Electric Lighting History

Many teams and individuals have been involved with electric lighting technology during the past 120 years. Their collective efforts turned the marvel of electric lighting into a mundane part of our technical infrastructure–and in the process changed the way we live. This section (to be expanded in future updates) presents some details of the history they have shaped.

Advertising: Ink Blotters

Light bulb makers have tried many methods of advertising their products. A common technique involved giving consumers (or retailers) a low-cost, useful item imprinted with an advertisement. In 1998 General Electric donated to the museum an archival collection that included an assortment of 38 ink blotters dating from early in the 20th century. Made of cardboard and measuring about 15.25 x 7.5 cm (6 x 3 inches), these blotters could be printed with the name of the participating store or electric utility.

Eighteen of the blotters are presented below. Click on any of the images for an enlarged view and additional information about that blotter. The General Electric Nela Park material is collection number 0789 in the museum's Archives Center. Researchers may view this material by making an appointment with the Archives Center.

All blotters images are reproduced through the courtesy of General Electric Lighting Co

Blotter number 112; image number: LAR_B112

In 1904, General Electric began advertising a new carbon-filament lamp (the GEM lamp) as more energy efficient than older designs. Five short years later, GE salespeople needed something to help them sell a newer, metal-filament lamp of even higher efficiency. They invented a trade-name, Mazda, taken from the Persian (Zoroastrian) god of light, Ahura Mazdah. The Mazda name first appeared in 1909 on tantalum-filament lamps, and then on first generation tungsten lamps made under license from Europe. GE also licensed the name to their subsidiary National Electric Lamp Companies, to Westinghouse and to British Thomson-Houston.

In 1910, William Coolidge at GE's research lab in Schenectady, New York, developed a way of drawing tungsten into a fine wire. GE quickly stopped making European-style tungsten lamps and switched to Coolidge's design. That lamp, the second generation tungsten lamp, became known in the trade as the "Mazda B." The earlier, European lamps were informally considered "Mazda A" lamps. GE continued using the Mazda name until 1949, when it was dropped during the settlement of an antitrust suit against the company.

However, the company maintains rights to the trademark to this day. The only other Mazda product in the U.S. is the Mazda automobile–named for the Zoroastrian god and also for company founder, Jujiro Matsuda.

The Sun's Rival logo became the visual centerpiece of this early ad campaign, appearing on everything from lamp packages to billboards. It sought to convey the message of a brighter, whiter light than that produced by older carbon-filament lamps. While the logo eventually was eventually dropped, comparing the output of a lamp to daylight remains common in lamp advertising.

Blotter number 109-7; image number: LAR_B1097.

Here the Sun's Rival logo begins to recede and complements the image of a young Thomas Edison deep in thought over his newly invented carbon lamp.

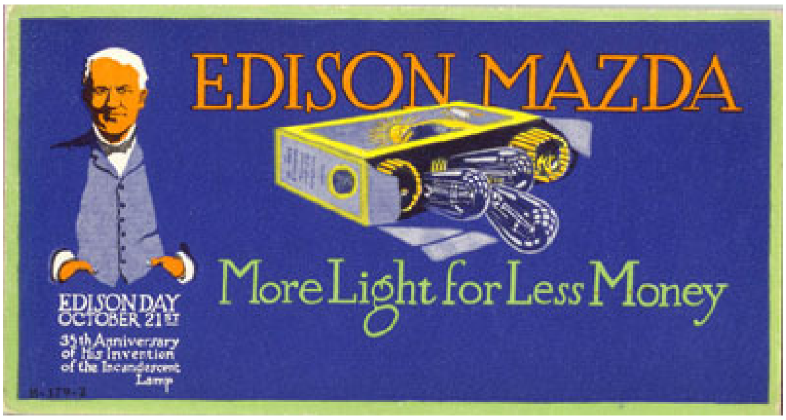
This idea of Edison, alone in his genius, recurs often in advertising of this era. The role of "Wizard of Menlo Park" helped Edison raise money for his work and sell the resulting products. This was one reason for establishing the myth of Edison as a lone inventor, even though he had the assistance of many able people. Though Edison all but abandoned work on electric lighting after the early 1890s, GE sold "Edison Mazda" lamps until after his death in 1931.

The "dream" refers to Edison's idea of creating a simple and inexpensive source of light. Edison had declared in 1882 at the opening of the Pearl Street Station that "I have accomplished all I promised," with his carbon lamp and central power plant to energize it. This blotter implies, however, that the realization of his work waited on the development of the second generation tungsten lamp.

Blotter number 214; image number: LAR_B214. This blotter from the mid-1920s shows the continued reduction in size of the Sun's Rival logo. The familiar General Electric script logo became equal in size to the older trademark. Light bulbs had become familiar devices by this time and the original comparison to the Sun lost appeal for a new generation of consumers. The sales-pitch changed focus from light to the research that lay behind improvements to the lamp.

GE shifted the target of the advertising from defeated competitors such as gas lighting companies to active competitors–independent lamp makers. GE could point to its strong innovative tradition. Here Edison is flanked by two laboratory scientists and linked to Benjamin Franklin. The figure reflected in the light bulb may be Irving Langmuir, who received a Nobel Prize for work done in the GE Laboratory. The identity of the other figure is less certain. Such a lineup conveyed a powerful message to a generation committed to the idea of social progress through technical advancement. And that message of "Progress" is explicit in the text of the blotter.

Notice also the portrayal of Edison as an older man rather than the young inventor seen earlier. His carbon lamp no longer represented the forefront of modern technology and he himself had moved on to other inventions. Edison's status as an American icon carried weight, however, and GE made this pitch using his name and his fame.



Blotter number 179-2; image number: LAR_B1792.

The mythology surrounding Thomas Edison's lamp invention focuses on 21 October 1879 as the day of the invention. However, work by historians Robert Friedel and Paul Israel sheds new light on events at Menlo Park. Laboratory notebooks record an on-going series of experiments during this time and, "October 21, ..., came to an end without the dramatic success that subsequent accounts of the electric light's invention attributed to it."

The following day Edison coworker Charles Batchelor recorded, "We made some very interesting experiments on straight carbons made from cotton thread." One of these experiments tested a lamp containing a simple length of carbonized sewing thread (lamp number 9 in a group of 11) that burned for fourteen and one-half, not forty, hours. This experiment told Edison and his team that they were close to the answer, and served to focus their research. In early December they began to feel confident that they had achieved their goal.

Public relations needed something more dramatic though, and using October 21 to celebrate Edison anniversaries quickly became commonplace. The 35th anniversary noted on the above blotter occurred in 1914 and was used both as a promotional opportunity and an opportunity to honor Edison himself. Special commemorative lamps were sold, "Edison Day" parades were held and retrospective articles appeared in newspapers and magazines.

Perhaps the largest such series of celebrations occurred in 1929 for the 50th anniversary, known as "Light's Golden Jubilee." Many realized it might be Edison's last major anniversary (indeed, he died two years later) so a national celebration was organized. Events included the lighting of specially-made 50,000 watt light bulbs and the opening of the reconstructed Menlo Park lab on the grounds of Henry Ford's Greenfield Village in Dearborn, Michigan.

Blotter number 172; image number: LAR_B172

"Have you electricity in your house?"

also on sign next to door:
"For sale or to rent. Inquire within."

The decision whether or not to adopt electric lighting in a given building often hinged on the expense of installing wires. Nineteenth century construction techniques made adding this new infrastructure difficult and expensive. Thus the very important question posed by the prospective home buyer in the above blotter. The advertising strategy was to make home owners consider the value electrification added to their property.

In homes, wires tended to be installed on the surfaces of walls and ceilings. Sometimes these would be concealed inside wooden moldings, but often they would be tacked up with wooden or porcelain cleats. Though the wires were insulated they could be damaged easily, resulting in a fire.

Occasionally, installers took a short-cut and ran wires through the pipes that supplied fuel to gaslight fixtures. This had the extra advantage of allowing the customer to have a combination fixture that could use either gas or electricity, electric service being erratic in the early years. Modern electricians still find these very dangerous installations in older buildings from time to time.

A typical room, especially in rental properties, had only a single lamp socket installed. As wall outlets were not developed until the years around 1910, early appliance cords came with screw-in plugs. The user either removed the light bulb and powered the appliance from the light fixture, or installed an adapter that allowed both lamp and appliance to be used at once.

Fires caused by inadequate wiring led to the establishment of Underwriters Laboratories in 1894 and the adoption of the first National Electric Code three years later.

The handwritten notation "59500 / 200M" on this blotter is a counting mark, not a museum marking. Apparently 200,000 blotters of this type were ordered. As the blotters were packed for shipment, this blotter happened to be on top of one stack and became number 59,500 in the print-run.

Blotter number 213; image number: LAR_B213.

