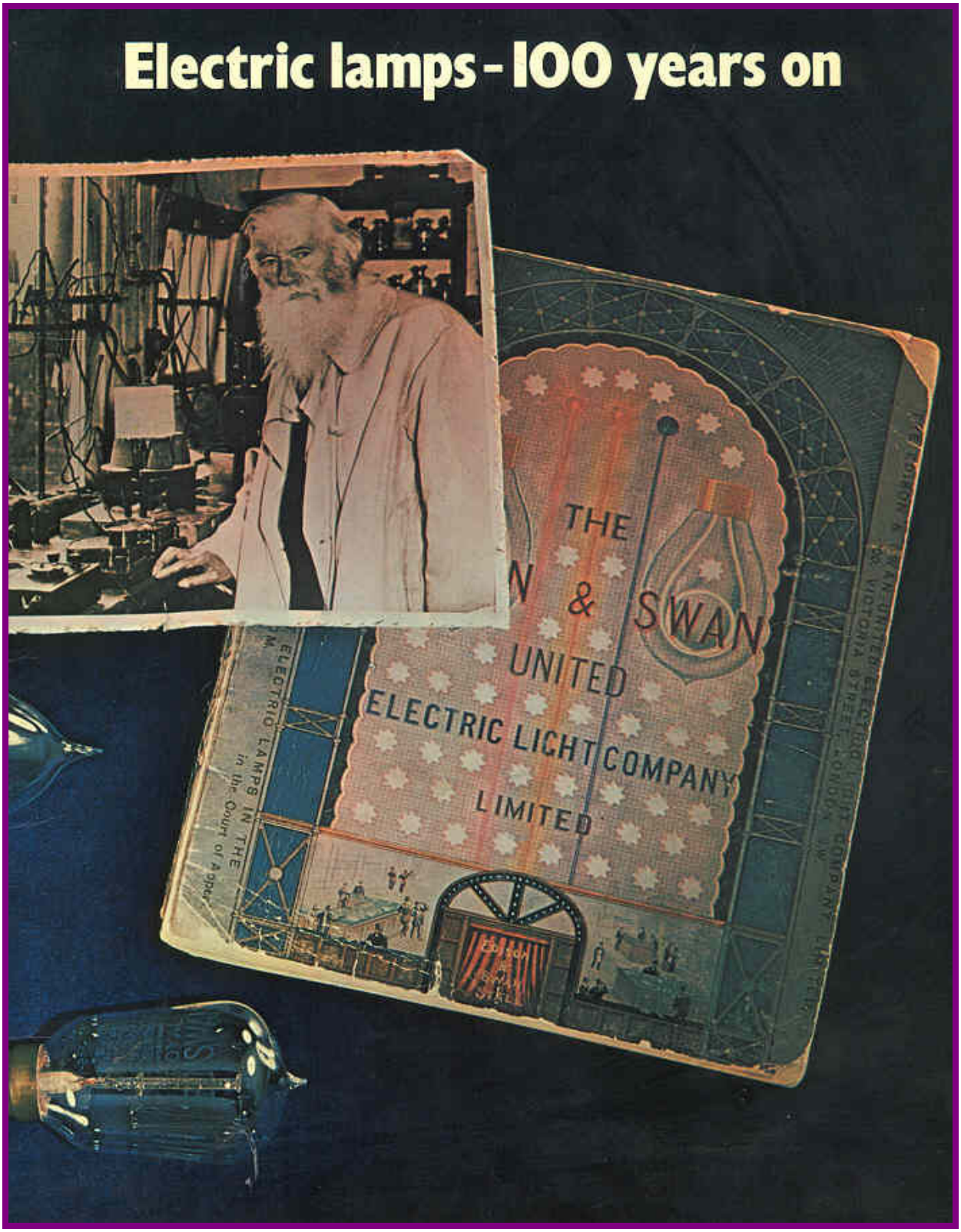
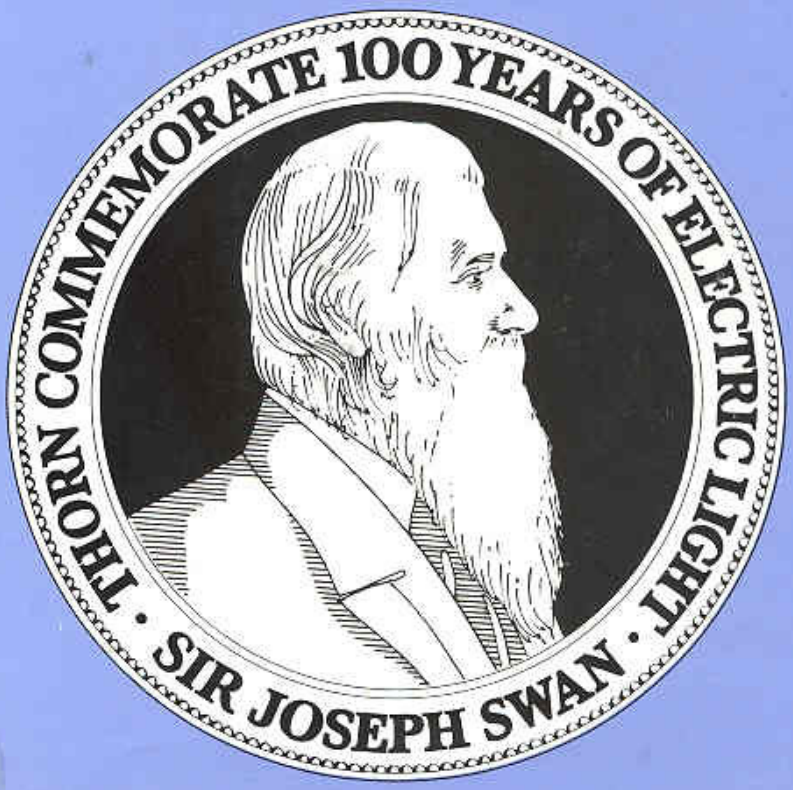


(Electric Lamps-100 Years On, Cyril Phillips, Thorn Lighting, 1979)

Electric lamps - 100 years on

by Cyril Phillips



Preface

In 1879 the British inventor, chemist and businessman, Joseph Wilson Swan, demonstrated the first successful electric filament lamp.

This was the most significant step in lighting since man had learnt to thread fibrous 'wicks' through dead fishes and birds to make primitive oil lamps, as it was to bring cheap and convenient light to millions and roll back the night for ever.

But the harnessing of the mysterious new force of electricity to produce flameless light for the many, depended not only on the pioneers who first produced electric lamps, but also on the entrepreneurs and mass producers who were to take this light source, develop it, and make it available to everyone at a cost of only a few shillings per bulb.

This booklet is published in 1979 to celebrate the centenary of Swan's achievement and to celebrate fifty years in which Thorn Lighting has developed as the leading force in the huge modern lighting industry we have today.

Newcastle~birthplace of the light bulb

The packed hall is hushed. All eyes focus on one man, Joseph Swan.

He makes a connection and a small glass bulb begins to glow with surprising brilliance, and stays glowing. Swan speaks, telling the audience of his flameless light; his 'electric incandescent vacuum lamp'. Few members of the audience could have been in any doubt that they were watching history being made.

This demonstration, on February 3rd 1879, before 700 members and guests of the Newcastle Literary and Philosophical Society, is now a legend in the north-east of England. Oddly, not many people realise that Newcastle is the birthplace of the light bulb. But the history of lighting is full of surprises.

There is no doubt that it was Swan who first demonstrated a practical filament lamp, an invention every bit as revolutionary as the wheel or the steam engine. But Swan was also the first to recognise that he was only the catalyst – the one who had succeeded in focusing several strands of developing technology towards the final brilliant achievement. Swan reached the summit; others before him had set up the base camp and marked the route.

But let's start the story a little further back – in the so-called 'age of elegance'.

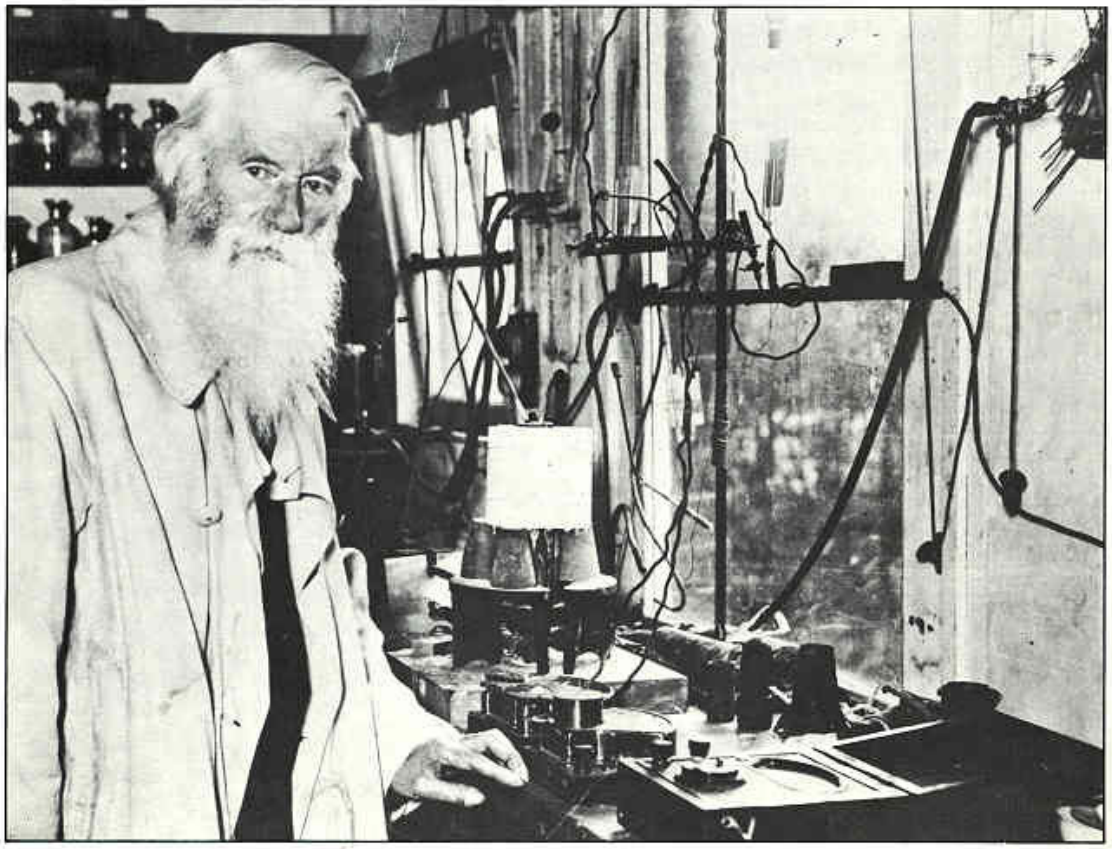
Before electricity

For several thousand years man used oil lamps – or wax candles – as his main artificial light source. Nobody could call them technically interesting; though doubtless in their day they were indispensible and even now some of the most brilliant people in lighting research would probably admit that for romance and atmosphere the candle is still a very attractive light source.

The use of coal gas was a major development, though it had its drawbacks because it was both poisonous and explosive, but nevertheless the 18th and 19th centuries did bring effective gas lighting to many towns and this was a major advance on what had gone before. Very superior types of oil lamp were developed. But all these light sources had one thing in common. They worked by burning fuel to produce light from a flame.

In the 19th century 'chemical light' was discovered. Instead of simply burning fuel, experimenters found that better light could be made by using the fuel indirectly to heat a chemical which then glowed brightly.

One of the first examples of this method of producing light worked by heating quicklime to incandescence. It was used in early



theatre floodlighting (hence the expression 'in the limelight'). Later it was found that certain materials glowed even more brightly than quicklime when heated, but only when in 1885 Count Aver von Welsbach invented the incandescent gas mantle, using thorium, was the idea widely applied. However, light was still being produced indirectly, by the use of a flame, with all the mess and inconvenience that went with it.

But by now man had discovered – and started to learn to harness – the most fundamental energy source of all. Clean, without smell, invisible, almost intangible but incredibly powerful – **Electricity.**

The invisible force

It was Dr. William Gilbert, physician to Elizabeth I, who first coined the word 'electricity', from the Greek word 'elektron', meaning amber. Gilbert was interested in phenomena associated with magnetism and what we now call 'static' electricity and he used amber in his experiments at court.

Far Left *Sir Joseph Swan at work in his laboratory.*
Above *Count Aver von Welsbach brought about an improvement in the light produced by the burning of a fuel when he invented the incandescent gas mantle, in 1885.*
Above Left *For thousands of years before the 19th century, man had relied on burning natural fats and oils in candles; and oil lamps such as this.*
Below *Dr. William Gilbert demonstrating static electricity to Queen Elizabeth I. It was Gilbert who first coined the word 'electricity', from the Greek word 'elektron' meaning amber. Amber was one of the materials he used to demonstrate static.*

Regrettably he died without ever understanding the full significance of his parlour tricks; and nobody knew what electricity was – only what it did.

To a large extent this is still true today. Our knowledge of electricity (despite Einstein's revelations about the relationship between energy and matter) is still largely empirical. But world-wide curiosity about electricity was unquenchable and it is worth noting the next famous name in our story – Benjamin Franklin.

Franklin was convinced that lightning was caused by this new-fangled thing called electricity. To prove it he flew a kite, on a silk line with a metal key at the end, during a thunderstorm. When he placed his finger near the key a spark jumped from the key to his finger.

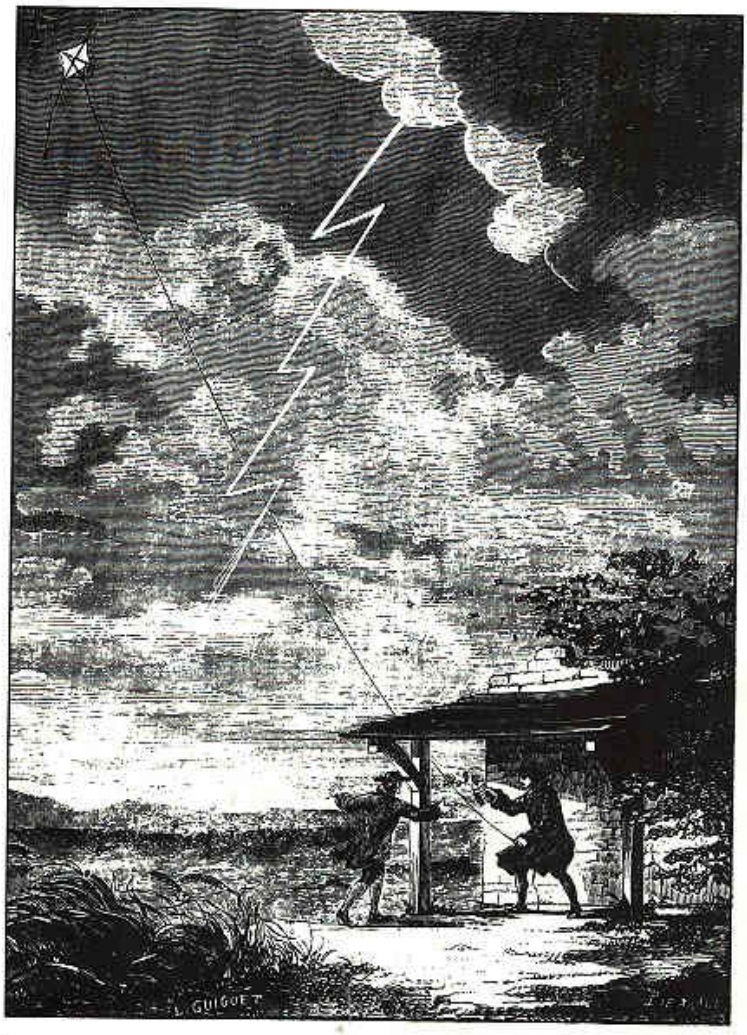
Franklin did not realise how dangerous this experiment was – but fortunately he was not electrocuted and lived on to help set up the American constitution! Incidentally, it was Franklin who invented bifocal spectacles. A man who could turn his hand to anything, it seems.

Of frogs and batteries...

Two gentlemen who are perhaps better known because their names have passed into electrical terminology are Volta and Galvani.

Around 1800 Alessandro Volta's experiments led him to demonstrate the first primitive battery, made from alternate plates of zinc and silver. Volta's batteries were, of course, nothing like present day batteries, but the principle had been established, and Volta's name lives on as one of the most frequently used electrical terms – the volt.

A contemporary of Volta's was Luigi Galvani, and who has not heard of the galvanometer? – or used the expression 'he was galvanised into activity'? But some historic figures, like King Alfred and his burnt cakes, are mainly remembered for ridiculous things. So it is with Galvani, who is remembered for his frog's legs. He

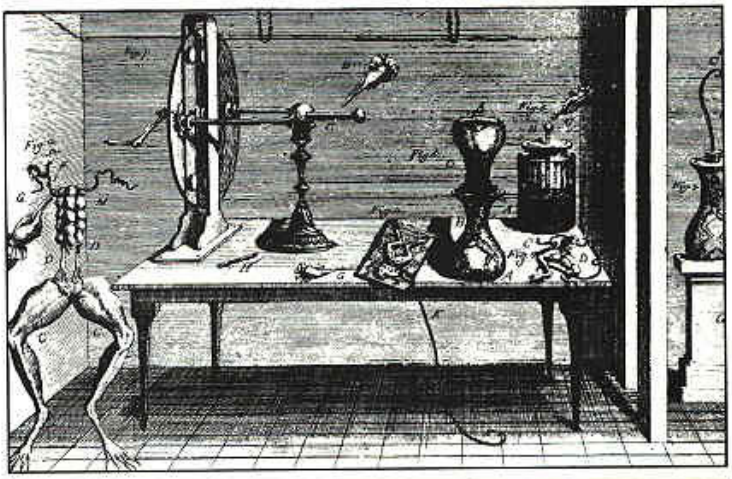


Left *Benjamin Franklin, better known as an 18th Century American politician, risked electrocution when he used a kite during a storm to show that lightning was caused by electricity.*
Below *The first primitive battery (or 'voltaic pile') was demonstrated around 1800 by Alessandro Volta. The volt was named after him.*
Bottom *Impressed with Volta's battery, Napoleon thought that electricity might contain the key to life itself.*

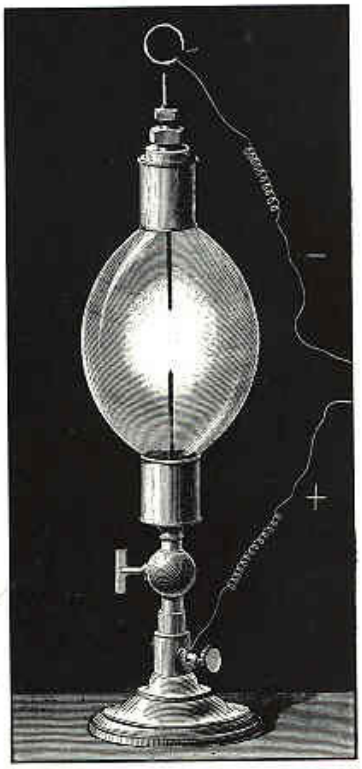
liked eating them and one day hung some out to dry on a metal balcony railing. A storm brewed and he noticed the legs twitching. He concluded that muscles were activated by electrical impulses and called this effect 'galvanism' or 'animal magnetism'. (Pedants please note that the term never did and has not now anything to do with sex attraction.) Galvani is assured of his place in history; perhaps in passing we should spare a thought for the frogs, animals which always seem to play an unwitting part in the march of science as well as gastronomy.

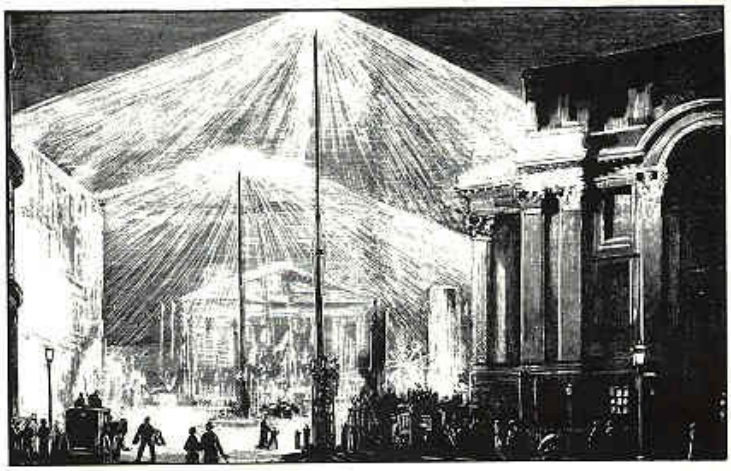
It was the widely respected scientist Humphrey Davy who was the first to show that electricity could be used to produce artificial light. Well known later for his miner's safety lamp, Davy demonstrated an electric light as early as 1810. This was an arc lamp; light being produced by an electric arc (or continuous 'spark') passing between two rods of carbon – almost touching – when a high voltage was applied.

Arc lamps came near to joining the mainstream of lighting 150 years ago. But there were problems; the carbon burned away rapidly and needed frequent adjustment, the process was smoky and messy, and there was no electricity supply industry to maintain a constant mains voltage. So these lamps did not develop quickly; though arc lamps can produce very bright light indeed (remember the wartime searchlights?) and were actually used for public lighting in the Place de la Concorde, Paris, in 1830 and somewhat later outside London's Royal Exchange.



Right *Gastronome Luigi Galvani noticed that frogs legs, being prepared for eating, twitched when a thunderstorm was brewing. He realised that muscles were activated by minute electrical impulses. He called the effect 'animal magnetism'.*
Middle Right *Machines and experiments by Galvani investigating 'galvanism'.*
Below *Humphrey Davy was the first man to produce artificial light from electricity, demonstrating this carbon arc lamp as early as 1810.*
Bottom Right *Carbon arc lighting outside the Royal Exchange in 1881.*





Almost from the days of the early experimenters it was comparatively easy to show that electricity could produce light. Franklin's demonstration had established that beyond doubt, for what is brighter than a flash of lightning? But an electric light is useless for most practical purposes unless it burns continuously. Hitherto the experimenters had only been able to demonstrate the 'flash-bang' principle, but proper artificial illumination using electricity needed some form of *continuous* electric current.

