammation. I tried Kunckel's, Canton's and Baldwin's phosphorus, and likewise the electrical light in close vessels, but without success. I had a lamp made with two valves, which closed in atmospheres contaminated with firedamp, by the increased heat of the flame produced by the combustion of gas . . .^{15a}

But since this lamp extinguished itself whenever the atmosphere surrounding it became explosive,^{2f} it did not answer the purpose.

The foundation for Davy's triumph was his thorough investigation of firedamp. From study of the samples provided him by Mr. Buddle and a Mr. Dunn, he concluded:

The fire-damp I find . . . to be (as it has always been supposed [and previously stated by Dr. Henry, a contemporary physician and chemist])^{15b} a hydro-carbonate. It is a chemical combination of hydrogen gas and carbon, in the proportion of 4 by weight of hydrogen gas, and 11½ of charcoal.^{2g}

In modern terms this is methane, CH₄.

The next step was to determine the circumstances necessary to explosion. In a communication to the Reverend Dr. Gray, dated Oct. 31, 1815, Davy summarized:

I find it will not explode, if mixed with less than six times, or more than fourteen times its volume of atmospheric air. Air, when rendered impure by the combustion of a candle, but in which the candle will

still burn, will not explode the gas from the mines; and when a lamp or candle is made to burn in a close vessel having apertures only above and below, an *explosive mixture* of gas admitted *merely enlarges* the light, and then gradually extinguishes it without explosion. Again,—the gas mixed in any proportion with common air, I have discovered, *will not explode* in a *small tube*, the diameter of which is less than ¼th of an inch. . . .

Explosive mixtures of this gas with air require much stronger heat for their explosion than mixtures of common inflammable gas. Red-hot charcoal, made so as not to flame, if blown up by a mixture of the mine gas and common air, does not explode it, but gives light in it; and iron, to cause the explosion of mixtures of this gas with air, must be made *white-hot*.^{2h}

These observations provided the basis for invention of an effective safety lamp, and in the same letter Davy described four contrivances that he had tested at the time of writing.

The Principle of Wire-Gauze Containment.—But all of these, though great improvements over mere candles in respect to safety, were soon to be surpassed. Methodical experimentation to determine the best dimensions of the tubes leading into and out of the lamp led to Davy's paramount contribution: the principle of isolating the lamp flame by means of a wire-gauze envelope or chimney. On Nov. 9, 1815, he was able to announce that a small explosion of firedamp (such as might occur inside a lantern) will not pass through wire gauze, since the mesh dissipates the heat of the flame too quickly.²ⁱ He described the discovery in his pamphlet of 1818 (Fig. 5):

I made several attempts to construct safety lamps which would give light in all explosive mixtures of fire damp, and after complicated combinations I at length arrived at one evidently the most simple, that of surrounding the light entirely by wire gauze, and making the same tissue feed the flame with air and emit light.

In plunging a light surrounded by a cylinder of fine wire gauze into an explosive mixture I saw the whole cylinder become quietly and gradually filled with flame. . . . I placed my lighted lamps in a large glass receiver, through which there was a current of atmospheric air, and by means of a gasometer filled with coal gas, I made the current of air which passed into the lamp more or less explosive, and caused it to change rapidly or slowly . . . so as to produce all possible varieties of inflammable and explosive mixtures; and I found that iron wire gauze, composed of wires from one-fortieth to one-sixtieth of an inch in diameter, and containing twenty-eight wires or 784 apertures to the inch, was safe under all circumstances in atmospheres of this kind: and I consequently adopted this material in guarding lamps for the coal mines, where in January, 1816, they were immediately adopted, and have long been in general use.^{15c}

Davy's wire gauze became the standard mesh for coal miners' safety lamps both in England and in America.¹⁶

Figure 6 shows the early Davy lamp with the wire-gauze shield.

Rivals and Counterclaims.—In his general report on his invention of the safety lamp, Sir Humphry thanked Michael

ON THE

Safety Lamp

FOR

COAL MINERS;

WITH SOME

RESEARCHES ON FLAME.

BY SIR HUMPHRY DAVY.



London:

PRINTED FOR R. HUNTER,
(SUCCESSOR TO MR. JOHNSON,
No. 72, ST. PAUL'S CHURCH-YARD.

1818.



Fig. 5. Title page of Davy's pamphlet on safety lamp for coal miners¹⁵ (from copy in History of Medicine Division, Mayo Clinic Library).