Electric lighting involves more than just a light bulb. Thomas Edison, George Westinghouse and their contemporaries sold systems, not just lamps, and these systems were not necessarily compatible. Edison developed a direct current (DC) system that operated at 120 volts. Westinghouse pushed an alternating current (AC) system. Thomson-Houston Company sold both AC and DC, but their incandescent lamps operated at 52 volts. Each of these systems' lamps had different bases and would not physically fit into the others' sockets. Though all were quick to design adapters.

More importantly, considerable research went into the generation and transmission technologies that supported each system. Companies like General Electric and Westinghouse that offered a complete line of electrical products could call attention to that work in their lamp advertising. This blotter for Edison Mazda lamps shows, among other things, a hydroelectric plant, transmission lines, an electric locomotive and a laboratory researcher. The sales-pitch implies that this lamp benefits in quality due to the many resources available to GE, resources that smaller competitors with limited product lines lacked.

Notice that the Sun's Rival logo has shrunk and moved behind the lamp, while the GE script logo appears over the horizon in the manner of the Sun in the older ads. Edison's name still appears (three times) but his face is nowhere to be seen.

Blotter number 178; image number: LAR_B178

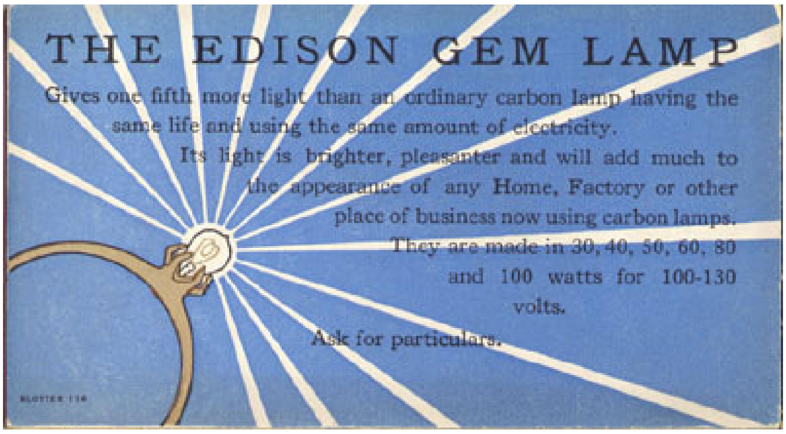
"My doctor said,
'Don't read in bed.
You'll waste the night,
and spoil your sight.'
But he's not quite
So recondite, —
For the light just right
Is Electric Light,
With the EDISON MAZDA lamp."

The convenience and (eventually) the economy of electric light led to far-reaching changes in American homes. People gained more control over their time and over the use of interior spaces. Rather than sleeping, one could stay awake and "waste the night" by reading in bed, as in this blotter for Edison Mazda lamps. Though some modern researchers studying sleep-deprivation might argue that the gentleman's doctor gave good advice.

Electricity solved some problems of lighting a bedroom and also raised a few concerns. Light sources that used an open flame such as candles and gas lamps were a fire hazard. No-one needed to fumble with matches to light an electric lamp in the middle of the night. Electric lamp makers printed lists of deaths attributed to gas light (often, it was suggested, due to the victim's failure to turn off the gas valve after blowing out the flame) in their advertising.

The new technology made some people nervous. Unused to electricity, they wondered about the safety of sleeping in an electrified room. Salespeople reported receiving questions asking if the electricity could leak out like gas. If one went to sleep with the lights on, would the room catch fire? Hotel owners were especially concerned in the late 19th century about operational safety issues for guests using electric lights for the first time.

The handwritten notation "13500 / 100M" on this blotter is a counting mark, not a museum marking. Apparently 100,000 blotters of this type were ordered. As the blotters were packed for shipment, this blotter happened to be on top of one stack and became number 13,500 in the print-run.



Blotter number 116; image number: LAR_B116.

"The Edison GEM Lamp. Gives one fifth more light than an ordinary carbon lamp having the same life and using the same amount of electricity. Its light is brighter, pleasanter and will add much to the appearance of any Home, Factory or other place of business now using carbon lamps. They are made in 30, 40, 50, 60, 80, and 100 watts for 100-130 volts. Ask for particulars."

GEM stood for General Electric Metallized, a type of carbon lamp introduced in 1904 and designed for greater energy efficiency than older carbon lamps. High energy costs in Europe spurred development there of an array of lamp designs intended to exceed the common carbon lamp's average of 3.2 lumens per watt (lpw). Trade agreements and lower energy prices gave less incentive to American producers to follow suit. But pressure to offer a more efficient lamp began to mount after Carl Auer von Welsbach's 1898 invention of a metal-filament (osmium) lamp which gave 5.5 lpw.

GE's Willis Whitney answered by baking a standard cellulose filament at high temperature using the newly invented electric-resistance furnace. This gave the filament metal-like properties (hence "metallized"). The resulting lamp operated at 4 lpw and became the most efficient carbon lamp ever made. The company designed the GEM lamp to make the most of their existing production facilities–the new lamp appeared almost identical to the regular carbon lamp it was intended to replace. So GE focused their advertising effort on the higher efficiency, and soon regretted the decision.

Consumers became confused when GE and others began marketing even more efficient tantalum and tungsten lamps just a few years later, forcing the company to revamp their advertising by creating the Mazda trade-name. However, many consumers continued to buy "efficient" GEM lamps, which were cheaper than metal filament lamps. Only during World War One could lamp makers finally stop mass-production of GEM lamps–in the name of materials rationing–without upsetting consumers. The range of wattages available (in all lamp types) was also "rationalized" during the war, resulting in today's common ratings of 40, 60, 75 and 100 watts.

Even today the GEM lamp creates confusion, though now among lamp collectors. It is very difficult to distinguish GEM lamps from the regular carbon lamps that many manufacturers continued to produce.

Blotter number 150; image number: LAR_B150.

"These three new lamps use no more current than one old one. For the same money that you now pay for current for the old-style carbon lamp, you can now have your choice of:
3-times as much light in each room–or
3-times as many rooms lighted–or
3-times as many hours of light
if, instead of the carbon lamp you use
Edison Mazda Lamps"

"Do you know the difference between the Edison Mazda Lamp and the old-style carbon lamp? Look at the pictures. Note the difference in the internal construction of the two kinds of lamps. Then look at your lamp. Which kind are you using? Call on us at any time and we will gladly show you the various sizes of Edison Mazda Lamps."

How does a company go about unselling a product after thirty years of marketing, especially if people are happy with that product? General Electric and other lamp makers found themselves faced with just that task in the years around 1910 as they introduced metal-filament lamps into the market.

The new lamps could operate at higher temperatures than older carbon lamps and so gave better energy efficiency (at higher tempertures more radiation is emitted as light and less as heat). Lamps made with tungsten produced about 12 lumens per watt compared to about 4 lpw for the best carbon lamps. The tungsten lamps were more expensive to buy however, and for many years people continued to purchase cheaper carbon lamps.

The blotter seen above shows GE emphasizing the advantages of higher efficiency by focusing on the cost of current. Sellers of compact fluorescent lamps today have a very similar problem and follow much the same strategy.

Blotter number 220; image number: LAR_B220.

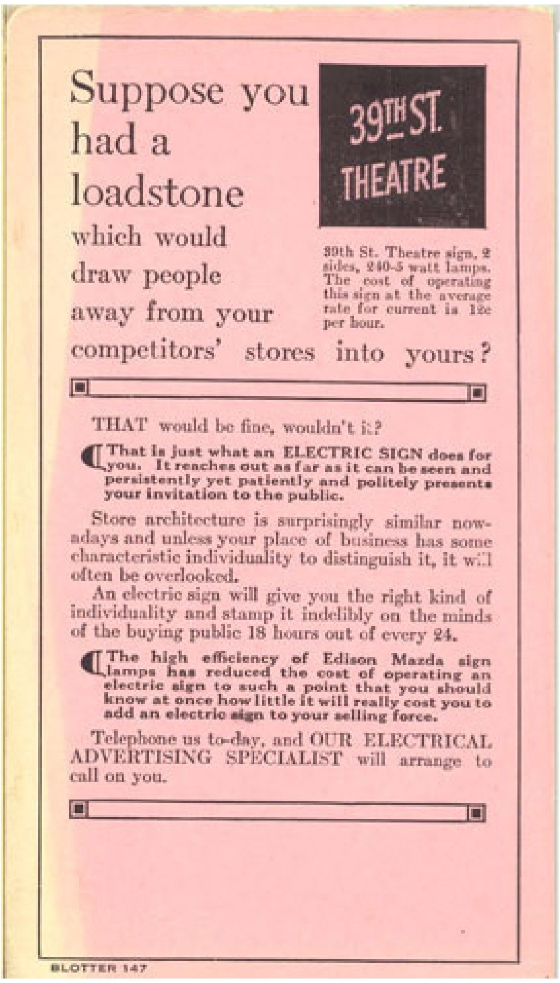
"A Lamp In Reserve. The best night lighting insurance is an Edison Mazda chest."

Also:
"The Philadelphia Electric Company Supply Dept. 132 South Eleventh Street, Philadelphia."

