For the 1889 Paris Exposition, Jules Bourdais, a prominent French architect, proposed to erect a tower 360 metres (1,200 feet) high in the centre of Paris, near the Pont-Neuf, with arc-lights strong enough to illuminate the whole city. By this means the *street* lighting of Paris, which at that time consisted of thousands of gas-lamps, was to be transformed into *city* lighting.

This proposal by the builder of the Trocadéro was the subject of detailed discussion, along with another vision involving a tower, that of the bridge construction engineer Gustave Eiffel. Eventually, however, the committee preparing the Exposition decided to accept Eiffel's project. No one doubted that it was technically possible to illuminate the whole of Paris from one source of light. In the end, Eiffel's tower was built, not because it was considered less far-fetched than Bourdais' — on the contrary, contemporaries feared being blinded by such a centralised light source.

Bourdais' Sun Tower (Tour Soleil) is a monument to nineteenth-century fantasies involving light. It is no less impressive for the fact that it was never built and soon fell into oblivion. The proposed tower marks the climax of a development in which earlier technical advances led people to believe that light could be produced in unlimited quantities. They thought in all seriousness of 'turning night into day', to cite a popular expression of the period. But although light was produced in unprecedented quantities and intensities in the nineteenth century, the ideal was never attained. Even Bourdais' tower would only have turned the night into a very dim artificial day.

It makes sense, historically, that this sort of project was conceived, discussed and almost realised in Paris. City of light, *ville lumière* — Paris gained this popular epithet thanks first to the eighteenth-century Enlightenment, of which it was the centre, and then to its brightly lit amusement boulevards, a product of the nineteenth century. On closer inspection, this city of light proves to have been an active centre in the history of artificial lighting. Time and again, it sent out important scientific, technical and psychological impulses. Is there some con-

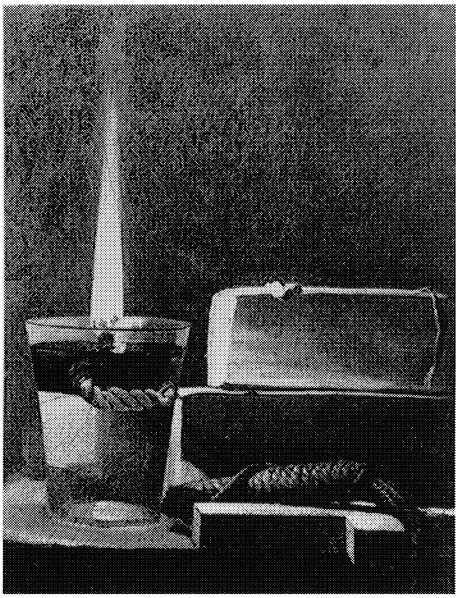
nection between the philosophical Enlightenment and actual illumination, perhaps along the lines that the philosophical need for enlightenment awakened an interest in real light? If this were the case, we should look for the link between Enlightenment and illumination in the natural sciences of the times, in particular, in chemistry, which was also a Parisian speciality. (Parallels in time and space suggest that Lavoisier's research, which allowed him to arrive at the modern theory of combustion, could be called a chemical 'enlightenment'.) Lavoisier's discovery that flames were not fed by a substance called phlogiston, as had previously been thought, but by the oxygen in the air, opens the more recent history of artificial lighting. Once the true chemical nature of the flame had been recognised, it could be manipulated in a completely new way and no longer had to be accepted as it had existed since time immemorial. With the help of an appropriate chemical apparatus, a flame could now be changed and made to perform at a higher level of efficiency — a process similar to the one that took place at about the same time when James Watt improved the steam engine.

A contemporary of Lavoisier's in Paris rationalised the flame in this way. But first, let us have a look at the development of the flame used exclusively for lighting.

Fire and Flame

Fire is the origin of artificial light. Electric light, too, 'burns' as soon as it is switched on. Fire provided three great cultural services for early mankind: cooking (later expanded to include metallurgy and pottery), heating and lighting. Originally the one undivided fire, around which people gathered after darkness had fallen, fulfilled all three functions. The unity of the primeval fire is the source of the magic that fire possesses for archaic cultures and in mythology.

As civilisation progressed, the original unity dissolved and the functions of fire were separated, although cooking and heating remained connected for a long time. The first element to be separated out was lighting. The most brightly burning logs



The wick
(Detail from George de la Tour, *Sainte Madeleine, Musée du Louvre*)

would be pulled out of the camp or cooking fire and set up as fire brands. This experience taught people to distinguish different types of wood in terms of their power of illumination, that is, by their resin content.

Up to this point, illumination depended entirely on the naturally occurring properties of wood. The next step was a technical innovation. Torches consist of logs of wood that have been treated artificially with a substance that burns particularly brightly — resin or pitch. This forms a lump at one end of the torch. The original log thus lost its significance. From now on it no longer provided the fuel but simply the shaft or mounting device.

The candle and the oil-lamp represent the next step in the technical development of lighting. They are usually described as a scaling-down and refinement of the torch. 'It was probably because the aforementioned light sources [i.e. the torch] were

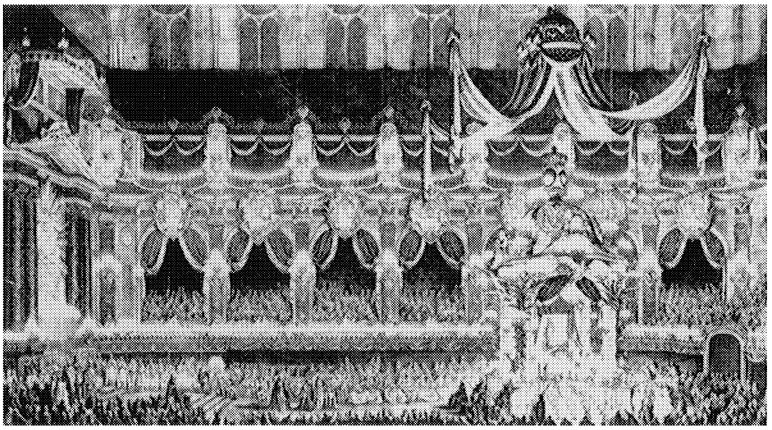
not versatile enough, that the candle was finally invented. Man was searching for a small compact torch which could be carried easily, had a long burning life, required no auxiliary fuel, gave off little smoke or soot, and was easily lighted.'[1] This list of the new qualities of the candle is correct as far as it goes, but it does not mention the fundamentally new technical principle behind the candle.

In the torch, the site of combustion and the fuel are one and the same thing, while in the candle they are clearly separated. From now on the *wick* acts as the sole site of combustion, and it is fed the material the flame needs by the fuel reservoir (the wax cylinder of the candle, the container of oil in the lamp), kept neatly distinct from the flame. The torch had remained a clearly recognisable, if much changed, log of wood from the hearth fire. The flame flickering around a wick for the first time burned totally and exclusively for the purpose of giving light. The wick was as revolutionary in the development of artificial lighting as the wheel in the history of transport.

Psychologically, this technical innovation was extremely significant. Seeing a flame burning around an almost imperceptible wick is a very different experience from seeing a flame flickering around a log or a torch. The log and the torch are physically consumed by the process of burning, but the flame burns around the wick without any visible sign of destruction. The wick remains unchanged (merely requiring to be 'trimmed' from time to time, and even that was unnecessary by the beginning of the nineteenth century), and it is only the fuel feeding it that diminishes. But this takes place at a rate so slow that an observer can perceive it only over a relatively long period of time. In the torch, people experienced the elemental, destructive power of fire — a reflection of their own still-untamed drives. In the candle flame, burning steadily and quietly, fire had become as pacified and regulated as the culture that it illuminated.

The flame cultivated for light thousands of years ago remained essentially unchanged until the eighteenth century. When more light was needed, it was produced simply by multiplying the number of individual lights. Like fireworks, festive illuminations were a standard part of seventeenth- and

1. N.S. Knaggs, *Adventures in Man's First Plastic* (New York, 1947), p. 107.

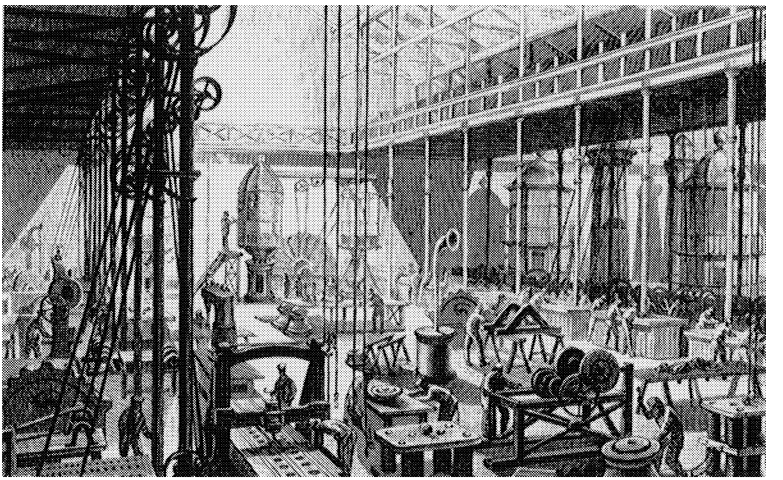


Ceremonial light display
Philip V of Spain's funeral in Notre Dame Paris, 1746.
(Science Museum, London)

eighteenth-century courtly culture. They were produced by burning thousands of individual lights, consuming sums similar to those spent on other forms of ostentatious waste under the *ancien régime*. In 1688, 24,000 lights were used to illuminate the park of Versailles alone,[2] presumably all wax candles — an extremely costly form of lighting normally used for royal displays. (Feudal light festivals in other forms were also expensive, especially fireworks, which had developed out of the primal bonfire. The motifs of waste and destruction are clearly but inseparably intertwined in an event that combined illumination, bonfire, funeral pyre and fireworks: 'In 1515, when news of Francis I's victory over the Swiss at Marignano reached Rome, one of the Orsinis acquired a whole block of houses, which he crammed with combustible materials and gunpowder and set alight as a bonfire of almost Neroesque proportions.'[3])

The expense of lighting materials limited the use of light in bourgeois households of the time. Artificial light was used for work, not for celebrations; it was employed in a rational, eco-

2. Arthur Lotz, *Das Feuerwerk* (Leipzig, n.d. [1940]), p. 66.
3. Ibid., p. 18.



Factory lit up by electric arc lighting
(*Source*: H. Fontaine, *Eclairage à l'électricité*, Paris, 1877)

nomical way, not as a vehicle for conspicuous consumption. It emancipated the working day from its dependence on natural daylight, a process that had begun with the introduction of mechanical clocks in the sixteenth century.[4] For craftsmen, the working day started and finished at set times: in winter, it started so many hours before sunrise and finished a certain number of hours after sunset.