Faraday, his helper, "for much able assistance in the prosecution of my experiments."^{15d} Also, he made mention of an earlier effort by another distinguished scientist. The German naturalist, Baron Alexander von Humboldt, deserved the credit given him for the first attempt at a safety lamp—though it was

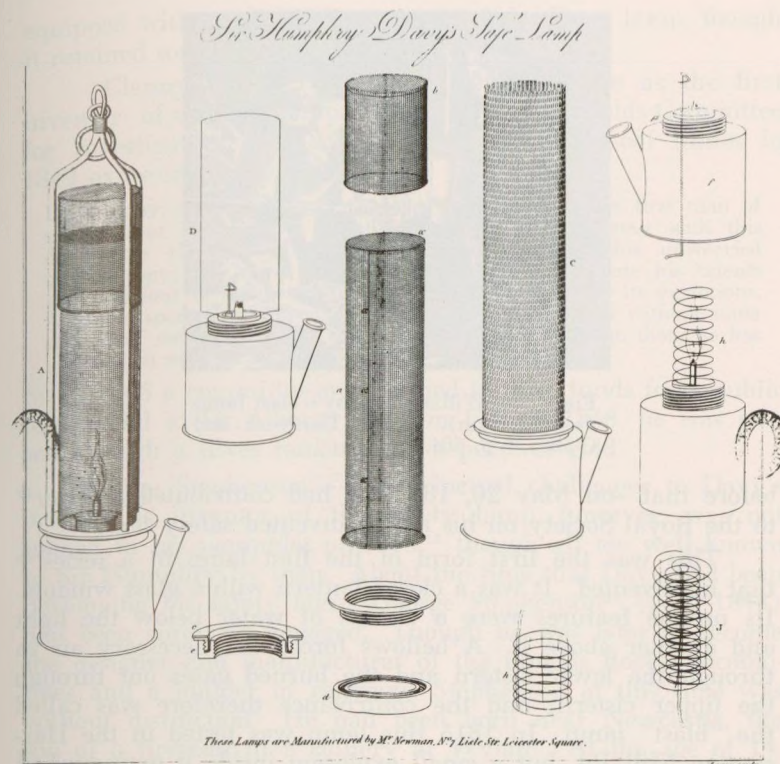


Fig. 6. Davy's safety lamp, with details and variations. (Frontispiece from his pamphlet,¹⁵ described on pp. 114-116 therein.)

not successful. That lamp, designed in 1796, was based on the principle of insulation from outer air and could only burn until the little air contained within it was exhausted.^{15e}

Davy also mentioned the lamp^{15e} invented in 1813 by Dr. Clanny of Bishop Wearmouth.

Dr. Clanny.—William Reid Clanny^{17, 18a} (1776-1850) was born at Bangor, County Down, Ireland. He studied medicine at Edinburgh, served for a time in the British navy as assistant surgeon, returned to Edinburgh and received his M.D. degree in 1803, and then settled for the remainder of his life at Bishop Wearmouth, where he practiced medicine. Clanny became physician in ordinary to the Duke of Sussex and wrote articles on medical subjects. In 1810 he became interested in explosions of firedamp in coal mines, and (as mentioned earlier) when the Society for Preventing Accidents in Coal Mines was formed in Sunderland, he became a member. Even



Fig. 7. Dr. William Clanny's blast lamp (second form). (From Hardwick and O'Shea,¹⁸ p. 564.)

before that—on May 20, 1813, he had contributed a paper¹⁹ to the Royal Society on his newly invented safety lamp.

This was the first form of the first lamp in a series^{18b} that he invented. It was a closed lantern with a glass window. Its unique features were a cistern of water below the light and another above it. A bellows forced the necessary air in through the lower cistern and the burned gases out through the upper cistern; and the contrivance therefore was called the "blast" lamp. In 1815 this lamp was tested in the Harrington Mill Pit, but a small explosion inside it extinguished the light. Davy saw the lamp at about this time, as mentioned by Thorpe,²⁰ but apparently was not impressed. An improved form of the lamp utilized the oil reservoir instead of water below the flame and relied on a narrow chimney instead of the water baffle above, but it still was cumbersome and required a boy to carry it on a belt and work the bellows (Fig. 7). The Royal Society of Arts awarded Clanny its silver medal for this lamp in 1816. A further development was to transport the lamp on a wheelbarrow whose wheel worked the bellows.

In his second lamp, water in a cistern above the flame was converted to steam in the combustion chamber to neutralize the explosiveness of firedamp there. This lamp was used in several mines, and the Society of Arts awarded Dr. Clanny a gold medal for it in 1817. A third type, the "gas-light" lamp was designed to burn firedamp instead of oil in an atmosphere charged with gas.

Dr. Clanny continued to invent and improve lamps, but his later models incorporated features from other sources, and the Clanny lamp that ultimately came into widest use was

equipped with gauze similar to that of the Davy lamp, though it retained some glass also.^{18c}

Clanny believed that he deserved notice as the first inventor of a safety lamp,^{18d} and the South Shields Committee for Investigating the Causes of Accidents in Coal Mines in 1843 expressed the opinion that

Dr. Clanny, in this country, appears to have been the first man of science that conceived it possible to enter into a contest with this destructive element [firedamp], and, sustained by his unwearied philanthropy, has never ceased, for 30 years, to devote his talents and exertions to mitigate the horrors consequent upon its explosions. A life so spent, it is hoped, will not be allowed to pass without some remark of respect from his country, or of gratitude from those he has laboured so much to benefit.^{18e}

So in 1846 a committee was formed to raise funds for a public testimonial to Dr. Clanny; and on Feb. 3, 1848, he was presented with a silver tankard and a purse of gold.