At the same time Americans began adopting electric lights, they also began adopting a new form of transportation–the automobile. Automotive lighting did not immediately benefit from electric lamps however. Early carbon filaments were too brittle to withstand severe shock and vibration. They were also quite dim and difficult to make to exact electrical and optical specifications. So early cars used oil or acetylene lamps.

The development of lamps with ductile tungsten filaments in the years around 1910 changed the situation. Tungsten filaments could be made small and bright, and they proved tougher than carbon. Placed at the focal point of a parabolic reflector (as in the headlight of the car in this blotter), a small tungsten lamp could throw a beam bright enough to be useful. And unlike oil or acetylene units, electric lamps did not need refueling.

They did need to be replaced occasionally though. The chest referred to in this blotter was a convenience package containing a variety of replacement lamps for headlights, tail lights and panel lights, all the spare bulbs a motorist might need. Early automotive lamps did not last as long as today's sealed beam or halogen lamps, and since streets were generally lighted only in urban areas drivers were encouraged to carry spare lamps just as they carried spare tires. Notice that an electrical company rather than an auto parts supplier sent out this blotter.



Blotter number 147; image number: LAR_B147.

"Suppose you had a loadstone which would draw people away from your competitors' stores into yours. That would be fine, wouldn't it?"

"That is just what an Electric Sign does for you. It reaches out as far as it can be seen and persistently yet patiently and politely presents your invitation to the public."

"Store architecture is surprisingly similar nowadays and unless your place of business has some characteristic individuality to distinguish it, it will often be overlooked. An electric sign will give you the right kind of individuality and stamp it indelibly on the minds of the buying public 18 hours out of every 24."

"The high efficiency of Edison Mazda sign lamps has reduced the cost of operating an electric sign to such a point that you should know at once how little it will really cost you to add an electric sign to your selling force."

"Telephone us today and our Electrical Advertising Specialist will arrange to call on you."

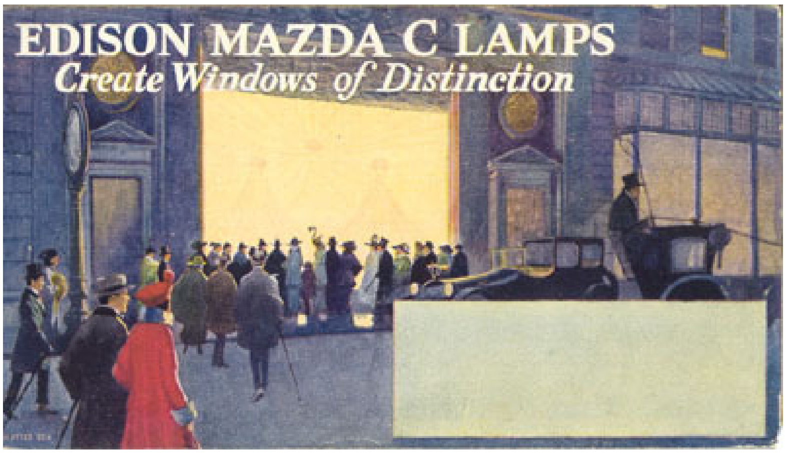
Also, caption under theater sign reads:
"39th St. Theater sign, 2-sides, 240-5 watt lamps. The cost of operating this sign at the average rate for current is 12¢ per hour."

is an instance of advertising aimed at business, rather than residential, lighting customers. Note the heavy use of text with only one small, bland image. The impression given is that a business customer would more likely respond to rational arguments and not emotional impulses.

In this instance we witness the need to actively sell electric signage, devices taken for granted today. Electric signs were a significant investment and business-people needed to be convinced that they worked. The cost of operating the sign is given for comparison with other advertising costs, and so anyone interested could estimate a budget.

Note also the comment about influencing "the minds of the buying public 18 hours out of every 24." Few businesses in this era planned on operating their signs 24 hours a day. "Sign lamps" refers to a type of incandescent lamp made especially for use in electric signs. Neon signs were developed in the 1910s and provided strong competition to incandescent signs.

The discolored strip along the blotter's left side appears on the actual blotter and may be fading due to light, or water damage.



Blotter number 224; image number: LAR_B224.

"Edison Mazda C Lamps Create Windows of Distinction."

Mazda trade-name first appeared in 1909 on tantalum filament lamps and on first generation tungsten lamps (so-called "non-ductile tungsten" lamps). General Electric built on William Cooledge's research into the metallurgy of tungsten to create a second generation tungsten lamp that became known as the "Mazda B" lamp. Irving Langmuir, also at GE, discovered that coiling the tungsten filament and putting nitrogen gas into the lamp resulted in higher energy efficiency. In 1913 GE introduced a third generation tungsten lamp based on Langmuir's design: the "Mazda C."

At first, Mazda C lamps were offered only in higher power ratings than Mazda B units, and so found use in large area lighting. Their ability to produce brighter light also made them popular for use in store windows, as seen in the above blotter. In an age before television, display windows offered an especially important opportunity for merchants to reach out to customers visually. Main Street merchants were usually quick to adopt electric lighting and to upgrade their installations with new, brighter lamps.

Blotter number 3904; image number: LAR_B3904

"If you can get better light and save more than half the current isn't it worth while to buy the new lamp and make a big saving on your bills?"

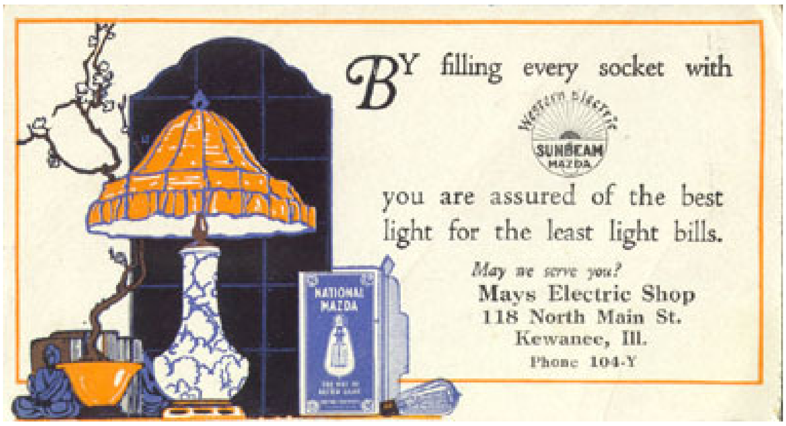
"The G.E. Mazda Lamp has an improved tungsten filament which turns more electricity into light and is, therefore, more economical than old style lamps. We can supply it at a price which will enable you to make an important saving in the cost of your lighting."

Also stamped on bottom:
"General Electric Company
Schenectady, N. Y.
Main Lamp Sales Offices
Harrison, N. J."

Lamps featuring substantial technology improvements typically cost more when first offered for sale. High-priced general purpose lamps pose a challenge for salespeople: how to convince buyers to spend the extra money when the improvement may not be obvious. Sellers of compact fluorescent lamps (CFLs) today face this problem with consumers accustomed to inexpensive incandescent lamps.

This same problem existed nearly a century ago as tungsten-filament lamps were introduced to consumers used to buying less-expensive carbon-filament lamps. Then, as now, salespeople tried to make their customers think in terms of long-term or "life-cycle" costs rather than the initial, upfront costs. This is the approach seen in the blotter above.

The salesman is literally pointing out the features of the new lamp to his customer, while the caption explains (quite truthfully) that these lamps are more economical than the old. The economy stemmed for the higher energy efficiency of tungsten over carbon filaments. "Better light" in this context meant brighter light.



Blotter: unnumbered; image number: LAR_BB2.

"By filling every socket with Western Electric Sunbeam Mazda you are assured of the best light for the least light bills."

also:
"May we serve you?
Mays Electric Shop
118 North Main St.
Kewanee, Ill.
Phone 104-Y"

Note that package is marked: "National Mazda"

The elaborate licensing agreements covering use of General Electric's lamp patents included permission to use the Mazda tradename. Companies that took licenses included Westinghouse (the only "Class A" licensee), British Thomson-Houston (controlled by GE), and the member firms of the National Electric Lamp Company. Product markings reflected that arrangement: "Edison Mazda" (used by GE until Thomas Edison's death), "Westinghouse Mazda" and "National Mazda" as seen on the blotter above.

The National companies were originally independent lamp makers who banded together in 1901, pooling resources to more effectively compete against GE. They built on a similar group called the Incandescent Lamp Manufacturers Association, formed in 1897 with the cooperation of GE. The National companies gained access to GE patents, and GE gained a measure of control over the competition. In 1911, antitrust proceedings revealed that GE owned 75% of the National stock and as part of a consent decree the National companies were absorbed into the larger company.

Sunbeam Incandescent Lamp Company of Chicago, founded in 1889, was one of the National companies. Other participating companies included: Bryan-Marsh, Buckeye Electric, Columbia Incandescent Lamp, Fostoria Incandescent Lamp, Fostoria Bulb and Bottle, General Incandescent Lamp, and about thirty others. Western Electric, the maker of telephone and other electrical equipment for the Bell System, was not a National member but rather a distributor of lamps made by Sunbeam.