As long as the work that needed to be lit up was tied to individual craftsmen and only the winter morning and evening hours required extra light, the glow provided by traditional candles and oil lamps was adequate. This changed with the introduction of industrial methods of production. Work processes were no longer regulated by the individual worker; they became integrated, comprehensive operations. The new factories needed new sources of light. Artificial light was needed to illuminate larger spaces for longer periods of time. In the facto-

4. Wolfgang Nahrstedt, *Die Entstehung der Freizeit, dargestellt am Beispiel Hamburgs* (Göttingen, 1972), p. 117.

ries, night was turned to day more consistently than anywhere else.

Industrial requirements could not be satisfied simply by multiplying traditional sources of light. To light up a cotton mill with hundreds or even thousands of candles in the eighteenth century would have cost as much as the festive illumination of a medium-sized chateau.

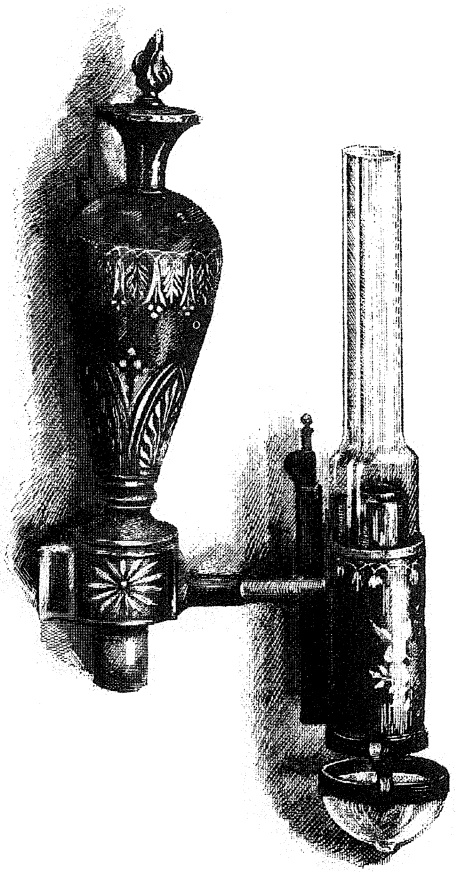
As the cost of multiplying the number of individual lights was prohibitive, the only way to increase the amount of light was to heighten the intensity of the individual light source.

Argand: The Modernisation of the Wick

At the end of the eighteenth century the technology of lighting, which had hardly changed for thousands of years, was in a state of flux. The incentive for change was the increased need for light; the immediate trigger was the theory of combustion developed by Lavoisier in the 1770s. He discovered that the oxygen in the air was as necessary for combustion as the carbon in the actual fuel. A new paradigm in chemistry was born, and it stimulated a similar paradigm shift in the technology of lighting. If the air contained a combustible substance of such importance, this factor had to be taken into account in the construction of lamps. In other words, the flame had to receive a bigger air supply than it had previously.

Even before Lavoisier, interest had focused on the actual site of combustion in the lamp. The wick, as we have seen, representing the first revolution in the history of artificial lighting, was still unchanged: a solid round cord of twisted or woven cotton or linen. By the eighteenth century a great deal of experience had been gathered about wicks and ways to improve them. The material, the type of weave and the diameter were all precisely laid down, and people were already going so far as to douse the wick in certain chemicals to make it tougher and more efficient.[5] In 1773 in France, a flat band was used as a wick for

5. Michael Schrøder, *The Argand Burner: Its Origin and Development in France and England 1780–1800* (Odense, 1969), pp. 124–5.



Argand lamp, late eighteenth century
(H.R. d'Allemagne, *Histoire du luminaire*, Paris, 1891)

the first time. This considerably enlarged the flame, giving the effect of a miniature wall of fire — a *surface* of light.[6]

None of these improvements, however, broke out of the traditional paradigm governing combustion and illumination.

In 1783 the chemist and designer Francois Ami Argand publicly unveiled a lamp in Paris that, by contrast, made direct,

6. Ibid., p. 123.

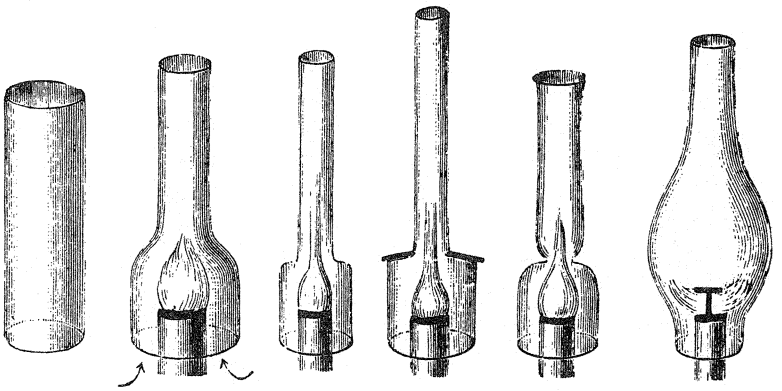
practical use of Lavoisier's findings. 'His lamp was not an isolated technical construction, but represented a philosophical conception of combustion.'[7]

(As with so many eighteenth-century figures, the boundaries between the scientist, the inventor and the entrepreneur were fluid in Argands' case. A 'project maker' combined all these interests and activities. Born in 1750 in Geneva, he studied with the Genevan chemist H. B. de Saussure. When he went to Paris, de Saussure recommended him to Fourcroy and Lavoisier. For some time Argand ran distilleries in Languedoc, with apparent success. He was a close friend and colleague of the Montgolfier brothers, whose hot-air balloon ascents combined sober scientific experiment with elements of a circus act. When Argand's lamp was not an immediate commercial success in Paris, he went straight to England. There he began negotiations with Watt & Boulton, the biggest industrial firm of the time which, he believed, could offer him better business opportunities than he could find in Paris.)

In the same year as the Montgolfier brothers first went up in a balloon, Argand introduced a lamp whose primary innovation was a fundamentally new type of wick. No longer solid, but hollow, the wick in the Argand burner consisted of a flat band rolled up into a small tube. This gave the flame, correspondingly shaped, a double air supply, from outside as well as from inside. Consequently, it burned at a higher temperature, completely consuming the carbon particles left largely unburned by the traditional wick. They had previously gone into the air as soot, dimming the light cast by the flame. Pierre Joseph Macquer, chemist and Fellow of the Académie des Sciences, writing in 1783, gives us an idea of the way in which this new, cylinder-shaped flame affected contemporary perceptions of the light:

> The effect of this lamp is exceptionally beautiful. Its extraordinary bright, lively and almost dazzling light surpasses that of all ordinary lamps, without producing any sort of smoke. I held a sheet of white paper over the flame for quite a long time. A sooty flame would have

7. Ibid., p. 96. Schrøder even suggests that the Argand burner might have developed directly from the burners used in chemical laboratories in the eighteenth century (ibid., p. 137).



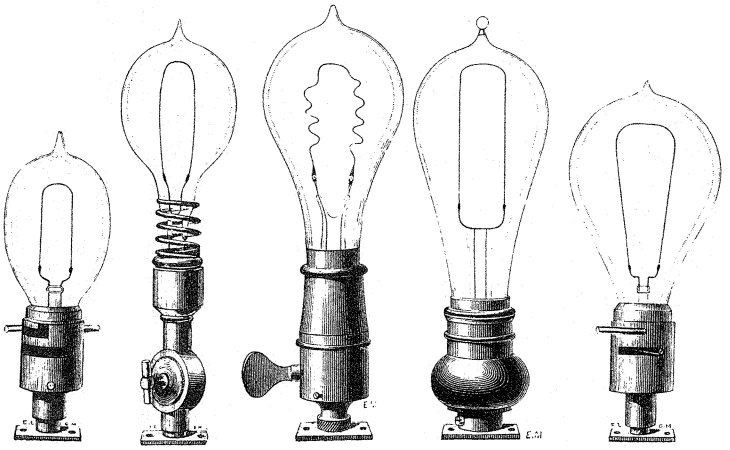
Glass cylinders for Argand lamps
(*Source*: *Buch der Erfindungen, Gewerbe und Industrien*, Leipzig, 1896)

blackened it quickly, but this sheet of paper stayed completely white. In addition, I could not smell the slightest odour near the flame.[8]

The effect of the double air supply was intensified by Argand's second significant innovation: enclosing the flame in a glass cylinder.[9] This acted as a chimney, and also protected the flame from air currents. Enclosed in glass, the flame had at last found its own space, separated from the outside world. Accord-

8. 'L'effet de cette lampe est des plus beaux; sa lumière très blanche, très vive, et presque éblouissante, surpasse de beaucoup celle de toutes les lampes qu'on a imaginées jusque' à presént, du moins à ma connaissance, elle n'est accompagnée d'aucune fumée. J'ai tenu au-dessus de la flamme de cette lampe un papier blanc pendant un temps asser [sic] long pour qu'il fut noirci et enfamé si la flamme eut été fuligineuse; mais ce papier est resté parfaitement blanc; je n'ai non plus remarqué aucune espèce d'odeur au dessus et aux environs de la flamme de la lampe de M. Argand.' Original French quoted from Schrøder, *The Argand Burner*, p. 62. The English version given in the text is translated from the German version in Wolfgang Schivelbusch, *Lichtblicke. Zur Geschichte der künstlichen Helligkeit im 19. Jahrhundert* (Munich and Vienna, 1983), p. 19.

9. In this context, the plagiarism dispute between Argand and his earlier colleagues Quinquet and Lange is not of direct interest. Encouraged by Argand's departure for England in 1783, these two gentlemen gave themselves out as the inventors of the lamp — a case of early 'industrial espionage', as Schrøder says. According to Schrøder, Argand was undoubtedly the original inventor of the lamp, but the addition of the glass cylinder does not seem to be so easily attributable to one or the other of this trio. Schrøder sums up the case on pp. 87–8 of *The Argand Burner*.