George Stephenson.—The principal challenger to Davy's priority as inventor of the safety lamp, however, was not named in his pamphlet of 1818,¹⁵ though all too well known to Sir Humphry by then. About the time that Davy had been developing his safety lamp, George Stephenson²¹ (1781-1848) had been similarly engaged. Though he was later to become the designer and manufacturer of the famous Rocket locomotives and a builder of railways, Stephenson at this time was without distinction. He had been born near Newcastle, the son of a fireman in a colliery at Wylam. At the age of 14, George became an assistant fireman to his father, who was then employed at the Dewley colliery. A year later George became a fireman and at the age of 17 a plugman (pump attendant) at the colliery. He learned to read when he was 18 years old, and spent his spare time in study to gain scientific knowledge. In 1808 Stephenson contracted to work the engines of the Killingworth pit. He became expert with the engines and in 1812 was employed as "engine-wright" to the Killingworth Colliery.

The first of Stephenson's inventions was his safety lamp (Fig. 8), which he described and defended in a pamphlet²² (Fig. 9) of 1817 which is now rare.

Several of my friends having expressed a wish that I would lay an engraved plan of my Safety Lamp before the public, with as correct an account of the dates of the invention as I am able, I have resolved to do so. I was, at the same time, advised to publish the steps by which I was led to this discovery, and the theory I had formed in my own mind upon the subject, which, with the facts from which I drew my conclusions, were freely communicated to several persons during the time I was engaged in the pursuit. With this I cannot persuade myself to comply: my habits, as a practical mechanic, make me afraid of publishing theories, and I am by no means satisfied that

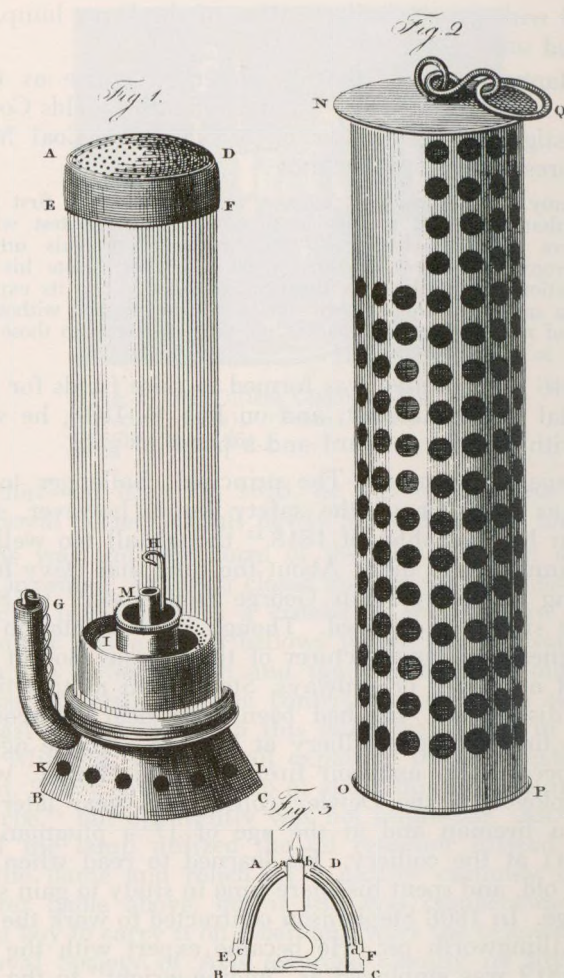


Fig. 8. Third Stephenson lamp (at left) with perforations below and at top, and glass cylinder; its protective cover (at right); and (below) section showing tubes that conveyed air from lower perforations to flame chamber. (From Stephenson,²² plate 3.)

my own reasons, or any of those I have seen published, why hydrogen gas will not explode through small apertures, are the true ones...

During the four years that I have been employed to superintend the engines of Killingworth Colliery... I have had frequent opportunities of employing my leisure hours in making experiments upon hydrogen gas: the result of these experiments has been the discovery of... facts above stated, and the consequent formation of a Safety lamp, which has been, and is still, used in that concern, and which my friends consider... as precisely the same in principle with that subsequently presented to their notice by Sir Humphrey [sic] Davy...

REPORT
 UPON
 THE CLAIMS
 OF
 MR. GEORGE STEPHENSON,
 RELATIVE TO THE INVENTION
 OF
 HIS SAFETY LAMP.
 BY THE COMMITTEE
 APPOINTED AT A MEETING HOLDEN IN NEWCASTLE,
 ON THE FIRST OF NOVEMBER, 1817.
 WITH
 AN APPENDIX,
 CONTAINING THE EVIDENCE.

