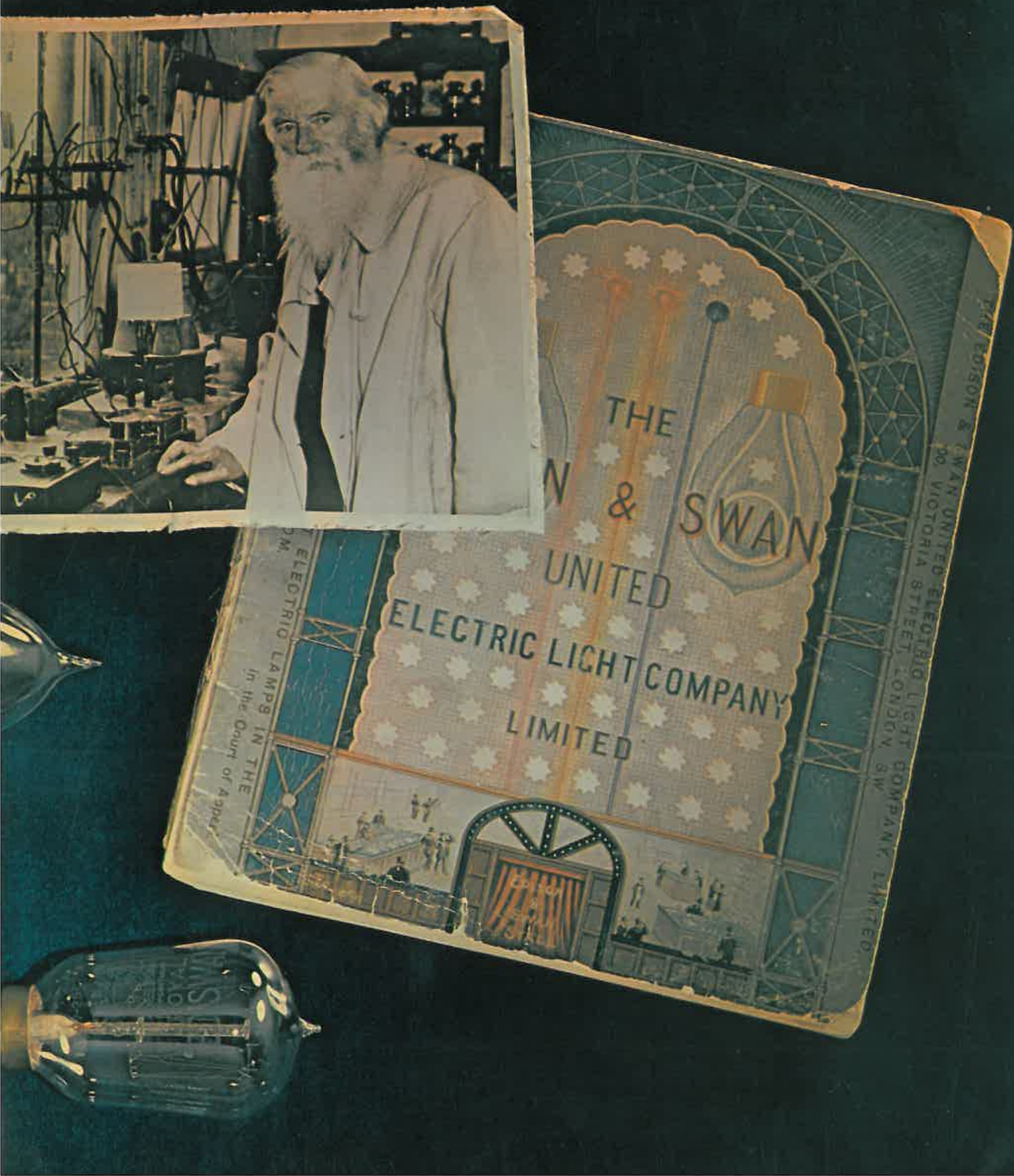
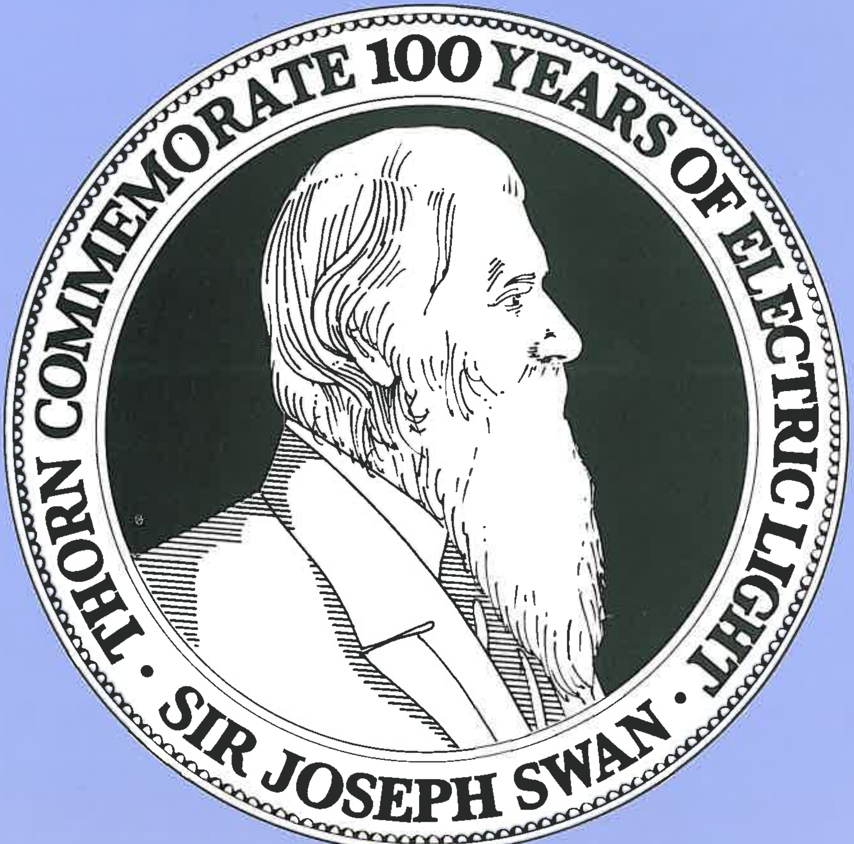
Electric lamps - 100 years on



Electric lamps - 100 years on

by Cyril Phillips



The author wishes to express his thanks to colleagues in the lighting and electrical industry, Dr B Bowers of the Science Museum, and the many other people who helped to supply information and photographs, particularly George Marsh, Renate Beigel, Bob Tate and Eddie Minshull.

This booklet is intended to give the average reader an insight into the fascinating history of electricity and electric light. A good deal of material has had to be omitted through lack of space, and regrettably it was not possible to deal with the technical aspects of the various light sources mentioned in any depth. Readers wishing to study this subject seriously are recommended to read 'Lamps and Lighting' by S T Henderson and A M Marsden, published by Edward Arnold.

THORN LIGHTING

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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'.

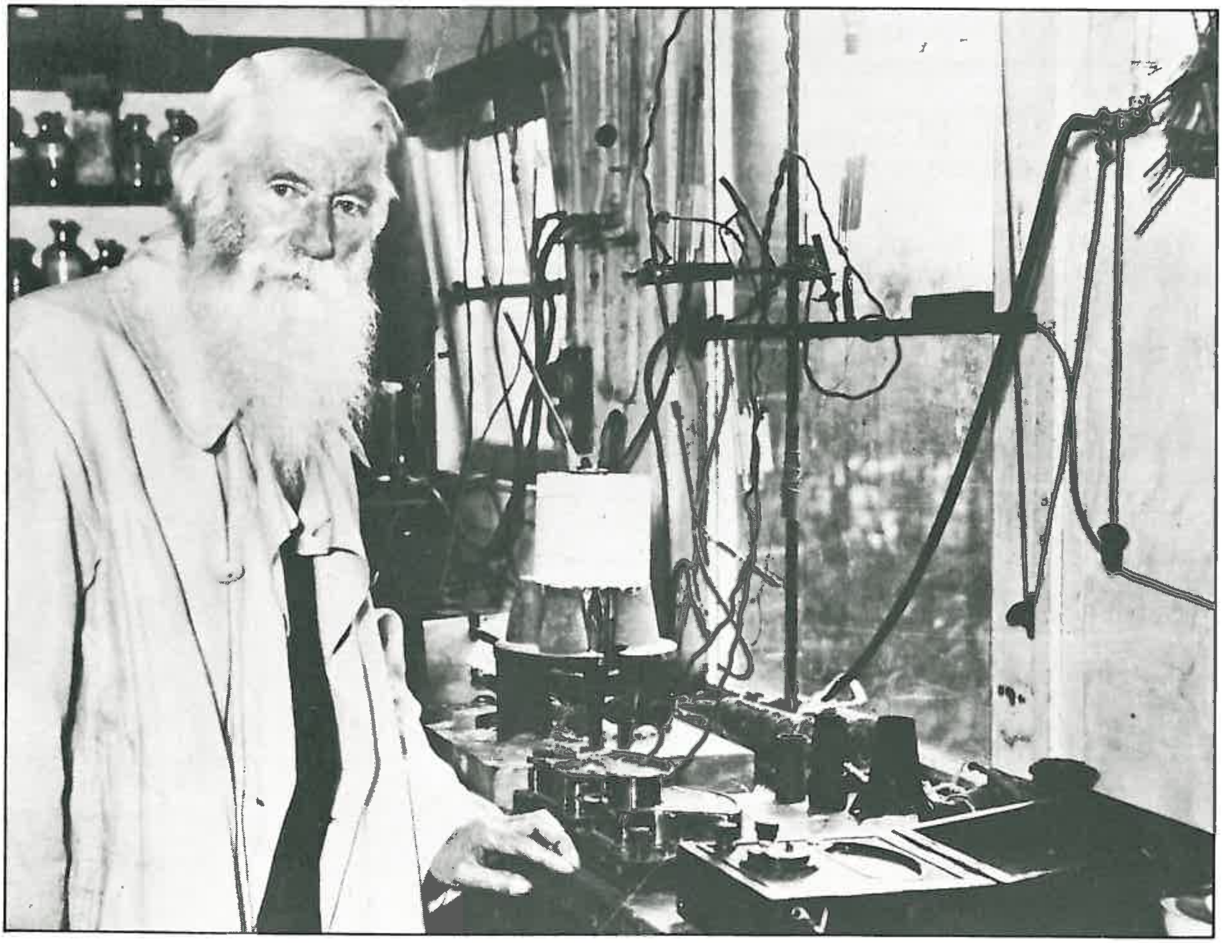
Before electricity

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.

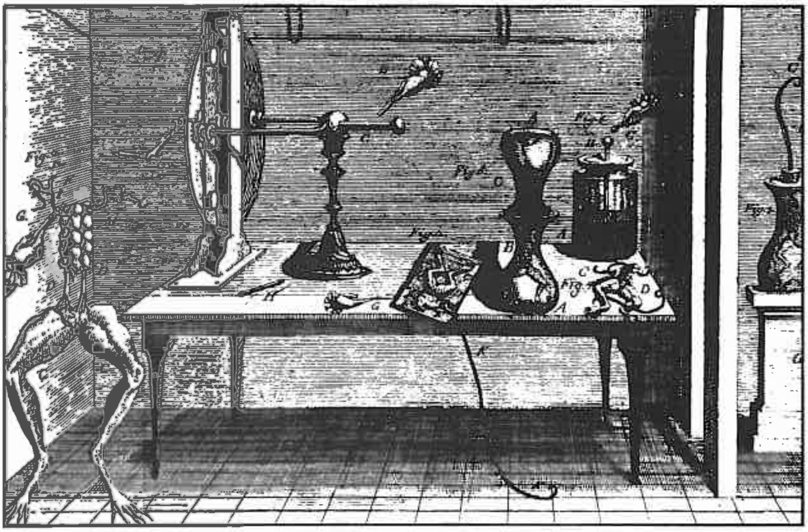
A contemporary of Volta's was Luigi Galvani, and who has not heard of the galvanometer? – or used the expression 'he was galvanised into activity'? But some historic figures, like King Alfred and his burnt cakes, are mainly remembered for ridiculous things. So it is with Galvani, who is remembered for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