Batteries were hardly adequate for continuous domestic or commercial illumination; they had their uses in scientific demonstrations but were absolutely impractical for the development of electricity as a major source of artificial illumination, and the man who made the biggest contribution to the whole science of electrical engineering; who virtually showed how the continuous generation and distribution of controlled current was possible, was Michael Faraday.

Faraday brought law and order to the mass of existing data and research on electricity. In 1831 he established the basic principles of electric dynamos and the first beginnings of the generating industry. We all owe a terrific debt to Faraday.

Naturally, in the latter half of the 19th century many experimenters became aware that electricity, when passed through a filament of some kind, could make it glow.

The problem, of course, was that when burned in air the filament combined with oxygen and after a short but brilliant life ceased to exist. In other words, where oxygen is present the filament burns away in just the same manner that coal does on a fire. Clearly, if a filament could be heated in an atmosphere free of oxygen, or even in a vacuum, a practical incandescent light would be possible.

It also has to be borne in mind that apart from problems of electrical engineering, the creation of a good vacuum in the 1860's and 70's was a major scientific problem in itself. However, it is at this point that we must turn to the hero of our story, Joseph Wilson Swan.

Genius of the lamp

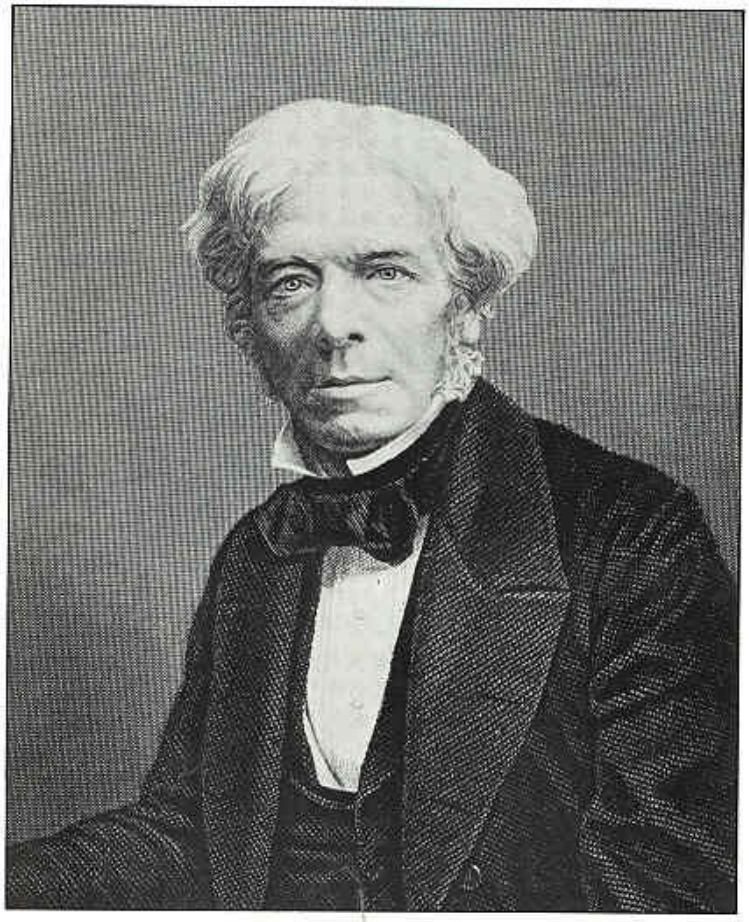
Joseph Wilson Swan was born in Sunderland in 1828 of Scottish descent. He had a fertile mind and though he left school at 13, launched himself into a scientific career by becoming apprenticed to a Sunderland firm of druggists.

In 1846 he joined his friend and future brother-in-law, John Mawson, as a chemist and druggist in Newcastle, later becoming a partner in the firm.

Swan first tried the idea of passing current through a thin filament to make it glow white hot, in the late 1840's but since at that time an efficient vacuum pump was not available, he had to put the idea on one side.

At the time most public interest was centred on carbon arc lighting. But it was clear that if a carbon *filament* lamp could be made it would be cleaner and more convenient. However, Swan's interest in carbon did not end with electric lighting.

Passionately interested in photography, he became widely known as an expert on this subject and succeeded in simplifying the development and washing of photographic plates (then a rather complicated process) by applying



Left *Michael Faraday brought law and order to the confusing mass of existing data and research on electricity in the early nineteenth century. He laid down the theoretical groundwork which made possible the large-scale generation of electricity. This, in turn, was to spread the benefits of lighting to nearly everyone.*

Opposite *Lighting pioneer Joseph Wilson Swan.*

Very truly yours
Joseph W. Swan

a carbon tissue coating to the emulsion, ensuring easier development and greater permanence. The process was commercially successful and many excellent prints survive to this day.

But to return to lighting, the main problem was to achieve a good vacuum, to avoid the filament burning away, and until Sprengel introduced an efficient vacuum pump in the early '70's this seemed impossible.

In 1875 Swan learnt that a Birkenhead bank clerk, Charles Stearn, had been carrying out experiments with high vacuum for Sir William Crooks (to whom we are indebted for the first cathode ray tube, which later developed into the television screens we use today) using the Sprengel pump. He wrote to him, then began to supply filaments to him for mounting in glass bulbs which were then evacuated of air.

By December 1878, Swan, Stearn and a young glass blower, Fred Topham, had produced a number of working light bulbs, one of which Swan showed but did not light at a meeting of the Chemical Society at Newcastle.

In January 1879 he exhibited his incandescent carbon filament lamp at Sunderland and operated it during the lecture. Then, in February, came the famous public lecture to over 700 people in Newcastle, repeated to an audience of 500 at Gateshead in March.

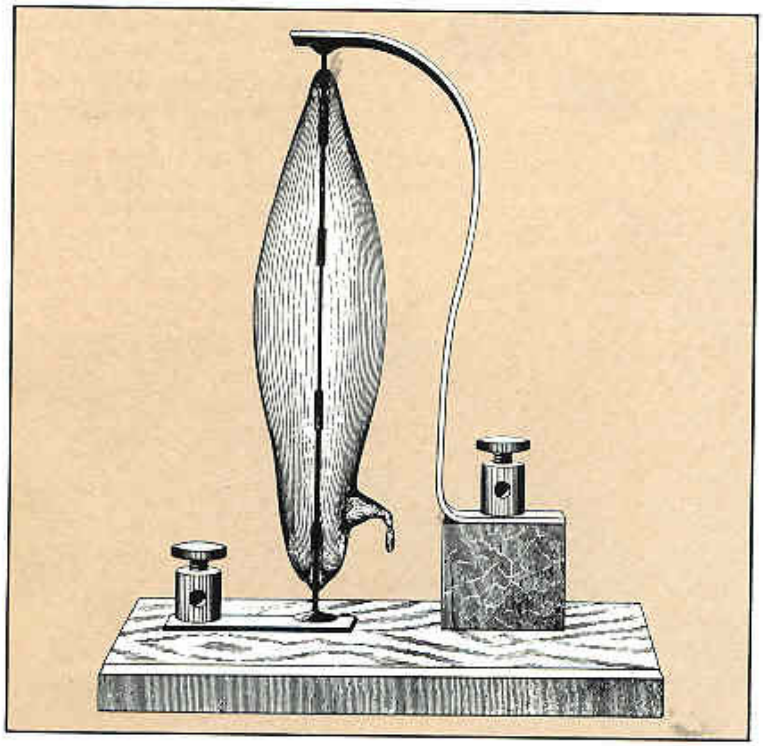
After several thousand years of oil, smoke, gas, candles and– when all else failed – the moon, Joseph Swan had succeeded in turning night into day at the 'click of a switch'.

The secret of Swan's success was to heat the filament to incandescence as the air was pumped from the bulb. This got rid of stray pockets of air in the filament, which had caused rapid blackening in previous experimental lamps.

Swan worked with Stearn to improve the filament and in 1880 introduced a filament of carbon on parchmentised thread which was to become an industry standard for years. Swan, though urged by Stearn to patent the lamp, thought that the broad features were not patentable, and this was why Thomas Edison, who hit on the same technique as Swan in October 1879, was granted the first British patent on a carbon filament vacuum lamp.

Nevertheless, the future of Swan's lamp was assured. By 1881, the newly formed Swan Electric Lamp Company was producing lamps in commercial quantities at a new factory in Benwell, Newcastle.

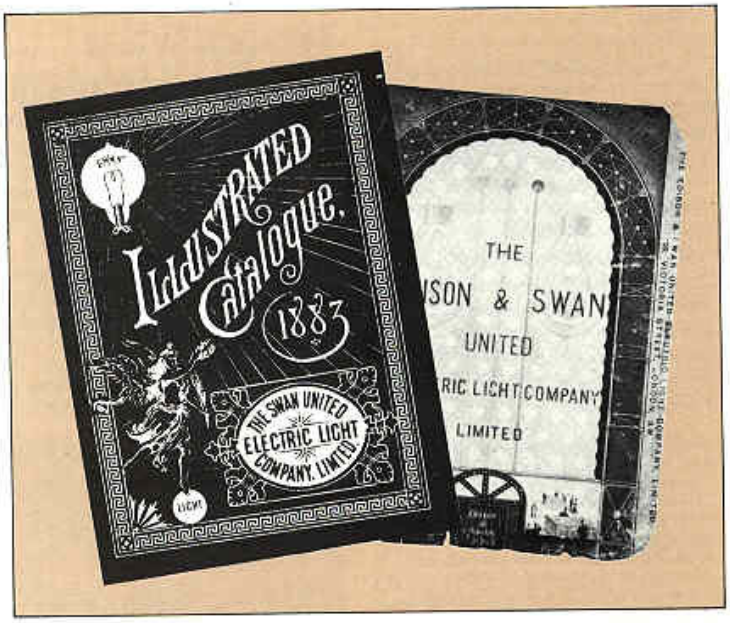
Many firsts then followed; the first shop lighting – Swan's



Top Left *This original Swan lamp is the type which so impressed the Newcastle Literary and Philosophical Society. The lamp has a carbon filament and an individually blown glass bulb.* ***Bottom Left*** *Staff at the Benwell factory, near Newcastle, where the world's first commercial production of filament lamps took place. Swan opened the factory in 1881 after forming the Swan Electric Lamp Company.*

chemist's shop at Newcastle – the first ship, the 'City of Richmond'; the first private residence to be electrically lit, the home of Sir William Armstrong at Cragside, Northumberland; followed by the lighting of the House of Commons, a special train and the d'Oyley Carte-managed Savoy Theatre in London.

In 1883, Swan joined forces with Edison to form the Edison and Swan United Electric Light Company. Their joint names lived on as Thorn Lighting's Ediswan brand until quite recently. Now the brand is not used in Britain but it is remembered.



Right *Early Swan and Edison/Swan catalogues. The 'Ediswan' brand name resulted from the decision of the two inventors to co-operate.*
Below *A Newcastle street lit by Swan lamps.*

Postscript

Nowadays light bulbs are so commonplace that hardly anyone gives them a second thought – until they fail. But they *are* precision instruments – and should be treated accordingly.

For instance, although the filaments are as robust as the lightmakers can make them, the lamps should not be subjected to undue shock, stress or vibration.

It is not generally realised, either, that all lamps are designed to be burned in a given position; cap up, cap down (as with decorative candle lamps) and in some cases, horizontal e.g. incandescent striplights – *not* to be confused with fluorescent lamps. Use the lamp incorrectly and the probable result will be early failure.

The commonest mistake is to burn a light bulb in too small a fitting or shade. Remembering the temperatures quoted earlier, this can easily result in overheating and early failure. Again the mains voltage should be constant and match the rating of the lamp. Too high a voltage can wreak havoc with a filament though you will get a very bright light from it.

By far the commonest myth about light bulbs – one that would have amused Joseph Swan – is that somehow manufacturers could, if they wished, make bulbs last almost for ever.

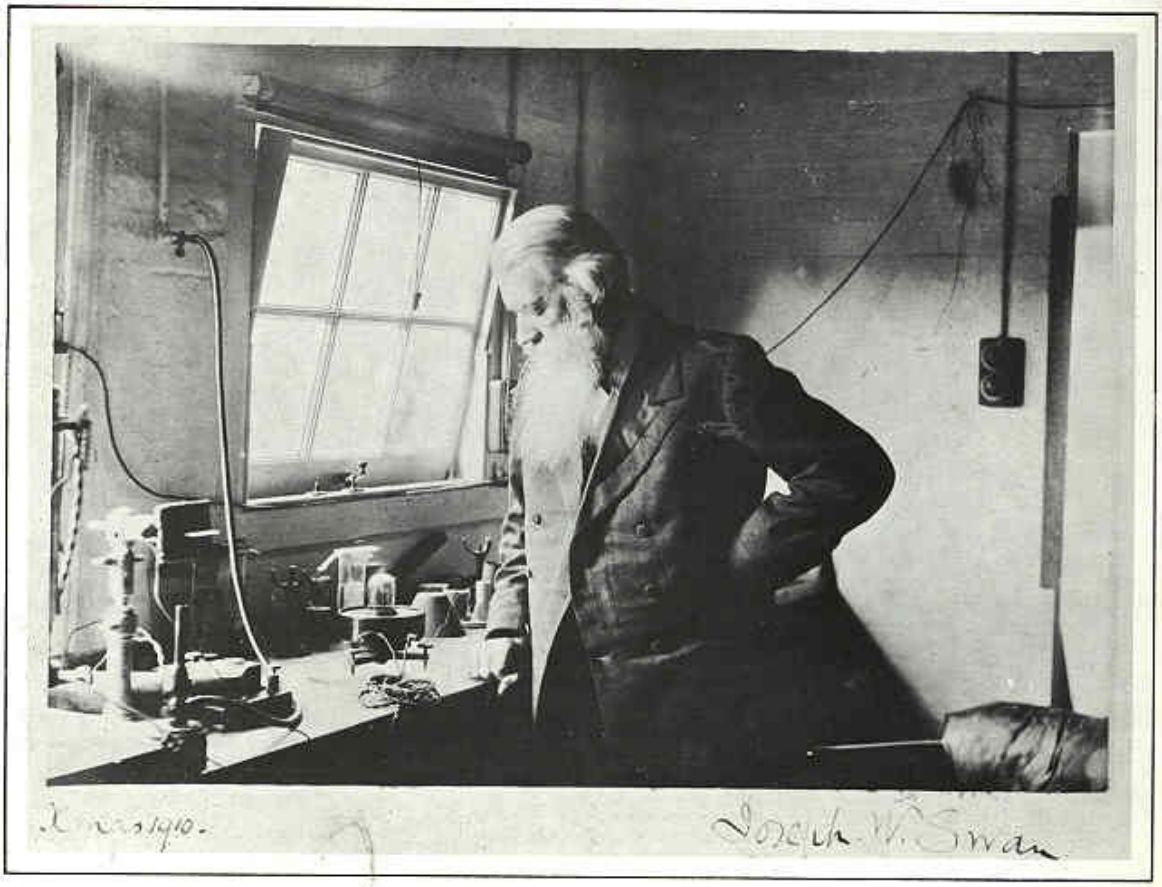
If only this were true! But the standards of quality now demanded of light bulbs have reached their zenith. Life can only be extended by greatly lowering the efficiency of the lamp; and the ratio between life and brightness is the one big enigma facing all lamp engineers. With something like a flashbulb, lasting only a few milliseconds, the answer is obvious; brilliance is everything.

At one time Swan would have given a fortune if he could have been shown how to make an electric lamp give well over 1000 lumens of light and last 2000 hours.

It is well to remember, one hundred years after his first faltering triumph, how the monumental service he performed for mankind is now so widely taken for granted, that piles of light bulbs appear in grocery shops along with the bread and butter, sell for half the price of a packet of cigarettes, and certainly cost the average household less than it does to feed the cat for a week.

We, in Thorn, pay tribute to this outstanding man and extend our good wishes to his home town, Newcastle.

If ever a man deserved to have his name up in lights, it is **Sir Joseph Swan.**



JOSEPH SWAN
1828-1914

JOS

1828 1914

A PICTORIAL ACCOUNT OF A NORTH EASTERN SCIENTIST'S LIFE AND WORK

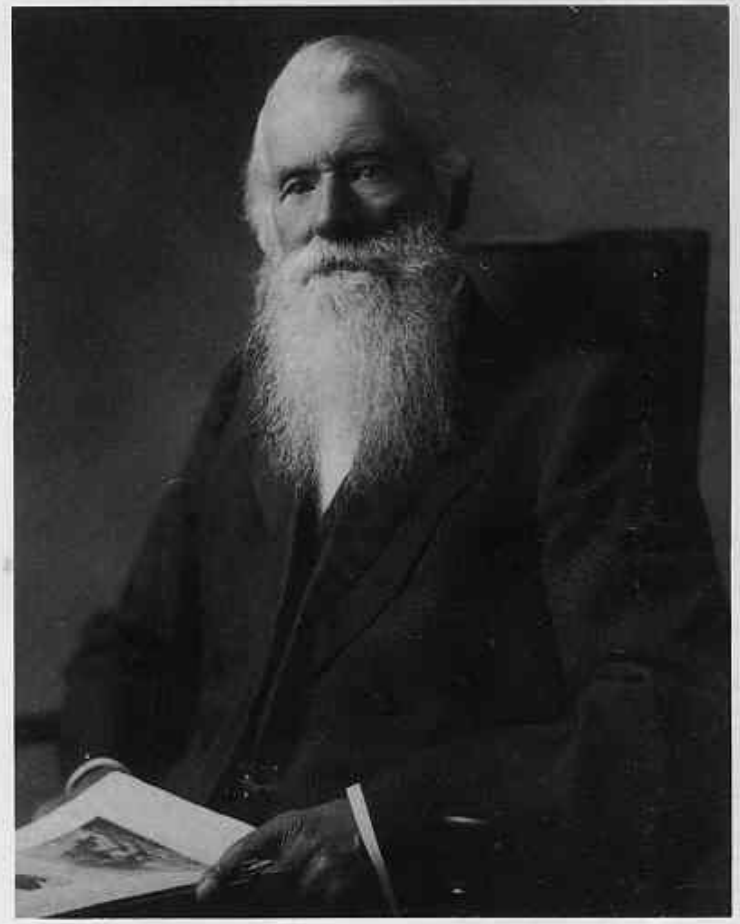
BY

DIANE CLOUTH

JOSEPH SWAN 1828–1914

"If I could have had the power of choice of the particular space of time within which my life should be spent I believe I would have chosen precisely my actual lifetime. What a glorious time it has been! Surely no other 78 years in all the long history of the world ever produced an equal harvest of invention and discovery for the beneficial use and enlightenment of mankind."

J. S. Swan, 1906.



The lifetime of Joseph Swan was an exciting period in British history. Queen Victoria was on the throne ruling an empire which embraced all the continents of the world – the largest empire mankind had known. Trade flourished, fortunes were made and the living standards of ordinary people were steadily improving. There seemed to be no end to the advance of science: everyday something new was being invented. Tyneside was in the forefront of many developments which now we accept as part of everyday life such as the railway system, the oil tanker, hydraulic machinery and electric power supply. The contribution of Joseph Swan to the development of photography and the electric lamp are part of this story.

Joseph Swan could not boast of an intensive formal education similar to that received by the youth of today. Learning to him did not necessitate quietly studying in a classroom for he was far happier scrambling along the banks of the Wear in attempts to discover the heights of the wooden ships and the widths of their sails; watching the glassblowers and blacksmiths at their work. By such activities Swan developed his intellectual curiosity and powers of observation which were to be invaluable assets in his later career as a scientist. The following pages serve as an introduction to the life of an outstanding Victorian gentleman, one of Tynesides many pioneers, Sir Joseph Wilson Swan.

John Swan 1795–1898
A quiet, practical man who made several inventions including an improved anchor, a life-boat and a system of fog signals for directing ships at sea. Unfortunately, his inventions were of little commercial value.

John Cameron 1827–1916
Joseph Swan's closest brother and companion, at the age of 14 John was apprenticed to a firm of drapers in Sunderland which he disliked and was later apprenticed to John Mawson, the chemist. In 1855 he set up as a general merchant eventually specialising in the sale of chemicals and metal.

Joseph Wilson 1828–1914
Major inventions included the carbon process for photographic printing, bromide printing paper for rapid photographic printing, the incandescent filament lamp, artificial cellulose thread for making artificial silk and the cellular lead plate storage battery.

George Henry 1833–1913
At the age of 19 George Henry went to the colonies in search of gold. This venture proved unsuccessful and he eventually set up as a photographer/chemist in Wellington, New Zealand. In 1863, the firm moved to Napier where Swan entered politics and ultimately became Lord Mayor.

Alfred 1835–1919
Alfred began his working life as an apprentice architect but in 1880 he became involved in his brothers lamp business. His major contribution was the perfection of the holders and caps for the bulbs and the development of 'vitrite', an insulating material which became universally adopted in lamp manufacture.

Isabella Cameron 1801–1884
An intelligent and determined woman of Scottish descent, Isabella came from an inventive family. Her eldest brother Robert was one of the earliest pioneers in New Zealand, inventing and making improvements in rope-spinning machinery and lifeboat construction.

Elizabeth 1822–1905
The eldest daughter who, upon the failure of her father's business, helped by teaching with mother in their home. Elizabeth was devoted to her family and stayed with them until her marriage to John Mawson in 1848.

Isabella 1830–1913
Little is known about this daughter except that she married a Mr. Thomas Atkinson on August 2nd 1885 and bore him one child – a daughter.

Mary Jane 1832–1914
Mary married John Pattinson one of Joseph's closest friends. Pattinson, a reknowned analytical chemist, was appointed public analyst to Newcastle, an appointment which later encompassed the counties of Northumberland, Durham and Berwick upon Tweed.