Electric light bulbs
(*Source*: *La Lumière électrique*, 1885)

ing to contemporary accounts, it burned there with amazing calmness and steadiness. The cylinder, wrote one observer, 'allows the flame to burn in complete peace and gives it a remarkable brightness'.[10] In Argand's words, 'the flame did not flicker in the slightest'.[11]

A third device in Argand's burner completed the modernisation of the flame: a mechanism for raising and lowering the wick, thereby varying its length. This made it possible to regulate the supply of oil and thus the intensity of light. Turning the wick up produced a larger flame and more light; turning the wick down had the opposite effect. As Meusnier, a Fellow of the Academy, pointed out in a report, this mechanism made it possible to create a balance 'between the quantity of fuel used and the amount of air necessary for combustion'.[12]

10. '. . . conserve à la flamme une tranquillité inaltérable et lui donne un éclat étonnant', Lange, Argand's colleague and later rival. The original French text is quoted from Schrøder, ibid., p. 110. The English version given in the text is translated from the German version given in Wolfgang Schivelbusch, *Lichtblicke*, p. 20.

11. '. . . impossibilité d'aucune vaccillation dans la flamme'; original French quoted from Schrøder, *The Argand Burner*, p. 207.The English version given in the text is translated from the German version in Schivelbusch, *Lichtblicke*, p. 20.

12. '. . . entre la quantité du combustible consommé et celle de l'air vital qui lui est

The Argand burner was to the nineteenth-century household what the electric light bulb is to that of the twentieth century. Its design clearly foreshadowed modern forms of lighting. The Argand burner possessed primitive equivalents of the elements technically perfected in an electric bulb: the glass cylinder corresponded to the glass outer casing of an electric bulb, the wick mechanism to the light switch, and the flame, intensified by the increased oxygen supply, to the filament.

But this is only one side of the story. Ultimately, the Argand burner did not transcend traditional lighting technology. In essence, it remained an *oil-lamp*, that is an open flame burning around a wick fed by its own fuel reservoir. It was simply an oil-lamp that had been improved in line with the findings of modern chemistry. In this form it survived the nineteenth century and, indeed, was to gain a new lease of life after the discovery of paraffin. The next step in the development of lighting, involving the application of industrial processes, opened the modern era in the history of illumination.

Gaslight

Clear, bright, and colourless
(*Monthly Magazine*, 1807)

La flamme est sortie blanche et brillante, l'oeil avait peine à en soutenir l'éclat.
(*Almanach sous verre*, 1812)

It completely penetrates the whole atmosphere . . . appears as natural and pure as daylight.
(Newspaper report, 1815)

Das Gaslicht ist zu rein für das menschliche Auge, und unsere Enkel werden blind werden.
(Ludwig Börne, *c.* 1824)

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fourni'; original French quoted from Schrøder, *The Argand Burner*, p. 118. The English version in the text is translated from the German version in Schivelbusch, *Lichtblicke*, p. 20.

Le gaz a remplacé le soleil.
(Jules Janin, 1839)

In the dazzling brightness of gaslight, the first thing people wanted to know was what had happened to the wick. 'Do you mean to tell us that it will be possible to have a light without a wick?', an MP asked the gas engineer William Murdoch at a hearing in the House of Commons in 1810.[13] What to ordinary perceptions seemed contrary to the nature of combustion was explained prominently in the numerous manuals on gas lighting that were published soon after. For example, we read in Samuel Clegg's *Practical Treatise on the Manufacture and Distribution of Coal-Gas*, a standard work that went through five editions, that

> the whole difference between the greater process of the gas-light operation and the miniature operation of a candle or a lamp, consists in having the distillatory apparatus at the gaslight manufactory, at a distance, instead of being in the wick of the candle or lamp — in having the crude inflammable matter decomposed, previous to the elastic fluid being wanted, and stored up for use, instead of being prepared and consumed as fast as it proceeds from the decomposed oil, wax, or tallow; and lastly, in transmitting the gas to any required distance, and igniting it at the burner or lamp of the conducting tube, instead of burning it at the apex of the wick.[14]

In his *Handbuch für Steinkohlengas-Beleuchtung* (Manual of Coal-Gas Lighting), Schilling expresses the same idea more briefly and more poetically: 'The flame of a candle or a lamp is . . . a true microcosm of a gas-works. It operates so reliably and silently in the tiny space at the end of a wick that for many centuries its presence went unnoticed.'[15]

It had been known since the seventeenth century at least that distilling coal or wood produces an inflammable gas. The first description of this phenomenon appears in a letter written by John Clayton, an amateur chemist, to Robert Boyle before 1691, though it was not published until 1739 in the journal *Philosophical Transactions of the Royal Society*. Clayton writes:

13. Samuel Smiles, *Lives of the Engineers: Boulton and Watt* (London, 1874), p. 349.
14. Samuel Clegg, Jr, *A Practical Treatise on the Manufacture and Distribution of Coal-Gas*, 1st edn (London, 1841), pp. 53–4.
15. N.H. Schilling, *Handbuch für Steinkohlengas-Beleuchtung*, 2nd edn (Munich, 1866).

> I got some coal, and distilled it in a retort in an open fire. At first there came over only phlegm, afterwards a black oil, and then likewise a spirit arose, which I could no ways condense; but it forced my lute, or broke my glasses. Once, when it had forced my lute, coming close thereto in order to try to repair it, I observed that the spirit which issued out, caught fire at the flame of the candle, and continued burning with violence as it issued out in a stream, which I blew out and lighted again alternately for several times. I then had a mind to try if I could save any of this spirit; in order to which I took a turbinated receiver, and, putting a candle to the pipe of the receiver, whilst the spirit arose, I observed that it catched [*sic*] flame, and continued burning at the end of the pipe, though you could not discern what fed the flame. I then blew it out and lighted it again several times.[16]

'Inflammable air' or 'spirit', as this gas was called, was officially known by 1739 at the latest. But even though people knew what it was and how to make it, no one put this knowledge to practical use in the decades that followed. Like many mechanical inventions of the period, gas was used only for fun. 'When I had a mind to divert strangers or friends', Clayton's letter continues,

> I have frequently taken one of these bladders [i.e. gas containers made of animals' bladders] and pricked a hole therein with a pin, and compressing gently the bladder near the flame of a candle till it took fire, it would then continue flaming till all the spirit was compressed out of the bladder; which was the more suprising because no one could discern any difference in the appearance between these bladders and those which are filled with common air.

The playful phase in the history of gaslight came to an end around 1800, with the sudden discovery that it was suitable for lighting the new English factories. At the time, these were sprouting like mushrooms, and they soon generated a great demand for light.

Modern gas lighting began as industrial lighting. It shares this industrial origin with the other great technological innovation of the nineteenth century, the railway. Railways were used to

16. *Philosophical Transactions of the Royal Society for the Year 1739*, vol.XLI, quoted from T.S. Peckston, *The Theory and Practice of Gas-Lighting* (London, 1819), p. 92.

transport coal in Newcastle before they become a general means of transportation. Both were natural outgrowths of the English industrial landscape, and this was shaped by coal. The coal industry gave birth to the Industrial Revolution in England.

This view is held by many historians, most strongly by John Nef,[17] and there is much to support it. Around 1600 England's industrial and technological position in Europe was marginal, even parasitical; a century later the positions were reversed. The driving force behind this change was England's enormous coal deposits. The exhaustion of wood supplies at the time made coal increasingly important, and England's reserves gave her an edge over the rest of Western Europe. The introduction of coal and coal-based technology into areas of production that had previously been wood-based resulted in a great technological spurt. John R. Harris writes:

> As it became clear in many segments of the economy that coal contained the potential of more efficient production and lower costs, industries that had not yet adopted coal looked to those that had made the change most successfully and borrowed and adapted techniques and apparatus already available. Moreover, each industry that switched to coal found it necessary to innovate and to modify existing equipment and procedures in order to accommodate the new fuel. Higher temperatures attained by burning coal, for example, demanded modification in the design of furnaces and made the need for improved refractory materials urgent.[18]

If the industrial culture of Europe before the eighteenth century was materially and technologically *wood-based,* as Werner Som-

17. John U. Nef., *Rise of the British Coal Industry*, 2 vols. (London, 1932).

18. John R. Harris, 'The Rise of Coal Technology', *Scientific American*, August 1974, p. 96. We should also like to refer to Maurice Daumas' approach. He suggests pursuing the 'inner logic' of any given technology and names the whole complex surrounding coal as a model: 'The close connections between mining, the steam engine and the production of iron using coke are one of the classic examples. A study of horizontal and vertical interlinkages furnishes further evidence. For example, an obvious logical link exists between the distillation of coke and the production of illuminating gas and between this and the preparation of artificial dyes and the development of the internal combustion engine. One also finds a link when investigating the influence of the steam engine on the forms of the first gas engines and of Froment's electro-magnetic motors' (M. Daumas, 'L'histoire des techniques: son objet, ses limites, ses méthodes', *Documents pour l'histoire des techniques*, 7, 1969; translated here from the German version in R. Rürup and K. Hausen (eds.), *Moderne Technikgeschichte*, Cologne, 1975, p. 41).

bart has suggested, then developments in England since the seventeenth century must be described as *coal-based*.

Let us go back to gas lighting. Gas could be produced without any technical innovations. It was obtained by more or less the same process as the one that turned coal into coke, first used by Abraham Darby early in the eighteenth century. After all, coke is nothing but coal that has been distilled. For a long time, only one of the by-products of this process was used for something else — tar for caulking ships — while the gas given off simply blew away in the air. The production of gas for lighting merely involved exploiting a previously ignored waste product. This economically attractive quality, combined with its power of illumination, made gas a suitable fuel for industrial lighting.

The first gas lighting systems were installed in the very stronghold of British industry, Watt & Boulton of Soho near Birmingham. The owners of this firm had already shown their interest in lighting innovations when they started producing Argand burners in the 1780s. They knew the inventor of the Argand burner personally; he had come to England because he hoped it would offer him better commercial opportunities than France had done. At Watt & Boulton, it was the William Murdoch mentioned above who took the lead in gas lighting, more or less on his own initiative. (Around 1800 Murdoch built the first functional model of a steam locomotive — another example of the nineteenth-century affinity between railways and gas lighting. Carl Gustav Carus calls gas and steam the 'two main driving forces of history'.) Murdoch's experiments in the last years of the eighteenth century illustrate how gas lighting progressed from an experimental to an industrial stage. We can see clearly how the inherent qualities of gas technology influenced later developments. There was no fully developed system from the start that kept the production, storage, distribution and consumption of gas clearly separate from each other.