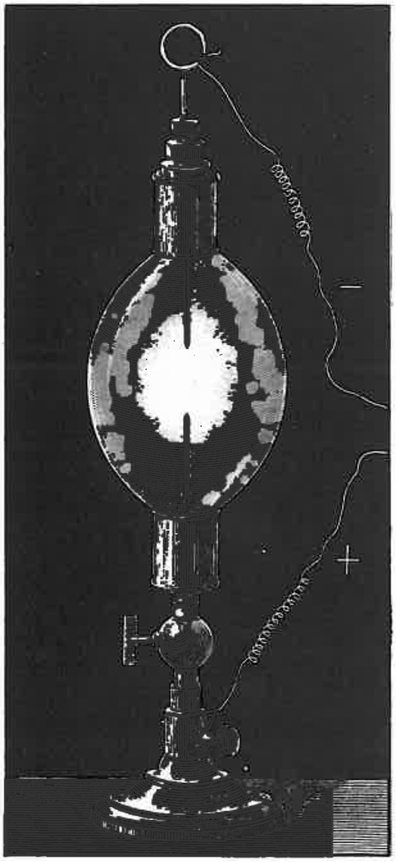
Left *Benjamin Franklin, better known as an 18th Century American politician, risked electrocution when he used a kite during a storm to show that lightning was caused by electricity.*
Below *The first primitive battery (or 'voltaic pile') was demonstrated around 1800 by Alessandro Volta. The volt was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

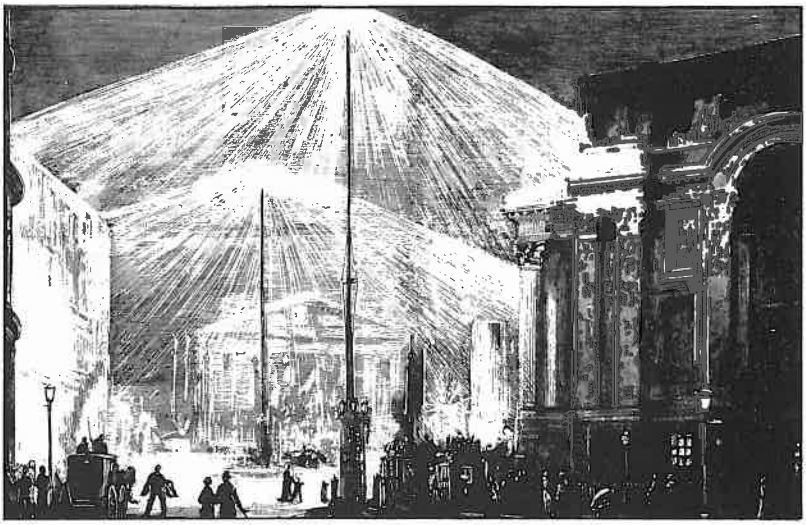
liked eating them and one day hung some out to dry on a metal balcony railing. A storm brewed and he noticed the legs twitching. He concluded that muscles were activated by electrical impulses and called this effect 'galvanism' or 'animal magnetism'. (Pedants please note that the term never did and has 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.

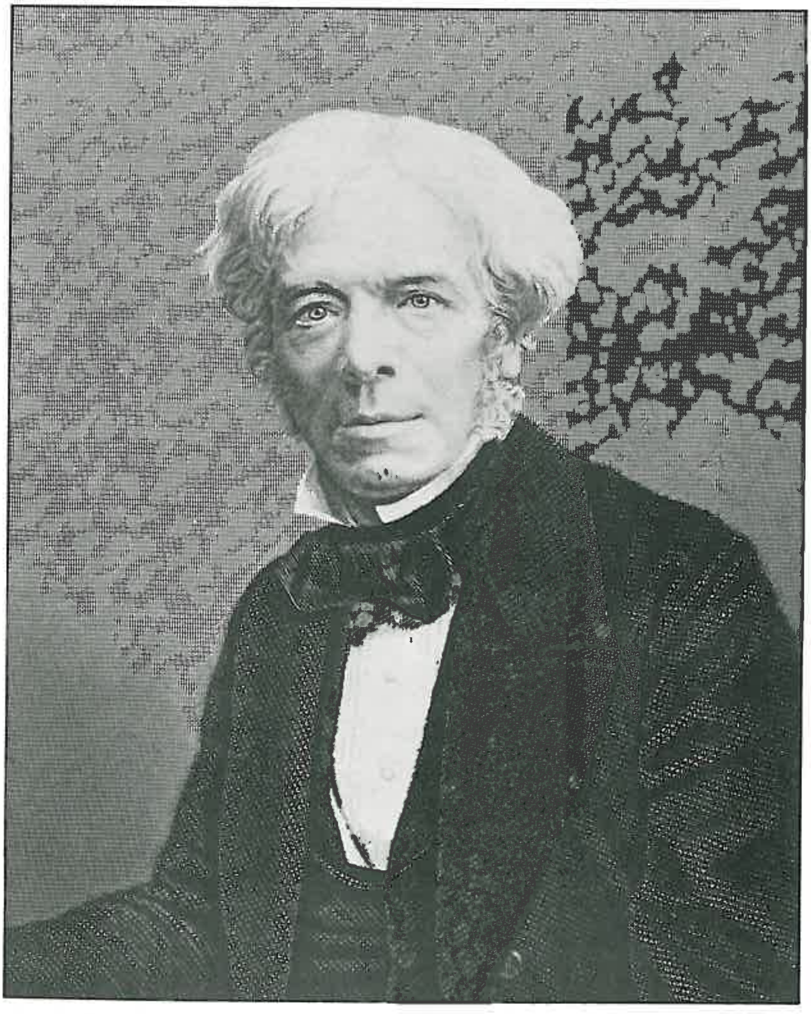
Batteries were hardly adequate for continuous domestic or commercial illumination; they had their uses in scientific demonstrations but were absolutely impractical for the development of electricity as a major source of artificial illumination, and the man who made the biggest contribution to the whole 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.*

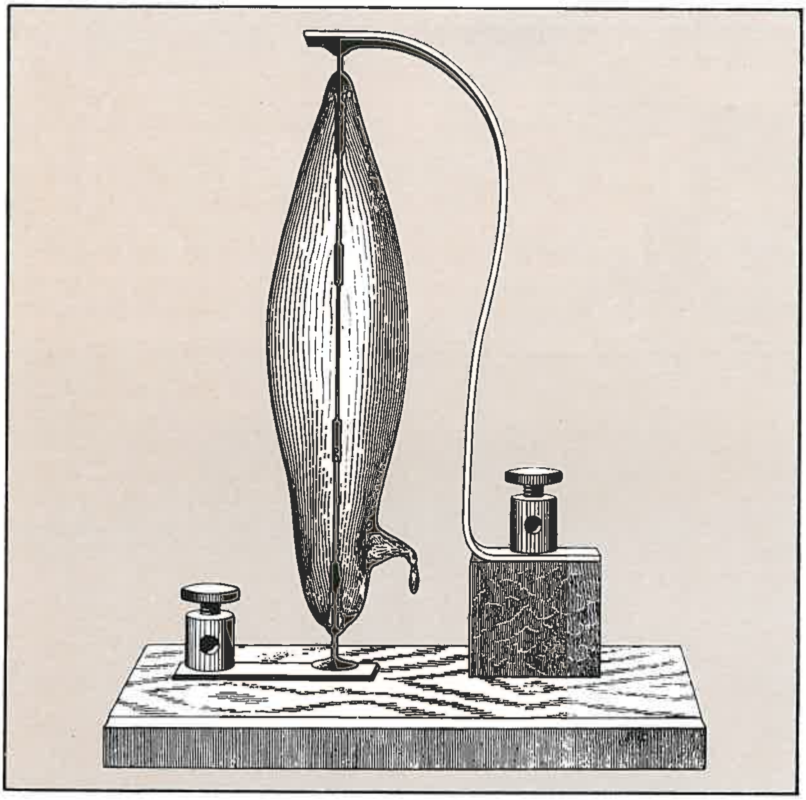
Opposite *Lighting pioneer Joseph Wilson Swan.*

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.

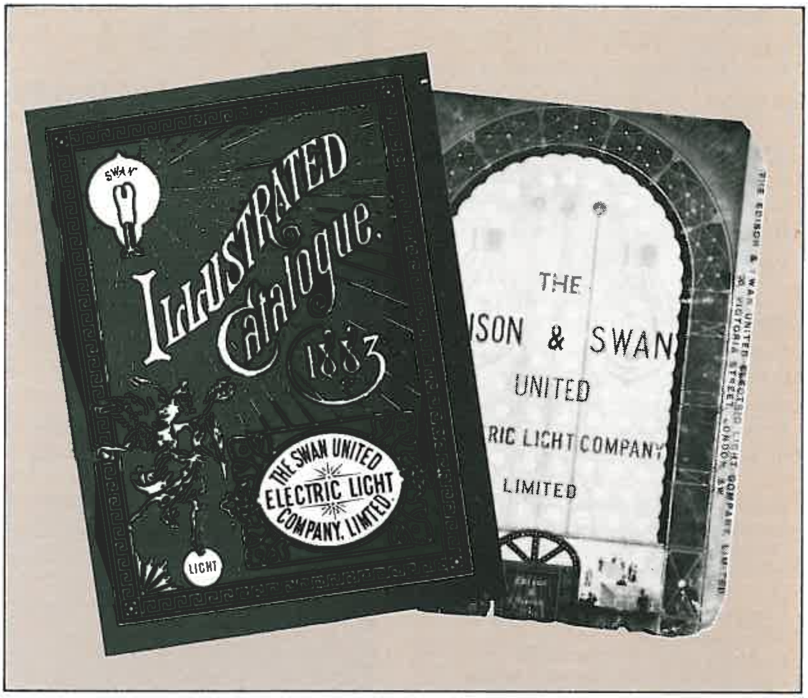
Nevertheless, the future of Swan's lamp was assured. By 1881, the newly formed Swan Electric Lamp Company was producing lamps in commercial quantities at a new factory in Benwell, Newcastle.

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.

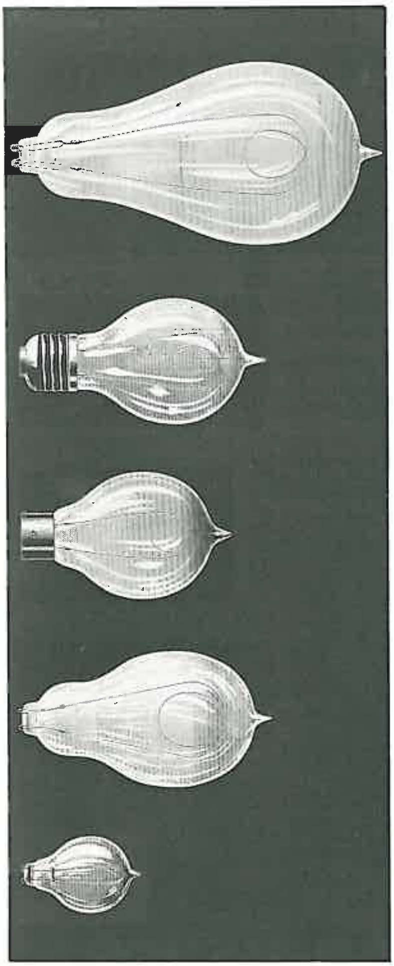


Right *Early Swan and Edison/Swan catalogues. The 'Ediswan' brand name resulted from the decision of the two inventors to co-operate.*
Below *A Newcastle street lit by Swan lamps.*

Swan went on to become president of the Institution of Electrical Engineers (1898/99), first president of the Faraday Society (1904) and continued to work on inventions, particularly in photo-engraving. He was elected to the Royal Society in 1894, which he regarded as his greatest honour, and knighted in 1904.

By the time he died in 1914, Swan had done more than any other man to bring the convenience and power of electric lighting to the masses. Truly he helped to roll back the night and start a new era in man's control of his environment.

Below *Early filament lamps. The earliest lamps had filaments of carbonised thread or paper, though carbonised bamboo fibre – introduced in 1880 – proved more durable. In 1893 improved filaments were made by squirting a solution of cellulose through a round die and carbonising the thread so obtained. Filaments could then be made of any length or diameter. Tungsten filaments first appeared about 1906.*

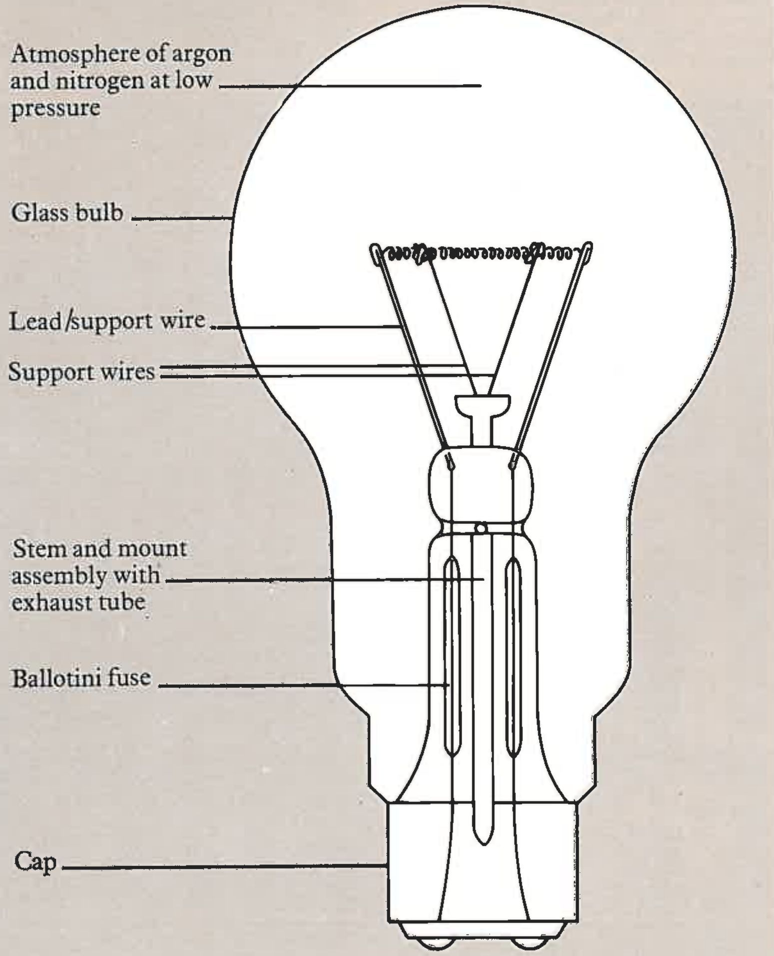


The light bulb – a precision instrument

It is not difficult to understand the working principle of the filament lamp. Electric current, flowing in a wire which is extremely thin and, therefore, of high resistance, heats it almost instantaneously to a temperature at which it becomes incandescent; that is, white hot and giving off a bright light.