NEWCASTLE:

PRINTED BY S. HODGSON, FOR EMERSON CHARNLEY;
 BALDWIN, CRADOCK, AND JOY, LONDON;
 AND CONSTABLE AND CO.
 EDINBURGH.

1817.

Fig. 9. Title page of Report Upon the Claims of Mr. George Stephenson, Relative to the Invention of His Safety Lamp²³ (from copy in the History of Medicine Division, Mayo Clinic Library).

The use of the wire gauze [Davy's invention] 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 the construction. If any other substance was to be used instead of the glass cylinder, for instance, the tin guard... it surely must have been immediately obvious that no apertures could be allowed in it greater than those through which I had ascertained explosion would not pass. As a discovery, the person who first constructed the perforated Tin Lantern in common use, may, with great justice, claim the merit of having surrounded the flame with a substance less liable to injury than glass, which, at the same time that it admits the air, transmits the light. It might be considered a want of candour were I not to take notice of the Lamp constructed by Dr. Clanny, but my reason

for not inserting it is, that I considered it as constructed upon a principle entirely different from mine, that of separating the external and internal hydrogen by means of *water*. If I am deceived, there can be no question upon the merit of the discovery, as there is no doubt but that gentleman had directed his talents to the subject, and had constructed his original Lamp long before I had reduced my ideas into practice.^{22a}

Stephenson then described his safety lamp and mentioned that it had been tried in Killingworth Colliery on Oct. 21, 1815:

The idea I had long entertained, and the drawing was shewn to several persons employed in that concern, two months before the day above mentioned, when, I carried it with safety into a part of the mine where a strong blower of hydrogen [a jet from a fault or fissure] was coming off. An experiment which was immediately repeated in the presence of two persons employed in that concern.^{22b}

The Controversy.—Priority, alone, is but a gilt crown; yet the prize is often contended for, even so. Dr. Clanny, though he sought the honor,^{18d} was not a strong contestant because his early lamps were not widely accepted in use. What called forth Stephenson's pamphlet in 1817 was the recognition accorded Sir Humphry by a large group of mine owners, who had proceeded from a letter of thanks in March 1816 to a testimonial dinner and presentation, on Sept. 25, 1817, of a table service of silver plate valued at £2,500.^{2j} Friends of Stephenson had raised their voices along the way;^{2k} and a gathering of them, on Nov. 1, 1817, declared themselves resolved

that Mr. George Stephenson discovered the fact that explosion of hydrogen gas will not pass through tubes and apertures of small dimensions; that he was the *first* to apply that principle in construction of a Safety Lamp, and that he was, therefore, entitled to a public reward.^{23a}

They supported this conclusion by publication of their evidence (Fig. 10) and appointed a special committee chaired by the Earl of Strathmore to raise a public subscription for Stephenson, with the result that Stephenson was presented £1,000 at a meeting on Jan. 12, 1818.²¹

The public acknowledgment to Stephenson brought a storm of protest from those who backed Davy as the inventor of the safety lamp. The newspapers displayed a series of resolutions and letters supporting each of the inventors.^{23b} Scientific backing for Sir Humphry was provided by the President of the Royal Society, Sir Joseph Banks, with William Thomas Brande, Charles Hatchett, W. H. Wollaston, and Thomas Young;²¹ but the Stephenson partisans were not silenced. On the practical side, however, they did make an interesting admission:

Upon the comparative *merits* of the metal plate and wire gauze lamps, the friends of Mr. Stephenson do not feel themselves called upon to

	MR. STEPHENSON.	SIR HUMPHRY DAVY.
1815, August to October.	Busy with those experiments upon blowers in Killingworth colliery, which led to the construction of his Lamps.	"The subject occupied his attention as an object of speculation."
Beginning of October.	Ordered his first Lamp, which was tried in the colliery on the 21st of that month.	"Commenced his experiments on fire-damp, and before the 18th of that month had discovered certain facts (the facts in question) respecting that inflammable substance; and states, in a letter dated Oct. 19th, that <i>if a lamp or lantern be made air-tight on the sides, and furnished with apertures to admit the air, it will not communicate flame to the outward atmosphere.</i> "
End of Oct.	Ordered his second Lamp.	In a letter, dated October 30th, describes to Mr. Hodgson a Lamp in which he adopted " <i>tubes and canals above and below.</i> "
November 4.	Tried his second Lamp in Killingworth colliery.	"Mr. Butler noticed Sir Humphry Davy's discoveries in an oration."
November 9.		Read to the Royal Society a paper, giving a detailed account of his experiments, and the various applications he had made of his discoveries; but without mentioning dates.
Nov. 19 or 20.	Ordered his third Lamp.	
November 30.	Tried his third Lamp in the Mine.	
December 5.	Exhibited his third Lamp to the Literary and Philosophical Society in Newcastle.	
December 31.		Before this period, "had presented to the miner the wire gauze Lamp."