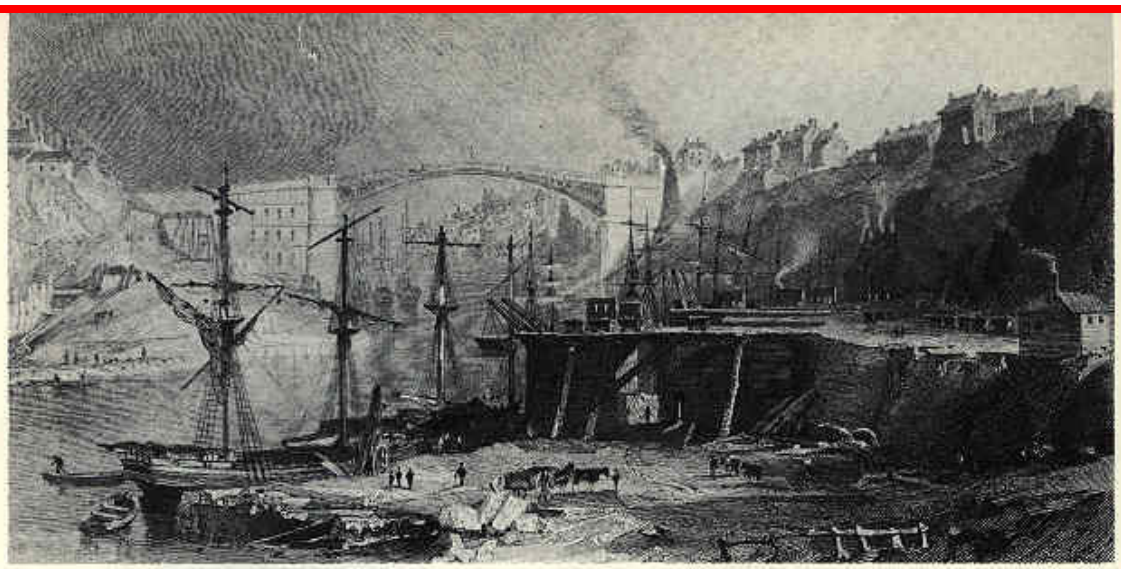
Emma 1837
Emma married Carl Frederick Leyel, a Swede employed by the shipping firm Borries, Craig and Company of Newcastle. Her husband's death in 1876 proved a great loss to Emma who after the death of her parents moved to London. It is not known when she died.

Hannah White (1837–1918)
In 1870 Swan decided to remarry, this time to Hannah who had, upon the death of her sister Fanny, come to the aid of the Swan family. The couple waited for a Bill, legalizing the marriage with a deceased wife's sister to be passed; it failed to pass. Joseph and Hannah then went to Switzerland, a country where there was no legal bar on such a union, and were married in Neuchatel on October 3rd 1871.

Elizabeth Mawson (1822–1905)
Upon the death of her husband Mrs Mawson was made a partner in the business of Mawson & Swan, this ensured her an income and an interest for the remainder of her life. The mother of five children she was an extremely active woman maintaining to her death an interest in all the great social and political questions of her day – in particular the anti-slavery movement and the temperance league. A generous and loving member of the Swan family she died in 1905 at the age of 73.

Francis White (died 1868)
A teacher and friend of the Mawson family it was upon her visits to Newcastle that she met Joseph Swan. They became engaged and in 1862 were married. Four children were born to the young couple but it was a short illness after the birth of twin sons which proved fatal for Fanny. She died in 1868 – a few months later the twin babies followed her to an early grave.

John Mawson (1815–1867)
He was Joseph Swan's friend and relative also partner in a successful chemist and druggist business. Mawson married twice. Firstly to Swan's aunt Jane who was, apparently, a very beautiful and saintly woman but possessed of a very delicate disposition. She died when only thirty leaving behind a daughter, Lydia Jane. John's second marriage was to Elizabeth, Swan's eldest sister. A methodist and tee-totaller Mawson was a pillar of society; a much loved and respected man he was appointed Sheriff of Newcastle. It was whilst carrying out his duties as sheriff that he was killed in an unfortunate explosion of nitro-glycerine on the town moor. An active worker in the cause of national peace and the abolition of slavery Mawson died aged 52.



Joseph Wilson Swan was born on 31st October, 1828, at Pallion Hall, Sunderland. His father, a quiet practical man, was an anchorsmith by trade but upon the failure of his business he became manager of the lime kilns at Pallion. Joseph was an inquisitive child finding much to occupy his active and observant mind in the surrounding neighbourhood. He later recalled:

> *'Before I was four I had visited all the works in the neighbourhood and I had been to the glasshouse and seen the process of glass-blowing, and looked into the square pits of the copper works. There was a fine view of the river from the end windows of our house which looked across it from a considerable height enabling me to see the shipbuilding going on on the opposite side of the river, and boats coming up and down.'*

Joseph's formal education began at the preparatory school run by the Misses Herries at Sunderland, 'three funny ladies' who taught reading, writing, sewing and knitting. According to an interview given in 1906, Swan was not a good boy at school – in fact he had the reputation of being idle and mischevious and was glad when school was over. However, there was one occasion when Swan was spellbound:

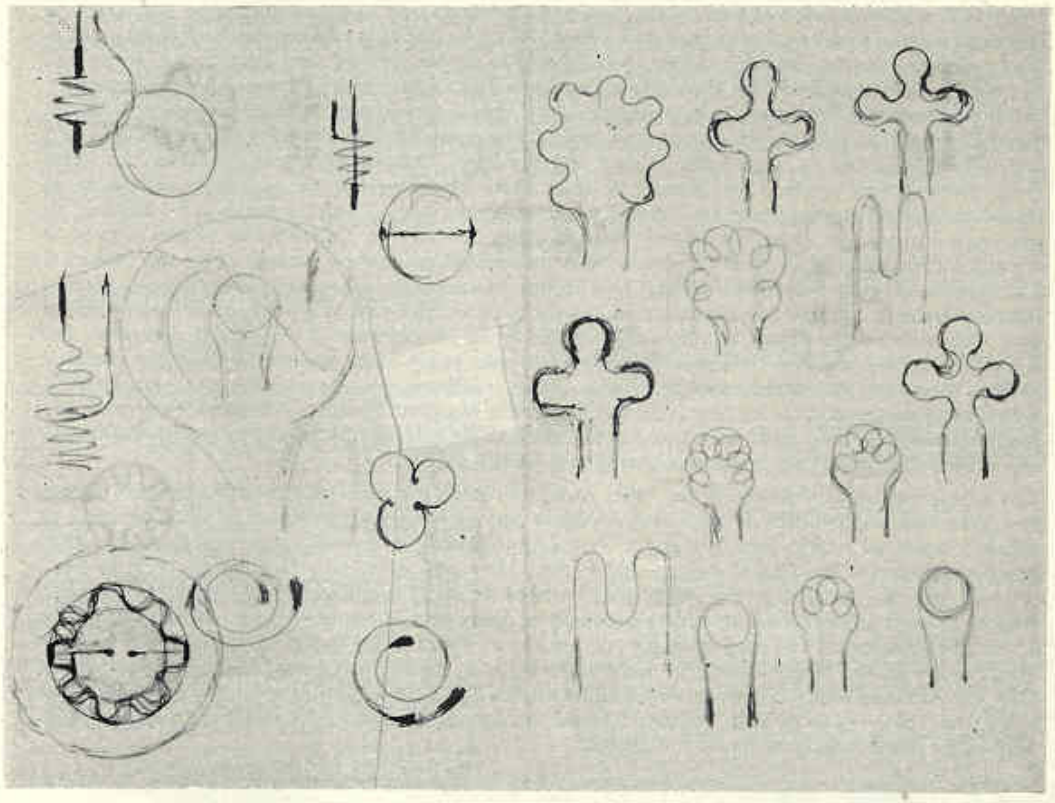
> *'One day there came into the classroom an old gentleman wearing a long dressing-gown, he looked just like the pictures of wizards. He had in his hand a glass prism and he held it so that the sunshine fell on it and made a rainbow on the schoolroom wall. I thought it very beautiful and have never forgotten it.'*

Swan was initiated into the mysteries of electricity by a friend of the family, Mr. Ridley, who had constructed an electrical machine and used the young Joseph Swan to aid him in his experiments. Joseph had to stand on a stool with a chain in his hand. The machine was set in motion and the electricity generated caused his hair to stand on end and sparks of electricity to be emitted from the tips of his fingers! This introduction to electricity could well have discouraged a boy of his age from further research but it served only to increase Swan's interest in electricity.

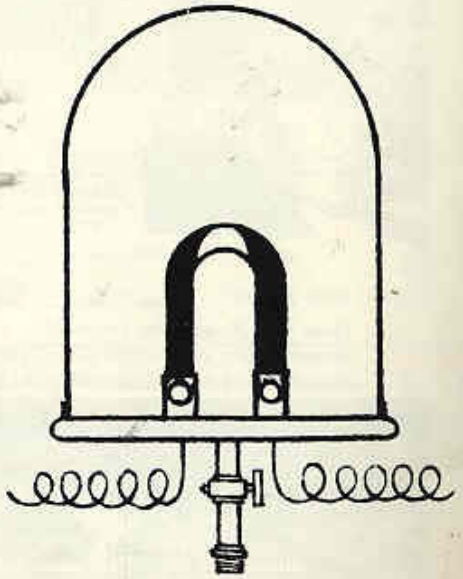
When Joseph was ten he moved to a larger school run by a Scottish minister in Hylton castle and it was here that Swan's interest in scientific experiments was observed and nurtured. Upon leaving school he was articled to a firm of chemists, Messrs. Hudson and Osbaldiston of Sunderland:

> *'It was October 31st, 1842 and I was fourteen when I entered on my apprenticeship as a chemist and druggist. This occupation gave me many opportunities for making chemical experiments and these were turned to account in the attainment of various objects that from time to time arrested my attention.'*

Unfortunately, both partners died within the first three years of Swan's apprenticeship leaving him free to join a friend and future brother-in-law, John Mawson, who had a chemists business in Newcastle. Work with Mawson proved enjoyable since Swan was allowed to pursue his own scientific research. Often he would work late into the night in the photographic studio on the upper floor of the premises in Mosley Street as the then new art of photography held a great fascination for Swan:



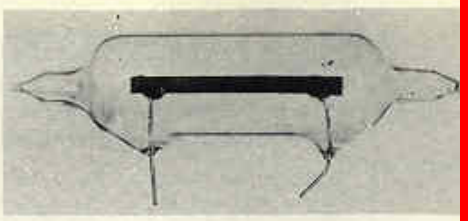
The page from Swan's note book reproduced above shows doodles of the various shapes for his carbon filaments. Over a period of several years successful durable and flexible filaments were produced. The next step was to render the strips incandescent which in turn meant the construction of a lamp. The diagram opposite of Swan's lamp of 1860 shows that the lamp was then nothing more than a glass bell jar inverted over a brass tray with a carbon arch clamped to two brass screws. In order to make the carbon arch glow the air within the jar had to be evacuated and a surge of electricity passed through the carbon. The experiment was not entirely successful for two reasons. At this point of time high vacuum techniques were relatively undeveloped: vacuum pumps working off a series of pistons and barrels were not very efficient. The second problem was electric power. In the 1860's primary batteries were the only source of current and they were not powerful enough to make the longer strips of carbon incandescent. It was not until the dynamo of Gramme became a commercial success in the 1870's that the problem of supply a constant source of sufficient power was solved.

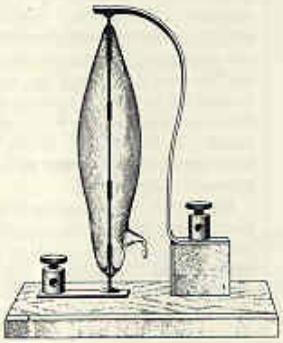


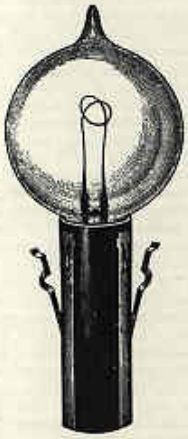
An advertisement in a newspaper of 1877 alerted Swan to the recent developments in high vacua technology by Mr. Stearn of Birkenhead. Swan immediately wrote off to Stearn asking if he would be interested in carrying out various tests on the carbon filaments. Stearn agreed and with the assistance of an expert glass blower, Fred Topham, he started to experiment. Difficulties arose over the mounting of the carbon strips in the glass bulbs and Stearn discovered that it was very difficult to exhaust the whole of the air from the bulb for the carbon itself was acting as a reservoir in which was stored air and other gases. The illustration opposite shows the experimental lamp of 1877: note the black strip of carbonised paper.

This observation proved to be a turning point in the research work. Swan solved the problem in a simple but ingeneous way: the lamp was evacuated as completely as possible and when this point was reached a strong electric current was passed through the carbon strip thereby rendering it incandescent whilst simultaneously evacuating the bulb. An extract from Swan's notes records that 'it was found that the carbon in a lamp this perfectly exhausted and sealed did not waste away and, provided the contact with the platinum was good, the bulb did not blacken.' On February 3rd 1879, Swan showed his lamp (illustrated opposite) in operation at a meeting of the Literary and Philosophical Society of Newcastle upon Tyne. This was an historic occasion. A month later the demonstration was repeated at Gateshead Town Hall in the presence of the mayor.

Various improvements followed most notably the development of the parchmentised thread filament which was made from cotton converted by the action of sulphuric acid into a plastic condition. The first commercial lamp of 1881 was the outcome: this is illustrated opposite. Early in 1881 the Swan Electric Light Company was formed and the process of lamp manufacture which had previously been carried out at Swan's home in Low Fell and Stearn's workshop at Birkenhead were brought under one roof at South Benwell, Newcastle. Some indication of the impact of these developments upon the society of the day can be gleaned from the newspaper articles reproduced on the next four pages.







THE NEWCASTLE DAILY CHRONICLE, TUESDAY,

THE ELECTRIC LIGHT.

Last night our townsman. Mr. J. W. Swan, lectured at the Literary and Philosophical Institute, Newcastle, on the subject of the electric light. There was a crowded audience. Sir William Armstrong occupied the chair, and, in introducing the lecturer, said that the subject was one which had excited a great amount of public interest. He felt sure they would be exceedingly glad to hear it treated by so able an investigator as Mr. Swan. Being a fellow-townsman, Mr. Swan needed no introduction at his hands; he had only to assure him on their behalf that they would listen to what he had to say with the greatest interest. (Applause.)

Mr. SWAN, who was received with great applause, said that during the last few months no subject, scientific or even popular, had occupied so large an amount of public attention as the electric light. Not only had men of science been discussing it, but almost everybody had been talking about it from one end of the country to the other. The subject had, for some considerable time before, been gradually acquiring importance, and gaining more and more attention both from scientific and practical men; but the crisis, if he might so call it, was reached in October of last year, when the following telegram from Mr. Edison to his London agent was fulminated:—"I have just solved the problem of the subdivision of the electric light indefinitely." This was immediately followed by the telegram:—"When the brilliancy and cheapness of the lights are made known to the public—which will be in a few weeks, or just as soon as I can thoroughly protect the process—illuminating by carburretted hydrogen gas will be discarded. With fifteen or twenty of these dynamo-electric machines, recently perfected by Mr. Wallace, I can light the entire lower part of New York City, using a 500 horse-power engine. I propose to establish one of these light centres in Nassau Street, whence wires can be run up town as far as the Cooper Institute down to the battery and across both rivers. These wires must be insulated and laid in the ground in the same manner as gas pipes. I also propose to utilise the gas-burners and chandeliers now in use. In each house I can place a light meter whence these wires will pass through the house tapping small metallic contrivances that may be placed over each burner. Then housekeepers may turn off their gas, and send the meters back to the companies whence they came. (Laughter.) Whenever it is desired to light a jet it will only be necessary to touch a little spring near it. No matches are required." The effect of the publication of these telegrams was electrical. For some time before these sensational telegrams were issued certain things of a very startling character had happened in connection with electrical science. Within a period of forty years this obscure branch of physics, previously unknown to practical people, or if known despised by them as useless, had in its results in several ways assumed an importance of the very highest degree. It was known that Mr. Edison was a man of extremely inventive genius, that he had invented an electric pen, a talking machine, a telephone, and no end of other wonderful things. Hence it happened [illegible] these telegrams were published the [illegible] world was [illegible] unquestioning amazement. Gas shares were immediately greatly depreciated in value, and those who possessed them were in the greatest state of alarm and even panic. He described various forms of electric light which the old-fashioned electrical machine produced, and gave an experiment to illustrate the kind of light producible by the ancient electrical machine. The discovery of the Voltaic battery, commonly but erroneously termed the galvanic battery, constituted the real starting point of the history of his subject. Up to the time of Volta, no means of producing a large quantity of electricity continuously were known. Hitherto it had been produced by friction, and in very small quantity. Volta discovered the means of producing electricity by chemical action, and in very large quantity. The lecturer explained the voltaic arc apparatus, by means of which he gave several wonderful experiments. The voltaic battery, efficient as it was, so far as concerned the production of electrical effects, was yet quite a hopeless means of obtaining these effects at a moderate cost, and so long as the production of electricity was expensive, so long would it be impracticable to apply electric lighting to common purposes. All the available forms of voltaic battery, so far devised, had in common this inherent vice, that the production of a certain quantity of electricity involved as a matter of necessity the oxydisation, in effect the burning of, a corresponding quantity of zinc. Zinc in the voltaic battery played the same part in the production of electricity that coal in a gas works did in the production of light and heat. Zinc, however, with us, was about fifty times the price of coal, and yet its possible effectiveness, weight for weight, was much less than that of coal; therefore, to use zinc as a fuel either for the production of light or heat; and whether by direct combustion, or indirectly by first producing electricity by its means, was to use a fuel at least fifty times more costly than coal. Cheap electricity—the one thing needful for the practical utilisation of electric light—had been obtained as the result of a discovery made by Faraday forty years ago; and he here gave an example of how a current of electricity was developed by motive power. The merit of first producing a machine that, by the action of motive power, would produce a perfectly continuous current, in all respects like that of the voltaic battery, belonged to M. Gramme, whose machine, and also that of Mr. Siemens, he described. They could now produce electricity by means of coal instead of zinc, and although they did not get really the full equivalent in electricity of the potential energy resident in coal and evolved as heat (because they only got it second-hand, the heat being first applied to produce motive power and the motive power to produce electricity), yet the advantages in point of cost, as compared with zinc-produced electricity, was so great as to completely change the position. Electro-lighting now rested on a new foundation. They had at last got a cheap source of electricity. He next referred to the various contrivances for applying the current most effectively to the production of light. There were two broadly distinct modes of producing electric light, one by means of the voltaic arc, and the other by means of the incandescence of an imperfect and infusible conductor such as platinum or carbon, both of which methods he minutely described. Next to the discovery of the principle of the Dynamo electric machine, nothing had given such a strong impulse to the industrial application of the electric light as the invention of the Joblochkoff candle, of which he had a few specimens for inspection. The light produced by the voltaic arc was so splendid that it was no wonder that great efforts had been made to utilise it and to overcome its chief defect, unsteadiness. It was wonderful how near an approach to perfect success in overcoming this defect had been achieved. Quite a sufficient degree of steadiness had been realised to render it serviceable for a number of purposes where a pure and very powerful light was required. So far, the most that had yet been done in the way of dividing [illegible] by the Jablochkoff candle. What did electric light cost? This was a question difficult to answer, except in the most general terms, for the cost varied exceedingly with variation of circumstances. For example, what electric light would cost depended primarily upon what motive power cost, and that depended upon whether it was produced by the steam-engine, and in that case upon the cost of coal, or whether some other motive power was used, as, for example, a gas engine or a waterfall. In the one case it might be rather expensive, and in the other very economical. Then it greatly depended upon whether the power was expended in producing a very few powerful lights, or a great number less powerful. There was great loss in dividing electric light. If in one case they had one light equal to 10,000 candles, and in another 10,000 candle light

FEBRUARY 4, 1879.

divided over 100 lamps, much more power would be expended to produce the same total quantity in the case of the divided light. If they took as the datum of cost of motive power that of the most economical working steam engine, consuming say 3lbs. of coal per horse-power per hour, and if they put one horse-power, at that rate of cost, into one light, they could get a light equal to at least 1,250 candles. The cost of maintaining this powerful light was therefore exceedingly small, looking at the matter in the abstract. The fuel consumed might be roughly estimated as about the same as that consumed in the same time in a good house fire, such as they were accustomed to in the North; and the money cost per hour would be sufficiently covered by that now obsolete coin, a farthing. This estimate took no account of the cost of the engine and apparatus, nor of attendance. These were very considerable additions to cost in working electric light on a small scale, but were much less serious in large operations. Neither did it include any charge for waste of carbons going on at the lamps; that waste might be looked upon as avoidable. If the current generated by the one-horse power were divided over ten lights, probably only one-tenth of the light would be obtained; but that would be 125 candles, or equal to eight large gas burners, an ample light for a large room, and which could be obtained for the small cost he had named. Was electric lighting going to supersede gas? He thought there was little probability of that, as there were many advantages in favour of gas. Gas could be stored in a reservoir, while electricity could not. Gas could be used for heat as well as light, whereas it was doubtful whether electric heat could be used instead of gas heat. It was evident that both gas light and electric light had their special uses. Gas would continue to be largely used, perhaps as largely as ever, and electric light would also come into extensive use in its own special field. Among the many uses to which the electric light was put, he mentioned the lighting of Sir William Armstrong's picture gallery at Cragside, Rothbury. In an abstract of a report by two engineers on the cost of working for a month on a small scale the Jablochkoff candle system at Westgate-on-the-Sea, the relative cost of electric light and gas light was put at four to one. The Jablochkoff candle system was costing not so much on account of the power expended in producing the light as on account of the candles themselves, which cost 7½d. each, and lasted nominally an hour and a half. What was required to make electric street lighting, and shop and house lighting, successful was an electric lamp in which there was no waste of carbon and no machinery. Mr. Edison said he had invented such a lamp. Mr. Sawyer said he also had. If this were true, and if, along with these advantages, those lamps gave a satisfactory return in light for the electricity spent, then the chief problem was solved, and they would not have to wait long for a very extended development of electric lighting. But in any event, even if it should happen that those inventors had not accomplished quite so much as we had been led to expect, the problem of a simple and an economical lamp would, he did not doubt, be ultimately solved, and with its solution electricity would become a common means of illumination. (Applause.)