The filament, which is flexible, is supported by rigid wires which also carry current to it from the contacts in the cap, these in turn being in contact with the lamp socket.

The filament 'burns out' if air is present so it is enclosed by an airtight glass envelope, or bulb, which is exhausted of air and refilled at a low pressure with a quantity of inert gas, usually argon and nitrogen (or sometimes krypton) introduced after air is pumped out. This enables the filament to operate at higher temperatures because the presence of the gas reduces the rate of evaporation of the metal filament.



Modern filament incandescent lamp

It may be difficult to imagine tungsten wire evaporating, but it does, getting thinner and thinner – and eventually the lamp fails.

The picture shows a modern filament bulb and though there are billions of them, each one is a miracle of engineering. The filament is probably the hottest object you are likely to meet in normal life – up to 2500°C, hot enough to melt brick. Some special lamp filaments (in halogen lamps) reach 3000°C, enough to melt asbestos.

Few materials can withstand these temperatures continuously. Carbon can, but tungsten is the one now used in lamps. It has a melting point of 3410°C and is a hard, brittle metal, difficult to work, yet to make a filament it is drawn through a die so fine that it emerges with a perfectly even cross section as little as .00172 ins (or .0437 mm) in diameter.

To achieve the right resistance to current at mains voltage and a useful length of glowing incandescent wire, the filament must be rather long – far longer than the gap between the support wires, so the filament is wound into a tiny coil. In the best modern lamps this is itself coiled to form a 'coiled coil' filament, so that the lamp operates even more efficiently. The filament in an average good quality 100W household bulb unwinds to 1147mm!

Above *Modern filaments are made of tungsten, a material which can withstand extremely high temperatures. So that they can be heated to incandescence quickly with a minimum amount of current they are made extremely fine – far finer than a human hair, as this picture shows.*

The thickness of the filament must be constant, and every coil and double coil accurate to within a few millionths of an inch. You may have noticed that if any uneveness develops in the element of an electric fire, you see 'hot' and 'cold' spots. In something as tiny and precise as a lamp filament, this could result in early failure. Such extraordinary precision engineering is far greater even than that found in a Rolls-Royce jet engine.

Another wonder is that filaments last so long. Bulbs must be completely exhausted of air so that the hot wire does not oxydise. It was Swan who discovered that, to make bulbs last, the filament should be heated even while the bulb is being pumped out because a new filament has stray pockets of air trapped in it and the bulb must not be sealed until these have been driven out by heat.

The lamp pioneers could not seal their bulbs reliably, and lamps often 'leaked' some time after they had been finished. This was because during any temperature change the lamp glass tended to expand or contract more slowly than the lead-in wires, causing seals to crack. Modern bulbs use platinum-to-glass seals since platinum, though expensive, has an expansion rate matching that of glass.

Miraculous though it seemed at the time, even the experts admit that the filament light bulb is an inefficient piece of mechanism.

It produces much more heat than light; over 90% of the energy is wasted as heat, less than 10% being converted to light.

We have seen how hot the filament must be and that it must be sealed into an enclosing envelope which is first exhausted to high vacuum then filled with an inert gas. The fine filament must be connected to terminals and, though suspended freely in space, must withstand shaking and vibration. The envelope must be of transparent fragile material, glass, so that the light may be seen, and the entire unit must be robust enough to be stacked and carried by road, rail, sea and air so that it is accessible to everyone. In other words, it is nearly impossible and a modern engineer instructed to develop such a device from scratch might well ask for years to do it and a budget of millions. Especially when told that each of the final units must not cost more than a few shillings!

Yet this is the lamp which has brought true light without flame and is still the most widely used form of artificial light. Why?

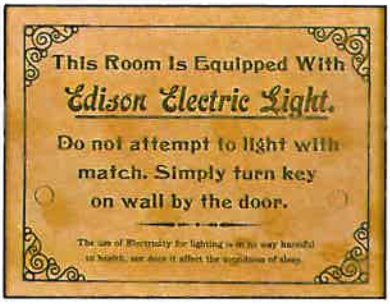
One answer is convenience. The filament lamp is compact, easily held in the hand or carried in a shopping bag. Not a lot of material is used in its construction and, as it can be mass produced, costs can be kept reasonably low. It is self contained, requiring no separate apparatus and no technical knowledge is needed to use it.

A modern bulb lasts a long time, does not need parts replacing and can tolerate changes in temperature and humidity. It weighs very little and can simply be hung on the end of the wire flex used to bring it power (though we hasten to add that this all-too-common form of usage is not recommended – live wires should *never* be used to take stress), and its light is virtually instantaneous. It also has an excellent safety record. Altogether a most practical lamp for the householder.

The other answer, perhaps, is price. Although bulbs are not efficient users of electricity, they are cheap to buy and install. More efficient light sources are more expensive to buy, and, to the layman, more complex to use. Although the *colour* of tungsten light is appealing, it is technically bad for colour rendering (so is sunshine, incidentally) but the yellowish white of the light bulb seems to be psychologically acceptable. All in all, Joseph Swan's light bulb will be around for quite a while yet.

Light for the people

Much progress has been made in the 100 years since Swan's spectacular demonstration. To appreciate this we have only to contrast the way people now accept the benefit of electric light – without giving it a thought – with how strange it seemed in the early days.

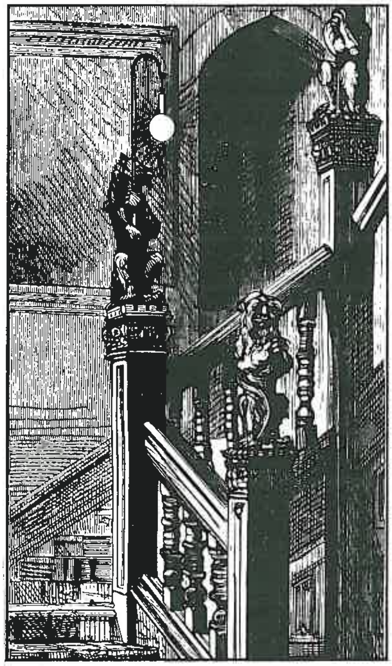


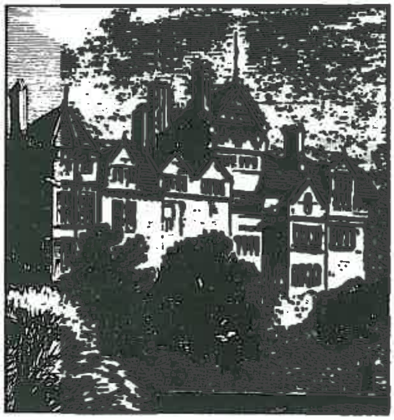
This wall plaque (dating from 1880) reassured people that the new invention was safe.

Of course, the light bulb could not be used by everyone until the electricity generating industry had evolved. When, within a month of his famous Newcastle lecture, Swan installed lamps at the first private house to be lit (Sir William Armstrong's home in Northumberland), the lamps were powered by a water-driven dynamo. Most early installations included their own DC generator and storage battery. Incidentally, Swan made a number of improvements in the lead-acid accumulator.

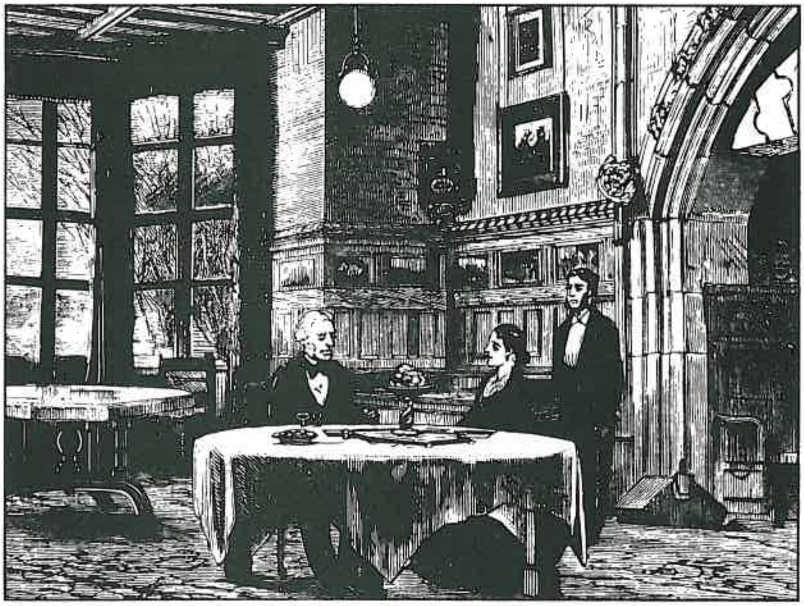
This extract (right) from an 1883 Swan catalogue shows how power generation was often included as part of the installation. Note the item 'year's wages for engine driver at 30/- per week'. In those days you needed a man to mind the donkey engine and regulate the voltage. Note also that lamps were expensive compared with the cost of the fuel. This was partly because they were produced only in small quantities.

For years it remained simpler to operate anything electrical from small generators, which is why electric lighting tended to be used first for ships, trains and in places which had their own power supply.





Above, Right & Below *Probably the earliest home to be lit by electric light bulbs was that of industrialist Sir William Armstrong at Cragside, Northumberland. The installation was powered by a water-driven dynamo.*



1883

Capital cost including installation of boiler and dynamos	**£1470**
Annual cost for 14,000 units of electricity	**£155**
Breakdown of Annual Cost Factors:	
Year's wages for engine driver at 30 shillings per week	**£78**
39 Tons of Coal at 20 shillings per ton	**£39**
155 Replacement Electric Lamps at 5 shillings	**£39**

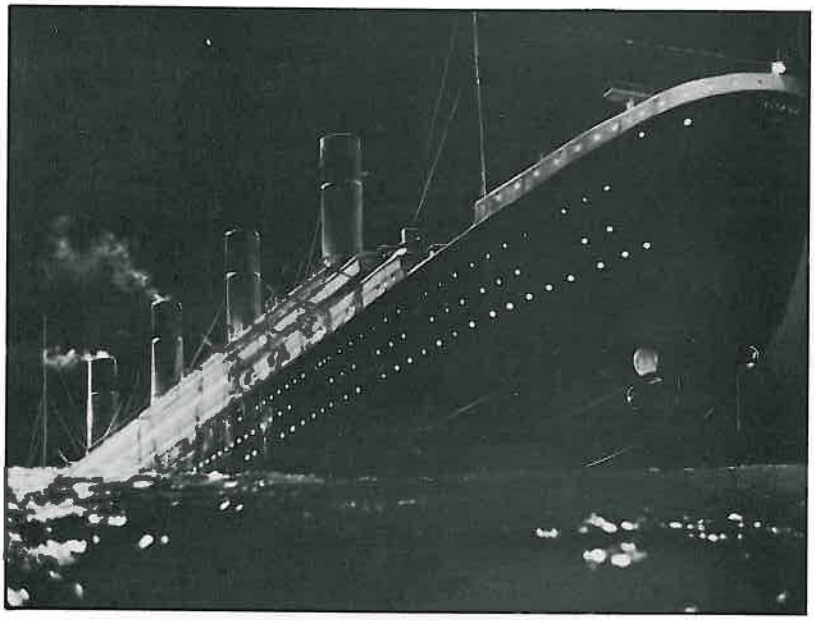
Witnesses tell us that when the R M S Titanic sank in 1912, she went down with her electric lights still burning! This historic oddity is worth noting, though it does not lessen the tragedy of that awful sinking.