As for Mays Electric Shop, the company that originally gave away this ink blotter nearly a century ago, it was established in the early 1920s by James R. May. In 1906, at age 17, May began working for Northern Illinois Light and Power. After a few years there, he started Mays Electric as an electrical contractor, but moved the business to his home during the Great Depression. His son Lester May started a wholesale electrical business (Electrical Supply Company) in 1937, "in the same home / garage as his father."* They moved the combined businesses to the present location two years later, just a few blocks away from the original Main Street location.

Today, James' grandson Thomas May continues to operate Mays Electrical & Communications Services, though he notes that, "now communications represents the majority of our business."*

Blotter number 3837; image number: LAR_B3837.

"It's a pleasure to turn on the light when you use G. E. Tungsten Lamps. They take 1/3 the current required by ordinary incandescent lamps, and the quality of light is unsurpassed."

Also stamped on the bottom:
"General Electric Company
Main Lamp Sales Offices
Harrison, N. J."

and:
"F. A. Holaday"

Newly-invented tungsten-filament incandescent lamps were more expensive than existing carbon-filament designs. To persuade a consumer to spend the extra money this ad's text invokes economy of use, but then shifts to selling the end-product, light–an appeal reinforced visually by the image. The lamps themselves are not seen; they are in the Tiffany fixture being operated by the well-dressed model. The vase of roses and the open book on the table enhances the upscale image. Another blotter in the collection (not shown) has the model seated at the table reading the book.

The reference to Harrison, N.J. recalls an early period in GE's operations. Thomas Edison initially produced light bulbs at Menlo Park. But demand soon outstripped the limited resources there, so in 1882 he built a manufacturing plant in nearby East Newark. Ten years later the merger of Edison Electric and Thomson-Houston that formed General Electric created a duplication within the new company. One lamp factory–either the Harrison Lamp Works, or Thomson-Houston's plant in Lynn, Massachusetts–had to go.

Company officials decided to put the plants in direct competition to decide their fate. Each plant produced fifty lamps which then were tested. The Edison lamps from Harrison were declared superior to the Thomson-Houston lamps from Lynn. Harrison kept the lamp works and GE consolidated manufacture of lightweight electrical equipment at Lynn.

Harrison's victory proved temporary as GE's lighting business continued to grow and the company assimilated it's National Lamp subsidiaries. From 1925 through 1930 the various departments at Harrison moved to GE's newly completed Nela Park campus in Cleveland, Ohio. The Sales Department was one of the last to move.

Blotter: unnumbered; image number: LAR_BB1.

"Be sure to protect your eyes with good light. Edison Mazda lamps. General Electric."

is "good light?" The question of proper light levels has been debated for over a century and continues to generate heated discussions. The debate often boils down to one issue: is brighter better? The answer seems to be: it depends.

The first users of electric light were accustomed to oil lamps and candles. Some urban residents used gas lighting wherein a typical gas jet produced about 16 candlepower. Thomas Edison deliberately designed his new incandescent lamps to give 16 candles so as to directly compete against gas, and this rating became a standard for many years.

Sixteen candles roughly equates to the output of a modern 25-watt lamp. Lamp makers throughout much of the twentieth century pushed consumers to buy higher output lamps, arguing that low levels of light created eyestrain as users struggled to read or perform other tasks. Notice the child's drawing in this late 1920s blotter carrying the caption, "I like lots of light." And indeed, objective studies indicated that both productivity and safety increased with higher light levels in the home and workplace.

By the 1970s "blankets of light" were commonly designed into buildings as discharge lamps with ever higher output became available; the "brighter is better" mantra reached a peak. However, soaring energy costs in that decade sparked a reevaluation of this policy as some engineers, designers and users began asking, how much light is enough?

Research on this question continues in both corporate and academic laboratories. Human eyesight changes as we age, and current research indicates that an "adequate" light level for seniors can be up to seven times higher than that considered "adequate" by young people. Cultural factors can also play a role. For example, one designer with offices in both countries noticed that light levels in France were generally lower than in the U.S.

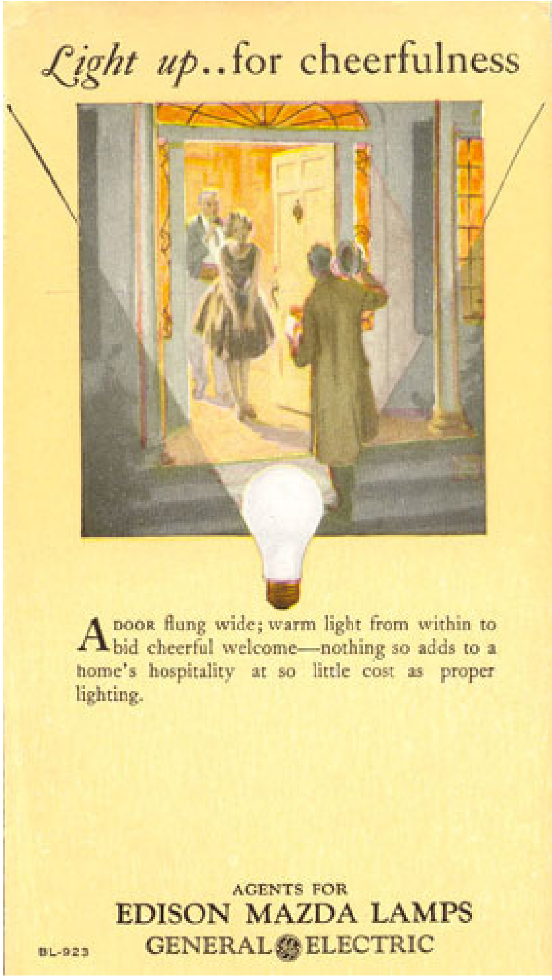
One result of the reevaluation is the growing design emphasis on "task lighting." This refers to a practice of putting higher levels of light where needed, such as a desktop, and less light in other areas.

Blotter number 153; image number: LAR_B153.

"Edison Mazda Lamps."

During the 1920s many artists, including Maxfield Parrish and Norman Rockwell, painted images for use in General Electric advertising. Artwork contracted by the company adorned calendars, matchbooks and the backs of playing cards–and ink blotters. Unfortunately, we do not know who painted this colorful Flamenco dancer. Experts who have seen this image doubt it is the work of either Parrish or Rockwell; viewers suggestions can be e-mailed to Lighting A Revolution.

This blotter has no text other than the brief title–no sales pitch, no description of product, just images. The dancer catches the eye, while two light bulb silhouettes and the unusual winged GE logo reinforce the title. The space at the bottom (as seen on many of the blotters) is left for the local lamp seller's imprint.



Blotter number 923; image number: LAR_B923.

"Light up .. for cheerfulness. A door flung wide; warm light from within to bid cheerful welcome—nothing so adds to a home's hospitality at do little cost as proper lighting."

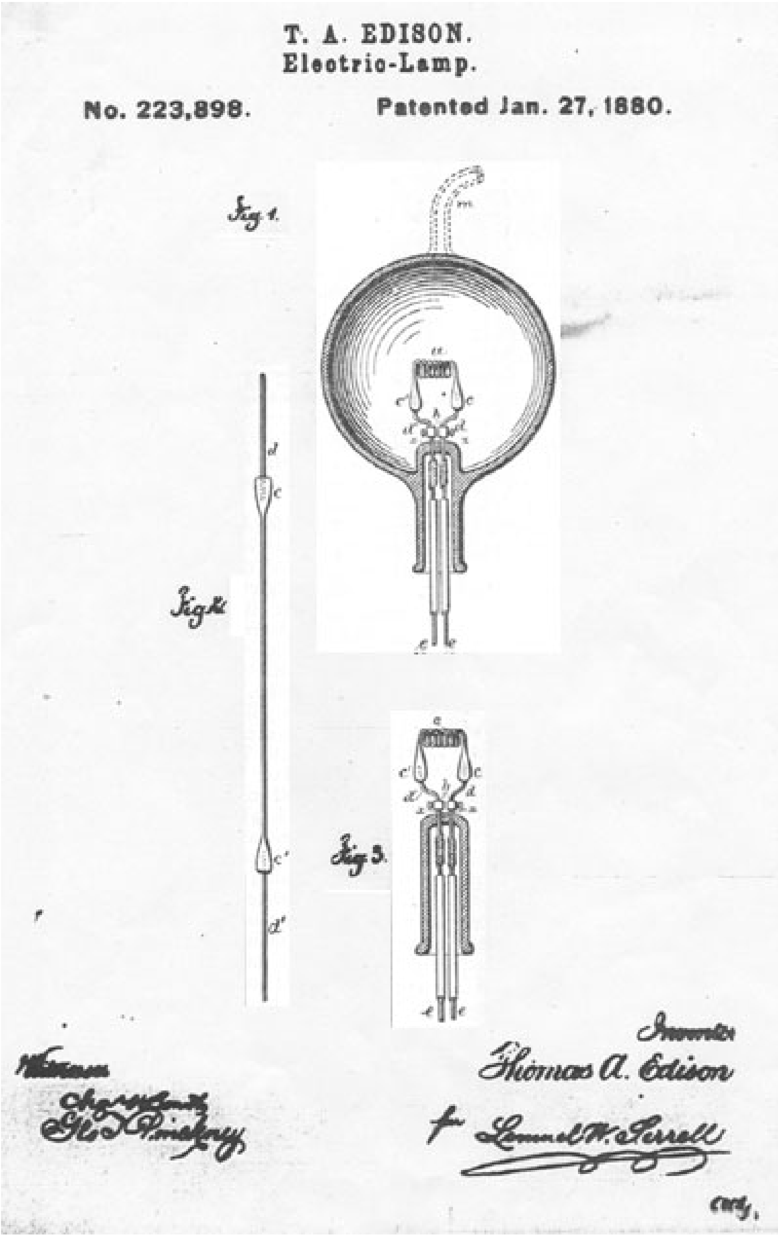
... and at bottom:
"Agents for Edison Mazda Lamps, General Electric"