Sir Wm. Armstrong moved a cordial vote of thanks to Mr. Swan for his highly interesting lecture, which was carried by acclamation.

The lecture throughout was rendered additionally attractive by the introduction of various experiments with the electric light, all of which passed off with an unusual degree of success.

NOXIOUS VAPOURS.—A special meeting of the North-Western Association of Medical Officers of Health has been held in Manchester, under the presidency of Dr. H. H. Vernon, of Southport, for the purpose of considering the report of the Royal Commission on Noxious Vapours. As the result of the meeting, it was decided to memorialise the President of the Local Government Board, and to urge upon him the desirability of amending and

THE ILLEKTRIC LEET

Written on Mr. J. W. Swan, the inventor of the incandescent lamp, lighting with electricity his (Mawson & Swan's) chemist shop, Mosley Street. The first shop in Newcastle lighted by electricity (1880).

Tune – 'Billy O'Rookes the Boy'

Aave seen some queer things in maw time,
When gas did oil eclipse, sor,
For aa remember Neshim's men,*
Whe myed wor mowls an'dips, sor,
The tinder box an' rag isteem'd
Begat the loosifors, sor;
Yit still wor greet inventive brain
Is floorie as the Gorze, sor.

Chorus:
The Illektric leet! the illektric leet!
The pet ov all the seasin;
We'll he'd hung up th' morrow neet
Or else we'll knaa the reasin.

We've had sum clivor cheps it hyem,
Ye'll knaa what they wor worth, sor;
The lion gob ov the North, sor
The glory ov the North, sor.
Its ingins push the ships aboot
Faster nor the breeze, sor;
It helps to win wor wives and bairns
Thor bits ov breed and cheese, sor.

Chorus:
The illektric leet! the illektric leet!

Noo Stevinson an' Watt, ye knaa,
Sent Geordies ower the seas, sor,
To teach mankind to de the trick,
Myek steam de as they please, sor.
Ye'll find wors in Astrillia,
In aal the isles aboot, sor;
Fur aa'll be bund ne class ov men
Mair blabbed the secret oot, sor!

Chorus:
The illektric leet! the illektric leet!

So here's te Swan, wor canny man;
His 'llektric leet is fine, sor,
That burns away an' rivals day
In honour ov wor Tyne, sor.
The aud wax candles had thor time,
The gas wor sarvant, tee, sor;
But seun Swan's leet 'll blink like stars
Frov Sanget te The Kee, sor.

Chorus:
The illektric leet! The illektric leet!

"Weekly Chronicle," 1880.

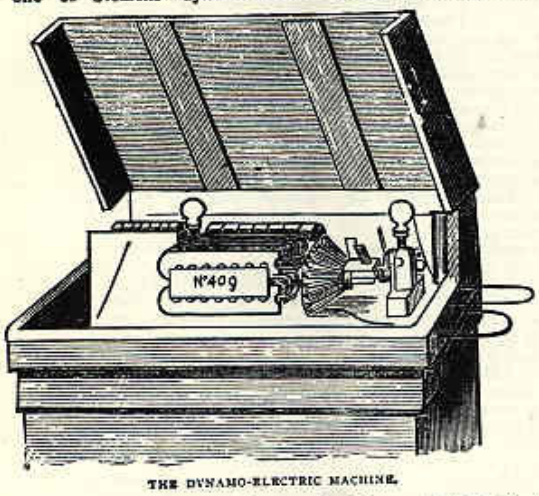
*About fifty years ago Mr. Nesham had a famous tallow-chandler's works on the site of Handyside's shops in New Bridge Street.

From The Graphic april 2nd 1881

SWAN'S ELECTRIC LIGHT AT CRAGSIDE

Two years ago Mr. Swan, of Newcastle, exhibited before the Literary and Philosophical Society, under the presidency of Sir William Armstrong, a new form of electric lamp, in which the light was produced by the white heat of a continuous carbon conductor enclosed in a small hermetically-sealed glass bulb. Many previous attempts had been made to utilise the incandescence of carbon, but never before had the difficulty of preventing the wasting of the carbon been so effectually surmounted. The distinguishing features of Mr. Swan's lamp were: its extreme simplicity, the durability of the carbon filament, and the economy with which light was produced.

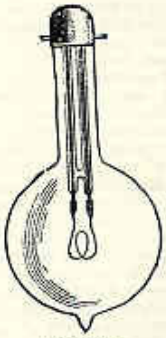
Since then Mr. Swan has devoted himself assiduously to improving his lamp, and he now has succeeded in bringing it into actual use for house and shop-lighting. Mr. Stearn, of Birkenhead, who aided Mr. Swan in the elaboration of his lamp, has lighted his house in this manner for several months past, and the business establishment of Mawson and Swan at Newcastle has been thus lighted uninterruptedly since October. But the largest and most complete application of the system has been the lighting of Sir William G. Armstrong's mansion at Cragside, which is depicted in our illustrations. At Cragside the electric current is generated by one of Siemens' dynamo-electric machines shown below,



THE DYNAMO-ELECTRIC MACHINE.

to which the motive power is supplied by a turbine of six-horse power worked by the overflow of a lake three-quarters of a mile distant from the house. The dynamo machine is placed close to the turbine, and the electricity is conducted to the house by a double line of copper wires.

Mr. Swan's lamp is exceedingly simple. It consists merely of a bulb of glass about three inches in diameter, containing a thin carbon conductor supported by two platinum wires, which, where they pass out of the bulb, are hermetically sealed into its wall by fusion of the glass around the wires. The air contained in the bulb is thoroughly exhausted.

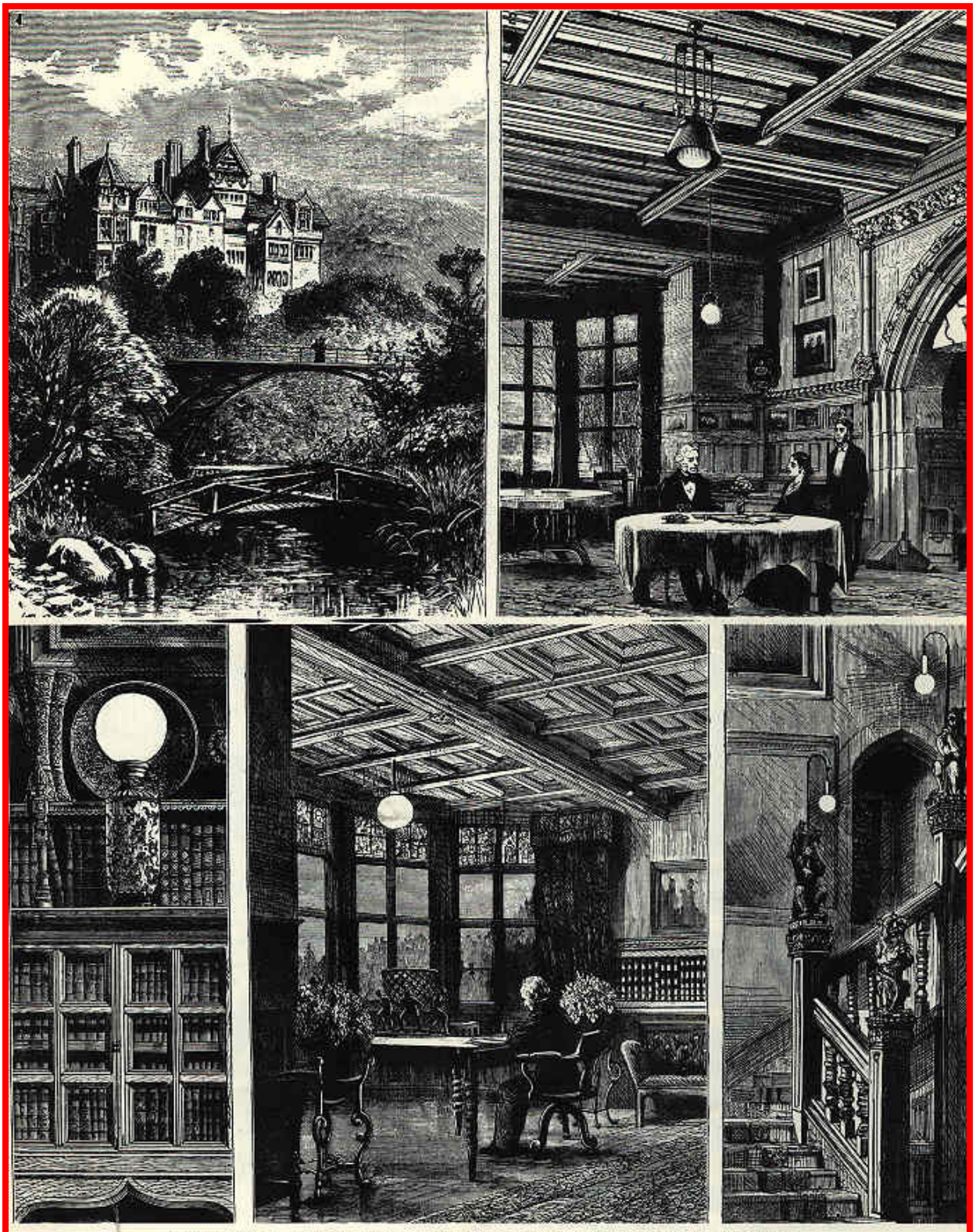


THE LAMP

The chief peculiarity of this lamp is the wonderfully thin and elastic filament of carbon, as thin as a hair, and almost as hard and springy as a steel wire. When the electric current traverses this filament it becomes white hot, and emits a soft and perfectly steady light. As the bulb contains no air or other gas capable of combining with carbon the filament does not burn away, but lasts without change for many months,—indeed, it becomes harder by continued use. The power of the light depends on the size of the carbon filament—the "wick" so to speak—and on the quantity of electric current flowing through it. The light emitted is totally devoid of that dazzling brilliancy which has generally characterised electric light of the old style, and therefore does not necessitate the screening of the light by opal or ground glass, though slightly frosted globes are mostly used at Cragside. Unlike the ordinary form of electric light, the Swan system can be divided absolutely to any extent without sacrifice of economy. Each lamp at Cragside has the power of two or three large gas lights. But it is just as easy, and no less economical, to make the lamps either much smaller or much more powerful. There are forty-five lamps in position. The current is turned on or off the lamps by small switches attached to the wall. It suffices to give one of these a slight turn, and the lamps immediately light up, and to reverse the movement and they all as quickly die out.

Sir William Armstrong has taken a warm interest in the installation of the light, and has himself directed all the details, and brought his wonted ingenuity to bear in adapting the new lamp to previously existing fittings; for example, the centre pendant in the dining-room was formerly used for an oil-lamp, this has been utilised to hold six Swan lamps; when these are lighted the effect on the table beneath is most beautiful. The pendant in the bay of the dining-room holds two other lamps.

A similar and equally happy adaptation of old lamp-fittings is shown in the vase lamp, Fig. 3, one of four (in addition to the pendant in the bay, which contains four lamps) employed for lighting the library. Each of the vase lamps has its proper place around the room, but is removable; they are so arranged by Sir William as to be lighted and extinguished by an exceedingly simple mechanical action. The picture gallery is lighted by twenty lamps contained in five frosted glass globes hanging from the arched roof. The peculiar suitability of a Swan lamp to the lighting of pictures is here demonstrated under the best possible conditions, for the pictures contained in the Cragside gallery are all of them masterpieces, the "Chill October" of Millais and a lurid sunset by Vicat Cole appear to equal advantage seen by the pure and steady light emitted by these lamps. There is a total absence of the prevailing violet light which characterises the ordinary electric light.



1. View of Cragside.—2. The Dining Room.—3. The Library.—4. The Bay Window in the Library.—5. The Staircase.

ELECTRIC LIGHTING BY THE SWAN SYSTEM AT SIR WILLIAM ARMSTRONG'S RESIDENCE, CRAGSIDE

Meanwhile, in America, Thomas Edison had also been working on the problem of developing cheap electric lighting since the autumn of 1878. Aided by a team of technicians, Edison tested more than 1,600 different materials to find a substance for the filament. Eventually, he decided that carbonised bamboo showed the most promising results and sent his assistants out into the jungles of the Orient and South America in order to find a species of bamboo which was, in Edison's words, 'almost geometrically parallel and with practically no pith from which we can make the kind of filaments the world needs.' After spending forty thousand dollars and countless hours of experiment Edison achieved success on 21st October, 1879 when a lamp with a filament of a carbonised piece of cotton sewing thread bent in the shape of a horseshoe glowed for over forty hours. Immediately, Edison set out to exploit the commercial potential of cheap electric lighting which attracted much publicity in the press of the day. Swan's surprise upon finding Edison breathing down his neck is expressed in the rough draft of a letter found amongst Swan's personal papers. Whether the letter was ever sent to Edison is not known. Fortunately, the legal tangle between Swan and Edison was settled peaceably. Both companies realised that it would be sensible to amalgamate and thereby strengthen their position against other lamp manufacturers. The Edison and Swan United Electric Light Company was formed and it held the monopoly of the British market until the expiry of their patents in 1893 and the development of tungsten as a filament.

EDISON'S LIGHT.

The Great Inventor's Triumph in Electric Illumination.

A SCRAP OF PAPER.

It Makes a Light, Without Gas or Flame, Cheaper Than Oil.

TRANSFORMED IN THE FURNACE.

Complete Details of the Perfected Carbon Lamp.

FIFTEEN MONTHS OF TOIL.

Story of His Tireless Experiments with Lamps, Burners and Generators.

SUCCESS IN A COTTON THREAD.

The Wizard's Byplay, with Bodily Pain and Gold "Tailings."

HISTORY OF ELECTRIC LIGHTING.

Newcastle
Septr 24/80

T. A. Edison Esqre
Dr Sir

For some years I have been working at the problem of Electric lighting by the incandescence of Carbon; ~~while~~

T. A. Edison Esq.

Newcastle
Sept 24/80

Dear Sir,

For some years I have been working at the problem of Electric Lighting by incandescence of carbon. I have watched with much interest your experiments in the same direction and the thought has occurred to me that we might with mutual advantage exchange ideas on the subject and to a certain extent share interests; that is to say you might have the benefit of what I have done for America and I have the benefit of what you have done for England and share interests for other countries.

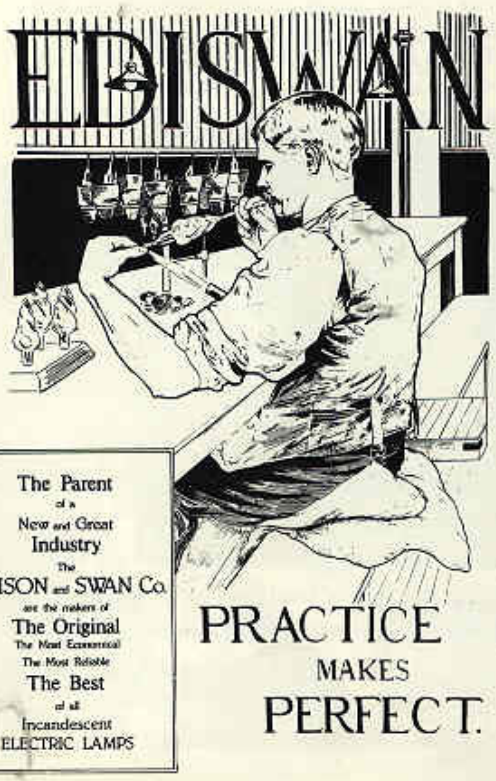
I have made very great progress in some essential points in the construction of lamps. So much so that now I feel quite certain the time has come for undertaking work on scale in competition with gas lighting for towns. I think I am in advance of you in several points especially in the making of the carbons – this I have carried to a very great degree of perfection. I have also ideas with regard to the distribution and measuring of the light such as town lighting would call into operation which I think could be usefully joined with your own.

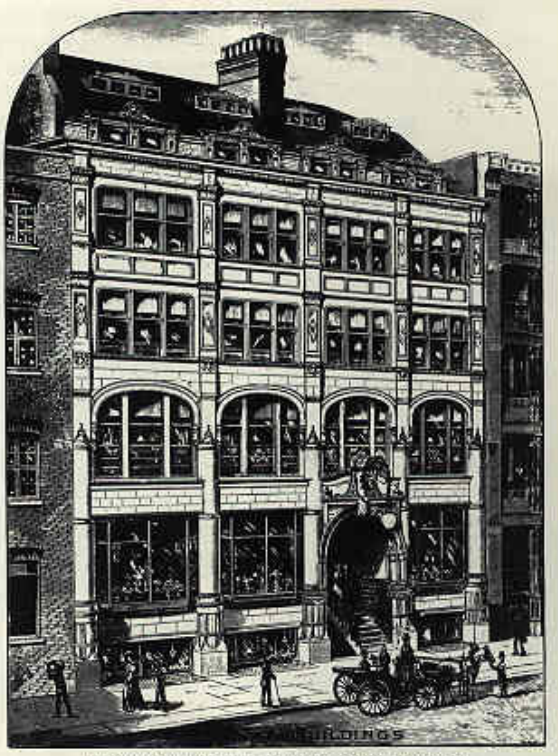
I can easily convince you if necessary that I have been working long on this subject and that carbonised cardboard was a material that I have for years been experimenting with and was actually working at the very time you announced your use of it. I was also at the time referred to using the simplest possible form of lamp, like your own composed entirely of glass, platinum and carbon, the platinum being fused into the glass and exhausted to a very high degree by a most expert manipulation with the Sprengel pump namely Mr. Stearn of Birkenhead.

I therefore had the mortification one fine morning of finding you on my track and in several particulars ahead of me – but now I think I have shot ahead of you and yet I feel that there is almost an infinity of detail to be wrought out in the large application now awaiting development and that your inventive genius as well as my own will find very ample room for exercise in carving out this gigantic work that awaits execution.

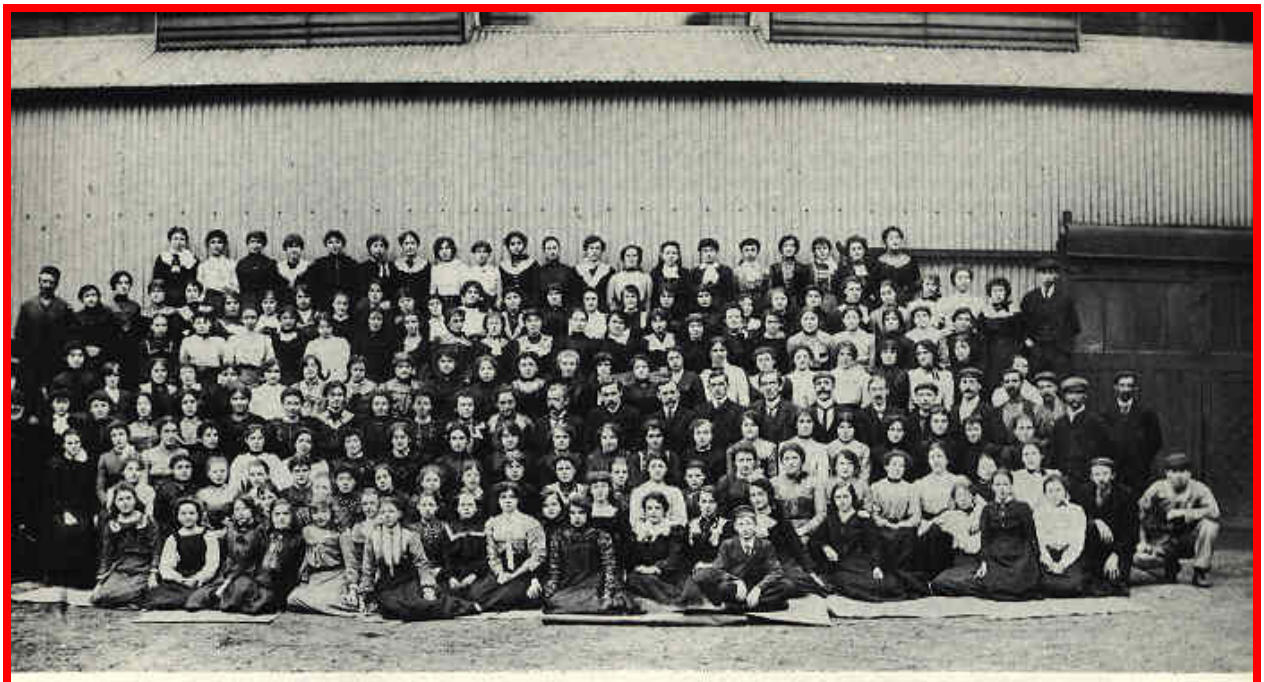
Your obedient servant,

J. W. Swan.

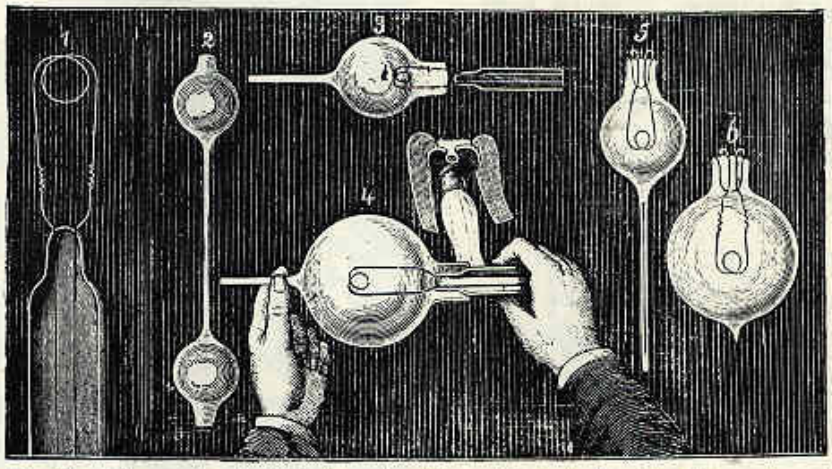




EDISWAN BUILDINGS, 36 & 37, QUEEN STREET, LONDON, E.C.