Naturally, the demand for electric lighting forced the pace in the electricity supply industry. Whenever electricity came to an area, electric lamps followed immediately. Lamp factories grew up to satisfy the demand; one of the earliest was the Benwell (Newcastle) factory of the Swan Electric Light Company. (This company later changed its name to the Edison and Swan United Electric Light Company when its joint founders agreed to pool resources rather than fight in the courts.)

Meanwhile, the lamps themselves were improving. 'Squirted' filaments of carbonised cellulose proved easier to produce, but by 1906 filaments of tungsten were appearing. Tungsten, though obviously superior to carbon, was very hard to work with, but by 1909 it was possible to draw a fine wire from specially processed tungsten by using dies. Filaments made from this 'ductile' form of tungsten have been used ever since.

Pre-1910 was the age of the pioneers, who faced plenty of challenge in simply making lamps that worked. After 1910 – roughly the modern era in lighting – lamps worked and the priorities were to produce them in vast quantities efficiently so that the price could be held down, and to sell them all over the world. Inevitably, the business entrepeneur became important as small companies were formed and, as these grew or merged into larger companies, it was not long before light bulbs were being produced in hundreds, thousands, then millions. It is estimated that British domestic users alone consume well in excess of 200 million bulbs a year and one type of machine at Thorn Lighting's Merthyr factory makes them at a speed of 5000 an hour!

By the 1930's electricity was accepted as having eclipsed gas for illumination. The 'stink and bang' industry (as it was once humorously called) gave way gracefully to the silent brilliance of the new light source and the hitherto gloomy streets and houses of Britain, and other advanced countries, began to glitter with the diamond-like brilliance of electric light.



The revolutionary industrialist

Jules (later Sir Jules) Thorn, who was to become one of the most influential men in the lighting industry, started his Electric Lamp Service Company in 1928, half a century after Swan's carbon lamp demonstration.

The first Thorn factory was set up at Edmonton in 1932 to mass produce light bulbs. In those days a bulb cost around five shillings, which could have been a big bite out of a weekly wage. Continually improving production techniques have meant that bulbs today are not only around the same price as all those years ago, about 25p, but a small part of anybody's wage.

Above Left *Some of the earliest lighting installations were on ships. RMS Titanic goes down in 1912 with her electric lights still burning.*
Bottom Left *Mass production of lamps really got under way during the 1920's and 1930's in factories like this Thorn factory, set up in Edmonton, North London, in 1932.*

Today, lamps are made in enormous quantities in factories like the one at Merthyr Tydfil in Wales.

Nowadays only companies with massive resources like Thorn can afford the research, investment and machinery needed to be successful.

Some of the big companies' research money goes into discovering ways to make lamps use less electricity. The modern filament bulb is over four times more efficient than Swan's early lamps, and lasts nearly three times as long, as the table shows.

As the cost of current consumed over the life of a bulb is far greater than the cost of a bulb, manufacturers have naturally concentrated on improving efficiency rather than life. Long-life bulbs *can* be made, but only at the sacrifice of efficiency. In 1977 Thorn offered the Mazda Double Life bulb with a slightly lower light output but, at 2000 hours, twice the normal life.

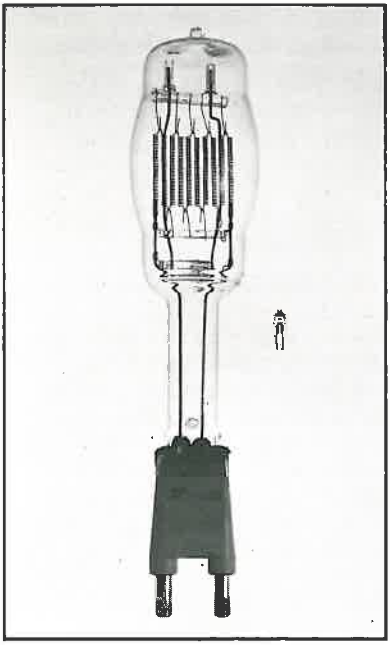
Of course, the normal household bulb is not the only kind of incandescent lamp. An amazing variety of types range from tiny lamps no bigger than a grain of rice – for indicator purposes or medical inspection – to giant 10kW lamps for film and TV studios.

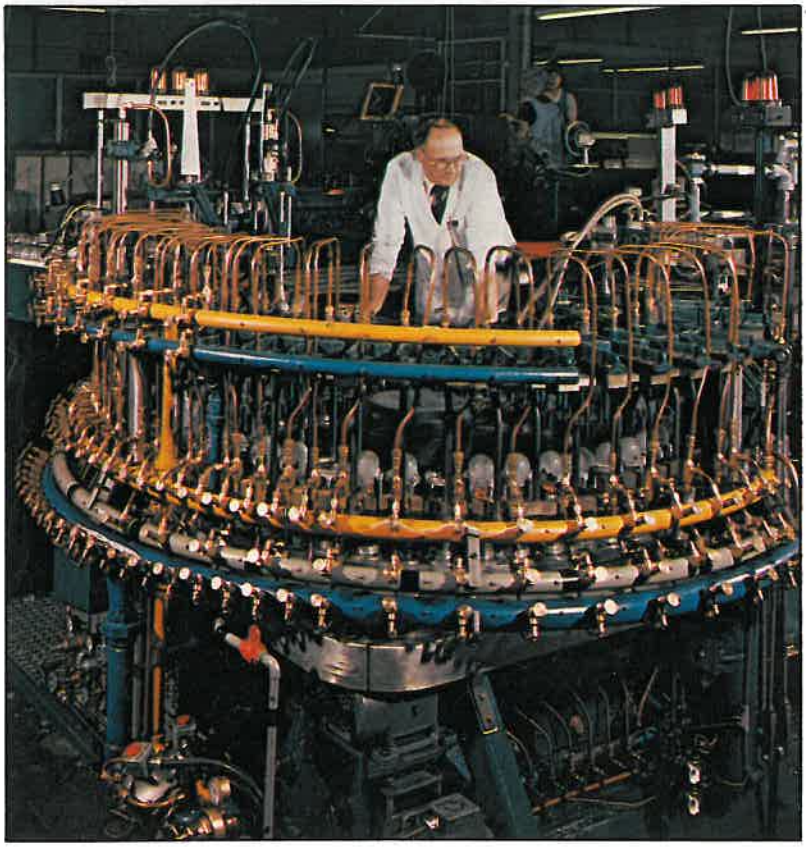
Filament lamps are here to stay. They are everywhere – in the streets, railway stations, airfields, factories, theatres, ships, offices, aircraft, trains, buses, telephone booths, public houses. They are in your home. Not only those you switch on when you walk into a room; you may have lights in your refrigerator, cooker, radio or hi-fi. There are probably about 30 lamps in your car, including the dashboard, tail and sidelights, interior lights and headlights. Filament lamps are still extremely convenient and versatile and have passed the test of a century.

However, technology moves on and the modern era has brought other forms of lighting with other strengths. These are proving more and more influential and will take lighting into the 21st century.

Description	Efficiency* (Lumens per watt)	Life (Hours)
Early Carbon Lamp	3	400
Squirted filament	8	1000
Drawn filament (vacuum lamp)	9	1000
Coiled filament (gas filled)	11.6	1000
Coiled-coil filament (gas filled)	12.6	1000
Double Life (coiled-coil filament)	11.4	2000

*Average throughout life





Above *Extremes in lamp size; a 10kW tungsten halogen projector lamp compared with the Thorn M29 tungsten halogen ciné film editor lamp. The 10kW lamp is still extremely small by old-fashioned standards:*
Right *This production line at the Thorn Merthyr Tydfil factory, Wales, produces 5000 lamps per hour.*

The next step – bottled lightning!

It may be hard for the average person to realise, having read of the struggles of the early pioneers, that heating a wire filament was by no means the obvious way of using electricity to produce light. In fact, it was and still is a far better way of producing heat. The average bulb – in engineering terms – could quite legitimately be regarded as an excellent heater that wastes some of its energy in dissipated light!

The fact that electricity could produce light had been dramatically revealed by Franklin. Von Musschenbroek (who first discovered how to 'charge' the water container now known as the Leyden Jar), must have been aware of the brilliant blue light produced by an electric spark. Incandescent filaments were unheard of then.

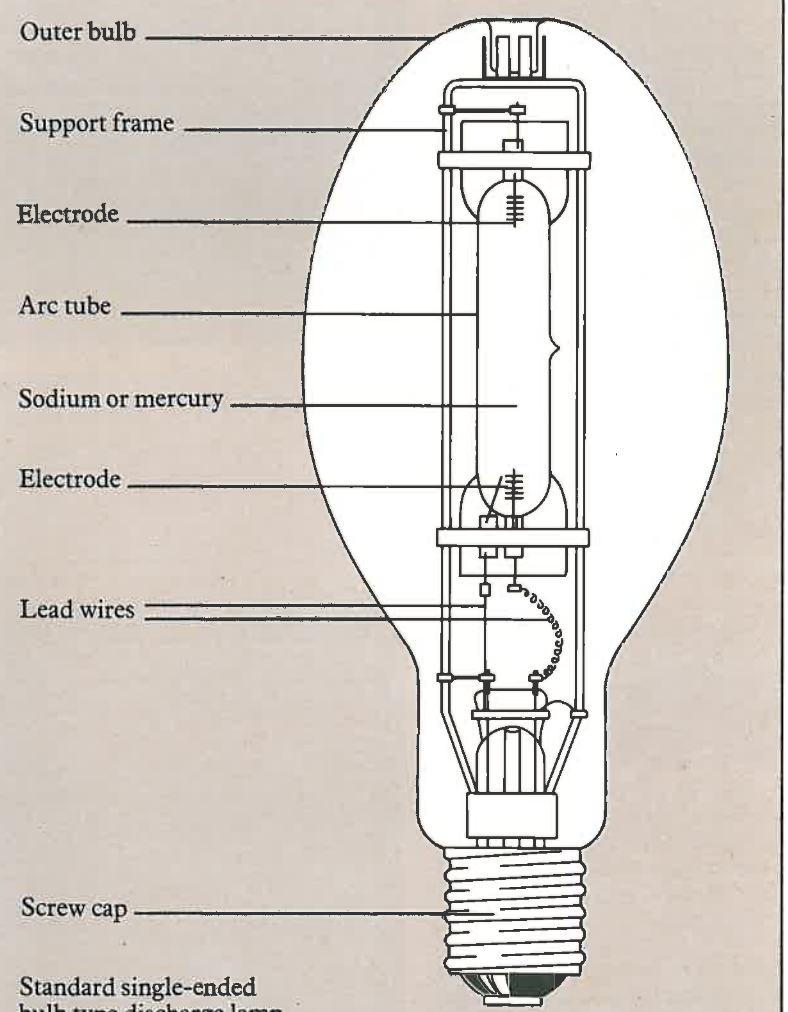
Seamen, steeped in superstition, were aware of the ghostly green glow, known as St. Elmo's Fire, that surrounded the masts and upper rigging of ships in thunderstorms. (Literary connoisseurs will remember Herman Melville's reference to it in 'Moby Dick'.)

So the early experimenters were familiar with the assortment of luminous phenomena associated with high electrical potential though they lacked the technology to analyse and harness it. Davy, with his arc lamp, showed how an instantaneous discharge (like lightning) could be harnessed and controlled to give continuous light, but the era of the discharge lamp – the 'obvious' light source, as we prefer to think of it, had to wait a little longer.

Discharge lamps are as different from filament lamps as chalk from cheese. All previous lamps in history have relied on heat, but the discharge lamp relies on light emitted by a gas or vapour when excited by an electric current flowing through it. The reader will be familiar with discharge lamps since they are almost universally used for street lighting.

The mauve colour of lightning is characteristic of a discharge in the atmosphere, but discharges in other vapours or gases produce many different effects and colours.

In a discharge lamp an arc, a miniature 'flash of lightning', is struck between two electrodes enclosed in a glass tube containing an inert gas or vapour. A choke or other device controls the flow of electricity so that it produces a steady glow instead of an instantaneous flash, and heat generated by the arc vapourises metals which emit their characteristic colours of light.



Standard single-ended bulb type discharge lamp

Discharge lamps use one of two metallic elements – sodium and mercury – which are both fascinating as chemicals in their own right. The metal is contained in an inner 'arc' tube which has a stream of electrons passing through it. The metal vapourises, becomes excited and emits radiation.

A sodium discharge is odd because at low pressure (which is how the most efficient lamps work) all the light is yellow. Mercury emits blue/green light, and sends off an awful lot of invisible ultra violet. Certain colours are missing from the light given out by the mercury arc and these can be partially restored by using the ultra violet to make phosphors glow on the inner surface of the bulb.