People attached great symbolic meaning to light long before the invention of electric lamps. This has been especially true in portraying domestic scenes: the romance of a candlelight dinner, the shared closeness of family and friends gathered around a fireplace hearth. Or, as seen in this blotter, the "cheerful welcome" conveyed by a "warm light from within." Whether used in art or advertising, lighting can evoke strong feelings of home.

This blotter dates from the late 1920s or very early 1930s. The modern shape of the bulb shown (known in the industry as the "A-shape") came into use around 1925, and GE phased out the use of Edison's name after the inventor's death in

1931. A push to raise light levels is seen in most companies' ads in this era. This push, combined with the effects of the Great Depression, culminated in an industry-wide sales campaign called "Better Light - Better Sight" beginning in 1933.

U.S. Patent 223,898
Thomas Edison's Incandescent Lamp



"To all whom it may concern: Be it known that I, Thomas Alva Edison, of Menlo Park, in the State of New Jersey, United States of America, have invented an improvement on Electric Lamps, and in the method of manufacturing the same, (Case No. 186,) of which the following is a specification. The object of this invention is to produce electric lamps giving light by incandescence, which lamps shall have high resistance, so as to allow of the practical subdivision of the electric light."

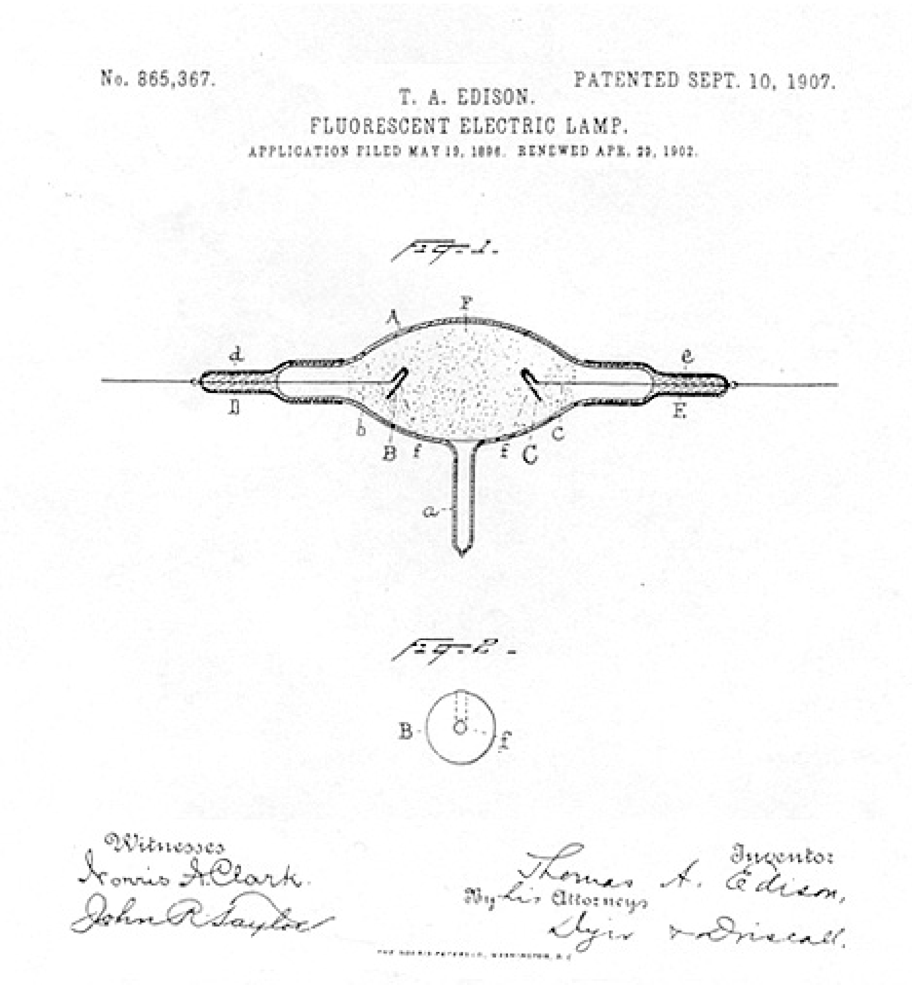
This opening paragraph from Edison's patent application formally presented his light bulb invention to both the U.S. government and the world. The application was filed on 4 November 1879 and the patent was quickly granted on 27 January 1880.

An interesting aspect of the above drawing is the coiled filament depicted in figures 1 and 3 ("a" on the drawing). Not only did Edison's patent drawing show spiral filaments but the application repeatedly referred to them. This rather small detail provides a glimpse into the pace of events at the Menlo Park lab.

Edison's laboratory notebooks indicate that significant experiments took place in October 1879 with many filament materials. As Edison noted in the patent, "I have carbonized and used cotton and linen thread, wood splints, papers coiled in various ways, also lamp black, plumbago, and carbon in various forms, mixed with tar and rolled out into wires of various lengths and diameters." Most of these materials could be coiled prior to baking. Having found measured success with carbon and knowing that other inventors were seeking to make a lamp, Edison wanted patent protection quickly. So he hurriedly filed an application based on the state of experiments in late October.

However, he departed from this experimental path even before the patent was granted. His demonstration lamps of late December used bristol-board filaments cut in a single arch, horse-shoe shape. The bamboo filaments used in commercial lamps from 1880 to 1893 also featured a single arch. Filaments with a tight spiral did not become common in commercial lamps until Irving Langmuir developed the gas-filled tungsten lamp in 1913.

U.S. Patent 865,367
Thomas Edison's Fluorescent Lamp



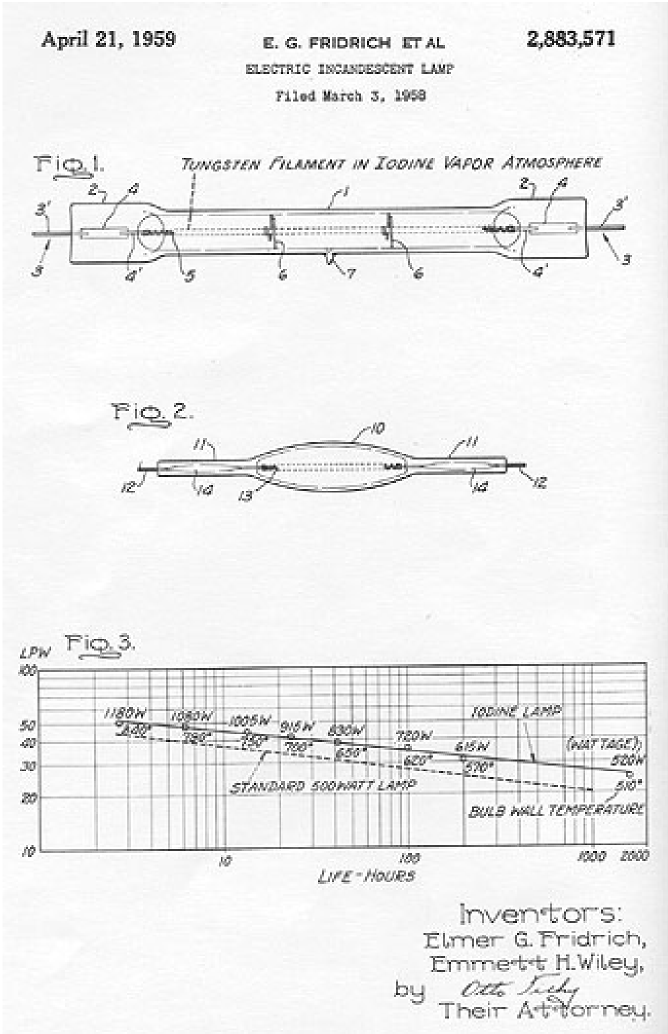
One of Thomas Edison's lesser known patents is this one, granted on 10 September 1907, for a fluorescent lamp. The application was initially filed on 19 May 1896 and renewed in 1902. There is no evidence that these lamps were ever offered for sale.