Fig. 10. Priority chart comparing Davy's and Stephenson's contributions to invention of safety lamp for miners. (From Report Upon the Claims of Mr. George Stephenson,²³ p. 9.)

pronounce, nor will the truth or propriety of their conduct or resolution be at all affected by the most unequivocal proofs of the superiority of the lamp constructed by Sir Humphry Davy, which is now in such general use, and to which they are anxious to assign its full share and tribute of applause.^{23c}

Davy himself considered the Stephenson lamp an unsatisfactory application of the principle he had studied and employed so elegantly. Without naming its inventor, he criticized it in his pamphlet of 1818 for having too little radiating surface to cool the flame as did his wire gauze:

Hence if mixtures of fire-damp are burnt from systems of tubes or canals, or metallic plates, which have small radiating and cooling surfaces: those systems are safe at first, [but] they become dangerous as heated. . . I warn the coal miners against any pretended safety lamps made in this manner, and which to superficial observers, may appear to be constructed upon principles of security, but in which these principles cannot really exist.^{15f}

That Davy was annoyed with Stephenson and Clanny over their claims of the priority and the excellence of their lamps is revealed by a letter he wrote to his friend J. G. Lambton on Oct. 29, 1816:

Mr. [Stephenson] is one of the persons, who after I had advanced a principle of security for a lamp, came upon the ground to endeavour to jockey me. I was not looking to a prize, I merely came forward to show an animal, the breed of which might be useful, when Mr. [Stephenson], Dr. [Clanny], &c. brought their sorry jades, which had never before been seen or heard of, to kick at my blood mare.

I had never heard a word of George Stephenson and his lamps till six weeks after my principle of security had been published; and the general impression of the scientific men in London, which is confirmed by what I heard at Newcastle, is that Stephenson had

some loose idea floating in his mind, which he had unsuccessfully attempted to put into practice till after my labours were made known; then, he made something like a safe lamp, except that it is not *safe*, for the apertures below are four times, and those above, twenty times too large; but, even if Stephenson's plans had not been posterior to my principles, still there is no analogy between his glass exploding machine, and my metallic tissue, permeable to light and air, and impermeable to flame. . . .

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, and believe, because they have for an instant intercepted a portion of her light, that they have hit their mark.^{2m}

This indignation was not based on avarice, however. Buddle had urged Davy to obtain a patent on his lamp, assuring him it would bring a large income; but Sir Humphry refused, saying that his whole object had been to serve the cause of humanity and success in this would be ample reward.²ⁿ Of course Sir Humphry had not lacked for money since his marriage; but the baronetcy conferred on him in 1818 may have reflected appreciation for this generous attitude as well as for his many accomplishments.

Ten years after Sir Humphry's death, Faraday presented before the Royal Institution a lecture entitled "Some General Remarks on Flame." In this lecture Faraday exhibited and explained the apparatus that Davy used when engaged in the investigations leading to his invention of the safety lamp. The object of the lecture was to show that notwithstanding the exceedingly high temperature of flame, in some cases its action is neutralized because of its slight density or because of the small amount of matter in combustion. In order to keep the flame hot, the area must be small and all cooling influences avoided. Faraday then referred to Davy's experiments (according to the report):

Thus again may be explained that remarkable and most useful result obtained by Sir H. Davy, in which it is seen, that flame, in passing through tubes, is so cooled down, that it is incapable of inflaming coal-gas; and that the smaller the tubes, by reason of the greater mass of cooling material in proportion to the heating matter, the shorter they may be made, until at last they become mere apertures, and consequently a sufficient screen may consist simply of a tissue of wire gauze. Thus also, as another illustration of the same thing, a piece of such gauze being brought down over the jet of a gas-light, the flame is unable to penetrate it; but it is to be observed, that if the jet is in any force, this mechanical aid will enable the flame to pass through it, or, which is the same thing, this effect will be produced, if the gauze is brought quickly down upon the flame. Sir Humphrey [sic] Davy was aware of this, but he depended, of course, on all ordinary care being observed in the using of the safety lamp. His apparatus for performing the preliminary experiments was very simple; it consisted of a small vessel charged with an explosive mixture of atmospheric air and coal-gas, and closed at the end with a cork,

having several glass tubes of different calibres fitted into it, through which the flame was to pass and enkindle a gas jet, when the contents were exploded by an electric spark. By presenting each tube in succession to the jet, it was seen by the explosion inflaming, or failing to inflame, the gas, what tubes would or would not allow the flame to pass.²⁴

To the reporter who had witnessed Faraday's lecture and demonstrations,

it was impossible not to be forcibly impressed with the danger which must attend the use of Sir Humphrey [sic] Davy's lamp, in the hands, not to say of careless, but even of careful miners. For, safety in the critical circumstance of a sudden inflammation of the fire damp in the body of the lamp, would depend rather on self-possession than on anything else—on such a presence of mind, indeed, as even the philosopher so situated may fail to exert—for what action of a man groping his way with the lamp stretched out before him, would be more natural, on such an occurrence unexpectedly taking place, or even if anticipated, than quickly to catch it away, by which movement the flame would be jetted out forwards, and inevitable destruction would be the result.