Discharge lamps have overwhelming advantages. One is the amount of light they give. Light is measured in 'lumens' and an incandescent bulb gives about 12 lumens per watt. Discharge lamps can radiate – and this is a fact that always appeals to ratepayers – up to 160 lumens per watt. Moreover, they are comparatively cool. An incandescent lamp of 1000 watts (as used perhaps in studios) is intensely hot and the wattage is out of all proportion to the light emitted. A 1000 watt discharge lamp is cooler, may be no bigger than an ostrich egg, and throws off seven times as much light. A slight snag is that discharge lamps cannot run direct from the mains supply, and need special circuitry (called 'control gear' in the trade).

It is easy to forget that the discharge lamp was discovered *and used* before the filament lamp. In the carbon arc lamp Davy demonstrated in 1810 the discharge took place in air between two carbon electrodes. As explained earlier, arc lamps *were* in use from the 1850's but they were difficult to control and gave a spluttering uneven light. When the more convenient filament lamp was produced, arcs lost popularity for nearly 70 years.

Apart from carbon arc lamps, the first discharge lamp to be produced commercially was one in which the discharge took place in mercury vapour. A mercury arc lamp – of a kind – was demonstrated as early as 1860, but more successfully by Peter Cooper-Hewitt in 1901. Commercial tubes were introduced in 1910. In those days mercury was placed in a long sealed tube in liquid form and to start the lamp it had to be tipped by hand so that mercury ran down to the lower electrode before the arc could be 'struck'. Once struck, the arc would vapourise enough of the mercury for the lamp to operate.

Similar lamps were used in photocopying machines until recently. In a smaller, high pressure version introduced for street lighting in the USA about 1916, the tube was tilted electrically.

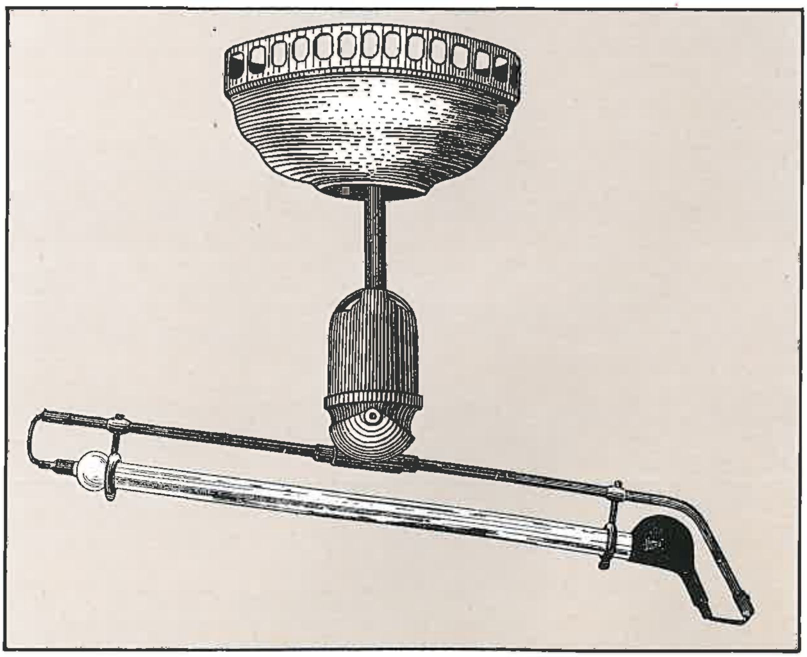
The tilting snag was overcome by sealing mercury into the tube with argon gas at low pressure. An external starter was used to provide a high voltage starting 'kick'. It was this improved version which was to give rise to modern mercury and fluorescent lamps.

In 1932, high pressure mercury and low pressure sodium lamps were introduced for streetlighting. Nowadays, when thousands of miles of motorway, main roads and city streets are lit by discharge lamps, it is hard to imagine what driving must have been like without them.

Low pressure sodium is one of the most widespread forms of discharge lamp and is a paradox. In one way it is incredibly good, but in another incredibly bad. The lamp is very efficient, producing up to 160 lumens per watt, and is not too difficult to make. It also has a long life. This is good for the ratepayer, who receives a lot of 'light-hours' for his money.

The bad thing is that sodium vapour at low pressure, when excited, emits only intense yellow light. This means that red and

Below *Dr. Maurice Cayless of the Thorn laboratories at Leicester. He was one of the scientists who made the high pressure sodium lamp feasible.*
Bottom *The first type of discharge lamp to be produced commercially was the mercury vapour lamp. This one was produced by Peter Cooper-Hewitt during the first decade of this century. To strike the arc, the tube had to be tilted by hand.*



green look the same and the observer can no longer see colours. (A slight advantage is that contrast is improved.) But at the moment it is the supreme lamp for road lighting because motorists are not critical about colour if visibility is good.

Fairly recently, researchers discovered a surprising effect. If the pressure of sodium vapour in a tube is raised to about one quarter of an atmosphere, the frequency of the emitted light spreads in an unexpected way over a wider part of the visible spectrum, giving a rich golden colour. In 1957 Dr. Maurice Cayless (now with the Thorn laboratories at Leicester) helped to develop this most important new light source – the high pressure sodium lamp. But it took ten years to make, on a commercial scale, components able to resist one of the most aggressive chemicals known – sodium vapour at 700-800°C. In a triumph of materials technology, Thorn perfected a small one-piece inner tube to hold the vapour. This was made of alumina oxide which can resist the vapour, but is transparent to light. The quality of both types of sodium lamp, especially the high pressure type, has now improved so much that one even sees the latter being used in swimming baths, workshops, foundries and other places where its golden white colour is very appealing.

It is easy to see how sodium lamps both high and low pressure have become such a tremendous boon, not only to street lighting authorities, but also to commerce, industry and a great many other places where it is necessary to see for long periods after dark and at the lowest possible cost. As a rule the larger the installation, and some installations (we need only mention the M1 motorway) are really enormous, then the lower relative running costs become.

Above *Steel rolling mills at Trostre, Wales, lit by high bay discharge lamps.*
Top Left *Spectacular scene a mile inside a north Wales mountain, illuminated by SONline high pressure sodium floodlights. The excavations are for the CEGB's Dinorwic pumped storage power station at Llanberis.*
Left *Section of motorway near Coventry illuminated by low pressure sodium lamps.*

Meanwhile, scientists had been busy trying to find ways of making use of the considerable amount of ultra-violet light emitted by a mercury arc tube.

It was known that certain chemicals (for those readers interested in chemistry, zinc cadmium sulphide is one of the most basic) can be made to glow brightly – or fluoresce – when bombarded with ultra-violet light. So the lamp engineers placed a fluorescent coating inside the mercury lamp, thereby making use not only of the direct light from the arc, but also converting the invisible ultra-violet to visible light to get a better effect. Between 1950 and 1970 huge strides were made by industrial chemists in the development of phosphors and it is now possible to make mercury discharge lamps which have quite good colour rendering.

The mercury discharge lamp has given rise to a number of interesting variations. The use of metallic iodine or bromine compounds in the arc tube has made it possible to change the normal bluish light from a mercury arc into a much whiter light, and changes have also taken place in the structure of the lamp. These lamps, called 'metal halide lamps', are supremely effective for floodlighting; they have a very high light output per watt, are extremely compact and are obtainable in high wattages. They therefore have all the characteristics required for splendid outdoor lighting schemes, or for the lighting of buildings which have very high ceilings, where the light needs to be bright to reach down to the work surface.

By achieving the best blend of halide, phosphor coating and inert gas filling, metal halide lamps have become very efficient (up to 85 lumens per watt), with great appeal for use in shops, hotels and commercial premises. However, perhaps the crowning achievement is the compact source iodide (CSI) lamp pioneered by Thorn.

No bigger than a walnut, the CSI lamp uses a mercury arc discharge, but has special metallic iodides added to the gas in the bulb and produces an intensely

brilliant white light. It was first used in 1969 to light West Ham Football Club, because BBC colour television had started outdoor sports broadcasts and colour TV cameras need better light than monochrome TV. A total of 324 of these lamps round the pitch gave a level of light approaching that of the inside of a well lit supermarket. Not that brightness is the only merit of CSI lamps. The real point is that they are so small that large numbers of them can be put on towers without any need to strengthen the towers and without creating the usual problem of wind stress. A 1000 watt CSI lamp, one and a half inches in diameter, gives about enough light to equal 80 average household bulbs. Efficiency is about 90 lumens per watt and its average life is still 1000 hours or more. The most exciting use for the compact source iodide lamp is probably filming, for example, many of the scenes from the film Star Wars – and also more recently Superman – were lit by CSI lamps, since it is absolutely ideal for cine photography.

Top Left *Thorn Kolorarc mercury-halide lamps illuminate Battle of Britain planes at Hendon Aircraft Museum.*
Middle Left *West Ham Football Club's ground at Upton Park started the ball rolling for CSI football floodlighting with the first installation, in 1969.*
Bottom Left *Thorn CSI (compact source iodide) floodlights make a night-time spectacle of the 11th century castle of Mont Orgueil overlooking the village and harbour of Gorey in Jersey.*
Above *Thorn CSI lamps helped 'Clark Kent' on his way in the film 'Superman'.*
Top Right *Lighting our way to victory; fluorescent lighting came in time to help wartime production.*
Bottom Right *Phosphor glowing under UV radiation.*

It would not be true to say that Joseph Swan never dreamed of a lamp such as this. He probably did, because above all he was a visionary. He *might*, perhaps, have under-estimated the formidable amount of engineering and development work needed to turn it into a commercial reality.

However, discharge lamps, though easily the most intriguing of today's light sources and almost certainly the ones which still have the greatest potential for development, are not manufactured or used in quantities anything like the fluorescent tube, which supplies 80% of all the world's artificial light.

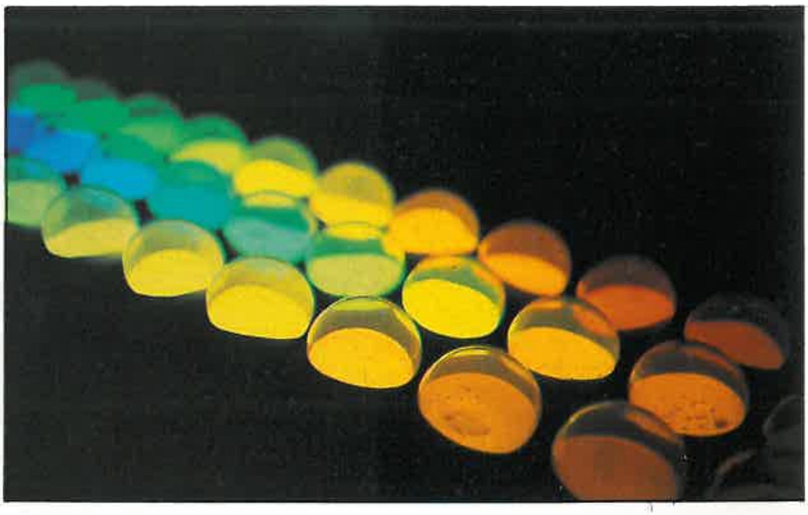
Light in strips

There is no doubt that from 1940 – 1970, fluorescent tubes became the dominant light source. In the previous chapter we touched on fluorescent chemicals and their significance in improving the performance of discharge lamps. It is important not to confuse fluorescence with phosphorescence. Phosphorescent substances glow of their own accord, though some of them appear to be able to absorb energy and re-emit it over a period, like the luminous numbers on the dial of your alarm clock, but fluorescent chemicals are quite different. They glow only when activated by ultra-violet light, or by other types of radiation.

The television set you sit watching each evening could not work unless there were fluorescent chemicals on the screen and, in fact a colour television screen is a very complex piece of mechanism using three different coloured phosphors – red, blue and green arranged in dots or lines almost too small to be visible to the naked eye and which when used in different combinations produce the whole range of colours that you see when, say, you watch Coronation Street.

Again, fluorescent chemicals have been used for many years in advertising signs and posters and these paints and printing inks have been known for some time in the trade as 'day-glo'. They simply use the ultra-violet light already penetrating the atmosphere from the sun and re-emit it as visible light, so that the lettering on a sign, or poster, appears much brighter than a standard printing ink.

It was in 1940 when the Blitz hit London, that fluorescent tubes were first used to light the arms factories which helped pave the way to victory. Many wartime factories were lit with the early fluorescent tubes, though the



fittings were a bit rough and ready. (Fluorescent lamps, like discharge lamps need special circuitry inside the fitting and cannot work straight off the mains.)

Within 15 years fluorescent lighting had become an unbelieveable success story – remember our estimate that nearly 80% of all artificial light is now fluorescent?

Surprising – until one remembers the lighting 'explosion' that took place in factories, shops, offices and public buildings, as well as the demand for higher light levels to match our increasing affluence, (as it was then!).

How did this new force in lighting come to challenge the supremacy of the filament lamp, and the awesome potential of the discharge lamp? Well, fluorescent tubes *are* a form of discharge lamp. Just as incandescence and electricity made the filament lamp possible, the discharge principle was wedded to fluorescence to produce a very effective lamp indeed.