Which is probably just as well. Unlike fluorescent lamps common today, Edison's lamps did not use ultraviolet radiation from mercury vapor to excite the phosphor. His lamp used x-rays. In late 1895 Wilhelm Roentgen of Germany discovered this radiation, and a fascinated Edison immediately began experimenting with it.

By May of 1896, after a fast series of experiments, Edison had developed a medical fluoroscope. By placing a calcium tungstate coating on the outside of the fluoroscope's clear x-ray tube, he developed the lamp in figure 1 above. The two electrodes in the lamp are platinum discs, seen end-on in figure 2.

Edison did not experiment long with x-rays. The death of assistant Clarence Dally at the West Orange lab from an x-ray overdose, and the difficulty of making reliable x-ray tubes cooled Edison's fervor and he turned to other projects.

U.S. Patent 2,883,571
Elmer Fridrich and Emmett Wiley's
Tungsten Halogen Lamp



This patent, granted on 21 April 1959, is for the tungsten halogen lamp. The lamp in figure 1 (at top) shows what has become the typical configuration for these lamps. Figure 2, however, shows a low-voltage configuration that is less familiar. The low-voltage design played a role in a little known project in the early 1970s.

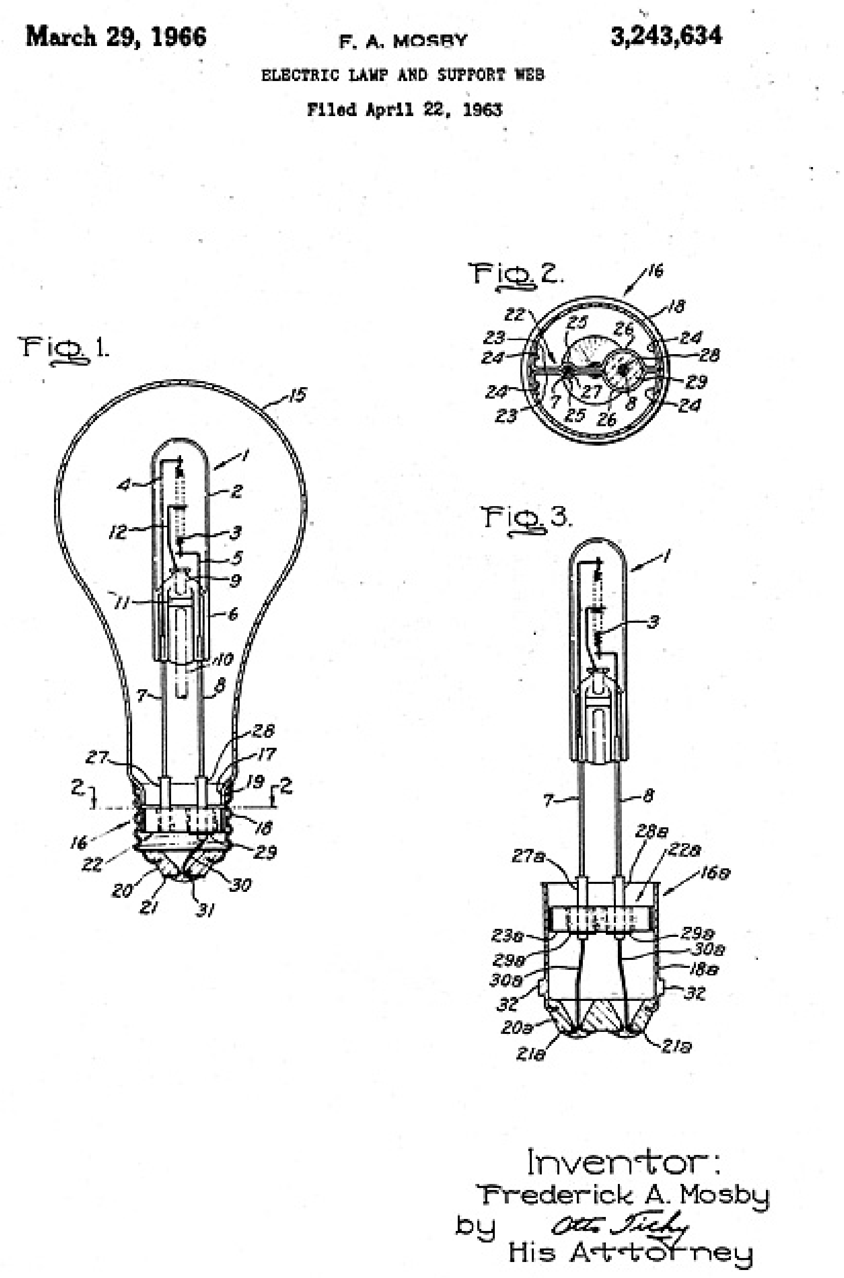
Around that time, lamp engineers at General Electric's Nela Park operation were looking for ways to more efficiently manufacture tungsten halogen lamps. Fridrich, one of the participating engineers in the project, became inspired to invent a new lamp he called "Gemini." His goal was to create a replacement for regular incandescent lamps.

Tungsten halogen lamps operate at higher pressures than regular lamps, and this creates a slight chance of an explosion. For this reason lamp makers have been very careful about tungsten halogen replacement lamps. (Today, these lamps often use thick, heavy glass envelopes that will not shatter in case of a problem.)

Fridrich's Gemini lamp avoided the problem by mounting two of the low-voltage capsules in electrical series inside a regular bulb. Since the lamps operated at low voltage, their internal pressures were reduced, lessening the chance of an explosive failure. The Gemini lamp was, however, not produced.

In 1996, Fridrich donated the original patent document to the National Museum of American History, along with other historical materials including a large collection of experimental lamps. A Gemini lamp mock-up, several experimental pieces, and some documents were part of the donation.

U.S. Patent 3,243,634
Frederick Mosby's Tungsten Halogen A-Lamp



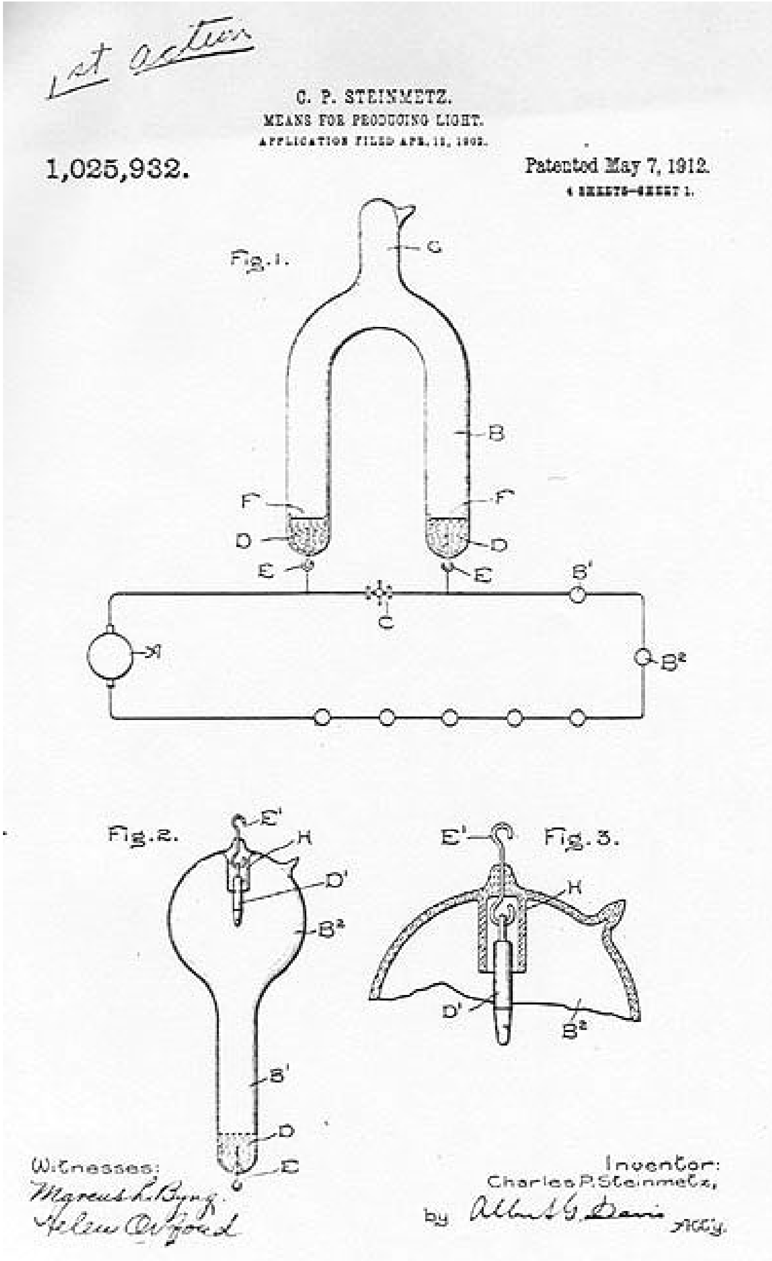
General Electric engineer Frederick Mosby developed this lamp not long after the invention of tungsten halogen lighting. Instead of a tubular lamp needing special fixtures, this lamp would replace a regular light bulb in any regular socket. In the lighting industry ordinary light bulbs are known as "A-Lamps" and an entire product line is an "A-Line."