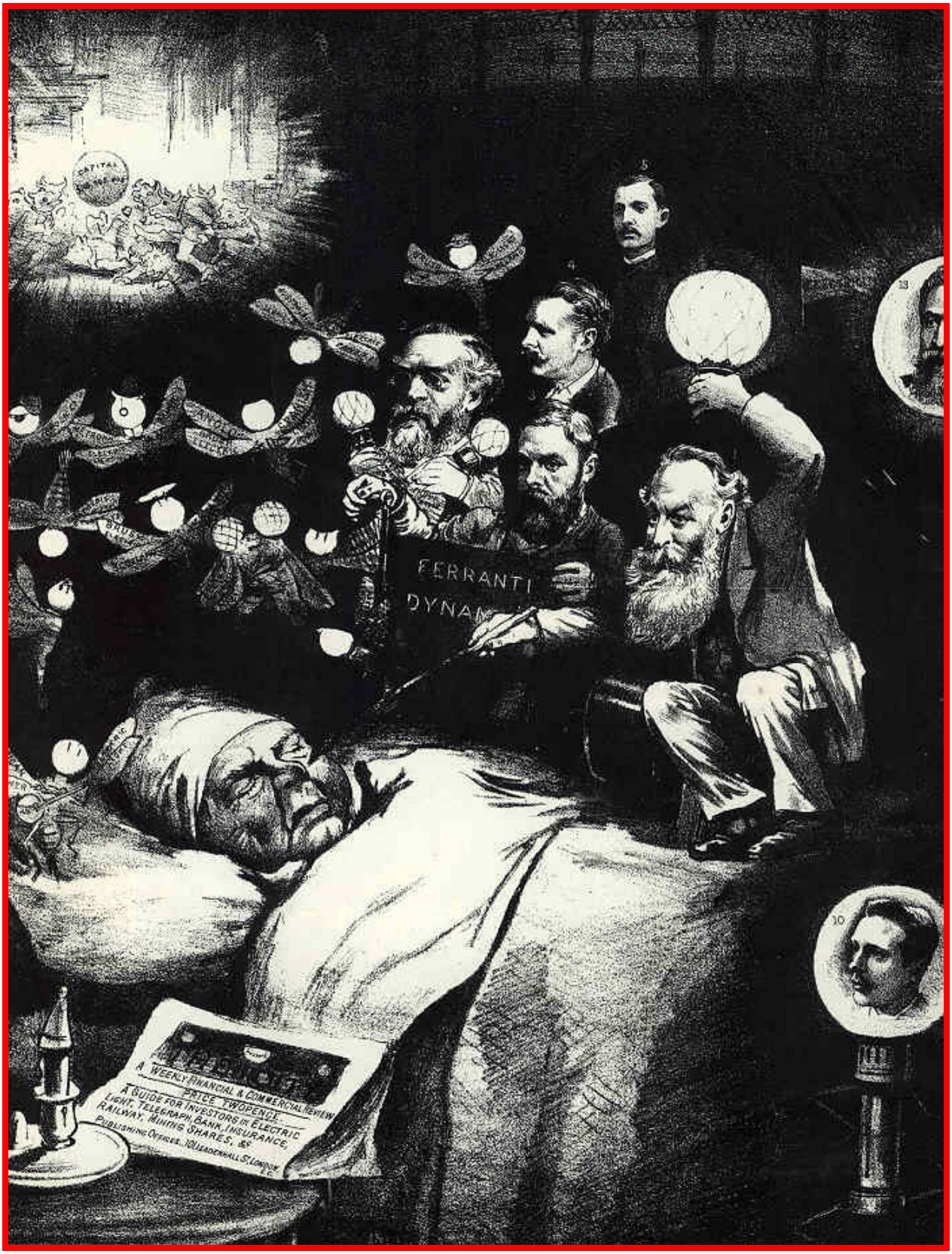
In 1881 an old tannery in South Benwell was converted into a lamp factory and it was considered something of a distinction to be employed in this new and exciting industry. The photograph above was taken outside the factory at Benwell, some three miles to the west of Newcastle, and it shows the large number of girls employed at the works. Victorian etiquette was rigidly maintained even on the factory floor: employees were strictly supervised and elaborate precautions were taken to prevent fraternization taking place between the men and the girls. No male was allowed to enter any of the workrooms without first seeking permission. These 'security' measures were further enforced by the arrangement which ensured that the male and the female workers arrived and left the factory at different hours! The illustrations below show the various stages in the making of a Swan lamp.

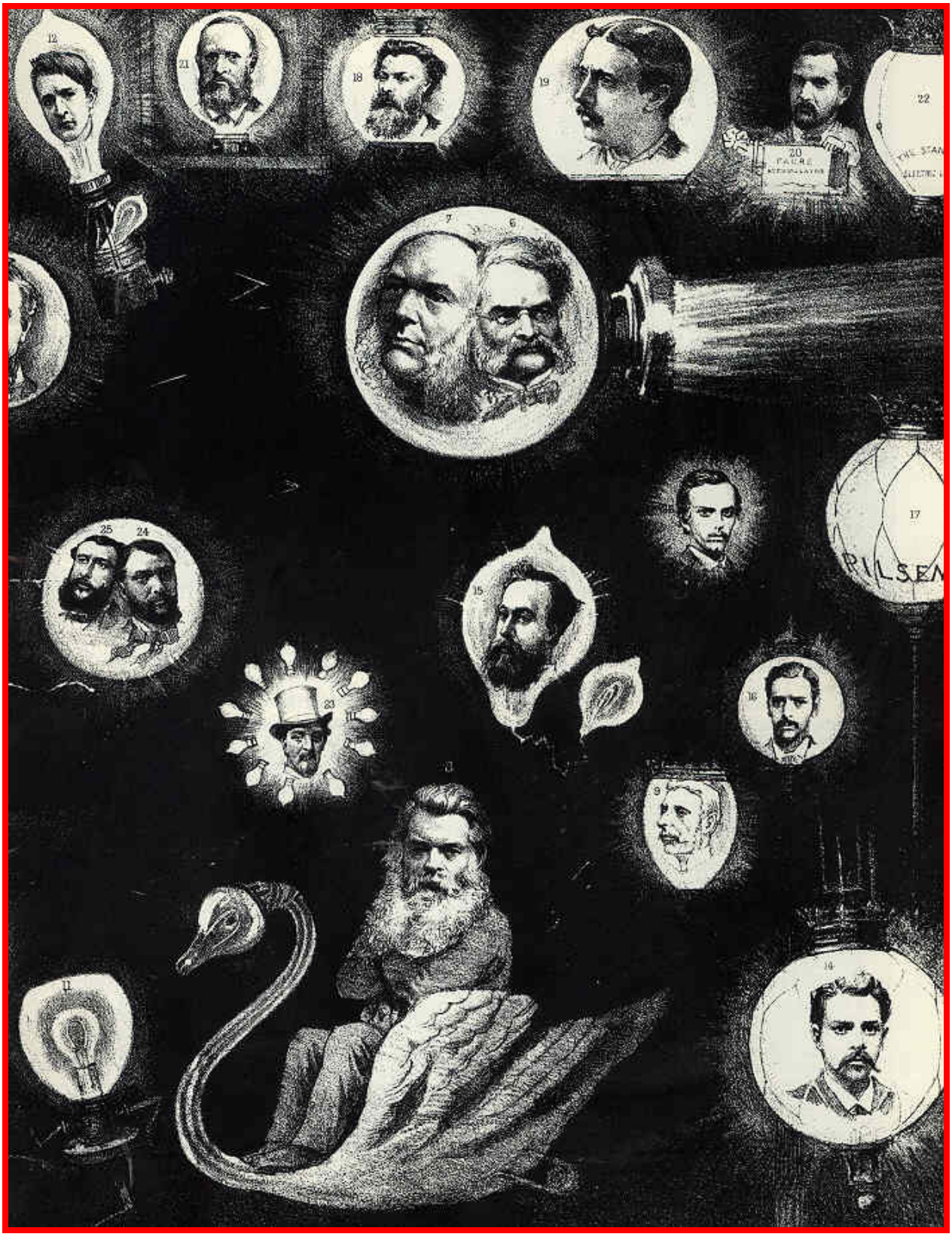


1) The platinum wires to which the carbon filament is attached are fused into a glass stopper.
2) A glass tube is drawn out and blown into bulbs leaving a stem attached for exhausting.
3) The glass stopper with platinum wires and filament attached is placed into the bulb.
4) The stopper is heated and the filament sealed in.
5) The lamp is exhausted of air by means of the stem.
6) The completed lamp.

The illustrations on this page are from Robertson's lamp factory in Newcastle where the work was similar to that carried out at Swan's factory in Benwell. The first illustration (top left) shows the process of exhausting the bulbs by Sprengel pumps. These were tested (top right) for various defects. The photograph (bottom left) shows the lamps undergoing a preliminary running test in actual holders and the final picture shows the lamps being stamped prior to delivery.

On the next two pages is reproduced a cartoon from a supplement to the financial newspaper 'The City' on November 4th, 1882 which depicts the nightmares of a gas director haunted by the thoughts of the electric light and its inventors and manufacturers. Gas shares plummeted upon the announcement of Edison's invention. Although the arrival of the gas mantle reinstated the position of gas lighting on the market, eventually the electric filament lamp supplanted gas lighting in the home.


CAPITAL
FERRANTI
DYNAM
A WEEKLY FINANCIAL & COMMERCIAL REVIEW
PRICE TWOPENCE
A GUIDE FOR INVESTORS IN ELECTRIC
LIGHT, TELEGRAPH, BANK, INSURANCE,
RAILWAY, MINING SHARES, &c
PUBLISHING OFFICES, 10, LEADENHALL ST. LONDON, E.C.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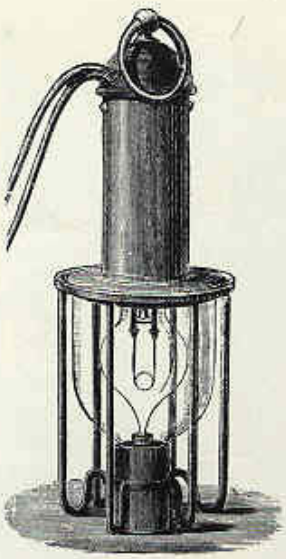
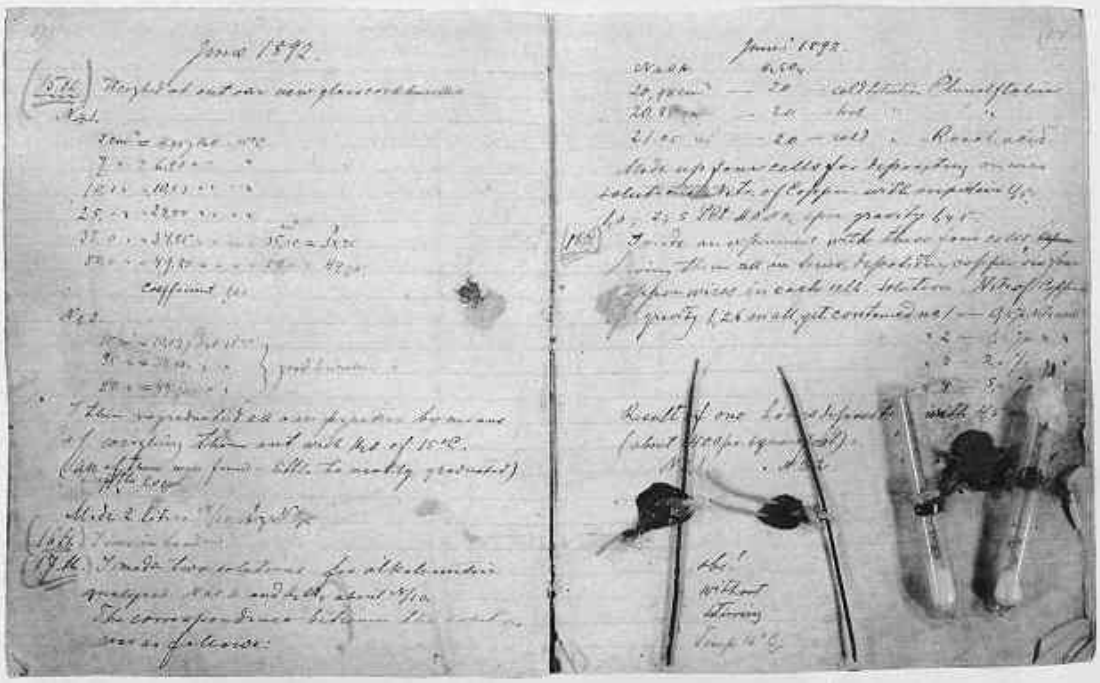
Increased business interests forced Swan to move from Tyneside nearer to London and the headquarters of the new Edison and Swan Electric Light Company. In 1883 Swan purchased Lauriston (above), a family house at Bromley in Kent. Once settled in his new home Swan began experiments to improve the quality of his filament lamps. He was convinced that a non-fibrous thread could prove a more efficient filament. Towards the end of 1883 Swan had succeeded in producing a new 'squirted filament' process. By this new process a continuous, uniform thread was formed which after washing could be cut to any desired length. In addition to providing a better filament there was something about the silky threads that caught Swan's eye. Their quality suggested the possibilities of a textile. Swan produced further threads of a special fineness which were crocheted into doyleys by his wife. This was the first artificial silk.



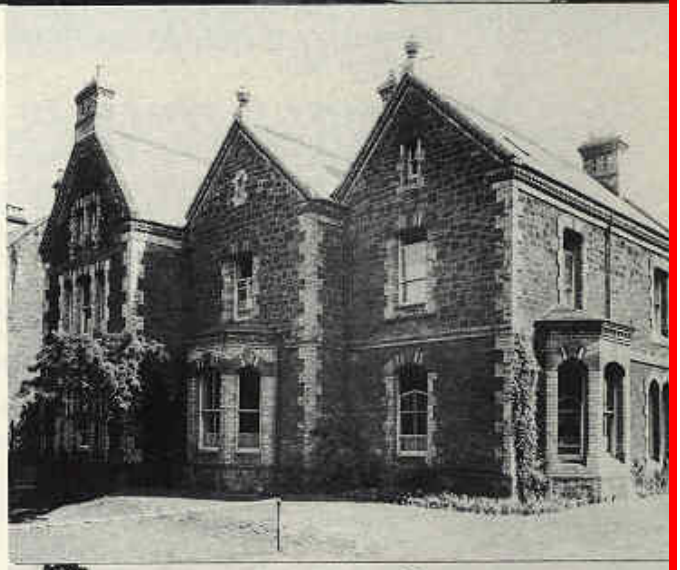
Swan developed an electric safety lamp for use in the mines and toured the country lecturing on the advantages of the new lamp. By 1892 he had turned his attentions to electrolysis and in 1894 he was elected a Fellow of the Royal Society for his research into the electrolytic deposition of copper. Eventually, the strain of travelling became too great and once again the family moved house, this time to 58 Holland Park, London. In the succeeding years Swan received many awards for his scientific work including the Albert medal presented by the Prince of Wales for 'his inventions in connection with the electric lamp and with photography'. In November 1904 Joseph Swan received a knighthood. However, the constant strain of work and public appearances proved too much for Sir Joseph's health. The heart trouble from which he had suffered for many years was growing progressively worse and on the advice of the doctor the family moved to a quiet village on the North Downs.

The picture below shows the interior of Swan's home in Holland Park.



Sir Joseph's enjoyment of family life can be seen in the photograph opposite. Rested and refreshed his inquisitive mind spurred him on to devote his leisure hours to further experiments. Two pages from the laboratory notebook kept by one of his assistants is reproduced opposite. The outcome was the production of an imperishable gas battery which produced electricity electro-chemically working on a similar basis to the fuel cells used in the Apollo spacecraft. However, despite many experiments, Sir Joseph and his assistant were unable to perfect this idea. In the spring of 1914 Newcastle Corporation belatedly decided to bestow the freedom of the city upon Sir Joseph and his friend Sir Charles Parsons. Sir Joseph looked forward to visiting Newcastle but asked if the ceremony could be postponed until warmer weather. As fate would have it Sir Joseph's health failed him – he died on May 27th, 1914.

There are still places associated with Sir Joseph Swan to be seen on Tyneside such as the family home at Underhill, Kells Lane, Gateshead or the business premises of Mawson, Swan and Morgan in Grey Street, Newcastle. But perhaps his finest monument is the electric bulb itself which is still produced in Gateshead at the Osram works on the Team Valley Trading Estate.



Edison wasn't the first to be working on incandescent lighting; work began as early as 1802. However, by Edison's period, the time was ripe, and Edison seized the opportunity. What made the crucial difference in his success—as he boasted—was the fact that he had an organized group, an organized laboratory, better resources, and a powerful methodology. His practical orientation also made a real difference. He analyzed the gas lighting industry, studied its strengths and weaknesses, its method of distribution, its customers, economics—everything. Only after this study did he begin bending electricity to the solution of the problem. From then on, the road to success was certain—at least in Edison's vision.

(EPRI Journal, March 1979)

SEIZING THE MOMENT

Age of the Inventor-Entrepreneur

Edison, age 30

The breakthrough came late in 1879 in Edison's laboratory in Menlo Park, New Jersey. Sometime between the evening of October 21st and the evening of October 22d, Edison and a small group of his associates maintained a watch over a thread that burned undiminished hour after hour in a glass bulb from which most of the air had been removed. Although the records are conflicting, that long watch came to be known as the 40-hour vigil, during which the researchers of Menlo Park realized that after more than a year of agonizing efforts, of seemingly endless trials, and of a near-blind process of elimination they had crossed over the threshold to success in their cooperative quest.

The dim reddish light of the incandescent filament, as Edison had named it, seemed to them one of the most beautiful sights in the world. As it became clear that the fragile carbonized thread could survive, Edison concluded the experiment by turning the voltage higher and higher so that the light grew brighter and brighter until suddenly it burned out. As Matthew Josephson depicts the scene in his classic biography of Edison, the men broke into cheers, and Edison announced, "If it can burn that number of hours, I know I can make it burn a hundred."

It was a mere nothing, a fragile glass bulb, a carbonized piece of ordinary sewing thread, two pieces of platinum, and

a sealed vacuum—not a perfect vacuum, but the very best achievable at that time. Yet this bare nothingness became the most breathtaking and elegant solution to one of the most perplexing problems of that period—namely, how to make a solid material luminous without burning it up. The incandescent light was the key to a system of domestic electric lighting that was to displace gas illumination.

Microscopic examination of the carbon filament revealed that the carbon had changed in character while it burned. It had become harder, more durable, more resistive, and more stable in its behavior, thus obviating the need for various regulatory devices that Edison had thought might be necessary. The solution, for the incandescent light at least, looked simpler and cleaner than they could have hoped for. Through earlier trials in the late summer and early fall of 1879, Edison and his men had come to realize that carbon could serve as the high-resistance element they had been seeking and that the key to success could lie in the development of an extremely high vacuum. In an authoritative article on the invention, Francis Upton, Edison's mathematician, attributed the success to advances in vacuum technology. Had vacuum technology been sufficiently advanced, preceding decades of experiments with enclosed incandescent lights and evacuated bulbs by other inventors might conceivably have succeeded.

However, there were many other factors that contributed to Edison's success at that moment. One, absent from many other inventors and researchers, was the irrational persistence, the lust for success that was Edison's special demon and made him appear a near-wizard in many people's eyes.

As Josephson observes, "Edison himself never wavered in his assertion that he was not a wizard or a genius—in fact, he despised the designation. When an acquaintance once referred to his 'Godlike genius,' Edison snorted, 'Godlike nothing! Sticking to it is the genius! Any other bright-minded fellow can accomplish just as much . . . if he will stick like hell and remember nothing that's any good works by itself just to please you. You got to make the damn thing work'."

That persistence and overweening ambition had seen Edison and his crew—Batchelor, Kruesi, Upton, Jehl, Boehm, and others—through countless obstacles and had drawn their combined inventiveness and skills to extraordinary lengths. From the time Edison seriously started his pursuit of the incandescent light in September 1878, his "invention factory" had made thousands of trials in the Menlo Park laboratory, using uncounted numbers of materials for filaments and leads, and had designed and invented numerous elements—generators, regulators, wiring methods, insulation materials—that would be needed in a practical system of domestic lighting.