The inventive Edison knew of fluorescence, back in 1896, though he never made a fluorescent lamp. But he was working on the right lines. He knew that if the outer glass tube of a discharge lamp was coated on its inside with certain powdered phosphors, the UV radiation emitted by the discharge might energise the powders to fluoresce brightly.

Because fluorescent lamps produce much less heat than filament types and because they convert most of their electrical energy into visible light, they are much more efficient; up to 90 lumens per watt can be produced.

Although workable fluorescent lamps were developed in Britain, they were first shown tentatively to the public at an exhibition in Cincinatti in 1935 and more convincingly in New York in 1938. Thorn involved itself in the new technology after the war and by 1946 had installed them in Old Broad Street and Brompton Road. In 1948, Thorn became the first European company to start mass-producing this new highly

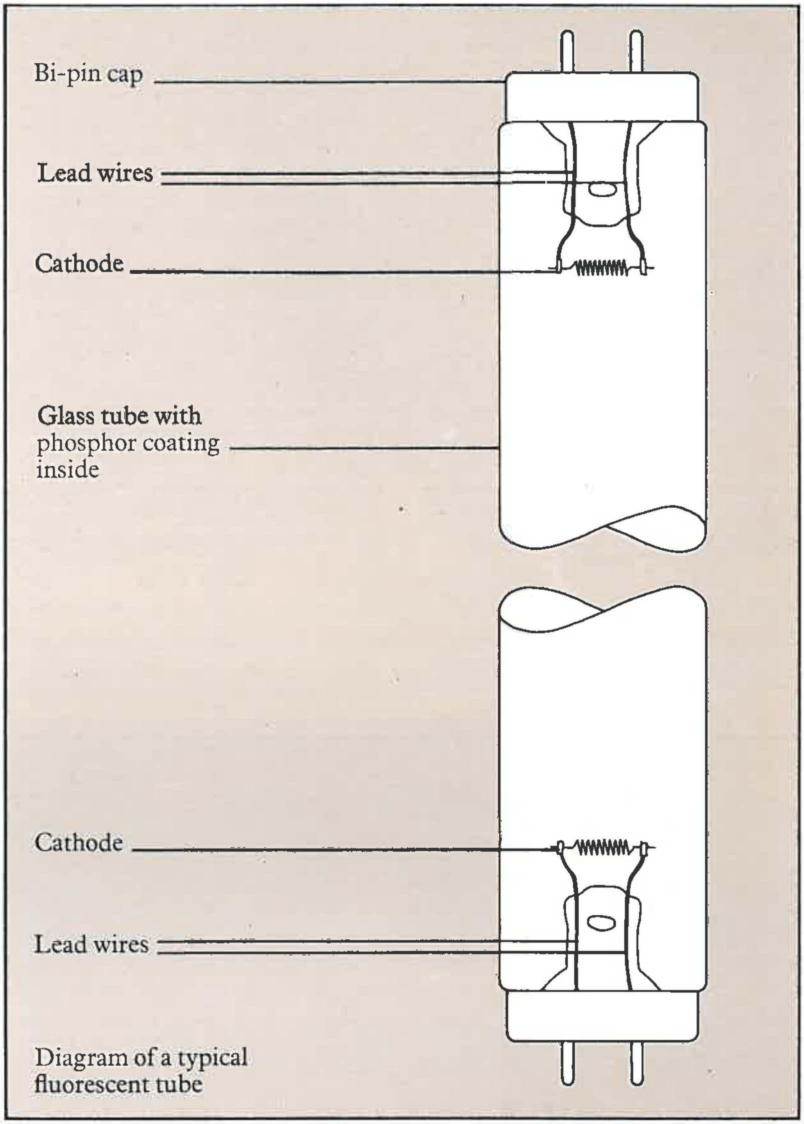
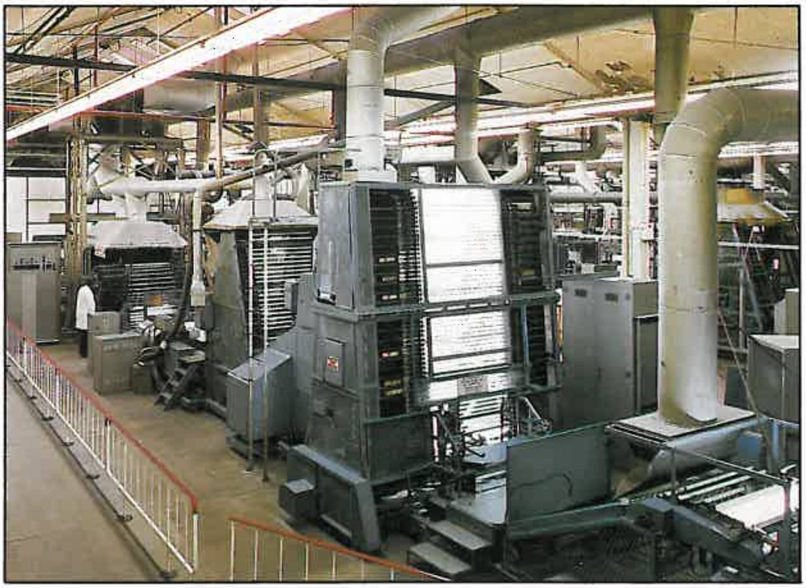


Diagram of a typical fluorescent tube



efficient form of lighting, and today it has one of the most modern fluorescent tube factories in the world, making 40 million tubes every year at Enfield. More than half are exported.

Phosphor development and manufacture is a science all on its own. Traces of rare elements added to a phosphor can completely alter its colour or efficiency, and the processes of refinement and purification are still producing improvements. Essentially the skill of industrial chemists has been to blend phosphors to produce the colours of light most people need, or like, rather than the cold bluish colour some early tubes are remembered for.

Yet good colour must be combined with efficiency. A major breakthrough came in 1951 when Dr. Peter Ranby, now Thorn Lighting's chief chemist, produced the first fluorescent halophosphate, an artificial phosphor which made possible high efficiency 'white' tubes. Even so, good colour sometimes has to be traded against efficiency, so customers are given a choice. Different tubes provide a wide choice of shades of white, from 'warm' to 'cool'.

Like the filament lamp, the cylinder of light which is 'just another fluorescent tube' is an engineering marvel. The modern tube can produce nearly 80 lumens per watt, compared with the paltry 35 lumens per watt of a 1940's tube, and its useful 'life' has been extended from 2000 to 7500 hours. In fact it will last an incredibly long time, but after several thousand hours the phosphor becomes exhausted and the light ouput falls. This is why fluorescent tubes should be replaced before they fail. (It is worth mentioning that *all* lamps – of whatever kind – have a characteristic high efficiency during their first few hours, after which the light output falls – rapidly at first, then more slowly.)

The range of fluorescent tube colours has been improved, and their efficiency in light hours is now seven times better than the product which first brought the concept of shadow-free lighting to the wartime factories of Britain.

A point about the fluorescent tube that is often overlooked is that unlike almost all other types of lamp it is linear and can be made up to 8 feet long. This means that the light it produces is far less directional than a filament lamp. Quite early on it was recognised that one of the biggest advantages of the fluorescent tube was that its length tended to disperse light more evenly and diffuse shadows. It has, therefore, become very popular as a light to work under. In an ordinary domestic kitchen for example most of the equipment is round the outside of the room. With a light bulb in the centre you would be standing in your own light all the time, but with a fluorescent tube the shadows seem to disappear.

Opposite *High speed fluorescent manufacture at Thorn's Enfield factory.*
Above *Tubes produced provide up to 30 distinct 'colours' including ultra-violet for display purposes (centre). The user has a wide choice of 'white' colours.*
Above Right *The 47-storey National Westminster Tower in Bishopsgate is lit by Thorn 'Plus White' fluorescent tubes in specially designed fittings which, placed end to end, would stretch 17 miles.*
Right *Modern fittings are often slim and elegant. This Arrowslim domestic fitting has a 1 inch diameter 50 watt 'White' tube.*

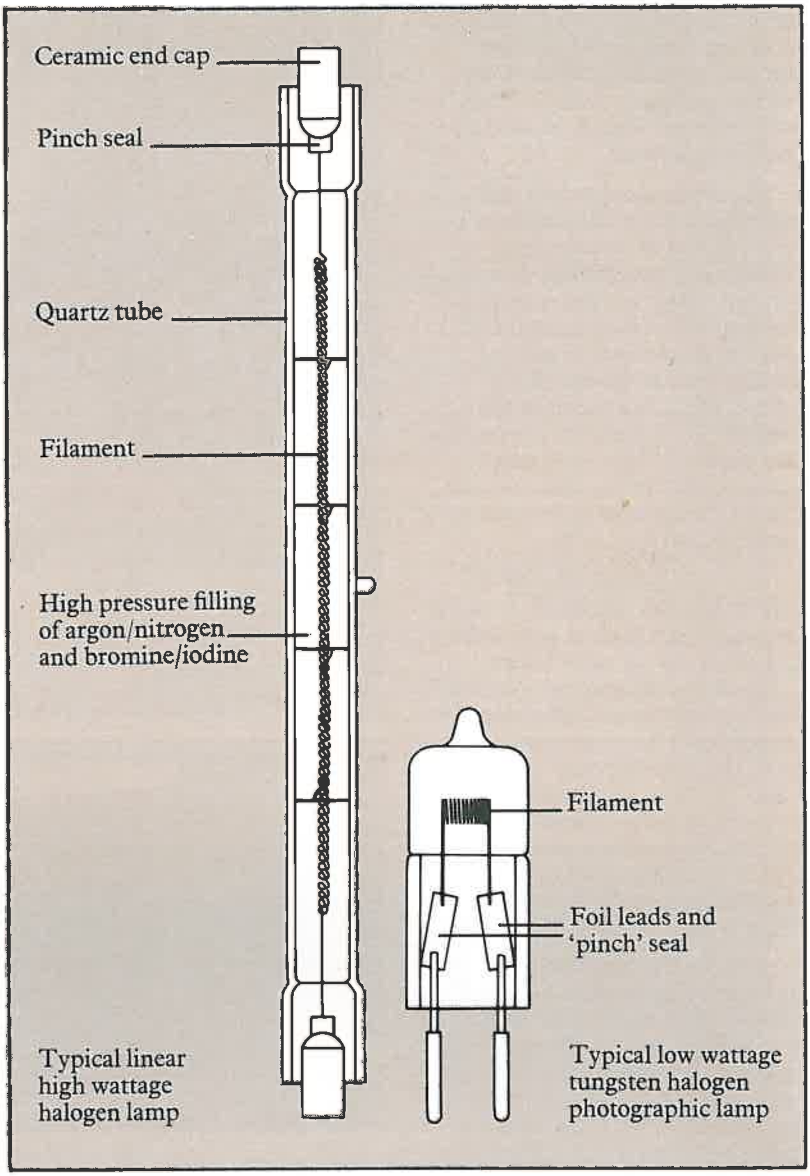
The filament rejuvenator

Though the filament lamp reigned supreme for the first half century after Swan, it has had to share the second half with fluorescent and discharge lamps. But in the 60s it made a comeback, in a new guise which Thorn helped to give it. This new development was originally called the quartz-iodine lamp. Regrettably, this delightful sci-fi soubriquet had to give way in the interests of accuracy to the name now used – the **tungsten-halogen lamp.**

We have said that a normal filament lamp is not efficient. Another flaw is that the light output diminishes gradually through the lamp's life because the filament burns away and the glass becomes blackened. Particles of tungsten evaporate from the hot filament and form a coating on the glass and the hotter the filament the blacker it gets. Old fashioned high power lamps for studios in which the filaments are operated at temperatures just below the melting-point of tungsten, had to have loose granules of tungsten in them so that between film sessions assistants could shake the bulb and scrape the 'soot' from inside!

However, if the escaping atoms could be captured and sent back to the filament, the blackening would be prevented and filament life prolonged. Amazingly, in the late 1950s scientists found a way of doing this, through the discovery of the 'halogen cycle'.