Murdoch began by heating coal in the small glass retorts that were commonly used in the science laboratories of the day. Clayton had probably used them too. After some time Murdoch switched to larger iron containers. Even these, however, did not hold more than 15 pounds of coal.[19] Like Clayton and other

19. William Matthews, *An Historical Sketch of the Origin, Progress and Present State of Gas-Lighting* (London, 1827), p. 24.

early-eighteenth-century experimenters, Murdoch filled the gas produced in this way into balloon-like containers. The chemist William Henry describes how they were carried around like a lamp or a candle. 'Bags of leather, and of varnished silk, bladders, and vessels of tinned iron, were filled with the gas, which was set fire to and carried about from room to room, with a view of ascertaining how far it could be made to answer the purposes of a moveable or transferable light.'[20]

But this form of storage and distribution soon proved to be unsuitable for gas. (Transportable gas was not feasible until compression techniques became available, and even then it was only developed for very limited purposes.) Murdoch saw that he would have to connect the site of production to the site where gas was consumed. He did this with pipes, which took the gas from the retort, where it was produced, to a gasometer, where it was stored. From here it could be drawn off for use at any time. More pipes conveyed the gas to the site of combustion. Valves regulated the whole process. Murdoch installed the first system of this kind in the forge at Soho in 1802; a second one, built for a Manchester cotton mill in 1805, was technically more complicated. Here gas technology, in its basic outlines, was already fully developed. The system designed for Phillips & Lee in Manchester consisted of retorts, a gasometer, pipelines, valves and, as a further improvement, a mechanism for purifying the gas. The journal *Philosophical Transactions of the Royal Society*, which seventy years earlier had published the report of Clayton's first experiment, printed Murdoch's description of his perfected system in 1808:

> The gas as it rises from them [the retorts] is conveyed by iron pipes into large reservoirs, or gazometers, where it is washed and purified, previous to its being conveyed through other pipes, called mains, to the mill. These mains branch off into a variety of ramifications (forming a total length of several miles), and diminish in size, as the quantity of gas required to be passed through them becomes less.[21]

This system is the prototype of all later gas-works, the only differences being in scale and technical detail. At this stage, we

20. Quoted from Peckston, *Theory and Practice of Gas-Lighting*, p. 95.
21. *Philosophical Transactions of the Royal Society* (1808), p. 125.

must remember, gaslight was used exclusively for lighting factories. Neither Murdoch nor his employers, Boulton and Watt, thought of any possible application outside industry. They knew the advantages of gaslight, but only as they applied to factory work. Murdoch pointed out that 'its being free from the inconvenience and danger, resulting from the sparks and frequent snuffing of candles, is a circumstance of material importance, as tending to diminish the hazard of fire, to which cotton mills are known to be much exposed'.[22] And the 'peculiar softness and clearness of this light', made much of by Murdoch, was also seen solely as an advantage in industry. As Murdoch said, these qualities brought the new light 'into great favour with the work people'.

Before gaslight could move out of the factory and be put to more general use, an invisible barrier had to be overcome. Gaslight had to be seen from a point of view and in the context of experiences quite different from those of the English industrial pioneers. This happened in Paris.

The 'Thermolamp'

France had not experienced anything like England's industrialisation. Coal led a marginal existence there and well into the nineteenth century it remained a *produit revolutionnaire*.[23] Wood continued to be the most important fuel.

In this situation Philippe Lebon, a graduate of the École des ponts et chaussées, had been experimenting with gas distilled from wood since the early 1790s. Lebon (1767–1804) was an inventor and 'project-maker' like François Argand: scientifically trained, in touch with the leading chemists of his day (Fourcroy, Guyton de Morveau) but also interested in the practical application — put more bluntly, the commercial exploitation — of his results. As he lacked the industrial framework within which Murdoch operated, his motives and goals were necessarily different. For Lebon, gas lighting was not an industrial development — as we have said, France did not yet have any industry.

22. Ibid.

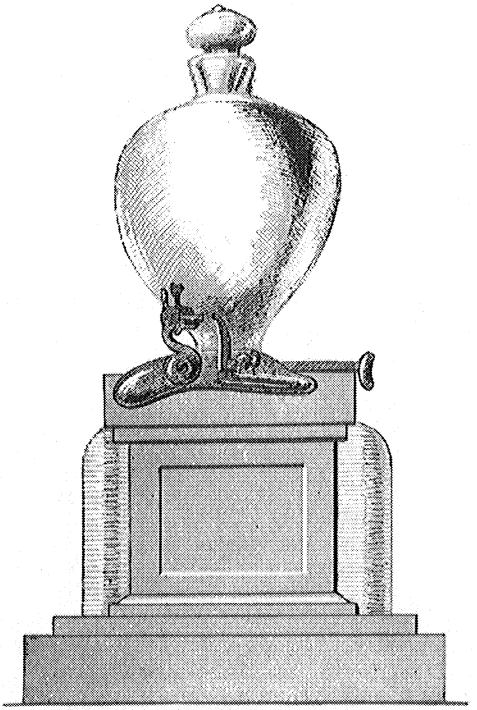
23. C. Fohlen, in 'Charbon et Sciences Humaines', *Colloque international de l'Université de Lille en mai 1963* (Lille, 1963), p. 148.

Instead, for Lebon, gas lighting possessed its own intrinsic value, as something that contributed to the civilisation and progress of humanity. Accordingly, he saw gas production less as the exploitation of a previously neglected waste product than as the realisation of a philosophical principle. (Lebon's concept of gas relates to Murdoch's as do Saint Simonianism and utopian socialism to English political economy. In both cases the prose of English economy was translated into the poetry of French humanitarian industrial systems.)

Lebon was interested in gas as something that did not have the disadvantages and impurities of naturally occurring fuels. In 1799 he published a work entitled 'Moyens nouveaux d'employer les combustibles plus utilement et à la chaleur et à la lumière et d'en recueillir les divers produits' (New methods for employing heating and lighting fuels more profitably and for collecting the various constituents), in which he described his starting point:

> Up to now, we have not been able to resolve fuel into various components. We have not possessed the technical means to separate out the constituents that help, or even hinder, the production of heat and light, which could perhaps be useful for other purposes. These substances include, above all, the pyroligneous acid contained in wood, that can be used to advantage in the production of porcelain blue as well as in various other operations. Up to now we have not been able to use the elements necessary for combustion separately and in a form so pure that a completely even heat and light are produced. We have not sufficiently mastered the principle upon which the production of heat and light rests (inflammable gas, also known as hydrogen gas). We have not been able to store it in order to use it for balloons or other purposes; we cannot conduct it at will so that its capacity for producing light and heat can be used at other, distant places.[24]

24. 'Jusqu'à présent nos moyens n'ont point offert séparément à notre disposition les diverses parties constituantes du combustible. Nous n'avons pu recueillir celles de ces parties qui étaient ou inutiles ou nuisibles à la combustion à la chaleur et à la lumière et qui pouvaient être précieuses pour d'autres usages. Parmi celles-ci on doit compter spécialement l'Acide pyroligneux contenu dans le bois et qui s'emploie avec avantage à former les chaux métalliques et diverses autres opérations. Nous n'avons pu offrir isolément à la combustion chacune de ces parties qui en était susceptible, régler une opération qui devênait trop compliquée, en coercer et recueillir les produit et obtenir des effets constants de lumière et de chaleur. Nous n'avons pu gouverner à tel point le principe qui poduit et de



Thermolamp, late eighteenth century
(*Source*: H.R. d'Allemagne, *Historie du luminaire*, Paris, 1891)

For Lebon distilling natural fuel meant reordering the chaos of nature by rational, scientific principles. The gas made this way was seen as pure energy, just as a hundred years later electricity would be seen as pure (in contrast to gas, which had become 'dirty' in the meantime).

Lebon's 'thermolamp' was technically almost identical with

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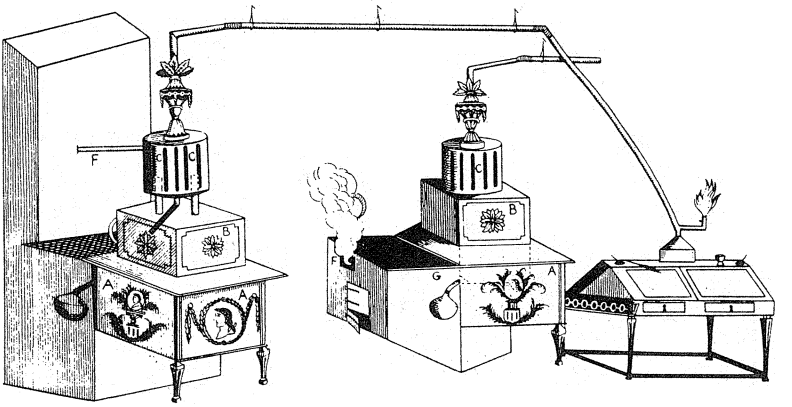
la lumière et de la chaleur (le gaz inflammable ou hydrogène) que l'on put à son gré le recuillir, soit pour le destiner aux aérostats, soit pour tout autre usage, le distribuer, modifier le nombre et la forme de ses jets, l'enflammer et lui faire porter à toute distance du foyer la lumière et la chaleur.' The original French is quoted from Charles Hunt, *A History of the Introduction of Gas Lighting* (London, 1907), p. 52. The English version in the text is translated from the German version given in Wolfgang Schivelbusch, *Lichtblicke*, p. 28.