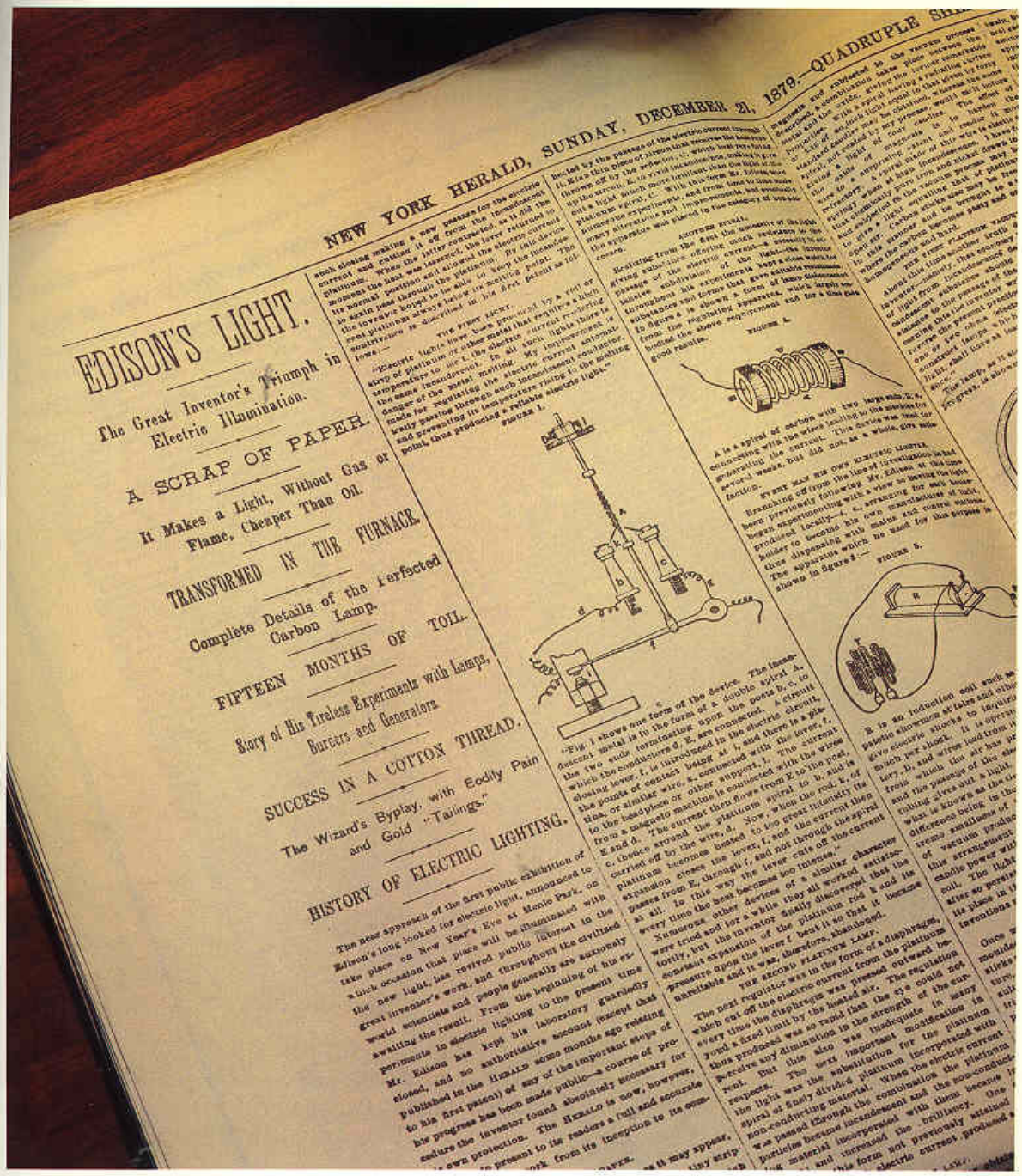
Edison had started with carbon for the burners, a material he had come to understand and appreciate in his work with telephones, but he had moved on to other materials. Then, after long efforts with platinum and as different experimental results began to fall together, he returned to carbon in July 1879 after reading about new experiments by Joseph Swan in England. Swan, who had abandoned incandescent experiments a decade earlier, had returned to the effort under the impetus of new and better vacuum equipment. It allowed him to keep a piece of carbon lit for several minutes in a vacuum. However, the crucial design decision that allowed Edison to outdistance Swan and others and that was a factor in later lawsuits on both sides of the Atlantic was Edison's development of a very fine, high-resistance filament that could be subjected to a constant voltage and that could carry a very small current, the opposite objective of other inventors.

On October 6th, using a new vacuum pump designed by Upton and another colleague, Edison's team discovered that they could create vacuums in which only one millionth of an atmosphere of air remained. About that same time, Charles Batchelor noted that silicon might be a good insulator for the platinum contacts; moreover, silicon was compatible with glass, thus reducing the problems of getting good seals on the vacuums. These and other factors lent a great air of anticipation and renewed intensity to their research efforts.

Yet, toward the end Edison had almost concluded that the incandescent light might indeed be an impossibility (he had set out to prove the case one way or the other), and he had begun to turn his thinking toward central stations to generate electric power for running motors, elevators, traction machines, sewing machines, and the like. At one point, when Edison was nearly overwhelmed by failures, when he was being derided in the press for his ridiculous claims, when his financial backers (including the giant J. P. Morgan) had become extremely skeptical and were trying to make him appear in New York for an accounting, he took to his bed. But supposedly after several days he rose refreshed and went back to the battle and soon was issuing typical announcements through the press that the electric light was an accomplished fact.

But Edison had made his boastful claims too often, and the financiers, the press, and the public remained skeptical. When Edison finally did make the breakthrough, there was still skepticism and derision. Only as visitors began to trickle out to Menlo Park in the latter weeks of 1879 to see the actual lights did doubt begin to be transformed into belief. Then, on December 21, 1879, the New York *Herald* printed its exclusive full-page account of Edison's spectacular success. By New Year's Eve, the news of Edison's invention had created such excitement that several thousand people went to Menlo Park by special trains and every other conveyance possible. The visitors were ecstatic at what they saw—lights strung up on poles around Menlo Park and the laboratory buildings aglow. It was reported that people found it difficult to tear their eyes away from those marvelous new electric lights.

Facsimile of the famous New York *Herald*'s exclusive story announcing Edison's success.



NEW YORK HERALD, SUNDAY, DECEMBER 21, 1879.—QUADRUPLE SH

EDISON'S LIGHT.

The Great Inventor's Triumph in Electric Illumination.

A SCRAP OF PAPER.

It Makes a Light, Without Gas or Flame, Cheaper Than Oil.

TRANSFORMED IN THE FURNACE.

Complete Details of the Perfected Carbon Lamp.

FIFTEEN MONTHS OF TOIL.

Story of His Tireless Experiments with Lamps, Burners and Generators.

SUCCESS IN A COTTON THREAD.

The Wizard's Byplay, with Bodily Pain and Gold "Tailings."

HISTORY OF ELECTRIC LIGHTING.

The near approach of the first public exhibition of Edison's long looked for electric light, announced to take place on New Year's Eve at Menlo Park, on which occasion that place will be illuminated with the new light, has revived public interest in the great inventor's work, and throughout the civilized world scientists and people generally are anxiously awaiting the result. From the beginning of his experiments in electric lighting to the present time Mr. Edison has kept his laboratory guardedly closed, and no authoritative account (except that published in the HERALD some months ago relating to his first patent) of any of the important steps of his progress has been made public—a course of procedure the inventor found absolutely necessary for his own protection. The HERALD is now, however, in a position to present to the readers a full and accurate [illegible] from its inception to its com-

such closing making a new passage for the electric current and causing it off from the incandescent platinum. When the latter contracted, as it did the moment the heat was lessened, the lever returned to its normal position and allowed the electric current to again pass through the platinum. By this device the inventor always kept the platinum at the proper temperature to insure the greatest brilliancy in his first patent as follows:—

THE FIRST LAMP.

"Electric lights have been produced by a coil or strip of platinum or other metal that requires a high temperature to insure the electric current producing the same incandescent. In all such lights there is danger of the metal melting. My improvement is made for regulating the electric current automatically passing through such incandescent conductor, and preventing its temperature rising to the melting point, thus producing a reliable electric light."

FIGURE 1.

"Fig. 1 shows one form of the device. The incandescent metal is in the form of a double spiral A, the two ends terminating upon the posts b, c, to which the conductors d, E, are connected. A circuit closing lever, f, is introduced in the electric circuit, the points of contact being at i, and there is a platina, or similar wire, k, connected with the lever, f, to the headpiece or other support, l. The current from a magneto machine is connected with the wires E and d. The current then flows from E to the post, c, thence around the platinum spiral to the post, b, and is carried off by the wire, d. Now, when the current platinum becomes heated to too great intensity the expansion closes the lever, f, and the current then passes from E, through f, and not through the spiral at all. In this way the lever cuts off the current every time the heat becomes too intense."

Numerous other devices of a similar character were tried and for a while they all worked satisfactorily, but the inventor finally discovered that the constant expansion of the platinum rod k and its pressure upon the lever f beat it so that it became unreliable and it was, therefore, abandoned.

THE SECOND PLATINUM LAMP.

The next regulator was in the form of a diaphragm, which cut off the electric current from the platinum every time the diaphragm was pressed outward beyond a fixed limit by the heated air. The regulation was so rapid that the eye could not perceive any diminution in the strength of the current. But this also was inadequate in many respects. The very important modification in the light was the substitution for the platinum spiral of finely divided platinum incorporated with non-conducting material. When the electric current was passed through the combination the platinum particles became incandescent and the non-conducting material incorporated with them became [illegible] and increased the brilliancy. One [illegible] form not previously attained [illegible] electric current produced a

Realizing from the first the necessity of the high giving substitution of the electric current—a necessity in accordance with his experiments kept close watch throughout his experiments kept close watch for substances and forms that gave reliable results. In figure 4 is shown a form of lamp discovered from the regulating apparatus, which largely modified the above experiment and for a time gave good results.

FIGURE 4.

A is a spiral of carbon with two large ends, B, C, connecting with the wires leading to the electric for generating the current. This device was tried for several weeks, but did not, as a whole, give satisfaction.

EVERY WAY HIS OWN MAGNETIC LAMPS.

Branching off from the line of investigation he had been previously following Mr. Edison at this time began experimenting with a view to having the light produced locally—i. e., arranging for each house-holder to become his own manufacturer of light, thus dispensing with mains and central stations. The apparatus which he used for the purpose is shown in figure 5.—

FIGURE 5.

R is an induction coil such as [illegible] palatic showmen at fairs and other [illegible] give electric shocks to [illegible] touch per block. It is operated [illegible] tery, B, and wires lead from it [illegible] from which the wire has [illegible] and the passage of the [illegible] taking gives out a light [illegible] what is known as the [illegible] difference being in the [illegible] tremo amalgam of [illegible] of vacuum produced [illegible] this arrangement [illegible] mobile power with [illegible] soil. The light [illegible] after so persistently [illegible] its place in [illegible] inventions [illegible]

Once [illegible] sticks [illegible]

The process of invention and the factory system

A leading American historian of technology, Thomas Hughes, has called the factory system "the most impressive general concept explaining the Industrial Revolution." It is clear, in fact, that the use of inanimate motive power based on steam encouraged a division of labor that was translatable, through machinery, into a division of power.

The mechanization of production had been going on for more than 50 years before Andrew Ure, a British engineer, gave it definitive expression in *The Philosophy of Manufacture*, published in 1835. Ure's system called for the substitution of mechanical science for hand skill, the division of the productive process into basic mechanizable components, and the organization of those components into a steady repeatable process of assembly of desired products. (In his teens Edison had studied his work.)

Conceived in Britain, the factory system and the methods of mechanization took root in the United States, where shortage of labor, costliness of skilled labor, and abundance of raw materials all supported its adaptation and where there was little craft-based opposition to mechanization. By the 1860s the habits of mechanical analysis and synthesis became a prominent stimulus to American inventiveness. Meanwhile, in Germany (the other nation that would surpass Britain technologically by the close of the century) British factory techniques were imported and implemented. They were also incorporated into an educational system that helped develop the German technical institute system.

The factory system method of production, the arrangement of mechanized action to produce a desired output, may well have inspired the invention of organized invention. For instance, the work at Menlo Park used an orderly division of labor, although it wasn't steam-driven machinery that dictated the division. The "motive force" was Edison and Edison's vision that the system of electric light could be developed through a methodical process of trial and error. It was abetted by strong belief that the goal could be achieved through development of a high-resistance incandescent filament.

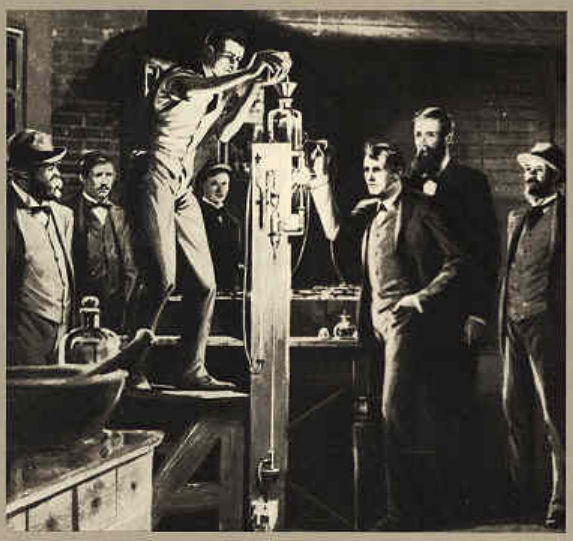
In order to realize the goal, Edison structured the work in the Menlo Park laboratory. Highly skilled workers performed tasks that compensated for the unavailability of basic theory or knowledge of the relevant structure or properties of materials. Hands and senses sought what theory might today predict, although a working background in physics and chemistry did influence many of the decisions.

The workers carried out a disciplined attack; they used a standard procedure through most of their 4000 or so trials of potential filament materials. For each trial, Edison himself selected the raw materials to be tested and prepared a filament. Another man carbonized the filament; a third supplied hand-crafted copper and platinum elements; and a fourth blew a glass stem and inserted the copper and platinum wires. The chain continued. The carbonized filament was placed on the glass stem by one man; the stem and filament were enclosed in a glass bulb by another man. The next worker placed the bulb on a vacuum pump and evacuated the air. Then Edison heated the filament, removed the gases released by the heated metal, and forwarded the bulb for systematic observation and testing.

This concept of arranging a rational search procedure and persisting in it in trial after trial has been of lasting significance. So has the scale of Edison's research (prohibitive for inventors less credible to investors than Edison). The scale and the repeated procedure are just two suggestive resemblances between the factory method and Edison's method.

Today, research, development, and production have all evolved into highly specialized functions. They can be carried out in isolated environments under controlled conditions, whether in laboratory or factory. Certain aspects of both the scientific method and factory production rely on precise repetition to ensure reproducible results or standardized products.

In both, the identity of the individual carrying out the task is relatively unimportant; one might even assert that once an inventive process is organized, any competent worker can carry out the specified functions.



On the eve of the breakthrough, Edison and his colleagues prepare the incandescent lamp for testing: (from left) John Kruesi, Martin Force, Francis Jehl, (pouring mercury in the Sprengel vacuum pump), Ludwig Boehm, Edison (driving out occluded gases from the filament with electric current from a battery), Francis Upton, and Charles Batchelor.

he mercury pump for producing high vacuums was the crucial technology that made the incandescent light ossible. Wrote Upton, "Following the laws of discovery, it has been for some time a speculation of the writer that the wonderful perfection to which vacuums d been brought pointed historically toward some direct connection between them and the electric lamp."

Below is Edison's Menlo Park laboratory as re-created at the Henry Ford Museum in Dearborn, Michigan.

Growth of the legend

Around that moment of a century ago, many legends have been woven about the making of the magic light, about the laboratory in Menlo Park in which the problem was solved, and about the person of Edison—legends that Edison himself helped to foster. To enliven his first official biography, for instance, he evidently told his biographers (Dyer, Martin, and Meadowcroft) a lot of stories with little concern for accuracy, and that early biography became the source for many successive writers. So interwoven were fact and fiction that today they are still difficult to sort out. This might seem slightly amazing; after all, it all happened just a century ago. Extensive laboratory records and notebooks were kept by Edison and his colleagues; "authorized" and scholarly biographies, such as that by Josephson, have been written; and thousands of articles have been published. Yet, a new biography of Edison, written by Robert Conot, who spent many months in the enormous Edison archives in West Orange, New Jersey, raises many new questions regarding the established image of Edison, and a newly launched 10-year scholarly program based at Rutgers University promises fresh insights into this seminal figure of universal electrification.

The evidence indicates that Edison, who had grown up in the Midwest when the telling of tall tales was an indigenous American art, was not loath to embellish the details of his own life. For instance, the famed 40-hour vigil may have been a transposition of a death watch that Edison and his colleagues actually conducted in 1879 between Friday, October 17th, and Sunday, October 19th, while they waited for news about Edison's nephew, who lay dying in Paris. Even Edison's famed ability to go without sleep is now disputed as more Edison theory than Edison fact. Said one familiar, "His genius for sleep equaled his genius for invention. He could go to sleep anywhere, anytime, on anything." And according to Conot, a colleague wrote to

Edison was a man of many sides, one being that of the practical jokester. On one occasion, when Edison was about to be interviewed, a colleague relates, "While the reporter was being ushered in, the Old Man disguised himself to resemble the heroic image of 'The Great Inventor, Thomas A. Edison' graven in the imagination of those who have no imagination. Suddenly gone were his natural boyishness of manner, his happy hooliganism. His features froze into immobility, he became statuesque . . . and his unblinking eyes assumed a faraway look like a circus lion thinking of the Nubian desert. He did not stir until the reporter tiptoed right up to him, then he slowly turned his head, as if reluctant to lose the vision of the Nubian desert." The next day the journalist wrote of the formidable "Wizard of Menlo Park." On many other occasions, however, Edison was the irrepressible storyteller.

Edison after reading one of his early accounts, "You can invent history as easy as other things. Now that Mark Twain has retired as humorist you are in line of promotion."

The new studies, however, do not threaten to disturb his image as an American culture hero or diminish his achievements. They will undoubtedly verify his role in the introduction of universal electrification, and they may succeed in illuminating further his role in establishing an organized process of invention, which may be seen as one root of modern R&D. As Edison's colleague Francis Jehl said in observing how closely Edison worked with his collaborators, "Edison is in reality a collective noun and means the work of many men." Such an appraisal is much more consonant with modern R&D experience than with the legend of towering individual genius.

To appreciate the specific nature of Edison's achievements and inventive drive, one must step back into the post–Civil War era to look at the state of the art of the electric light, at the preelectric society, at the entire field of inventive activity, both in the United States and abroad, at Edison's earlier career and approach to invention, and at the gas illuminating industry. Even a brief look reveals why Edison became a legend in his own time. More important, it shows that Edison not only invented a system of electric lighting, but he was also the principal creator of a system of invention that has had as deep an effect on this past century as electrification itself. Alfred North Whitehead, among others, regards the Edison approach to the method of invention as the greatest invention of the nineteenth century.

What emerges is the picture of a man who was defiant of authority, stubborn in his own path, willing to borrow freely, unlettered in the traditional sense, uncredentialed, and caustic about theorists.

Early Influences on Edison

It is probably impossible to determine all the forces and influences that turned the young Edison into a professional inventor, but it is likely that the Civil War and its aftermath helped to shape his direction and his character. Edison was in his teens during the war and became an itinerant telegrapher soon after. Although he had been fascinated with chemical and electrical experiments from early childhood, it was during his period as a telegrapher that he took his first steps toward becoming a full-time inventor.

The Civil War precipitated profound changes, not only by its ferocity but also by its enhanced mechanization, and gave industrialization preeminence in America. In the two decades following the war, as if in preparation for electrification, industrialization gathered power and prestige. The freed blacks of the South and the immigrant laborers from Europe poured into the industrial basins of the North—Detroit, Cleveland, Chicago, Pittsburgh, New York. Thus, the old, nearly equal split of power between the planters and the traders was decisively altered. The traders—the capitalists and industrialists—were in charge, and the railroad and the telegraph rather than the horse, the canal, and the Mississippi steamboat were the emblems of change.

Inventions and inventors flourished in this period. The American conviction that each man was as good as the next spurred the mass production of former luxuries and transformed them into common household necessities. By 1865 mechanized apple peelers, knife cleaners, clothes wringers, and egg beaters, for instance, were found in many American homes.

A long line of commercial inventors—Whitney (cotton gin, 1792), Fulton (steamboat, 1806), Hunt (safety pin, 1825), Colt (revolver, 1835), Morse (telegraph, 1844), Howe (sewing machine, 1846), Scholes (typewriter, 1867), and Hills (lawnmower, 1868)—had become American heroes and inspired young men to follow in their tracks. In the 1830s Alexis de Tocqueville had noted how Americans esteemed technologists: "Every new method," he wrote, "that leads by a shorter road to wealth, every machine that spares labor, every discovery that facilitates pleasures or augments them, seems [to Americans] to be the grandest effort of the human intellect." The prestige associated with practical inventions was in itself a powerful incentive to young men like Edison and many of his contemporaries.

In the post–Civil War period itinerant telegraphers like Edison possessed a craft and a skill that allowed them to work and drift wherever they would. They were a fraternity, were all in touch with one another, and could easily find a bed and a new post. They experimented and learned, sharpening their skill and making gradual improvements in the equipment. At an early age many of them acquired an understanding of electrical connectivity for the continent and with Europe via the trans-Atlantic cable (successfully laid in 1866). These young men probably also understood the meaning and significance of such connectivity and communication in the building of the nation. From railroad scheduling and business messages to Reuters and other international dispatches, the telegraphers were privy to the hour-by-hour workings of national enterprises. From telegraphy, Edison moved to improvements and inventions in stock tickers, which took him a step closer to grasping the central operations of finance and capitalist maneuver. It was undoubtedly a part of his training in becoming an entrepreneur with his own inventions.

Edison's conscious appreciation of the power of telegraphy came at the age of 14 when he was selling newspapers on the Grand Trunk Railroad, which ran between Port Huron and Detroit. It was April 1862, and the first accounts of the terrible Battle of Shiloh were coming in by telegraph. Seeing the awful newspaper headlines—60,000 reportedly killed and wounded—and the excitement in Detroit, Edison had the Detroit telegrapher wire ahead to all the stops so the news he was carrying could be chalked up on station notice boards. He ordered a thousand

Edison after reading one of his early accounts, "You can invent history as easy as other things. Now that Mark Twain has retired as humorist you are in line of promotion."

The new studies, however, do not threaten to disturb his image as an American culture hero or diminish his achievements. They will undoubtedly verify his role in the introduction of universal electrification, and they may succeed in illuminating further his role in establishing an organized process of invention, which may be seen as one root of modern R&D. As Edison's colleague Francis Jehl said in observing how closely Edison worked with his collaborators, "Edison is in reality a collective noun and means the work of many men." Such an appraisal is much more consonant with modern R&D experience than with the legend of towering individual genius.

To appreciate the specific nature of Edison's achievements and inventive drive, one must step back into the post–Civil War era to look at the state of the art of the electric light, at the preelectric society, at the entire field of inventive activity, both in the United States and abroad, at Edison's earlier career and approach to invention, and at the gas illuminating industry. Even a brief look reveals why Edison became a legend in his own time. More important, it shows that Edison not only invented a system of electric lighting, but he was also the principal creator of a system of invention that has had as deep an effect on this past century as electrification itself. Alfred North Whitehead, among others, regards the Edison approach to the method of invention as the greatest invention of the nineteenth century.