If a very small quantity of one of the less corrosive halogens, such as iodine or bromine is added to the



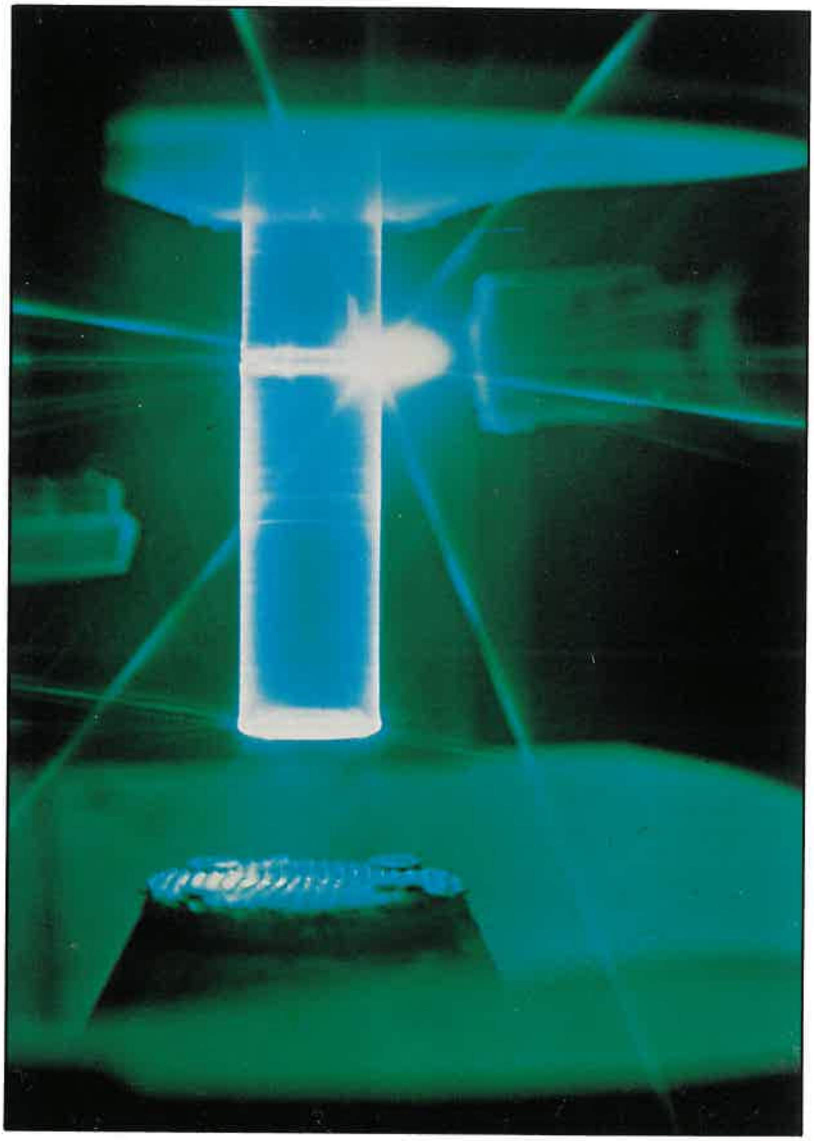
conventional gas filling, it combines with the evaporated tungsten to form tungsten-halide, preventing deposition on the glass. Movement of the gases in the bulb carries the tungsten-halide back to the filament, where the tungsten settles on to the cooler parts. This allowed a much smaller bulb to be used, so that the gas pressure could be increased from about half to about four atmospheres, reducing the rate of evaporation of the filament.

Because of this discovery, engineers could either make the filament last longer, or else run it at a higher temperature providing extra brightness over the same life. In practice, typical tungsten halogen lamps combine both advantages, by being 50% brighter and lasting twice as long as a normal lamp. At the same time, lamp efficiency is doubled – to about 25 lumens per watt.

Predictably there were difficulties getting the wonder filament lamp into production. The bulb wall operates at around 250°C because it has been brought closer to the hot filament by reducing bulb size. As glass would have melted, the bulb was made from a more robust transparent material, quartz. But quartz is hard on the normal diamond disc cutters used in production, so the engineers brought in a high technology cutter – the laser. A beam from a powerful industrial laser cuts through the quartz tubing in a matter of seconds. Incidentally, this was probably the first time lasers were used in productive work in manufacturing industry. An incidental problem was that quartz will not adhere readily to metal and this made it difficult to seal the point where the lead-in wires entered the lamp. This snag was overcome by using specially designed molybdenum seal with a very fine cross section, able to flex when the seal is 'pinched'.

At first, iodine was the halogen used, which is why the first lamps that came on the market in 1961 were called 'quartz-iodine'; now bromine is used in photographic lamps. Its colour qualities are better, but iodine is still the normal halogen for mains–voltage lamps. Perhaps the greatest contribution made by British engineers to tungsten halogen techniques lay in achieving close control of the halogen 'dosage'. Too much halogen eats away the lead wires to the filament, while too little permits the blackening of the bulb that the halogen is added to prevent. The new lamps also called for superb manufacturing skills because to the existing difficulties of working the particularly stubborn metal tungsten were added the intransigence of quartz glass – a very hard substance with a higher melting point and more difficult to manipulate than glass.

But the world now has a new form of filament lamp; very bright, very small and long lasting. It is too expensive to threaten the established filament lamp in the home, but has taken over in many applications where small, extra-bright lamps are needed. When, in 1967 Thorn hauled a Mini onto the third floor of the London Hilton, the company showed the world's press one such application – the first dip-beam tungsten halogen car headlamps. The Automobile Association was so impressed that it gave Thorn an AA award for contributing to road safety by providing much brighter light without dazzle. The company also received one of its four Queens Awards for its contribution to tungsten halogen technology.



Left *Front of a Cortina showing Thorn H4 tungsten halogen headlamp. Thorn helped pioneer this technology which has enhanced road safety.*
Right *Latest technology; a powerful industrial laser is used to cut quartz during production of tungsten halogen lamps.*

Tungsten halogen brought a revolution in floodlighting since, with such compact sources, lamps, reflectors and complete floodlights could be made much smaller. Sports clubs could do away with the large, clumsy floodlights they had been using, which needed very strong towers or masts. The new small floodlights were cheaper to buy and cheaper to run for the same amount of light, and floodlit sport became the norm rather than the exception.

Efficient and robust tungsten halogen lamps also now widely used for vehicle headlamps and foglamps, airfield landing lights and aircraft.

The most profound change, however, has been in the photographic world, where whole new generations of cine and slide projectors, as well as the lamp housings themselves, have been designed round the marvellous compactness and brilliance of this lamp.

Above *The amazing compactness and power of modern ciné projectors is due very largely to the tungsten halogen amateur and professional lamp, a light source which combines small size with very white, even, bright light and durability. Older carbon-arc professional projectors were much larger, and had to have elaborate ventilation.*
Top Right *One hundred years ago the Royal Cornwall Gazette recorded that the Redruth Rugby Club installed electric floodlighting (carbon arc). It was probably the first sports club to do so.*
Right *Thorn floodlights used for a major international show-jumping event at the National Exhibition Centre, Birmingham.*

The Royal Cornwall Gazette

FALMOUTH PACKET, CORNISH WEEKLY NEWS AND GENERAL ADVERTISER.

8987 | TRURO, FRIDAY MORNING, JANUARY 10, 1879. | PRICE ONE

REDRUTH FOOTBALL CLUB.

ELECTRIC LIGHT!

THE COMMITTEE of the above Club has made arrangements for a Grand County FOOTBALL MATCH by ELECTRIC LIGHT, to be played at REDRUTH, in a Field in GREEN LANE, kindly lent by R. Pryor, Esq., on MONDAY, 13th January 1879.

The two Teams will be chosen from the different towns of the county.

The Band of the 17th D.C.R.V. will be in attendance.

Admission—by Ticket, 1s.; for holders of which special accommodation will be provided. To other parts of the field, 6d.

The game will commence at 7 30; Gates open at 6 30. Ticket holders admitted at 6 o'clock.

Tickets may be obtained of the leading Stationers and Booksellers, and others throughout the County, and of any of the Club Committee.

Special trains have been arranged for. For particulars see Company's bills.

J. W. EVERETT, F. WOOLF. } Hon. Secretaries.

What of the future?

Swan, with his filament lamp, gave mankind his first bright unwavering light. Later, the choice of electric light broadened to include fluorescent and discharge lighting. But technology cannot stand still. What will light our way into the twenty-first century?

Some promising ideas are already with us, but need more research to make them both cheap and practical. Aldington in 1947 discovered the remarkable properties of an electric discharge in xenon gas at high pressure, but only a few applications have been found for it.

A 2 kilowatt xenon lamp installed in a New Zealand lighthouse is so bright that it can be seen 20 miles away in daylight. Yet the lamp, in a quartz globe, is little over 30 centimetres long and 900 grams in weight. (It also required a 40 000V 'starting kick'!) This amazing lamp has a surface brightness almost the same as the sun!

Alternative gas fillings have been developed for fluorescent tubes. For instance, a mixture of neon and argon enables a tube to be operated at a higher voltage, so increasing light output for a given length of tube. Krypton filling also increases the output though the gas is expensive.

There are also other ways of exciting the gas or vapour to produce more light. Engineers are developing very high frequency tubes – lamps operated at 20kHz from direct current sources through electronic circuits. These tubes give up to a fifth more light, but more important benefits include lighter, smaller control gear, and freedom from flicker.

Then too, there is more to be learned about phosphors. It has been discovered that some phosphors can actually turn heat into light, so that in time some of the power wasted in all types of lamps may be converted into luminous energy. This is a rich field for further scientific work.

Another development relying on phosphors is the electro-luminescent panel, a glowing panel of light used in information signs in aircraft, car dashboards and other applications where low brightness is sufficient. They are also used, for instance, as caption panels in the nocturnal mammal house at London Zoo.

Even more fascinating is the image retaining panel, in which phosphors are sandwiched between two plates, one of which is transparent. These plates are able to retain patterns of light (like photographic plates) some time after exposure to say, light or X-rays. They are used in radar display tubes, scientific instruments and equipment providing instant X-ray pictures of, say suspicious parcels.

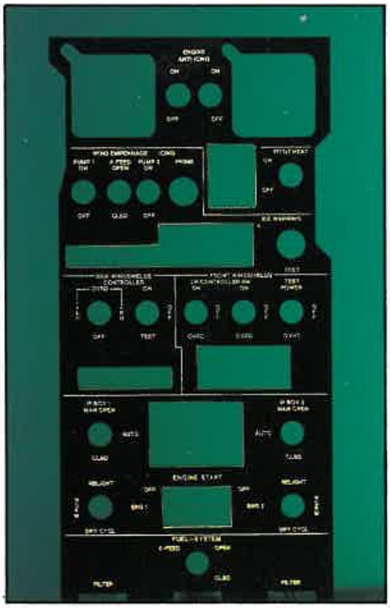
As for other future light sources, who knows? One space-age type being used already is the tritium light, which relies on the radio-active decay of tritium gas and requires no power at all. The gas is sealed into a capsule which can be any shape or size, and emits a low level, cold, white light which is being used in instruments, night sights for guns, obstacle markers, in vehicles and on boats. The light is tough, needs no attention, and lasts up to 20 years. It is also harmless to health as the level of radiation is very small, but it is not nearly bright enough to light your living room.

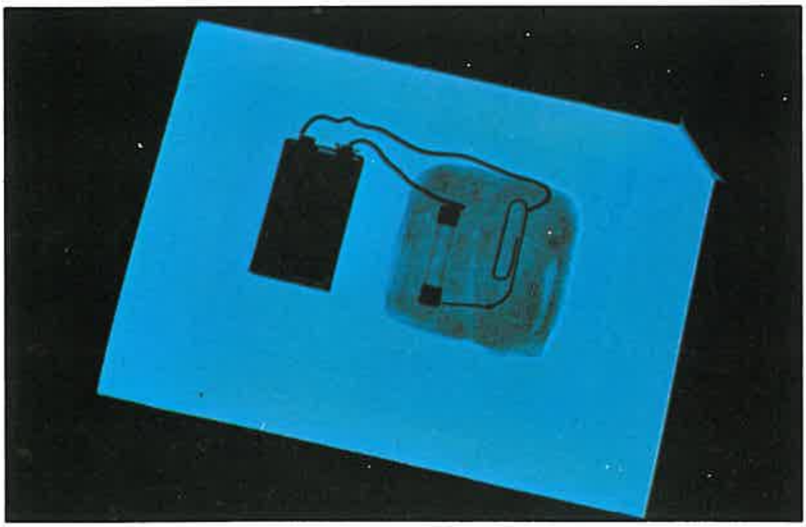
Other sources could rely on new ways of exciting phosphors or gases, possibly even using lasers. A laser is itself a light source, providing intensely 'pure' light of a single wavelength and in narrow beams that are virtually parallel and do not spread out. A laser can concentrate light so powerfully as to produce incredible concentrations of energy, which is why some laser beams can slice through solid materials such as steel. These abilities could lead to novel light sources in the next century.

We can also foresee self or heat excited phosphors which can be used to make whole areas fluoresce. A touch of a switch, for example, and a complete ceiling may light up, or a wall.

Light emitting diodes – like transistors but emitting light – are already in use as indicator lamps, but at the moment cannot radiate sufficient light for general purposes. But we shall see.