Mosby described this patent in a 1996 interview, "When we were developing the [tungsten halogen] lamp, we could see was just millions and millions of lamps because that's what we sell in A-Lines. Certainly, I felt that if we ever got it to the point where we knew how to control things and make it, we would replace standard incandescent lamps with halogens.

"Some of our managers didn't agree with that, they felt it was a specialty lamp, and would never get into the high-volume markets. It was just our opinion against theirs, because you really don't know until you get the lamp out. We were wrong, management was right. Once they got to the point where they could shrink the fluorescent lamps, make them compact, then obviously that's the way to go rather than this."

Although GE elected to shelve the design at the time, events in the 1970s caused the company (and other lamp makers) to take a fresh look at tungsten halogen. Today, though they have not universally replaced regular light bulbs, lamps very similar to Mosby's design can be found in most hardware and grocery stores.

U.S. Patent 1,025,932
Charles Steinmetz's Metal Halide Lamp



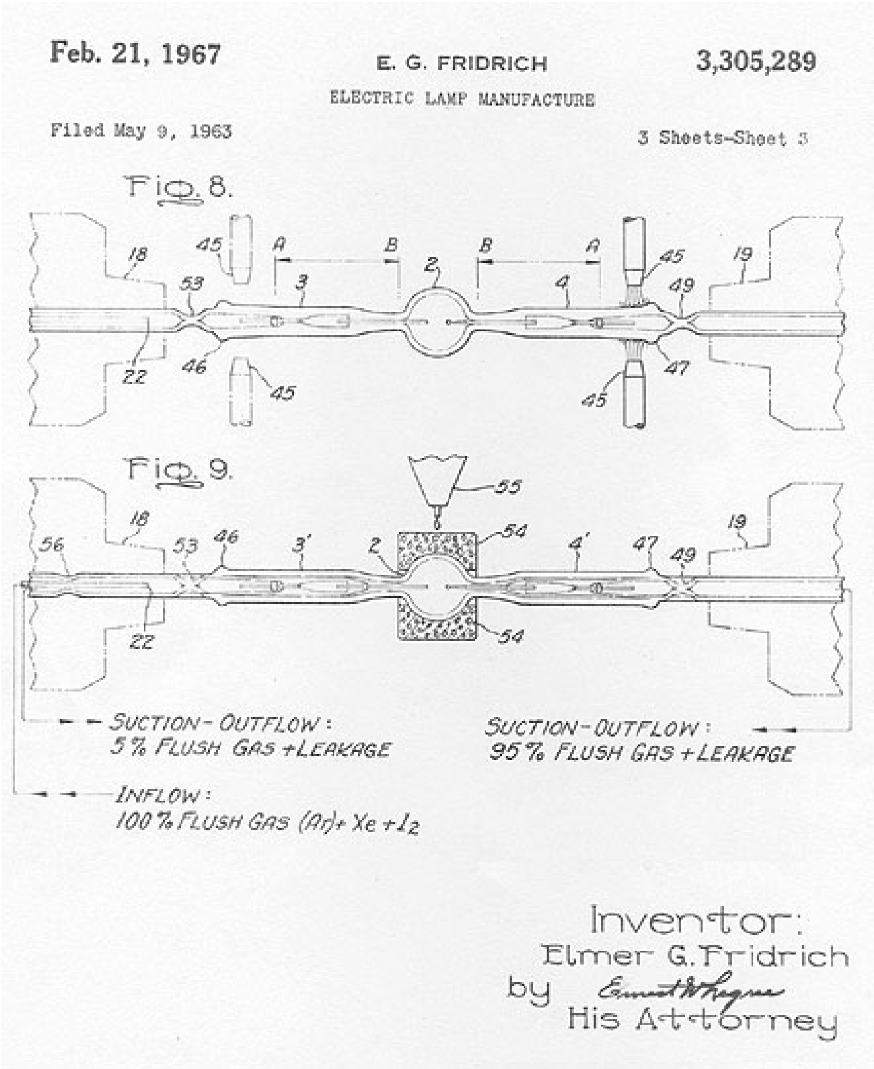
This patent, granted on 7 May 1912, shows an attempt by Charles Proteus Steinmetz to improve the color of mercury vapor lamps by adding halide salts. The lamp used mercury "pools" as electrodes (labeled "D" in Figure 1), with a layer of metallic halides on the surface of the pools. ("F" in the same figure). The problem with this design was that the electrical arc danced around on the surface of the pool, preventing a consistent color from being generated.

The handwritten notation "1st action" in the upper left corner is significant. In 1961 GE physicist Gilbert Reiling filed for a patent on what would become the modern metal halide lamp. This copy of Steinmetz's patent (among others) was sent to GE in 1962, along with the first of several rejections by the Patent Office examiner. According to the examiner, "To use the metal iodides of Beese and Steinmetz in the metal vapor lamp of Pomfrett would not involve invention."

GE replied that, "the combination [of these patents] is contrary to the teachings of either and hence is not a proper combination." In 1964, after a series of rejections, GE fabricated several lamps according to the specifications in Steinmetz's patent. They then sent both the replicas and Reiling himself to Washington, DC. Reiling demonstrated to the examiner that his lamp operated differently than Steinmetz's, and argued that the new lamp should receive a patent. Apparently the examiner was convinced, as U.S. patent 3,234,421 was granted in 1966.

In 1996, Reiling donated his original patent document, the copy of Steinmetz's patent seen above, and one of the Steinmetz replicas to the National Museum of American History. The replica is currently on display.

U.S. Patent 3,305,289
Elmer Fridrich's Machine for Making Short-arc Lamps



This patent, granted on 21 February 1967, shows a method of manufacturing short-arc discharge lamps.

Elmer Fridrich, co-inventor of the tungsten halogen lamp, began his career at General Electric as a machinist working the night-shift. After he began inventing lamps for GE, his skills as a machinist allowed him to anticipate the type of problems that would arise when products moved from the lab to the production line. Several of his patents describe production equipment like the one seen above.

Short-arc lamps may be recognized by most people as the strange, bluish headlight now being adopted in automotive designs. A difficulty with making such lamps is quickly extracting the air from inside the small bulb, and installing a gas such as xenon. The machine described above, not only takes care of the atmosphere inside the lamps, but also installs the electrodes and seals the ends.

In 1996, Fridrich donated the original patent document to the National Museum of American History, along with other historical materials including a large collection of experimental lamps.

A 19th Century Invention Factory

The story of one of Edison's brighter inventions - the electric light bulb - is explored in this section.

Preconditions for Edison's Lamp

"If I have seen farther [than others], it is by standing upon the shoulders of Giants."
Issac Newton, in a letter to Robert Hooke, 1675.

Thomas Edison received over 1000 U.S. patents, the most issued to any individual. Some people also credit him with an invention that received no patent: the modern corporate research laboratory. While this conclusion is arguable, his Menlo Park laboratory was intentionally designed to be an invention factory. It housed a large reference library, and often served to showcase the Wizard's work. Some who worked in or visited the lab later became competitors.

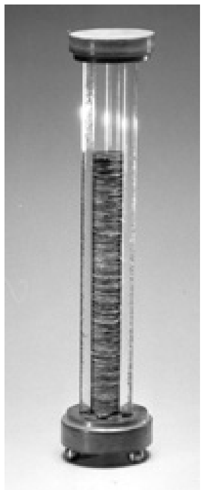
Almost seventy years after his death, Thomas Edison remains an icon of invention. His record of 1,093 patents is still the most issued to any individual. Three major books, a television movie, and 4 volumes of his papers were published in the 1990s alone. A 1999 *Time-Life* publication even named Edison the most important person of the past 1000 years. Yet, for all of his accomplishments, Edison did not start from scratch.

By 1869, when Edison declared his intention to become a professional inventor, an electrical industry was already established. Telegraphy had provided employment for Edison and the opportunity to learn about electrical technology. Pioneering work by Franklin, Faraday, Volta, Morse and many others laid a foundation upon which Edison built. Some of the more important prior developments are shown below.