We have no disposition whatever to detract from the merit or the brilliancy of Sir H. Davy's discovery as a scientific fact—it was a beautiful philosophical conception, and most scientifically was it educed, but even the authority of his high name will not seduce us into the opinion, that in seeking to embody it in a mechanical form, he evinced the slightest degree of practical skill and judgment. The philosophy of the lamp is *perfect*, but the lamp itself is a poor fragile thing—no better principle of safety is it possible to propose, but a worse application of it could scarcely have been devised. . . .

Probably the critical reporter was too severe with Davy. The safety lamp itself contributed to a rapid growth of the coal industry. Explosions continued to occur and the number of miners killed did not diminish because the number of miners employed greatly increased and there was more exposure to danger as the mines became deeper.²⁵

Later Discoveries and Developments.—Recognized today as a far more powerful factor than firedamp in many mine explosions is coal dust. Hartmann gave particular attention to this in his extensive research on industrial dust explosions.

In coal mines, the production of dust is an inherent part of the mining operation. Through the ages very fine dust has been formed in coal seams. . . . This dust is held in slip planes in the seam and is released during mining. Coal dust is also produced during undercutting of the coal seam preliminary to blasting, during drilling of holes for placement of explosive charges, during blasting of the coal with explosives, during mining by continuous mining machines, and during loading and haulage. The total quantity of dust formed daily in the operation of coal mines may amount to as much as 3 to 5 percent of the total coal production.²⁶

Hartmann observed that the dangerousness of coal dust was not recognized for many years. It existed in Davy's time, to be sure, but was not thought to be a serious cause of explosion. It did not much impair the use of the Davy lamp. Buddle said in a letter to Davy:

The only inconvenience experienced [in use of the Davy lamp] arises from the great quantity of dust, produced in some situations by working the coal, closing up the meshes of the wire-gauze, and obscuring the light; but the workmen very soon removed this inconvenience by the application of a small brush.^{15g}

Because of continued disastrous explosions in coal mines, several British and French investigators experimented. Faraday, said Hartmann,

observed that in some explosions coal dust helped to spread the flames . . . and eventually it was established that coal dust alone, in the absence of flammable gas in the mine air, can produce explosions when dispersed and ignited.²⁶

And coal-mine explosions still occur, though their frequency is decreased by preventive measures.²⁶

Although Davy had produced a lamp that would both test for gas and provide adequate illumination, it was suggested by Beard 60 years ago that the two functions are not wholly compatible—a good lamp for testing is not a good lamp for general use.

Sensitivity to gas, the principal requirement of a testing lamp, requires the lamp to be so constructed as to allow good circulation in and out. Davy's lamp provided this effect, as did Stephenson's and the later Clanny models. The second requirement of a testing lamp is that it must protect against strong air currents and not allow the transmission of the flame at the top of the lamp. The third requirement of a testing lamp is that it provided for accuracy in measurement of the flame cap produced by gas present in the air.^{12c}

The lamp for general purposes has as its first requirement the maximal illumination consistent with safety, but the early lamps were weak in this respect. The Davy lamps provided not more than 0.16 candlepower, the Stephenson "Geordie" not more than 0.10 candlepower, and the improved Clanny lamps, 0.25 to 0.50 candlepower, whereas the later Wolf naphtha lamp gave 1 candlepower when first lighted.^{12d}

Hardwick and O'Shea^{18f} concluded that the safety lamp was not used so extensively as might have been expected even by 1835, the reason being its ineffectiveness in lighting the work. In some situations the lamps were used mostly for exploration and trial.

In France the Davy lamp had become known shortly after its invention, and in 1816 an article in the *Annales des Mines* strongly recommended its use. By 1825, probably 2,000 Davy lamps were in use in the mines about Anzin in the Département du Nord. In that same year the Davy lamp was put to use in the mines of the Loire and brought about a not-

able decrease in the rate of death from explosions. The Davy lamps were also used in Belgium and in Germany. Improvements in safety lamps were made in the different countries.