It is not enough to develop a new light source. The light we have must be used effectively and directed to where it will do most good. The design of fittings and





Above *Electroluminescent panels are thin plates using a layer of phosphor between thin conducting surfaces. Although of low brightness, they use little current and because they are in effect sheets of light – which can be masked where required – they are ideal for instrument panels on aircraft or as passenger warning signs.*

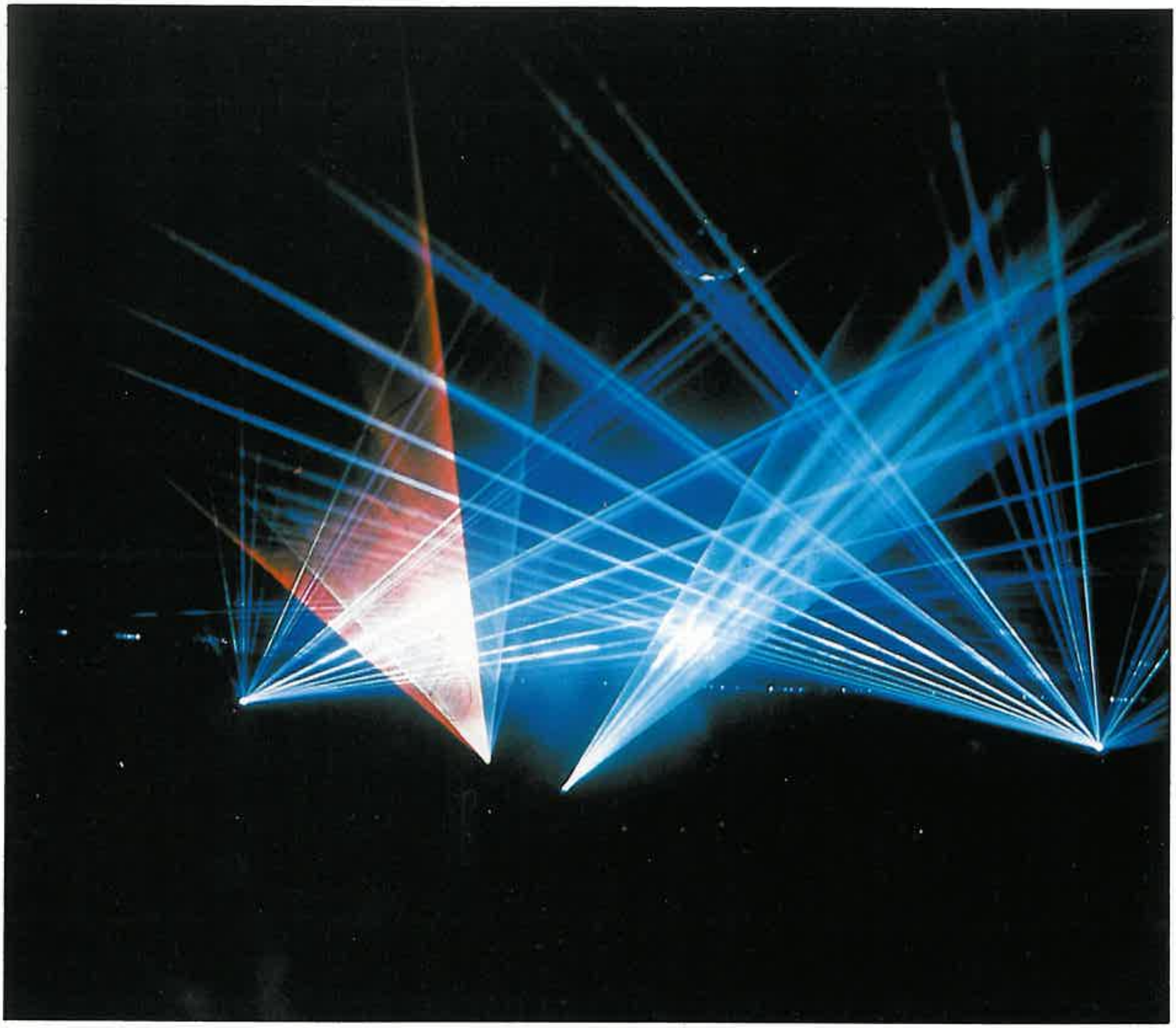
Right *Two developments stemming from electroluminescent panels are Image Retaining Panels and Image Storage Panels. They have the peculiar property of emitting light only when triggered by external radiation – such as light or X-rays – in addition to electric current and can therefore retain shadow images; like a photographic plate.*

The image storage panel shown is being used to give an instant X-ray of a parcel bomb.

complete lamp units, or luminaires, is something we can only touch on, but engineers are working patiently to improve them. Many office and factory lighting schemes rely on fluorescent tubes but the lamps, fittings and ceilings are designed together as complete integral systems aimed at providing comfortable working conditions. Some of these are heat recovery systems in which the heat produced by the lamps, instead of being wasted, is used to warm the air being introduced by the air conditioning. Another fifty years will see even more progress in the field of integrated environment control.

While there is always room for inspired innovators and inventors, most future progress will be made by the major lighting companies. Thorn invest £3 million a year in research and development alone, have built one of the most advanced lighting research laboratories in the world and have a large staff of skilled scientists able to take new discoveries and develop them. These, with the production engineers and the marketing specialists, are the people who will take lighting on – to 2000 AD and beyond.

Below *A laser light show.*



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.

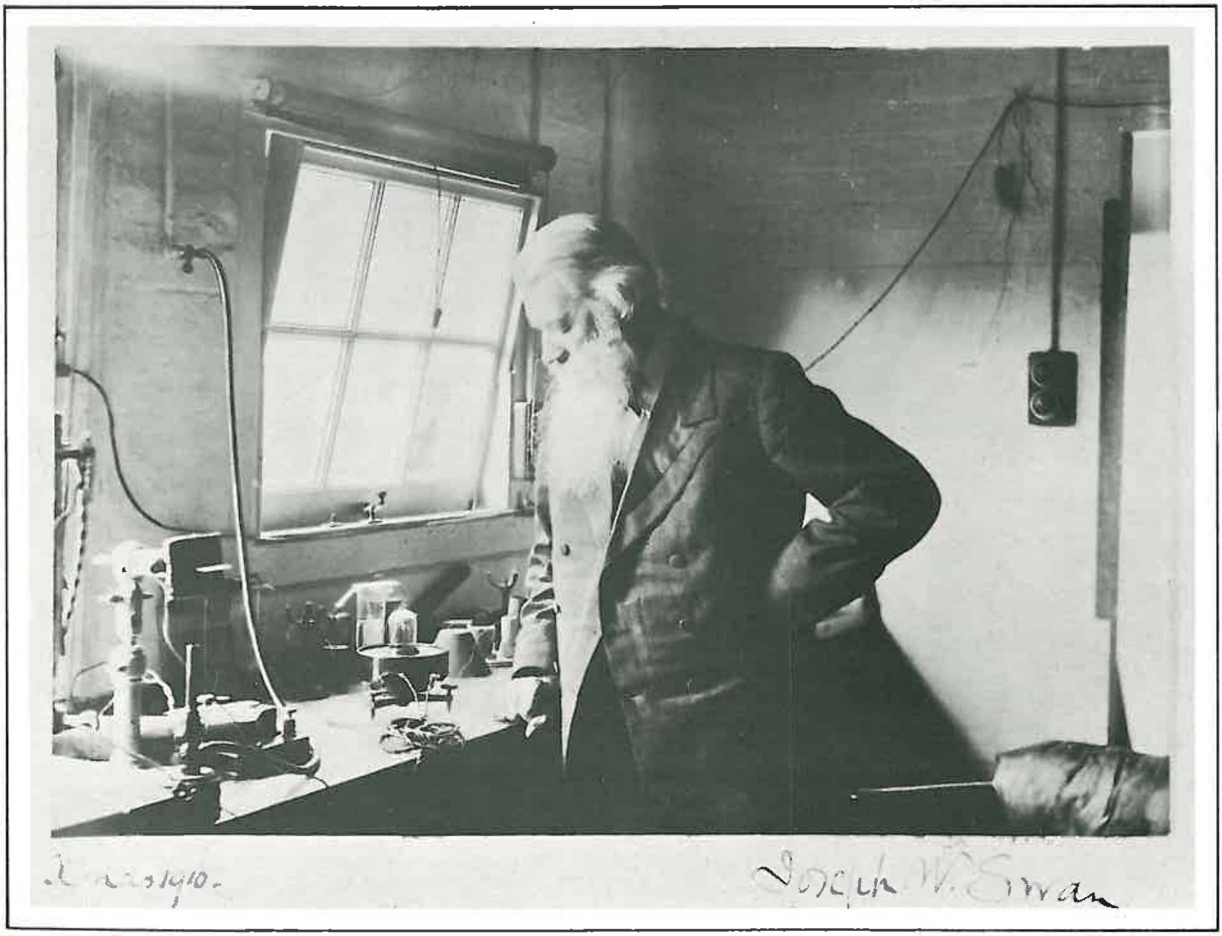
If only this were true! But the standards of quality now demanded of light bulbs have reached their zenith. Life can only be extended by greatly lowering the efficiency of the lamp; and the ratio between life and brightness is the one big enigma facing all lamp engineers. With something like a flashbulb,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

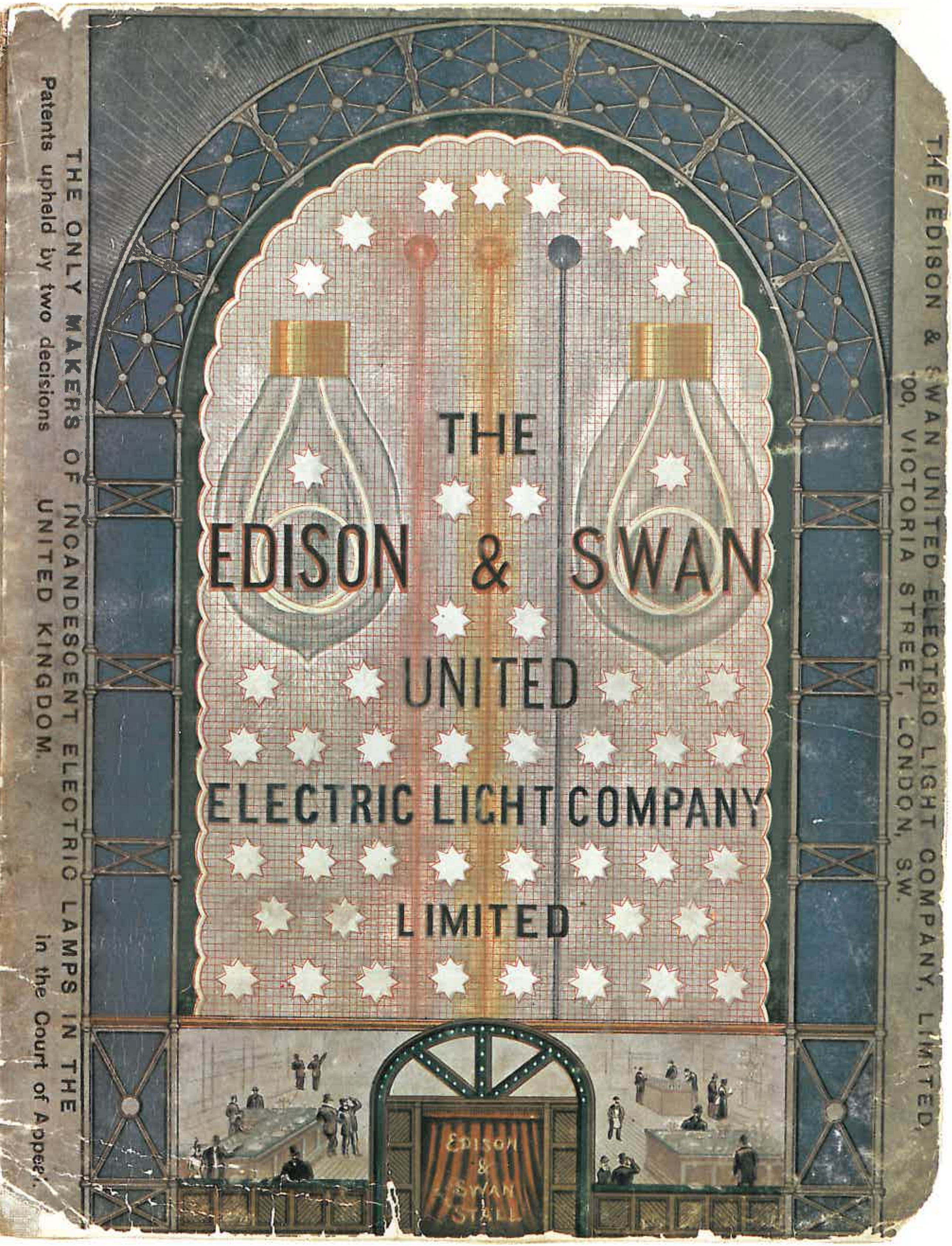
At one time Swan would have given a fortune if he could have been shown how to make an electric lamp give well over 1000 lumens of light and last 2000 hours.

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.**

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