Murdoch's system: gas was produced in a retort, stored in a container and conveyed to the site of combustion by pipes. The difference lay in the intended application. The thermolamp emitted not only light but also heat, and beyond this, was to serve as a general energy source. The title under which Lebon published a description of his apparatus in 1801 makes it sound like a technical utopia: 'Thermolampe ou poêle qui chauffe et éclaire avec économie et offre avec plusiers produits précieux une force motrice applicable à toutes sortes de machines' (Discovery of a thermolamp or storage stove that heats every room in the whole house, provides light and can be used to give all machines locomotive power). The text describes a house with a centralised lighting and heating system:

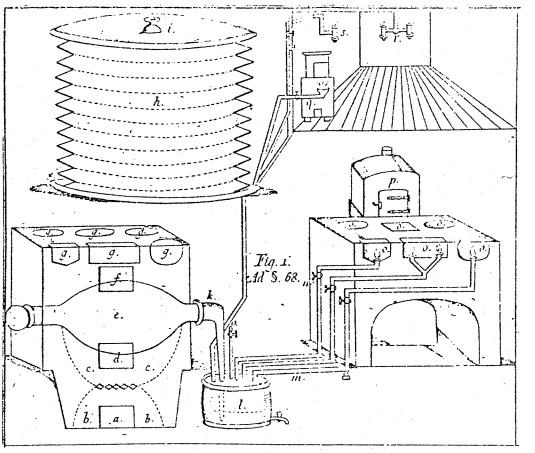
> By an arrangement so very easy, a single stove may supersede all the chimneys of a house. The inflammable gas is ready to extend every where the most sensible heat and the softest lights, either joined or separated at our pleasure. In a moment we can make our lights pass from one chamber into another — an advantage as commodious as oeconomical — and which our common chimneys can never be made to furnish. No sparks, coals or soot will incommode us any longer. Neither can cinders ashes coals or wood, render our apartments black or dirty nor require the least care. Night and Day we may have fire in our rooms without any servant being obliged to enter, to stir it or to watch over its dangerous effects.[25]

For practical purposes, the thermolamp was a flop. Lebon installed one in his Paris house and opened it to the public, charging three francs admission. It aroused the same sort of interest as William Trevithick's steam engine. At roughly the same time in England, Trevithick put on public display a steam locomotive driving around in a circle, and also charged for admission. It is one of the ironies of history that the two

25. The English text is quoted from *Description of the Thermolamp invented by Lebon of Paris, Published with remarks by F. A. W.* [Winsor], in English, German and French (Brunswick, 1802), pp. 11–12. The original French text is quoted in Henry-René d'Allemagne, *Histoire du luminaire* (Paris, 1891), pp. 557–8). The title of this paper given in English in the text is translated from the German: 'Nachricht von einer ganz neuen außerordentlichen, vom pariser National-Institut geprüften, und durch ein Erfindungs-Patent authorisierten *Entdeckung einer Thermo-Lampe* oder eines *Spar-Ofens*, welcher alle Zimmer im ganzen Hause heizt, beleuchtet, und allen Maschinen eine Bewegkraft zu geben, anwendbar ist. Erfunden von Hrn. Phillip Lebon' (Stadtamhof, 1802).



Two thermolamps (1802).
A fire lit in the furnace (A) heats up the retort (B), from which the gas passes into the condenser (C). From there, a pipe conveys it to the site of combustion. Excess gas is removed via a pipe (F) which takes it to a storage container or releases it unused into the air.
(*Source*: T.M. Daisenberger, *Beschreibung der daisenbergerschen Thermolampe*, Stadt am Hof, 1802)



Thermolamp (1803)
Bottom left: the retort, from which the distilled gas is conveyed to a container in which it is purified (1). Then it passes into a still small gasometer where it is stored (h). From there it is taken to the stove (o, p) and to the lights (r, s).
(*Source*: Z. Winzler, *Die Thermolampe in Deutschaland*, Brno, 1803)

arguably most important innovations of the nineteenth century first appeared in public as something like a circus act.

Even if the thermolamp was not an immediate success, it did for the first time point to the possibility of *central* lighting and heating systems. It was a remarkable blend of traditional and progressive ideas. Lebon's concept of a universal energy source to provide light, heat and power was ahead of its time, but he was still governed by tradition in restricting the central supply to one house. The idea of a thermolamp for a whole city, or at least for a particular district, did not occur to him. The thermolamp remained a Heath Robinson-like central supply station, inspired by the same spirit of individualism as the equally self-sufficient gas lighting systems in English factories.

Central Supply

By about 1800 the foundations for the gas lighting of the future were fully developed. The technology existed in Watt & Boulton's industrial installations; the idea of a more general use, not restricted to factories, was born with Lebon's thermolamp. In retrospect, we can see these developments as two loose ends, waiting to be tied up to create modern gas lighting. This was achieved by Friedrich Albert Winsor, a German 'project-maker' who had migrated to England. (Originally his name was Winzer, not to be confused, as he so often is by historians of the gas industry, with the Austrian gas pioneer and follower of Lebon, Zacharias Andreas Winzler.) Winsor first familiarised himself with Lebon's work. Still in Germany, he published a translation of Lebon's book on the thermolamp in 1802. A little later in London he initiated a campaign that was to go on for years. Its aim was to promote gas lighting by setting up a company to deliver gas to consumers. Winsor eventually achieved his aim in 1810, when his company received a charter and began trading.

Winsor cannot be pigeonholed as a scientist-inventor, or as a capitalist entrepreneur. Without possessing the qualities of either, he was able to mediate between them, acting as a catalyst. According to contemporary accounts, Winsor had little knowledge of the matter he was so interested in promoting. 'He possessed scarcely any knowledge of chemistry, and was so

deficient in mechanical information, that he was unable to give proper directions for the construction of the apparatus', wrote William Matthews in the first history of gas lighting, published in 1827.[26] The *Edinburgh Review* accused him of 'ignorance, quackery, extravagance, and false calculation'.[27] His enterprise was compared to the scandalous South Sea Bubble of 150 years earlier. But despite this unpleasantness, the public displayed interest in his lectures and demonstrations (which included illuminating the Mall). 'Their brilliance was surprisingly attractive, and allured the public to inspect them', noted William Matthews (after venting his criticism), 'and his explanations and illustrations so far elucidated the subject of gas as to enable others to form some estimate of its utility as an agent for producing light. His representations may justly be deemed extravagant and deceptive, and certainly exposed him to ridicule and suspicion; but it must be allowed that his efforts tended, in a high degree, to fix public attention to Gas-Lighting.'[28]

Ultimately, despite the success of gas — or perhaps because of it — Winsor got as little out of it as Lebon, from whose pioneering work he had profited. After Winsor had founded his company and business proved to be good, 'serious' entrepreneurs took over the directorship, and Winsor was squeezed out. He decided to move on and repeat his English experience somewhere else. Paris, the other great metropolis of the time, seemed an obvious choice. Winsor tried to use again the techniques that had worked in London: staging practical demonstrations, giving lectures and publishing pamphlets. In 1816 he installed gaslight in a public house in the Passage des Panoramas as a demonstration, but it was as unsuccessful as all his later ventures in Paris. Soon after this, his company went bankrupt. Winsor died, impoverished, in Paris in 1830.

Winsor was not the original inventor of gas lighting and, perhaps, not a serious capitalist entrepreneur. But he established the concept that allowed gas lighting to make the transition from individual to general use: the idea of supplying consumers of gas from a central production site by means of gas

26. Matthews, *Historical Sketch*, p. 28.
27. Chandler and Lacey, *The Rise of the Gas Industry in Britain*, p. 130.
28. Matthews, *Historical Sketch*, p. 30.

mains. The idea was, in fact, nothing new. As the title of one of Winsor's many advertising pamphlets shows, the water supply provided the model: 'A National Light and Heat Company, for providing streets and houses with light and heat, on similar principles, as they are now supplied with water.' The author of the first analytical description of gas lighting, Frederick Accum, a colleague of Winsor's and also a German emigré, makes a special point of this analogy: 'By means of gas we may have a pure and agreeable light at command in every room of our house, just as we have the command of water.'[29] The translator of the German edition added an explanatory note for his readers, who were unfamiliar with a centralised water supply: 'In England, many private houses are so arranged, with pipes etc. inside the walls, that in almost every room one can obtain water at any time simply by opening a tap.' London had been supplied with tap water since the early eighteenth century. A report written in 1726 by de Saussure, a Swiss traveller, however, shows that London's water supply initially consisted of a large number of fountains rather than of taps in the modern sense: 'In every street there is a large principal pipe made of oak wood and little leaden pipes are adapted to this principal pipe to carry water into all houses. Every private individual may have one or two fountains in his house, according to his means, and pays so much a year for each fountain.'[30]

The technical principle behind a central gas supply for a whole city is the same as the one behind a thermolamp supplying a single house. The only difference is in the size of the system and the length of the pipes. A thermolamp operated according to the principles of the central heating system known since Roman times, and a centralised gas supply was simply a public version of the same thing. And as the Austrian Andreas Zacharias Winzler, an enthusiastic supporter of the thermolamp, foresaw correctly, the notion of expansion was inherent in the idea of the thermolamp:

29. Frederick Accum, *A Practical Treatise on Gas-Light; Exhibiting a Summary Description of the Apparatus and Machinery Best Calculated for Illuminating Streets, Houses, and Manufactories* . . . (London, 1815), p. 111.

30. Quoted from Frederick William Robins, *The Story of Water Supply* (London, New York and Toronto, 1946), p. 106.

> The installation of thermolamps in large hospitals, in barracks, courts, offices, factories, monasteries, convents and communal buildings of all sorts . . . obviously follows quite naturally. It is also easy to appreciate that this inestimable invention could be used with great advantage to light the streets. But the fact that one stove could provide light and heat for all the houses of a whole municipality deserves special mention here because there might be cases in which this sort of arrangement would be of the greatest benefit to the inhabitants of whole villages.[31]

Expanding a thermolamp into a gas-works was not a technical innovation, but it did have far-reaching consequences. Once a house was connected to a central gas supply, its autonomy was over. The thermolamp had merely centralised heating and lighting within one house; now these systems were relocated outside the house, at a distance beyond the control of the paterfamilias. With a public gas supply, domestic lighting entered its industrial — and dependent — stage. No longer self-sufficiently producing its own heat and light, each house was inextricably tied to an industrial energy producer.