What emerges is the picture of a man who was defiant of authority, stubborn in his own path, willing to borrow freely, unlettered in the traditional sense, uncredentialed, and caustic about theorists.

Early Influences on Edison

It is probably impossible to determine all the forces and influences that turned the young Edison into a professional inventor, but it is likely that the Civil War and its aftermath helped to shape his direction and his character. Edison was in his teens during the war and became an itinerant telegrapher soon after. Although he had been fascinated with chemical and electrical experiments from early childhood, it was during his period as a telegrapher that he took his first steps toward becoming a full-time inventor.

The Civil War precipitated profound changes, not only by its ferocity but also by its enhanced mechanization, and gave industrialization preeminence in America. In the two decades following the war, as if in preparation for electrification, industrialization gathered power and prestige. The freed blacks of the South and the immigrant laborers from Europe poured into the industrial basins of the North—Detroit, Cleveland, Chicago, Pittsburgh, New York. Thus, the old, nearly equal split of power between the planters and the traders was decisively altered. The traders—the capitalists and industrialists—were in charge, and the railroad and the telegraph rather than the horse, the canal, and the Mississippi steamboat were the emblems of change.

Inventions and inventors flourished in this period. The American conviction that each man was as good as the next spurred the mass production of former luxuries and transformed them into common household necessities. By 1865 mechanized apple peelers, knife cleaners, clothes wringers, and egg beaters, for instance, were found in many American homes.

A long line of commercial inventors—Whitney (cotton gin, 1792), Fulton (steamboat, 1806), Hunt (safety pin, 1825), Colt (revolver, 1835), Morse (telegraph, 1844), Howe (sewing machine, 1846), Scholes (typewriter, 1867), and Hills (lawnmower, 1868)—had become American heroes and inspired young men to follow in their tracks. In the 1830s Alexis de Tocqueville had noted how Americans esteemed technologists: "Every new method," he wrote, "that leads by a shorter road to wealth, every machine that spares labor, every discovery that facilitates pleasures or augments them, seems [to Americans] to be the grandest effort of the human intellect." The prestige associated with practical inventions was in itself a powerful incentive to young men like Edison and many of his contemporaries.

In the post–Civil War period itinerant telegraphers like Edison possessed a craft and a skill that allowed them to work and drift wherever they would. They were a fraternity, were all in touch with one another, and could easily find a bed and a new post. They experimented and learned, sharpening their skill and making gradual improvements in the equipment. At an early age many of them acquired an understanding of electrical connectivity for the continent and with Europe via the trans-Atlantic cable (successfully laid in 1866). These young men probably also understood the meaning and significance of such connectivity and communication in the building of the nation. From railroad scheduling and business messages to Reuters and other international dispatches, the telegraphers were privy to the hour-by-hour workings of national enterprises. From telegraphy, Edison moved to improvements and inventions in stock tickers, which took him a step closer to grasping the central operations of finance and capitalist maneuver. It was undoubtedly a part of his training in becoming an entrepreneur with his own inventions.

Edison's conscious appreciation of the power of telegraphy came at the age of 14 when he was selling newspapers on the Grand Trunk Railroad, which ran between Port Huron and Detroit. It was April 1862, and the first accounts of the terrible Battle of Shiloh were coming in by telegraph. Seeing the awful newspaper headlines—60,000 reportedly killed and wounded—and the excitement in Detroit, Edison had the Detroit telegrapher wire ahead to all the stops so the news he was carrying could be chalked up on station notice boards. He ordered a thousand

copies of the *Free Press* (he normally took 200). At each stop he was met by large crowds anxious to read the news, and he raised the price of his papers from 5 cents to 10 cents to 15 cents to 25 cents. It was then, Edison later related, that he realized the telegraph was a great invention.

The story is most provocative. The young Edison saw the conjunction of several media carrying the same message—newspaper, train, chalkboard, telegraph—and he saw the commercial power of that conjunction. People grasped the message with greater vividness because it came through different media, at different levels, and therefore conveyed a greater sense of reality. For Edison, the lesson was never forgotten. In fact, a large proportion of Edison's inventions were related to communications media.

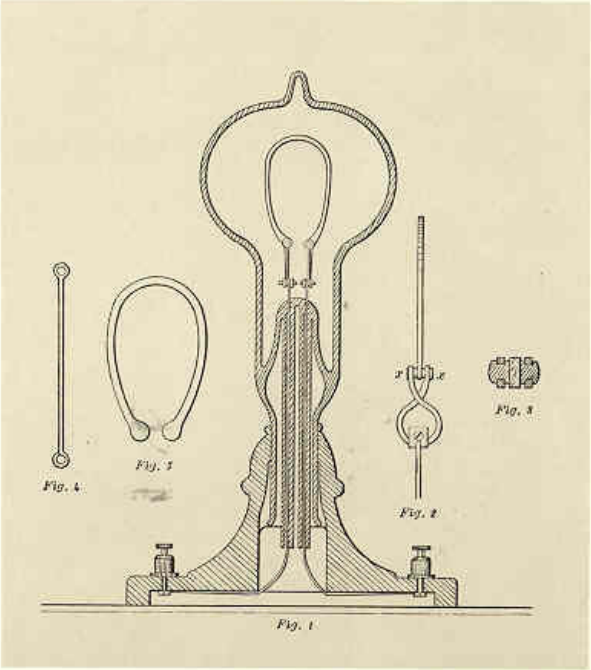
Building on earlier work

When Edison turned his attention to electric light in 1878, there was already a long history of developmental effort, and the field abounded in competitors. As early as 1802, the British chemist Sir Humphry Davy demonstrated the phenomenon of incandescence before the Royal Society in London. Using a stack of voltaic cells, he ran current through a platinum strip, causing it to turn white hot before the material eventually burned away. In fact, Volta's development of the first electric battery only two years earlier (1800) provided the basis for such experimentation. Following on Volta's work, Davy demonstrated the voltage arc light in 1808, which, with but few refinements, became the electric light for the better part of a century. By forcing an electric voltage to leap across a gap between two wire tips, he produced a brilliant arc of light five inches in length. Later experiments showed that carbon was the best material for such tips. It was possible to produce a fairly constant light, if the current was kept flowing and the distance between the tips was properly regulated.

Although they gradually came into practical use, arc lights suffered serious drawbacks. The tips gradually burned away (in anywhere from 2 to 10 hours) and had to be replaced. The lights required complicated regulating devices to maintain the length of the gap; they emitted noxious fumes and gave off such a brilliant, glaring light that they could only be used outside for street illumination or in very large indoor spaces, such as theaters and factories.

Early experiments in incandescent lighting fared less well. In 1845 a 24-year-old American named J. W. Starr obtained an English patent for a carbon incandescent light in vacuo (even though this may have been based on work by De Moleyns, who in 1841 used incandescent charcoal in an evacuated globe). But such early vacuums were not sufficient, and the insides of the glass bulbs became blackened from the interaction of the carbon and remaining oxygen. The first experiments with a bulb shaped like those we recognize today were those of M. J. Roberts in 1852, but his light proved ineffective.

Meanwhile, British inventor Joseph Swan, who was destined to rival Edison, had become interested in incandescent lighting after hearing a lecture by electric lighting pioneer W. E. Staite in 1845. Studying existing patent publications, Swan found Starr's description of his carbon light. He began a series of experiments, combining features of Starr's lamp and one designed by Staite. Swan deduced that thin, high-resistance burners would be better than thick ones—the thinner the strip, the greater the heat, the brighter the light, he reasoned—and he made various horseshoe-shaped burners of platinum, which has a higher resistance than carbon. Although he was in advance



Edison's patent application of December 8, 1879, for the paper carbon filament contains the following description: "Fig. 1 is a vertical section complete; Fig. 2 is a side view on large size of the clamping device; Fig. 3 is a section at the line *xx* in still large size; Fig. 4 is the wire forming one of the clamps before it is bent up to shape; Fig. 5 is the paper blank before it is carbonized."

Edison's career

Thomas Alva Edison was born in Milan, Ohio, of modest circumstances on February 11, 1847, and was largely schooled at home by his mother. By his tenth year he discovered a love for chemical and electrical experiments. He went to work selling newspapers on the railroad and then printed his own newspapers during his early teens, the years of the American Civil War. He devoured books, pursued his experiments, and occasionally got into trouble. Then, after an Horatio Alger–like rescue of a child, the child's father taught young Edison the Morse code and the elements of telegraphy, the first major industry to use electricity.

As a young man, he worked as an itinerant telegrapher in a number of cities—Fort Wayne, Cincinnati, Nashville, Memphis, Louisville. All the while, his experimenting went on. In 1868 he made his way to Boston, a city of busy experimental and intellectual activity, with the second highest per capita patent rate in the nation (in 1880 it was first). There he made his first patented invention, a telegraphic vote recorder, which he learned rather painfully was not something that politicians or anyone else much wanted. Thereafter, Edison considered the feasibility of profitable development before undertaking any sizable inventive effort.

By the time his vote recorder was rejected, he had seriously embarked upon a career of invention, buttressed by his reading of the works of the great English electrical experimenter and theorist, Michael Faraday. Edison repeated Faraday's experiments and evidently found a decisive role model in Faraday, whose early childhood and inclinations somewhat resembled his own. Faraday's dedication to experiment and to the facts that emerge from experiment reinforced Edison's empirical inclination. In Boston, Edison worked for a time in Charles Williams's shop, apparently a Mecca for many young would-be inventors, including Alexander Graham Bell, who invented the telephone in 1876.

Following his Boston experience, Edison's own course was much bolder and more determined. His experiments and his early patents were, like those of so many of his contemporaries, related to improvements and innovations in telegraphy, and he gained some notice and support. Although his work was not yet remarkably different from that of many other young inventors, he revealed an unusual mettle. He went on from invention to invention. Then, burdened by business debts, he moved to New York, the city that beckoned so many others from the small towns of America.

In the heart of New York's Wall Street he managed to fix a telegraphic gold indicator broken at a critical moment. As a result, Edison found himself with a well-paying job in the center of the financial operations of the day. From then on his work flowered; he gained more access to financial backers for his inventions; and his reputation grew. If one were writing about an artist, one might say that at this period he was beginning to find his own style. In October 1869 he set up perhaps the first electrical engineering consulting service in this country in partnership with Franklin Pope, who later became president of the American Institute of Electrical Engineers. He invented equipment improvements for the giant Western Union Telegraph Company (a company that employed many inventors). In his first year in New York he took out seven patents, and in due course he was being paid handsomely for his inventive work. He received $40,000, an incredible sum then, for a stock ticker improvement. In 1871, at age 24, holding orders worth $500,000, he opened a manufacturing plant in Newark, New Jersey. In 1872 he improved the system of the Automatic Telegraph Company.

In 1873 he went abroad for the first time, to England, again on a telegraphy mission. By that time, his reputation clearly allowed him to attract venture capital in whatever he undertook, and he had come to know the financial tycoons of the day. Ingenious and indefatigable, the young man produced invention upon invention, gradually expanding beyond telegraphy, but always commercially aimed. In 1874 it was the duplex and quadruplex telegraphs; in 1876, after Bell invented the telephone, it was an improved carbon

Edison's stockticker inventions proved to be his passport to becoming a full-time professional inventor.

(EPRI Journal, March 1979)

transmitter telephone. While working on what he intended to be a telephone repeater device in 1877, he invented the phonograph, which astonished the world. And in 1878 (the same year in which a biography appeared describing him as a great inventor) he undertook the invention of the incandescent light, in which he succeeded in 1879 at age 32.

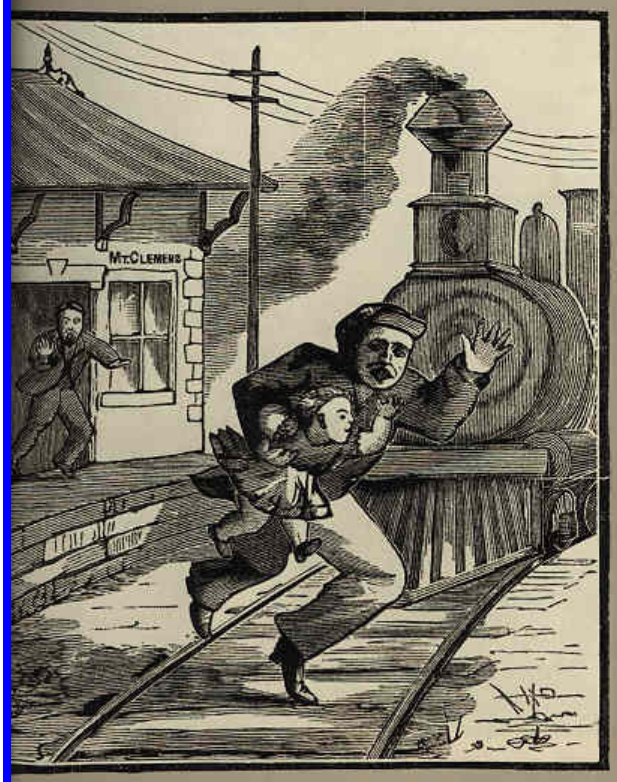
Almost simultaneously, he went on to invent and develop all the elements of an entire electric lighting system. In 1882 he built and installed the famous New York Pearl Street central station, which was the first step in the development of the electric utility now known as Consolidated Edison Company of New York. During this intense period of developing the electric light and support system with a team of inventive colleagues, craftsmen, lawyers, and manufacturing aides, his patent production was unmatched: 60 patents in 1880, 89 patents in 1881, 107 patents in 1882, most of which were connected with electric light systems. He founded manufacturing companies for dynamos, for underground conductors, for lights, for meters, for generators, and more.

In 1889 these companies consolidated as the Edison General Electric Company. During this period, European Edison Illuminating companies were licensed, and Edison emissaries traveled through America establishing electric lighting companies in cities and towns everywhere.

Although the peak of his great inventivity had been reached by 1884, he took out 1093 patents in his lifetime, more than any other individual ever. Scholars are now beginning to attempt to clarify how the ideas of Edison's colleagues contributed to this record, but it is clear that Edison was a major driving force in the great inventive period in the latter part of the last century and the beginning of this. As his authorized biographers F. L. Dyer, T. C. Martin, and W. H. Meadowcroft wrote in 1910, "It will be admitted that in Edison one deals with a central figure of the great age that saw the invention and introduction in practical form of the telegraph, the submarine cable, the telephone, the electric light, the electric railway, the electric trolley car, the storage battery, the electric motor, the phonograph, the wireless telegraph; and that the influence of these on the world's affairs has not been excelled at any time by that of any other corresponding advances in the arts and sciences."

Although the world has witnessed many more revolutionary scientific and technological advances since 1910, they take away nothing from this earlier Edison era. The style and the acceptance of R&D was set then.

Later in his career, Edison went on to invent methods of magnetic ore separation, improved portland cement, storage batteries, motion pictures, artificial rubber, and much more. He lived until 1931, witness to the tremendous growth of all forms of electrification and witness to the growth of his own legend. By the time of his death he had become a culture hero, deeply identified with the development of America itself.



A chance rescue by Edison led him into telegraphy, the foundation for his later work in electricity and communications. Horatio Alger, it is said, modeled some of his novels on Edison's escapades.

of other inventors, Swan was stymied by the lack of good methods for obtaining a vacuum, and in 1860 he discontinued his experiments. It was not until 1875 that Swan heard of the mercury vacuum pump, which had been invented by Herman Sprengel, and he resumed his experiments, using high vacuums and straight carbon burners. Thus, by 1878 these two inventors on either side of the Atlantic were moving neck and neck toward *the* invention. But two crucial distinctions would eventually separate Edison's and Swan's efforts. One was that Swan's burners, although small, were still relatively wide carbon strips, whereas Edison's filament was extremely small in cross section. The other was that Swan was concentrating on the incandescent light alone, whereas Edison started with a concept of an electric lighting system in which the light was but one piece.

In addition to the early work in incandescence, the electrical pioneers were pursuing an adequate means of generation for arc light systems. All the early lighting experiments had been hampered by the lack of effective generators for producing electricity. But in the 1860s significant improvements in generators began to be developed when it was found that steam power could be converted to electricity. By 1862 Michael Faraday, who was Edison's special hero, introduced an arc light in a British lighthouse. Thereafter, experiments with electric lights gained momentum both on the Continent and in the United States.

At the 1876 Philadelphia Exposition, which made the world really aware of the technological advances going on in America, Moses Farmer and William Wallace demonstrated an electric dynamo that ran three glaring arc lights. That dynamo light system inspired many young inventors to pursue the possibilities of electricity.

To the inventors and entrepreneurs (men like Charles F. Brush, Charles J. Van Depoele, Elihu Thomson, and others in America and Swan, Jablochkoff, Siemens, and others in Europe), it was becoming clear that electricity had a far greater practical future than in telegraphy alone. Both in the United States and abroad there was great public excitement as blazing arc lights came into use in streets, in large stores, and in factories. In Paris in 1877, for instance, the engineer Paul Jablochkoff was installing his new designs of arc lights, called electric candles, and by 1878 a half-mile length of the Avenue de l'Opéra was brilliantly lit. That was the news of the day when Edison—a latecomer to the lighting problem—decided he could find the solution before anyone else.

Edison steps into the ring

It was apparently on the long train ride after an unsuccessful experiment in Wyoming during the July 1878 total eclipse of the sun that Edison was drawn to the problem of a practical electric light. His companion on that trip, George F. Barker of the University of Pennsylvania, had become very excited with the possibilities of electric lighting, and he pressed Edison to turn his inventive capabilities to the problem. Edison, who had willingly accepted Barker's invitation to join the eclipse expedition, was at a turning point, at which he felt he needed to take up something new. He had scored major successes in telegraphy and telephony, and he had just invented the phonograph, which added to his renown. But problems with his hearing were making it increasingly difficult for him to work in these media. He needed a new kind of problem, a more visual one.

He had become intrigued by the problem of electric lighting, had performed some arc light experiments in 1877, and had even pasted reports of Jablochkoff's work in his notebooks. On his return from Wyoming his interest was further reinforced by papers sent him by his friend and longtime supporter, Grosvenor P. Lowrey, then counsel general to Western Union. These papers included news of the Paris Exposition and more on the Jablochkoff artificial lights, which had aroused great admiration in Europe.

With his interest growing and persuaded by the advice of Barker and Lowrey, Edison accompanied Barker to Ansonia, Connecticut, on September 8, 1878, to visit William Wallace's establishment and to see his arc light system. It consisted of eight arc lights of 500 candlepower each, run by an eight-horsepower dynamo that was a newer version of the dynamo shown at the 1876 Philadelphia Exposition.

Seeing the Wallace system, Edison seems to have had an immediate insight into what could be done and to have determined on the spot the character of his own campaign. He even announced ungraciously to his host, "I believe I can best you in making the electric light. I do not think you are working in the right direction."

After leaving Ansonia, Edison began, as he said, his "usual course of collecting data" and making numerous calculations. He was soon to report, "I saw for the first time everything in practical operation. I saw the thing had not gone so far but that I had a chance. I saw that what had been done had never been made practically useful. The intense light had not been subdivided so that it could be brought into private houses. In all electric lights theretofore obtained, the intensity of the light was very great and the quantity [of units] very low. I came home and made experiments two nights in succession. I discovered the necessary secret, so simple that a bootblack might understand it. It suddenly came to me, like the secret of the speaking phonograph. It was real and no phantom . . . the subdivision of light is all right." That intuition escaped those authorities of electricity who had denied the possibility of subdivision of light. According to Josephson, "The leading electricians, physicists, and experts of the period had been studying the subject for more than a quarter of a century and, with but one known exception, had proved mathematically and by close reasoning that the subdivision of the electric light, as it was then termed, was practically beyond attain-

ment." They were thinking in terms of the large currents that were delivered for arc lights and of the existing dynamos that delivered a high and constant current. If that current were to be fed to a number of lights in the same circuit, then the light emitted by each would indeed diminish as the number of lights increased.

Edison's answer, which he realized quite early, was what has become popularly known in our day as a systems solution. Most would-be inventors were focusing their efforts on the bulbs and, as with arc lights, believed they would be drawing high currents and would need something like the existing dynamos to generate that current. Edison deduced that the filaments of the lights should be highly resistant, drawing only a small current; that the dynamo would have to be redesigned to supply a high, constant voltage and a varying current, depending upon the total number of lamps being supplied; and that the lamps should be hooked up in parallel, or ladder-type, circuits, so if any lamp were turned off or burned out, the remainder would be unaffected. All that was needed, then, was to invent the light, the keystone of the whole system, within the context of these specifications. No one else was taking such a systems approach. Any home electrician today recognizes these as obvious facts, but they were not so obvious in 1878.

This systems solution simultaneously answered another problem that would have been raised by the high-current systems—namely, that there would not have been enough copper in the world to have supplied the distribution lines. The constant-voltage, low-current system reduced the necessary copper dramatically and made the vision a practical reality. Another aspect of the total-system problem was the development of an economical method of feeding current throughout a wide customer area. It was solved in 1883 by a method analogous to the gas distribution system and became known as the three-wire system.

Even when Edison had reached his goal in the closing months of 1879 and created a world sensation, his competitors were still slow to grasp the full significance of his very thin, high-resistance filament. They understood it later, however, and they copied it. And understandably, Swan in England, who in 1869 had worked with carbonized paper filaments, claimed prior rights. Later litigation established that the invention—with its unique, extremely thin filament—was Edison's. Given the sensational character of the incandescent light itself, what was obscured for a long time was Edison's systems approach to the problems of invention and implementation.

The Edison methodology

The laborious search for the right filament material, the thousands of experiments, the countless theories that Edison and his colleagues at Menlo Park painstakingly explored, and the 40-hour vigil have been much romanticized over the years. It was clearly hard work, requiring incredible patience, persistence, and endurance. And it is clear from all accounts that Edison had the kind of indomitable spirit that kept his experimenters going.