In 1835—six years after Sir Humphry's death—a Select Committee on Accidents in Mines was appointed in Great Britain. Its members witnessed some tests conducted at London University, and found that flame could be passed by the common Davy lamp, the Davy with seams, Dr. Clanny's new lamp, Stephenson's lamp with glass, and several others. A similar committee formed in Belgium studied and reported on the variety of lamps available by then. A committee at South Shields (near Newcastle) declared in 1843 that

No mere safety lamp, however ingenious in its construction, is able to secure fiery mines from explosion; and that a reliance on lamps alone is a fatal error, conducive to those dreadful calamities which they are intended to prevent . . . the naked Davy lamp is, without a complete shield, a most dangerous instrument.²⁷

It was remarked long ago that use of the safety lamp changed. Davy, Stephenson, and others had directed their efforts to enabling miners to work in the presence of a dangerous quantity of gas; but a century later the lamp was used to give warning when gas was present, so that the miners should not continue their work in danger.²⁸

By the 1920's the flame safety lamp was replaced by the electric lamp as a device for illuminating the miner's work. Still, as mentioned earlier, the illuminating lamp could not take the place of the safety lamp. To an experienced miner the character of the safety lamp's flame can indicate gas percentages much lower than the explosive limit; and the safety lamp can be used (though it should not be) in a mine atmosphere that contains an explosive mixture of gas and air without great likelihood of explosion. Moreover, flame lamps will not burn in an atmosphere deficient in oxygen and this is a warning for miners to withdraw to a place of safety. For the above reasons flame safety lamps are still used rather widely in the United States to detect gas, and for illumination also; and indeed, several states have required that a given number of such lamps be kept available for emergency use.^{9b}

Conclusion.—In retrospect, even though the safety lamp for miners has gone through a series of modifications and the electric lamp now serves as the common means of illumination, one cannot ignore the pioneer work of Clanny, Stephenson, and Davy in making the flame safety lamp an important feature of coal-mine safety. The fact that the principles of the safety lamp now in use have not changed since the three inventors applied them independently more than 140 years

ago keeps us still in their debt. To Davy, however, for his beautifully conceived and executed experiments, I believe the greatest share of credit must go.

A Legacy.—In his will,²⁰ Sir Humphry Davy left several bequests to his beloved brother, John; and one of these (to be conveyed after the decease of Lady Davy) was the silver service presented to him for his invention of the safety lamp. Sir Humphry desired that, if his brother should not be in a condition to use it, the service should be sold to endow a prize medal; and John Davy in turn made a bequest in accordance with his brother's wish. Thus a prize (worth about £30 a year at the time) was established for the best chemical discovery in Europe or America. It is of interest that the Davy medal is still being awarded.²⁹ Recent recipients have included I. M. Heilbron (1944) "in recognition of his many notable contributions to organic chemistry, especially to the chemistry of natural products of physiological importance";³⁰ Linus Pauling (1947) "in recognition of his distinguished researches on molecular structure";³¹ and most recently (1967) to Sir Ewart Jones, who "has contributed to the chemistry of many classes of organic compounds, the most important of which are polyenes, steroids, triterpenoids, and acetylenic compounds (especially polyacetylenes)."³²

LATER CAREER

Though Sir Humphry was only 38 years of age at the time of his work on flame and invention of the safety lamp, his career had reached its climax. Probably anyone who had contributed so much to the advancement of science today would be just as highly rewarded and feted by the scientific world.

In May 1818 Sir Humphry and Lady Davy embarked upon a second trip to Europe. Their first destination was the coal mines in Belgium, where he had been invited in appreciation for his development of the safety lamp. The principal object of the journey was to try to unroll and make legible some papyrus manuscripts from Herculaneum that were in the museum at Naples.

His efforts with the papyri were unsuccessful, and he apparently encountered difficulties with the museum staff also. Eventually he discontinued the project, although the failure vexed him. According to Sir Harold Hartley,^{3b} aside from personal considerations the condition of the papyri made the task impossible.

Sir Humphry was abroad until the summer of 1820,

staying in Naples more than anywhere else but moving about rather frequently. At Lucca he examined the water to which that delightful spa owes its attraction, and there he rejoined Lady Davy. Often they went their separate ways. Wherever he went, Sir Humphry devoted a good deal of time to fly-fishing for trout. One such interval was spent in Styria and Carinthia, where he fished several rivers that were new to him.

Sir Humphry returned to London in June 1820 because of the severe illness of Sir Joseph Banks, his dear friend and President of the Royal Society. Sir Joseph died on June 19; and Davy, who had his heart set upon the Presidency, campaigned ardently for this position. It appears that the fellows of the Royal Society would have preferred as President Dr. W. H. Wollaston, the physiologist, chemist, physicist, and fly-fishing companion of Sir Humphry. Hartley^{3c} has attributed this disfavor to Davy's high-handed manner, his arrogance, his impatience of opposition to his scientific views, and the fear that he might involve the Royal Society in controversy with learned European societies. Meanwhile Wollaston was appointed President ad interim.

Sir Humphry and his wife then spent a holiday in Scotland, where he fished and also visited with Sir Walter Scott. Returning to London, Davy was elected to the Presidency in November 1820.

For the next 6 years he was reelected unanimously. Davy took his Presidency seriously and apparently did well, gradually overcoming the opposition to him and gaining favor with the membership.

Besides his papyrus investigation, another research problem conducted by Davy terminated unfavorably. The British navy was greatly concerned over the rapid decay of copper sheeting on the bottoms of its ships of war. The Royal Society was consulted in 1823 and Davy took over the investigation. He carried out experiments over a 2-year period. Because of some electrical experiments, he formed the opinion that the corrosion was due to electrolytic action and that if copper could be rendered weakly negative instead of positive the trouble would not occur. His early results appeared to be satisfactory.