This loss of domestic autonomy is part of the larger dissolution of the 'total household'.[32] A market and exchange economy, based on the division of labour, absorbed ever more activities and functions originally performed by individual households. Removing the production of light and heat from the house gave this process a new quality. When the household lost its hearth fire, it lost what since time immemorial had been the focus of its life. Although refined and civilised over the centuries in the form of stoves, oil lamps and candles, fire had always remained clearly and physically recognisable as not merely a product but also the soul of the house. As Gaston Bachelard puts it, 'the lamp is the spirit that watches over every room. It is the centre of the house. A house without a lamp is as unthinkable as a lamp without a house'.[33]

Bachelard is referring here only to the domestic oil-lamp. Its replacement by industrially produced gas lighting affected peo-

31. Zacharias Andreas Winzler, *Die Thermolampe in Deutschland* (Brno, 1803), p. 155.

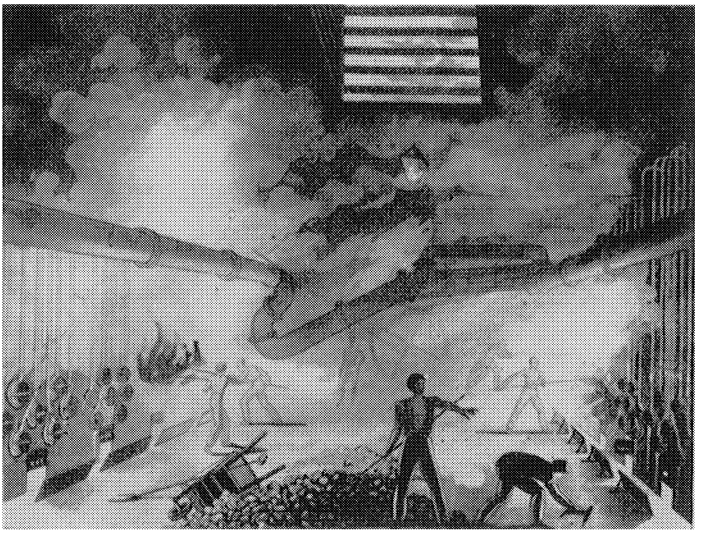
32. See Otto Brunner, "Das "ganzes Haus" und die alteuropäische "Ökonomik"", in *Neue Wege zur Sozialgeschichte* (Göttingen, 1956), pp. 33–61. The expression 'ganzes Haus', here translated as 'total household', was coined by the folklorist W.H. Riehl.

33. Gaston Bachelard, *La Flamme d'une chandelle* (Paris, 1961), p. 8.

ple in much the same way as did the replacement of the coach by the railway. Gaslight and the railway were often compared in the nineteenth century. These two industrial innovations came into the world at the same time, with similar technologies. 'A gas-work, like a railway, must be viewed as one entire and indivisible machine; the mains in one case being analogous to the rails in the other.'[34] To contemporaries it seemed that industries were expanding, sending out tentacles, octapus-like, into every house. Being connected to them as consumers made people uneasy. They clearly felt a loss of personal freedom. The railway put an end to the freedom of guiding an individual conveyance at will. Similarly, gaslight made it impossible for people to become absorbed in contemplating the 'individual' flame of an oil-lamp or candle. Railway travellers, no longer living in the landscape through which they were being transported, felt like parcels in a pneumatic tube. People gazing at a gaslight no longer lost themselves in dreams of the primeval fire;[35] if anything, they were thinking of the gas bill. As a rule, though, no one looked at the gas flame any more at all.

In economic organisation, too, the railways and the gas industry led to the loss of individual entrepreneurial freedom. The principle of free competition could not be reconciled with this new technology. Attempts to uphold it at all costs produced absurd, inefficient and ultimately chaotic conditions. At first, competing gas companies laid their mains in the same areas. 'It was not at all unusual for three, four or even five different companies to have mains in the same street.'[36] Later, regions were divided into districts, for which individual companies received monopolies. On the Continent, where political traditions were more centralised and less liberal, the railway and gas systems developed differently from the start. Strict governmental supervision ensured that private companies co-ordinated their operations. In France, the railway network was centrally planned from the beginning — various private companies received monopolies for various lines. The same was true of the gas industry. The first regulations concerning the gas industry

34. J.O.N. Rutter, *Gas-Lighting: Its Progress and Its Prospects* (London, 1849), p. 54.
35. Bacheland, *La Flamme*, p. 3.
36. George Livesay, quoted from Chandler and Lacey, *The Rise of the Gas Industry in Britain*, p. 74.



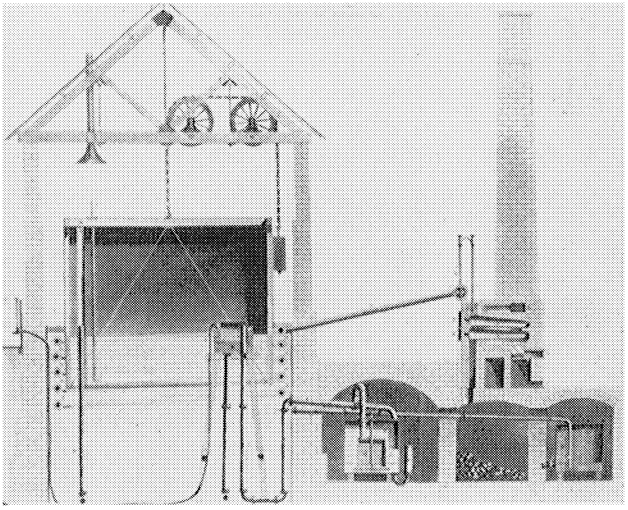
Retort room in a London gas-works, 1821
(*Source*: C. Mackenzie, *One Thousand Experiments in Chemistry*, London, 1822)

laid down by the Prefect of the Département Seine prescribed that 'only one company may construct its mains in any one street'.[37] Later provisions established this system in ever greater detail. In 1839 Paris was finally divided into districts, in which individual companies exercised their monopolies.[38] Germany developed in much the same way.

Expansion

The speed with which the gas industry took hold varied with the speed of industrialisation in the different European countries. England was the first to come under its thrall, and the industry developed most quickly there; the Continent lagged behind.

37. Henri Besnard, *L'Industrie du gaz à Paris depuis ses origines* (Paris, 1942), p. 36.
38. Ibid., p. 42.



The first gas-works, London, 1814
Left: the storage container (gasometer); under the chimney the transverse retorts; beneath these the coal store, purifying plant and basin to catch the tar given off as a by-product of the process.
(*Source*: F. Accum, *A Practical Treatise on Gas-Light*, London, 1815)

Within a few years, London became the first metropolis to be largely supplied with gas. In 1814 there was one company, founded by Winsor, which possessed a single gasometer with a capacity of 14,000 cubic feet. Eight years later, in 1822, there were already four companies and forty-seven gasometers with a total volume of almost one million cubic feet.[39] By this time, 200 miles of mains with a diameter of eighteen inches had been laid.[40] Later, gas-works expanded again. The development of gasometers, one of the most potent industrial symbols of the nineteenth century, illustrates this most clearly. In the 1820s gasometers were rarely bigger than 20,000 cubic feet. By the 1860s their average size was one million cubic feet. After London, the gas industry spread to the rest of England: 'Gas had

39. Matthews, *Historical Sketch*, p. 145.
40. Peckston, *Theory and Practice of Gas-Lighting*, pp. 294–5.

become common in London in 1816, and by 1819 gas works were in operation throughout the country.'[41] In the mid-1820s most of the big cities were supplied with gas; by the late 1840s it had reached the small towns and even villages.[42]

The gas industry spread incomparably more slowly in France and Germany. As Winsor's failure in Paris shows, there was no market there yet for the new type of light. Developments after Winsor's time confirm that this remained true for years. Companies founded in the 1820s were 'loin de prospérer'; between 1820 and 1835, bankruptcies of gas companies accounted for capital losses of 8 million francs.[43] Only from 1829 did gas begin to be used for street lighting, and then its use spread at snail's pace. The first streets and squares with gas lighting were the Place du Carousel, Rue de Rivoli, Rue de la Paix, Place Vendôme and the Palais Royal. Not until the mid-1840s was gas lighting so well established in Paris that, as the historian Henri Besnard declares, it enjoyed the 'confiance du public'.[44] Given Paris's traditions of light, this was a surprising delay. The French historian Allemagne later found it painful 'to have to record that other countries valued the advantages of Lebon's great invention more highly than we did. Our neighbours quickly found a variety of uses for it'.[45]

In Germany progress was just as slow. Although people were experimenting with gaslight there — Lampadius, for example, and Winzler — the industry as such was imported from Britain. The Imperial Continental Gas Association, established in England solely as an export company, set up gas-works in Hanover, Berlin, Aachen, Cologne and Vienna in the 1820s. Soon domestic industry took up the idea, but there were only twenty-four gas-works in operation by 1850.[46] The breakthrough did not occur until the 1850s, marked most clearly, perhaps, by the

41. Chandler and Lacey, *The Rise of the Gas Industry in Britain*, p. 71.

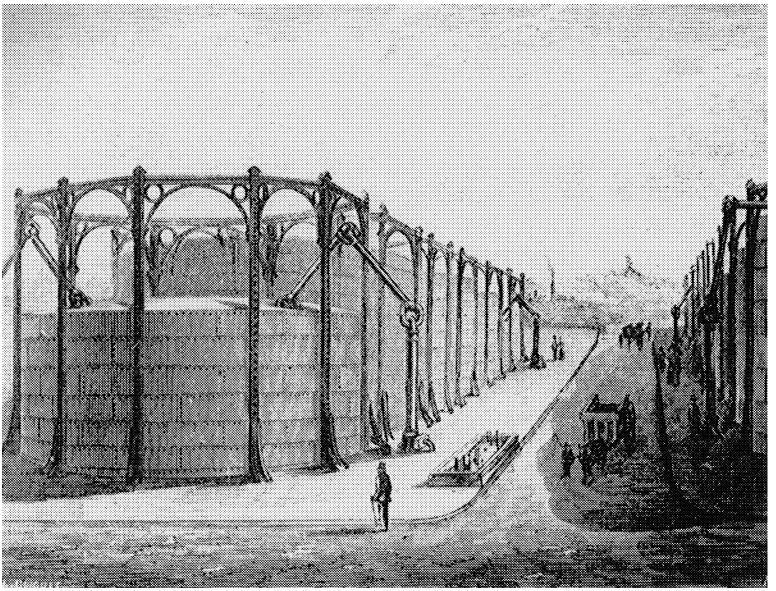
42. W.J. Liberty, 'The Centenary of Gas Lighting', *Illuminating Engineer*, vol. 6, 1913 (London), p. 185. The exact figures are as follows: in 1823, fifty-three English cities had gas companies (Georg Moritz Sigismund Blochman, *Beiträge zur Geschichte der Gasbeleuchtung*, Dresden, n.d. [1871], p. 99); around 1850 more than 700 companies had a share of the market (Rutter, *Gas-Lighting*, p. 26; Blochmann, *Beiträge*; by 1868 there were 1,134 (ibid.).

43. Besnard, *L'Industrie du gaz à Paris*, p. 24.

44. Ibid., p. 32.

45. d'Allemagne, *Histoire du luminaire*, p. 576.