Just as important was the fact that Edison threw the resources of his colleagues and his laboratory into a broad, methodical attack. In just four years of intense activity, Edison and his team succeeded in solving the key problems of incandescence, and in a seven-point program they developed the components of an entire system. According to Josephson the goals of Edison's systems engineering program included the development of (1) the parallel circuit, (2) the durable, high-resistance light, (3) the improved dynamo, (4) the underground conductor network, (5) the devices for maintaining constant voltage, (6) safety fuses and insulating materials, and (7) light sockets with on-off switches. Every one of these elements had to be invented and then, through careful trial and error, developed into practical, commercial, reproducible components.

From the time Edison began his work on the electric light problem in 1878 to his construction, development, and commercialization of an electric lighting system in 1882 was a lapse of only four years. In that time Edison and his group did everything—from invention to development, from financing to manufacture, to marketing surveys, to operating a functioning utility that served customers in a square-mile area (the First District) in the heart of New York City.

Pearl Street and after

Edison's predominance in the first era of incandescent lighting comes not only from his invention of an entire lighting system but also from his ability to follow through. He improved on his basic inventions and was entrepreneur, industrialist, and capitalist in the development of individual or isolated generating systems, as well as initiator of a host of manufacturing enterprises to supply the necessary equipment, including lamp production facilities. The vision of all this must have been with Edison from the very beginning of his work on the light itself. In an interview with a reporter from the New York *Sun* on October 25, 1878, just a few weeks after his visit to William Wallace, Edison laid out a scheme for a central station for electric lighting in New York, which would supply a myriad of household lights over a network of lines. According to Edison, the model for the system was that of the central gashouse and its distributing system, of gas mains running to smaller branch pipes and leading into many dwelling places. Just four years after Edison's 1878 prediction, the famous Pearl Street Station in New York became the first central station for supplying incandescent lighting.

Even during his work on the incandescent problem, Edison was moving on other fronts as well. Almost simultaneously with the 40-hour vigil, the *Scientific American* of October 18, 1879, was carrying an article by Francis Upton on the "long-legged Mary Ann," the special

Edison's target: the gas illuminating industry

The gas era began in England in 1792 when Thomas Murdock discovered how to distill gas from coal and to pipe it into his home for lighting burners. Very soon thereafter, various methods of producing gas were developed. Gas began to supplant candles and oil lamps, which had changed little since ancient times. By the early 1800s, when electricity was a mere infant, gas lighting was making strong headway, especially in urban areas.

The need for street lighting had been a chronic urban problem, and gas lighting was a boon. Municipal governments were the initial customers for gas company products and hastened the expansion of gas lighting into factories and homes. Older cities like Baltimore and Philadelphia had employed some gas lights as early as 1807, and New York began experiments with gas lights in City Hall Park in 1812. Thereafter, gas lighting and gas utilities grew at a rapid pace in many cities.

Since Charles F. Brush's success in 1878, electric arc lights had gradually made inroads in the gas street-lighting market. But except for large railway stations or factories, the glare of arc lights prevented them from competing with gas indoors.

But Edison was on a different track. One entry in his notebook read, "Object: Edison to effect exact imitation of all done by gas, so as to replace lighting by gas by lighting by electricity. To improve the illumination to such an extent as to meet all requirements of natural, artificial, and commercial conditions."

That the gas companies were the clear target of Edison's efforts with electric light is evident in the authoritative article written in 1880 by his assistant Francis Upton for *Scribner's* magazine: "The crowning discovery of Mr. Edison—the electric light for domestic use—is at last a scientific and practical success. A mistaken idea has been afloat that this new light was intended to be a rival of the sun, rather than what it really is—a rival of gas. The generator of the electricity is simpler than a gas generator, and the wires for its distribution are more manageable than are gas mains and pipes. The light is equal to gas in brightness and whiter in color; it is enclosed and, consequently, perfectly steady; it gives off no appreciable heat; it consumes no oxygen; it yields up no noxious gases, and, finally, it costs less than gas." Even the first crude incandescent electric lighting systems were far superior to gas lighting in nearly all respects. Incandescent bulbs, according to an 1882 account, diffused the light, making reading a "delight" while gas lighting made it "irksome."

A British cartoonist's view of a gas manufacturer's nightmare at the time when many inventors in many countries were working feverishly to develop commercially practical electric lights.

Many authors quote the sharp drop in gas company stocks when Edison first advertised his electrical system and leave the impression that the companies slid into bankruptcy, but this was not the case. Through consolidations they could control the price of their product better than the struggling electric firms. As late as 1908, the cost of gas lighting per hour was 28 cents compared with electricity's 55 cents. Moreover, as the establishment, the gas firms retained their rights to dig up streets for laying mains. In 1880 New York City alone had 860 miles of gas mains in public streets; that total rose to 1300 miles in 1899. Although the electric light gradually forced gaslight vendors out of interior lighting into street lighting, the market for gaslights still appeared strong enough even in New York to attract new operations like the Equitable Gas Light Company in 1884 and the Standard Gas Light Company sometime later.

Although the gas companies appeared confident that electric light would never challenge the price of gas, they did not assume an idle stance toward innovation. Even in earlier years, some firms improved their systems. For instance, in 1870 the Mutual Gas Light Company increased the candlepower of gas by enriching coal gas with naphtha. A more radical breakthrough came in 1876 when the French engineer Tessie de Motey developed a method of producing hydrogen gas admired for its brilliant white glow. Although the method required two mains, one for oxygen gas and one for hydrogen, companies eager for an edge installed them. Another company equipped its wrought iron gas mains with screw joints to lessen leakage.

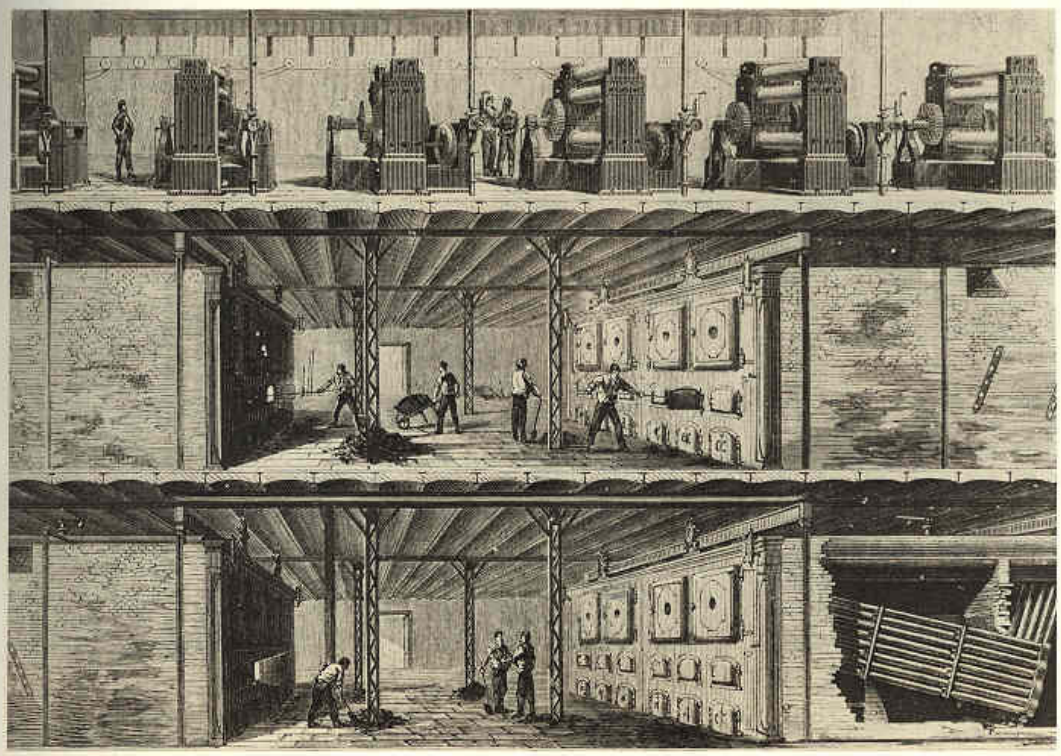
With the advent of the gas range, gas lighting companies added to their list of salable conveniences and services that included street and home lighting, heating, and power derived from gasoline engines.

Yet the gas industry could not overcome the fundamental drawbacks to its product in all but heating and cooking. Nausea from leaks and smoke from gas burners were normal conditions, which the companies never satisfactorily eliminated. The severe limits on the distance central gas works could pipe gas and the minimum amount of gas needed to produce a lamp were barriers the gas companies never crossed. And after the electrical entrepreneurs made basic improvements in lightning arresters and insulation, thus reducing the damages of electrical shocks, the risk/benefit ratio tilted markedly in favor of electricity.

generator designed for the incandescent lighting system, which had a much higher efficiency than existing dynamos. Edison named it the Faradic machine in honor of Michael Faraday. Although the machine seemed to be a radical departure from existing designs, historian Thomas P. Hughes, in an incisive monograph on Edison, notes, "Upton brought to Edison and the design thorough knowledge of the well-made Siemens arc-lighting generator, and Upton also drew upon the analysis of generator characteristics made by the brilliant British engineer and scientist John Hopkinson." The same Hopkinson served as an advisor when the English Edison Electric Light Company was organized to build and operate the Holborn Viaduct central station in London, the British counterpart of the Pearl Street Station.

Pearl Street Station actually began to supply electricity to the lamps in the First District on September 4, 1882. From that time until January 2, 1890, the station supplied electricity to its customers with only one three-hour interruption, thereby establishing a standard for reliability in the utility industry. In his study of Edison's career and methodology, Hughes concludes, "In the first decade of its existence, the Edison direct-current, low-voltage, central-station system, introduced at Holborn Viaduct and at Pearl Street, spread throughout the United States and the world. The acceptance of an American system offered convincing additional evidence of the rising technological power of the United States."

Central systems grew much more slowly than Edison had hoped. In fact, electric lighting coexisted with gas lighting for many years, and the stimulus from the competition actually led to improvements and innovations in gas lights.



Thomas Edison's first practical central station, located in two buildings at 255–257 Pearl Street in lower Manhattan, was put into operation on September 4, 1882. The "jumbo" dynamos shown on the upper floor supplied electricity for customers in New York's First District.

The electric lighting industry would not have a million customers until a few years into the twentieth century.

Seeds of universal electrification

The atmosphere of Edison's headquarters at the Edison Electric Illuminating Company of New York (the direct predecessor of Consolidated Edison Company of New York) during the period when he was masterminding these activities was frantic. Edison was everywhere at once, organizing companies to manufacture electrical components, doing public relations work with New York aldermen to get permits to lay underground mains, working at inventions and improvements on electrical components at Menlo Park, working in the trenches as the mains were being laid, solving insulation and interconnection problems, and raising capital for the multipronged but integrated enterprises being founded.

The Edison Machine Works in New York built the generators, including the famous Jumbo named for P. T. Barnum's great elephant; the Edison Electric Tube Company manufactured the underground conductors; the Edison Lamp Works in Menlo Park began mass-producing the lamps; and the Bergmann Company in New York manufactured electrical fixtures and other elements. All these and some others merged later in 1890 to become the Edison General Electric Company, and then in 1892, in a further merger with Thomson-Houston companies, became the General Electric Company we know today.

Edison's skills and leadership extended also into the exploitation of media and market research. For example, soon after initiating his program, Edison launched a shrewd media campaign designed to shake the gas lighting companies and, more pointedly, to stimulate financiers to support his research. Perhaps it was not the first case of the conjunction of financial capital and technological innovation, of industrialists and entrepreneurs sponsoring an invention that was yet to be made, but it is certainly the most publicized one. It was to herald a way of sponsoring R&D that has become standard and accepted.

Edison's market research was also a solid model for the kinds of planning that many modern corporations undertake. On launching his efforts in electric light, he made a thorough investigation of gas illumination. He collected a large library and made actual observations of gas jet distribution in New York City. He made calculations of every aspect of gas economics and point by point made comparisons with what he might expect of electric lighting systems. These calculations more clearly defined the constraints his lighting system would have to meet. An expert from the gas industry, whom Edison hired as a consultant, reported later that he had never met anyone who knew as much about gas as Edison.

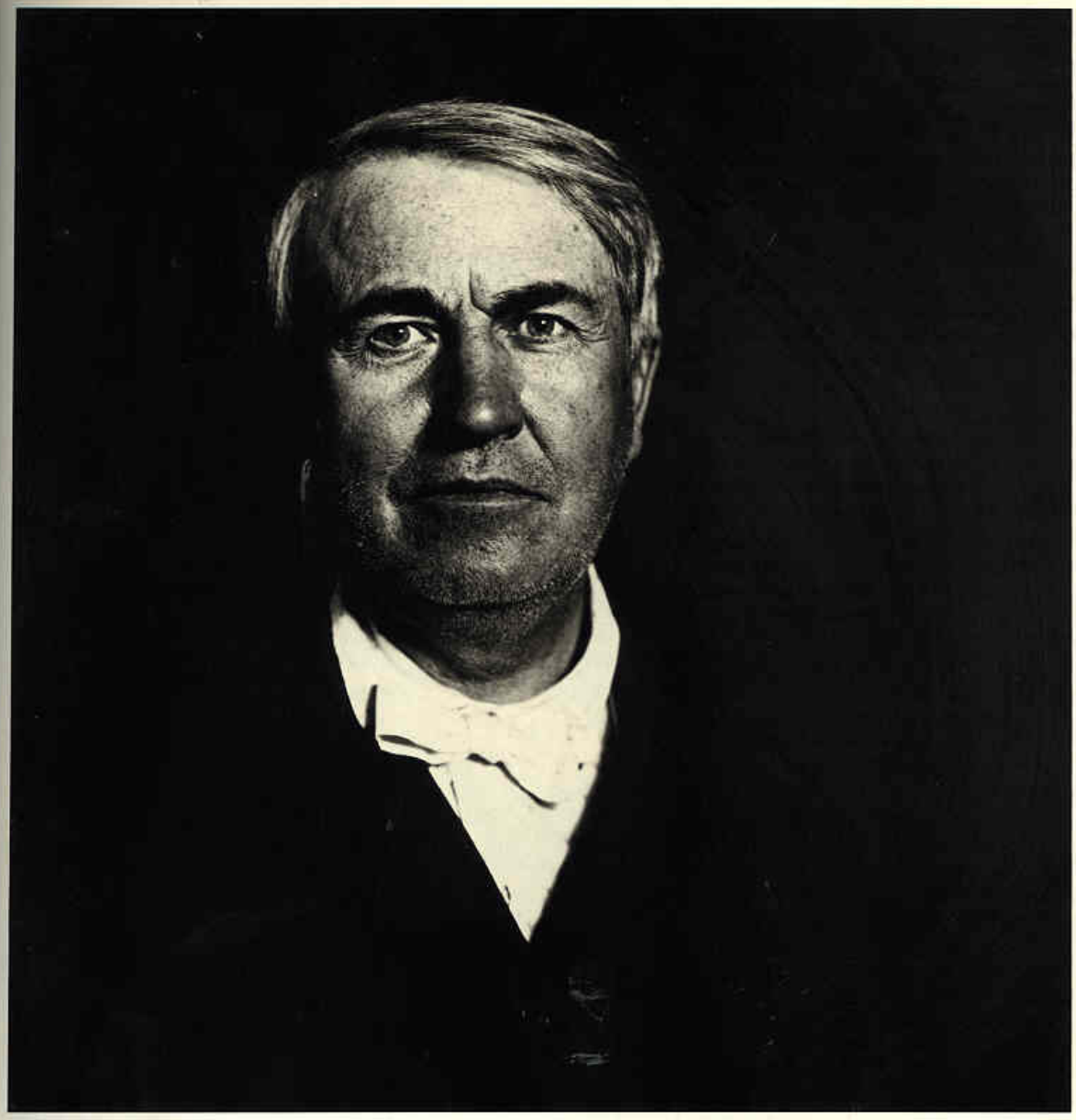
Later, when Edison pushed forward with his first central electric generating station in New York City, he took equal care in his business strategy. "I got an insurance map of New York," he recounted, "in which every elevator shaft and boiler and housetop and firewall was set down and studied it carefully. Then I laid out a district and figured out an idea of the central station to feed that part of the town. . . . I worked on a system, and soon knew where every hatchway and bulkhead door in the district I had marked was and what every man paid for his gas. How did I know? Simplest thing in the world. I hired a man to start in every day about two o'clock and walk around through the district, noting the number of gas lights burning in the various premises; then at three o'clock he went around again and made more notes, and at four o'clock, and up to every other hour to two or three o'clock in the morning. In that way it was easy enough to figure out the gas consumption of every tenant and of the whole district."

The choice of the First District was equally shrewd. It was bounded by Wall Street, Spruce Street, Ferry Street, Nassau Street, and the East River and included a residential area as well as factories, thus in Edison's original thinking, "evening up the daytime and nighttime loads" (although initially power was not to be supplied during the daytime). "Even more important," according to one description, "the First District included the financial capital of the nation, the Stock Exchange and the great banking houses, as well as the offices of some of the city's most influential newspapers. When the light went on in the First District, the bankers, brokers, and editors would be the first to sing their praises."

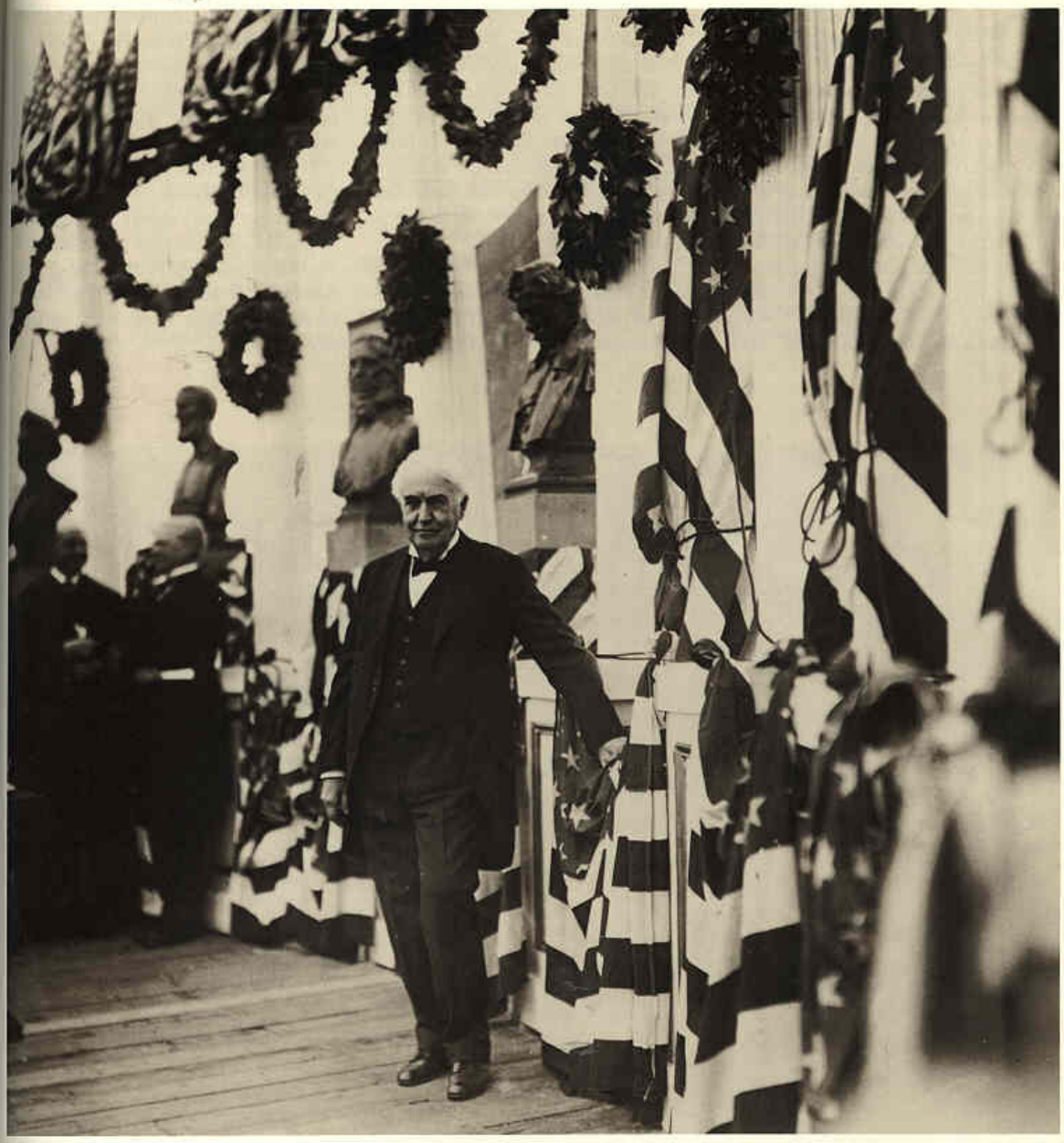
An appraisal

What we see in the Edison era are two major and related events: the birth of organized R&D that depends largely on a team approach to problem solving and the birth of the electric utility industry (although in the Edison period it was still part of electrical manufacturing). That first event, which has been viewed as the most significant invention of the nineteenth century, was certainly not one of Edison's goals; for him it was but the means to an end. That end, widespread electrification, was Edison's conscious goal from the very beginning of his entry into the electric light contest. He aimed for it and succeeded.

One cannot go so far as to claim that Edison alone was responsible for originating the organized R&D approach; there were other laboratories for research preceding his. Yet his eminence (and popularity) in the field of invention went a long way in creating a climate of acceptance for organized R&D. The very idea that people could organize resources in order to invent was really a revolutionary social idea that began to be accepted seriously in the Edison era. Edison's many successes gave credence to the idea and tended to take the mystique out of invention. Edison's insistence that invention was 1% inspiration and 99% perspiration was to have a lasting and profound effect. It lent support to the idea that technology could do anything. This idea has been a dominant factor in the twentieth century.



The determined inventor-entrepreneurs set into motion the age of electricity, but once the path seemed clear they were besieged by competitors on every hand. After his initial successes with dc systems, Edison was confronted with a new form of electric power system based on ac, a form he refused to countenance. Many, many years later, he would admit, "I was wrong."



From the beginning, Edison symbolized the electric age to the American people, no matter how many other ingenious inventors, scientists, and engineers made significant contributions. But the passing of Edison and the coming world crisis of World War II would finally close that great age of individual inventors.