A small piece of zinc seemed to preserve several square inches of copper. After more experimentation, bars of iron 6 inches wide at their base and 3 inches in thickness at the center, and of rounded outer surface, were placed at intervals on each side of a ship. Then many navy ships were fitted

with "Davy protectors," but shellfish, sea weed, and small marine life fastened themselves to the copper sheeting and interfered with the electrical action Davy desired to achieve. This also slowed down the vessels and caused some of them to flounder. In 1825 the British government ordered the discontinuance of the protectors on seagoing vessels and in 1828 on the vessels that were kept in the harbor.

The failure of Davy's efforts was most disappointing to him. Besides, there were bitter attacks made upon him by the newspaper writers. It is thought that these disappointments and press attacks might have undermined his constitution. Then, too, the fatal illness in September 1826 of his mother, to whom he was deeply attached, seemed to affect his own health. Sir Humphry's condition deteriorated rapidly, and he suffered a paralytic attack.^{33a}

When Sir Humphry delivered his annual discourse as the six-time President of the Royal Society in November 1826, it was done with considerable effort. Those near him feared that he would suffer an apoplectic seizure. Even though he was elected to a seventh term as President, he was unable to attend the annual dinner.

By January 1827 he had somewhat recovered and undertook a Continental trip. After a month's travel in severe winter weather, he arrived in Ravenna. On July 1, in Salzburg and still not feeling at his best, Davy resigned the Presidency of the Royal Society by a letter to its Vice-President, his friend Davies Gilbert. On Nov. 6, 1827, the Royal Society accepted Davy's resignation and appointed Gilbert to fill the chair until the anniversary meeting.

Meanwhile Sir Humphry returned to England, arriving in London on Oct. 6. Though he still felt ill, he did at this time complete for publication his *Salmonia; or Days of Fly-Fishing*.³⁴ Davy's interest in fishing had persisted from his early youth, as mentioned earlier.³⁵ *Salmonia*, which went through many editions, was patterned after Izaak Walton's *The Compleat Angler*. In it Sir Humphry hoped to do for the fly-fisherman what Walton in his earlier classic had done for the bait-fisherman. Like *The Compleat Angler*, *Salmonia* is a series of conversations; and the characters, though not positively identified, are thought to include himself and his actual fishing friends—particularly Drs. Wollaston and Babington (Fig. 11). In this volume is found some of Davy's remarkable prose. He could write beautifully, as the following passage indicates:

How delightful in the early spring, after the dull and tedious time of



Fig. 11. Sir Humphry Davy and his fishing companions, Dr. Wollaston (left) and Dr. Babington (right). (From Davy, H.: *Salmonia*.³⁴)

winter, when the frosts disappear and the sunshine warms the earth and waters, to wander forth by some clear stream, to see the leaf bursting from the purple bud, to scent the odours of the bank perfumed by the violet, and enamelled, as it were, with the primrose and the daisy; to wander upon the fresh turf below the shade of trees, whose bright blossoms are filled with the music of the bee; and on the surface of the waters to view the gaudy flies sparkling like animated gems in the sunbeams, whilst the bright and beautiful trout is watching them from below. . . .^{34a}

Because Davy found no improvement in his health, he decided on another trip to Europe. This was to be his last. Leaving London at the end of March 1828, he traveled to his favorite regions in the Alps of southern Austria. When he felt like it he hunted and fished and extended his observations on natural history. He gradually proceeded southward, spending some time on additions for a second edition of *Salmonia* and working on his last publication, *Consolations in Travel; or, the Last Days of a Philosopher*.³⁶ This was to be published by his brother in 1830, after Sir Humphry's death.

Davy's continued physical impairment is evidenced from his letter to his brother from Rome dated Jan. 30, 1829: "... I have suffered more, both in my limbs and stomach, than at

any time since my illness. The pain and palpitation in the region of the heart has increased almost alarmingly. . . ."^{33b}

On Feb. 23, 1829, Davy suffered another stroke, and on Feb. 25 he dictated a note to his brother John that he was dying and that he wanted his brother to come to him. John had already embarked and reached Davy at Rome on Mar. 16, 1829. Sir Humphry rallied from his illness, and Lady Davy came in April. The party started the return trip to England but death claimed Sir Humphry in Geneva on May 29, 1829, at 51 years of age. In conformity with his wish to be buried where he died, he was interred in Geneva, in the cemetery of Plain-Palais. His widow placed a tablet to his memory in Westminster Abbey and a statue of him was erected at his birthplace, Penzance.

In telling the story of Davy, especially his work on the safety lamp, I hope that I have appraised him justly. He has been characterized as the most romantic of chemists; but he was more than that—he was a lover of his fellowmen, and this is the way he shall always be remembered.

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