46. Schilling, *Handbuch für Steinkohlengas-Beleuchtung*, p. 13.



Gasometer, about 1870
(Archiv für Kunst und Geschichte, Berlin)

foundation of the *Journal für Gasbeleuchtung* (Journal of gas lighting) in 1858. Nevertheless, the English influence continued for a long time. For example, as late as 1862 more than 40 per cent of the coal used in German gas production was imported from England.[47] At this time London alone consumed twice as much gas as the whole of Germany.[48]

The Danger of Explosion

During his visit to London, Carl Gustav Carus recorded the following impression of the industrial landscape on the Thames: 'masses of houses, warehouses, big breweries and enormous iron gasometers, standing free like huge towers or colossal blast

47. Ibid., p. 15.
48. Ibid., p. 16.

furnaces; almost everything put up without order or symmetry, just as present need dictates, mostly blackened and dirtied by coal smoke, but always giving the impression of enormous mass'.[49] It is no coincidence that gasometers are twice described as 'enormous' in this passage. For the nineteenth century, these unwieldy, massive containers came to symbolise both the amorphousness and the danger of the gas industry. Steam and gas struck the same fear into the nineteenth-century heart. Boilers and gasometers were both expected to explode at any moment.

Let us look at the report of a fairly 'ordinary' gas explosion that took place in 1862 in Paris. The *Journal für Gasbeleuchtung*, which as a professional journal, cannot be accused of exaggeration, describes the following scene:

> The café above the casino was blown up, and the two shops adjacent to the ballroom on the ground floor were totally destroyed. The heavy counter in the bar was lifted out of its moorings and flung through the air. There were casualties on the street, too, at the entrance to the casino. A woman standing in the doorway, on the pavement, was struck down dead, as if by lightning. A cart left nearby, the property of a washerwoman, was flung twenty paces by the blast. The wife of the baker across the street was badly injured, and a passerby had his nose sliced off as if by a razor blade. The gas forced its way through the passage leading to the Rue Cadet, and there exploded in a column of flame five storeys high. The blast was so powerful that people in the Rue Rochechouart at the time, 500 paces from the scene of the accident, thought that a hurricane had suddenly struck.[50]

In 1865 the measuring station of a London gas-works suffered an explosion in which ten workers lost their lives. The public was convinced that the huge gasometer, with a capacity of one million cubic feet had exploded. *The Times* considered it proven that gasometers

> are practically capable of exploding with terrible force, and that those who live near them and the buildings in their neighbourhood are

49. Carl Gustav Carus, *Denkwürdigkeiten aus Europa*, ed. by Manfred Schlösser (Hamburg, 1963), p. 575.

50. *Journal für Gasbeleuchtung*, 5 (1862), p. 54.

> exposed to as serious consequences as if they were placed over a powder-magazine . . . at present it is clear every gasometer is a powder-magazine, and to have a gas manufactory near Westminster Abbey, St. Paul's, or one of the bridges, is much the same as if we were to store our gunpowder on the Thames Embankment.[51]

Right from the start, the gas industry was confronted with this deep-seated fear of explosions. Public attention concentrated on the gasometer, a tangible reminder of an otherwise invisible danger. In his *Historical Sketch,* William Matthews wrote:

> The great increase in the number of these very capacious vessels, containing such a large quantity of gas, and their being placed in the vicinity of such a dense population, gave rise to serious considerations with respect to their safety. Besides, some explosions had occasionally happened, either from carelessness or accident; and though the mischief produced by them was comparatively trivial, yet they had of course created alarm.[52]

After the 1865 explosion in London, the *Journal of Gas Lighting, Water Supply, and Sanitary Improvement* noted that it was 'now generally admitted that gasholders will not explode, but those immense storehouses of highly inflammable gas are nevertheless looked upon suspiciously as portending some dire disaster.'[53]

Every large gas explosion fuelled the public's anxieties, and governments began to reassure their citizens. The London explosion of 1865 is a typical example. The *Journal of Gas Lighting* reported that 'in consequence of the great interest that the . . . explosion of a gasholder has excited, not only in all parts of the Kingdom, but on the Continent, Managers from the largest provincial gas-works were deputed to inspect the scene of the catastrophe, and representatives from foreign gas companies also visited the works'.[54]

From 1813 commissions were set up after every large gas

51. Quoted from *Journal of Gas Lighting, Water Supply, and Sanitary Improvement,* 14 November 1865, p. 807.

52. Matthews, *Historical Sketch,* p. 132.

53. *Journal of Gas Lighting, Water Supply, and Sanitary Improvement,* p. 808.

54. Ibid., p. 810.

explosion to establish the cause, propose improvements and allay public fears. After London's first explosion the Royal Society called together a commission of inquiry chaired by the explosives expert and chemist Sir William Congreve, well known for his experiments on rockets. The commission's report for the first time quantified the explosive power of gas, the quality that had seized the public's imagination:

> We find that the whole mechanical power of an explosion of 15,000 cubic feet of a mixture of coal gas and common air, is equal to that of the explosion of six cubic feet, or four barrels of gunpowder. . . . A more precise idea of the effects of such an explosion may be obtained from the calculation of its projectile effects, which would carry some parts of the wall of the surrounding building to a height of nearly 150 yards, and others to a distance of nearly 300. If the walls were in immediate contact with the gasometer, the height and distance would be twice as great. . . . Supposing the explosion of the gas to be unconfined, the shock would throw down a brick wall 9 feet high, and 18 inches thick, at the distance of about 50 feet from the centre; it would probably break glass windows at 150 yards.[55]

These findings led the commission to recommend that 'if Gas-lighting is to be generally introduced, the works supplying the gas should be placed at a certain distance from all other buildings; or if they are erected near houses, that reservoirs should be on a much smaller scale'.[56] In a later report, dated 1823, Congreve came to similar conclusions. When a bill to monitor the gas industry was submitted to the House of Commons, the gas industry reacted as predictably as the nuclear lobby does today. William Matthews, a spokesman for the gas industry, reported on its protest a few years later:

> The provisions of the bill were calculated to place the different gas companies completely in the power of the inspector; and, by leaving them little control over the management of their own property, very materially affected their welfare. They might be subjected to the most harassing and vexatious interruptions which either caprice, or interest, or want of adequate information, might occasion, and this without the means of redress. Besides, it was conceived, that if the

55. Quoted from Matthews, *Historical Sketch*, pp. 348–9.
56. Ibid., p. 135.

> proposed enactments were passed into a law, they would probably prove a source of continual contention, and might ultimately destroy all their sanguine hopes of prosperity; for no improvement could be attempted without the consent of the inspector; and whatever knowledge, ingenuity, or industry, they might possess, must be guided by his discretion, and governed by his decisions![57]

The public's fears on the one side, the industry's obvious lack of concern on the other, and governmental supervisory bodies mediating between them — this is how the lines of battle were drawn up when the nineteenth century spawned industries that posed a potential threat to health. Positions have not changed much to the present day. The industry's employees, who generally consider public fears irrational, nevertheless may themselves suffer the consequences of an accident when equipment breaks down. An early example of the split professional personality this can give rise to is contained in the parliamentary hearing on the Congreve Commission's 1823 report. Samuel Clegg, a leading gas engineer of the day, was asked his opinion of the safety of gasometers. He replied: 'I should have no objection to my bed being placed on the top of one of them; I should sleep as sound there as in any other place.'[58] At the same hearing, Clegg described the injuries he had sustained in a gas explosion: 'The effect of it was, that it blew my hat off my head, and destroyed it, and blew it all to pieces, and knocked down two nine-inch walls, and injured me very much at the time, and burnt all the skin of my face, and the hair of my head, and I was laid up a fortnight or three weeks by it.'[59]

The Danger of Poisoning

The gasometer most clearly embodied the danger of explosion simply because of the amount of gas it contained, but it was not the only threat. Gas users far from the centre were exposed to the same danger through the existence of mains. The qualities of gas that Accum presents as especially beneficial in his *Practical*

57. Ibid., p. 151.
58. Ibid., p. 154.
59. Ibid., pp. 67–8.

Treatise on Gas-Light take on a sinister ring in this context. 'The gas', he said 'may be distributed through an infinity of ramifications of tubes with the utmost facility. . . . There is nothing to indicate its presence; no noise at the opening of the stop-cock or valve — no disturbance in the transparency of the atmosphere.'[60] Its silence, invisibility and speed were precisely the qualities that made gas seem uncanny and gas mains dangerous. Early fears concerning gas were clearly atavistic; it was believed, for example, that the pipes transmitted fire. The engineer Samuel Clegg reports that the 'the curious often applied their gloved hands to the pipes to ascertain their temperature'.[61] Even after such fears were dispelled, people tended to keep their distance. Instructions for the use of gas urged customers to turn off the main tap (the connection between the house and the gas mains) as often as possible. Blochmann suggested that 'in the interests of the occupants' safety, the tap should be kept closed when gas is not required, so that no gas can escape from the pipes'.[62] The normal time for turning off the main gas-tap was at night. While they slept, people preferred to sever all connection with such a dangerous element and restore the household's original autonomy for a few hours. Accum, an enthusiastic promoter of gas lighting, sees this precautionary measure as offering a further advantage. He presents turning off the main gas-tap as the modern equivalent of the paterfamilias locking up his house at night. 'Where gas is used, the master of the house, when he has turned the main stop-cock which conveys the gas into the collateral branch pipes, may retire to rest free from any of those apprehensions, which before harassed him, lest a candle might have been left burning, or lest the accidental dropping of a spark might become the cause of enveloping himself and family in destruction.'[63]

60. Accum, *A Practical Treatise on Gas Light . . .*, p. 100.

61. Quoted from Chandler and Lacey, *The Rise of the Gas Industry in Britain*, p. 71.

62. G.M.S. Blochmann, *Fünf Vorträge über Beleuchtung für Gasconsumenten* (Dresden, 1873), pp. 33–4. 'Turning off the main tap at night is a wise precaution; of course, this is impossible if the gas is to be on in a bedroom or nursery. But one can allow only as much gas as is needed for one or two lights to enter the pipes by positioning the tap carefully' (J.O.N. Rutter, *Das Ganze der Gasbeleuchtung, nach ihrem jetzigen Standpunkte*, Quedlinburg and Leipzig, 1835, p. 432).

63. Frederick Accum, *Description of the Process of Manufacturing Coal Gas for the Lighting of Streets, Houses, and Public Buildings . . .* (London, 1819), p. 10.

Explosions are a dramatic consequence of secretly leaking gas. But there are others, too, for gas has the additional property of being a more or less poisonous chemical. Its smell points to this side of the story. From the start, it was felt to be unpleasant, but at the same time welcomed as a useful warning. 'Its penetrating odour is a fortunate quality of gas', wrote Schilling in his manual:

> It makes gas its own best warning. A person in the waking state will rarely or never be a victim of gas poisoning. In almost all confirmed cases the accident happened at night while the victim was asleep. Generally, he had irresponsibly ignored the smell that was already clearly perceptible in the evening, and had nevertheless retired peacefully to bed. If everyone would follow the rule of never sleeping in a room in which gas can be smelled, then we would hear little of gas poisoning.[64]

Gas poisoning was soon to become a standard method of committing suicide. But apart from poisoning individuals, gas could also contaminate the soil and pollute the air. Here again gas-works were most readily identifiable as potential culprits. This consideration influenced the choice of location: 'One should try to choose a somewhat isolated site, preferably on the side where the prevailing wind blows away from the town. If there is running water, it should be used below not above the town.' To be sure, Schilling, who gives this advice, adds immediately: 'All these considerations are more a concession to the fears and prejudices of the public than strictly required by the nature of the substance.'[65]

Contamination of the soil was not limited to the immediate vicinity of the gas-works. It extended as far as the network of gas mains. Where these leaked, gas seeped into the soil. According to a report by the Medical Officer for Health in 1860, 386 million cubic feet of gas escaped into the soil in this way every year in London alone; other estimates double this figure.[66] The gas, continues the report, 'darkens the soil and makes it so offensive that the emanations from it can hardly be endured,

64. Schilling, *Handbuch für Steinkohlengas-Beleuchtung*, 3rd edn (1879).
65. Ibid., 2nd edn (1866).
66. Liberty, 'The Centenary of Gas Lighting', p. 188.

renders the basement rooms of houses uninhabitable from the poisonous action of the gas, and even dangerous from explosions, and taints the water with filthy odours'. The gradual poisoning of cities from underground was a nightmare that became more and more real as the gas industry expanded:

> Gas lighting in the inner cities undoubtedly represents a more or less acute danger to health. Gas permeates and contaminates the subsoil with sulphur and ammonia. It pollutes water in wells and cisterns, and from leaks in the mains it escapes into the air, where it is also injurious to health. This lighting gas makes all excavation work potentially dangerous, as under certain circumstances gas can create conditions that promote the development of fevers, gangrenous rashes and a particularly virulent strain of smallpox.[67]

The Gas Flame

Gaslight, as we have said, began the industrialisation of lighting. The gas burner that replaced the oil-lamp or the candle was no longer a lamp in the strict sense, but an extension of the gas-works. Fears of explosion and poisoning sprang from the uneasiness people felt at being directly connected to such a dangerous industry. Let us look at the effects of this technical revolution on the actual product, the flame.

The most outstanding feature of gaslight was its brightness. The same words crop up again and again in descriptions. Gaslight was 'dazzlingly white', 'as bright as day', or 'an artificial sun' beside which traditional sources of light paled into a weak, reddish glow. However standardised the descriptive vocabulary, when it came to establishing the intensity of the light, claims varied widely. According to figures give by Accum, a gas flame was three times as bright as a tallow candle,[68] while Schilling thought it was six to ten times brighter than a wax candle.[69] These variations are due to the pre-scientific method of measuring light intensity in use at the time. It consisted of

67. E. Bertulus, *Memoire d'hygiène publique sur cette question: Rechercher l'influence que peut exercer l'éclairage au gaz sur la santé des masses dans l'intérieur des villes* (Marseilles, 1853), pp. 63–4.

68. Matthews, *Historical Sketch*, p. 280.

69. Schilling, *Handbuch für Steinkohlengas-Beleuchtung*, 2nd edn (1866), p. 118.

Gas flames
(Science Museum, London)

simply comparing the shadows that two lights of different brightness cast over a given distance. On this basis, one decided how much stronger or weaker they were in relation to each other. This totally subjective procedure could obviously give only approximate values.

Standards of comparison were equally inexact. There was no precisely defined and internationally recognised unit of illumination, such as was developed later — the 'standard candle', for example, which was still only a national standard, or today's units of lux and lumen. The brightness of the flames with which the gas flame was compared varied considerably, from the dim tallow candle to the relatively bright wax candle. And on top of this, flames of different sizes were often compared.

Given all these uncertainties, it is not worth trying to express light intensities precisely in figures. We shall merely say that in flames of the same size, gaslight was distinctly brighter than any other source of light known at the time. (The reason was that

gas's higher temperature of combustion allowed the carbon particles that make up a flame to become white hot, while they only reached a reddish orange glow in the flames of the oil-lamp and candle.)

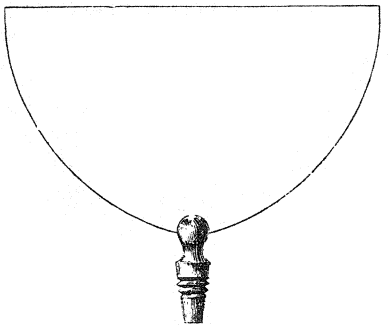
Higher intensity was not the only thing making gaslight bright. The larger size of its flame was also a factor. When the flame was anchored to the wick as the site of combustion, the wick determined the size and shape of the flame and the direction in which it burned. This was true of Argand's cylindrical wick and of Leger's flat wick, although they supported a much larger flame than anything else before. Only when the wick disappeared altogether did the flame become free to evolve new sizes and shapes, and to burn in directions undreamed of up till then. For example, there was no longer any law that said flames could only burn upright. Gas flames burned at an angle, sideways, and even upside down — all equally naturally. The pioneers of gas cited this unlimited potential in support of their case. Lebon, for example, the first to describe the flexibility of the gas flame, wrote: 'Soft and pure, this light may be moulded into every shape, into flowers, festoons, etc., every form suiting the flame, which may descend from a ceiling in the shape of a chalice of flowers, and spread above our heads a clear light not masked or shaded by any support whatever, darkened by no wicks, or tarnished by the least black or smoke.'[70]

We can see the eighteenth-century enthusiasm for festive illumination still at work in early gas propaganda that made much of the amusing shapes the flame could take, but in practice, a series of standard flame shapes soon evolved. They all shared a broad, flat surface, hence their names: bat-wing and fish-tail. Their shape derived from the way in which the gas issued through what was known as a 'slit burner'.[71] Compared with the illuminating surface of a candle flame, that of a gas flame was like a fully opened fan to a single segment.

Another novelty of the gas flame, apart from its brightness, was its uniformity. The light intensity of a flame burning around

70. Lebon, as in note 25. Quoted here from Hunt, *A History of the Introduction of Gas Lighting*, p. 54.

71. Another option was to have two separate flames burning at an angle to each other so that they merged to form a single, broad flame. But this is one of the technical details that we cannot pursue further here.



a wick varied enormously. 'It is never the same for two moments in succession. If there is the slightest variation in the length of the wick, or if the wick burns down to ash — for example, if a draught moves the flame — then the light emitted immediately becomes brighter or dimmer.'[72] Count Rumford's experiments showed that the luminosity of a candle decreases from 100 to 16 within half an hour if the wick is not continually trimmed as the process of combustion proceeds.[73] Trimming the wick, with scissors specially adapted for the purpose, required continuous attention, something like watching the hearth fire. Goethe's saying, 'Wüßte nicht was sie besseres erfinden könnten/als wenn die Lichter ohne Putzen brennten'[74] (I could not think of a better invention than lights that burn without needing to be trimmed) shows us how irritating people found tending the flame around 1800. Any tasks done by candlelight were continually interrupted. Gaslight, burning as evenly as the gas issued from the pipe, did not require the least attention. The only variations to which the gas flame was subject resulted from an occasional change in the pressure under which the gas-works sent out their product.

The third significant new feature of gaslight, after its brightness and uniformity, was that it could be regulated. Accum points out that 'the size, shape and intensity of the gas-flame

72. A.L. Lavoisier, *Oeuvres* (Paris, 1865), Vol. 3, p. 80.

73. Gösta Bergman, *Lighting in the Theatre* (Stockholm, 1977), p. 54.

74. From 'Sprüche und Reime', Cotta edition (1855), Vol. 3, p. 13 (quoted from Otto Hallauer, 'Beleuchtung und Auge', unpublished manuscript of the Bernoullianum Lecture, given on 19 November 1908, p. 13).

may be regulated by simply turning a stop-cock which supplies the gas to the burner. It may at command be made to burn with an intensity sufficient to illuminate every corner of a room, or so low and dim as barely to be perceived.'[75] Or, to quote from J.W. Schmitz's *Populäres Handbuch der Gas-Beleuchtung* (1839) (Popular Manual of Gas Lighting), 'it requires only the touch of a finger to turn up the light from the tiniest spot to its dazzling full brightness'.

The ability to regulate the intensity of light was derived from Argand's wick mechanism. This had first made it possible to vary the supply of fuel and therefore the size of the flame. The advantage of the gas-tap over the wick mechanism was that lamps no longer had to be individually tended. All the lamps connected to the gas mains could be adjusted at the same time. This meant that for the first time ever, a flame could be altered from a distance. The gas-tap was the precursor of the electric switch. Technically, it was the link between the switch and the Argand burner's wick mechanism.

The technical qualities of gas lighting and its impact on perceptions can be summed up in a single word: distance. The candle and the oil-lamp were extremely intimate forms of light, as they put out only enough light to illuminate a small area. Distance, however, was inherent in gaslight from the start. Not only did its fuel come from the distant gas-works, not only could it be adjusted from a distance, without needing trimming — beyond all this, it was quite literally out of the observer's field of vision. This in turn was a consequence of its brightness. The gas flame gave out such an intense glare that people could not look at it directly. It was therefore covered with shades made of material such as frosted glass, which dissolved the concentrated core of the light. From now on, it was not the flame that glowed, but the lamp shade, which allowed an amorphous, diffuse light to filter through. (We shall have more to say about covering up the flame in the chapter 'The Drawing-room', p. 155f.). Another device also emphasised the distanced, indirect nature of gas light.

75. Accum, *A Practical Treatise on Gas-Light* . . . p. 104.