Batteries

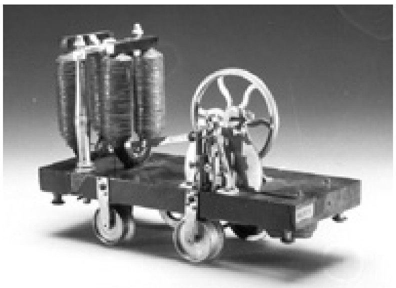
The most exciting electrical invention at the beginning of the 19th century was the battery. It produced a constant electric current, opening the way for many other discoveries and inventions; it also provided power for the telegraph and telephone industries.

In 1800, Alessandro Volta announced his invention of a battery similar to the one shown at right. The "voltaic pile" operated by placing pieces of cloth soaked in salt water between alternating zinc and copper discs. Contact between the two metals produced an electric current. Many refinements were introduced by the 1870s that lengthened battery life and addressed problems like "polarization."



Voltaic pile
S.I. image #79-9465.28

Motors



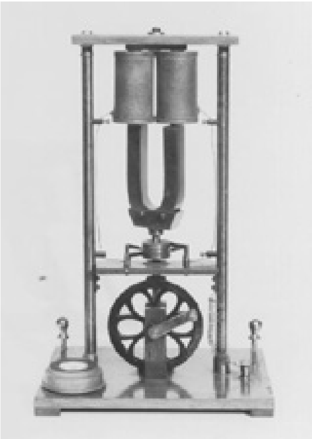
Colton motor
S.I. image #79-9464.18

Within a year after Hans C. Oersted found a relationship between electricity and magnetism, Michael Faraday used this knowledge to build a simple motor. More than 50 years would pass, however, before motors became useful -- mainly due to the need for a strong source of current.

In 1847 Gardiner Colton, a New York doctor, built this motor to illustrate his scientific lectures. It moved around a small circular track.

Generators

In 1831 Michael Faraday discovered that moving a magnet near a loop of wire produced an electric current in the wire. This is the basic operating principle of a generator. Hippolyte Pixii built this "magneto generator" soon after Faraday's announcement. The term "magneto" means that the magnetic force is supplied by a permanent magnet. In Pixii's machine the magnet rotates under the coils of wire.


Pixii magneto generator S.I. image #44,552

A critical breakthrough, the "self-excited dynamo," emerged from the work of Charles Wheatstone and Werner Siemens in 1867. Working independently, both inventors developed generators in which a wire coil rotates between the poles of an electromagnet which gets its electricity from the machine itself. The dynamo could produce much more electrical energy than the magneto and thus made possible efficient use of motors and lighting systems.

Meters


Nobili galvanometer S.I. image #79-9465.06

Scientists studying electricity quickly saw the need for accurate and reliable meters. Later, telegraphers and other users of electricity found it necessary to devise meters for their special needs.

In 1825 Leopoldo Nobili designed the first precision instrument for measuring electric current. Current in a coil produces a magnetic field which causes a needle inside the coil to twist. The amount of twist is the measure of the current. A second needle placed outside the coil allows the device to account for earth's magnetic field.

Electromagnets

The electromagnet proved a critical element in most major electrical inventions of the 19th century. Motors, generators, telegraphs and telephones were the major examples. Any electric current produces a magnetic effect. William Sturgeon made an electromagnet in 1825 by passing a current through a bare wire wrapped around an iron rod.

Joseph Henry constructed powerful electromagnets by using many windings of insulated wires. The iron core shown here is from Henry's experiments of 1827. Henry later became the Smithsonian's first secretary, due mainly to his international scientific reputation.


Henry electromagnet S.I. image #79-9466.32

Arc Lamps


Brush arc lamp S.I. image #79-9469.25

Humphry Davy demonstrated to the Royal Society in 1806 that a powerful light could be produced by establishing an electric arc between two charcoal rods. His experiments, powered by banks of batteries, did not result in practical lighting devices. But, the appearance of good generators in the 1860s and 1870s encouraged the invention and application of a wide variety of arc lamps.

Arc lamps like this Brush patent model from the 1870s provided many cities with their first electric streetlights. Operating an arc lamp was labor intensive since the carbon rods were consumed as the lamp burned and had to be replaced often. The light was so bright and powerful, however, that arc lamps continued in use well into the 20th century.

Edison's goal lay in "subdividing the light" of an arc lamp, meaning to develop a lamp that produced a small amount of light suitable for use indoors. Ideally, many small lights would operate for the same current as one arc lamp and could be turned on and off at will.

Inventing Edison's Lamp

"Well, I'm not a scientist, I'm an inventor."
(Thomas Edison, as quoted by his private secretary, A. O. Tate)

Of course, some scientists are also inventors. But there is a difference. A person acting scientifically is trying to understand the natural world, whether or not that understanding is economically useful. An inventor tries to create something new that will have practical application. In both cases there is a sense of challenge in the pursuit and a sense of achievement in the result.

The Inventor

Thomas Alva Edison was born 11 February 1847 in Milan, Ohio. He received little formal education, but showed an interest in chemistry and began experimenting to teach himself more about the subject. At age 12 he went to work selling newspapers and sundries on a train between Port Huron and Detroit. This gave him money to buy experimental materials, and also gave the voracious reader access to the Detroit Public Library.

Thomas Edison, 1880
S.I. image #87-1590

When Edison saved the life of a child in 1863, the grateful father (manager of the Mount Clemens railroad station) taught Edison telegraphy. Entranced by the new technology, Edison took up the life of an itinerant "Knight of the Key." But he continued to experiment with chemistry and began tinkering with electrical devices. He received his first patent (for an electric vote recorder) in 1868, but this invention failed to sell. During the next six years he developed a new stock ticker and a "quadruplex" telegraph, inventions that not only sold well but allowed him to establish an "invention factory" in 1876.

Menlo Park


Menlo Park, 1880-81
S.I. Image #80-16529

Edison's laboratory in Menlo Park, New Jersey, proved critical to the inventor's success. The two-story, frame building contained as many chemicals and instruments as he could afford, as well as talented associates. Several other buildings were added as the need arose. Menlo Park was the embryo of the modern research laboratory -- a place where the inventor could have at his fingertips the materials and expertise to turn his ideas into physical form. None of his contemporaries had such a marvelous tool.

Edison built a house for his family just down the lane from the laboratory. Other (married) members of the staff also built homes nearby. Most of the bachelors stayed in a boarding house run by Mrs. Sarah Jordan, a distant Edison relative. This close proximity suited Edison, who often had his lunch brought in and thought nothing of working with his men late into the night. At one end of the large room on the second floor was placed a pipe-organ, which Edison would occasionally play for relaxation.

An early project to improve on Bell's newly invented telephone resulted in a carbon transmitter and something unexpected -- the phonograph. This invention made his reputation as "the Wizard of Menlo Park." People were astounded by a machine that could talk, and the accomplishment gave investors and potential customers confidence in Edison. He now had both the lab and the financial backing to tackle a problem that had frustrated inventors since the 1820s, how to make a practical incandescent light bulb.

The Supporting Cast


Edison and his team
S.I. Image #80-16718

Edison's growing reputation also helped him to attract and retain skilled assistants. Though he was the undisputed leader of the team, Edison built up a cadre of artisans and researchers who had strengths that complemented his.

Not everyone who worked for Edison found the experience satisfying--the hours were long and Edison's goals dominated the work. Those who (like Nikola Tesla) could not put aside personal goals and visions, or who (like Ludwig Boehm) found the environment too coarse, soon left. But those who could subordinate their interests to Edison's and who could work the odd hours as "one of the boys" often stayed with Edison for years. Some of those important to Edison's light bulb work are profiled below.

Francis R. Upton (1852-1921)

Upton was the best educated of Edison's Menlo Park assistants, having graduated from Bowdoin College and taken graduate work at Princeton and in Germany. He was recruited by investors who felt it couldn't hurt to supplement Edison's wizardry with some advanced scientific training. They were right, and Upton's understanding of mathematics and physics was of critical assistance in the development of the light bulb, the dynamo, and other elements of Edison's system. Nicknamed "Culture" by his colleagues, he was placed in charge of the Edison Lamp Works in 1881. In 1918, Upton became the first president of the Edison Pioneers.

Francis R. Upton
S.I. Image #80-16690

Charles Batchelor (1845-1910)

Batchelor was born in London, but raised in Manchester and apprenticed there as a mechanic. At age 22 he came to America to help a firm in Newark, N.J. with the installation of machinery. Finishing this work, he moved to Edison's Newark factory and rapidly became an indispensable part of Edison's crew. He participated in most of the early inventions, from the electric pen to the phonograph and the electric light.

Charles W. Batchelor
S.I. Image #80-16685

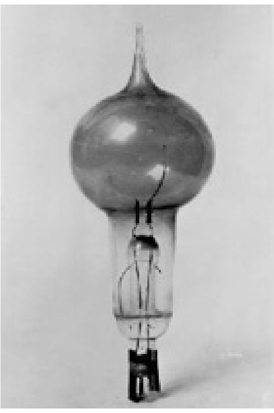
"Batch" was valued for his versatility and his good mechanical sense. In 1881, he was sent to Europe to promote the Edison system and remained there for three years. Upon his return he took charge of the Edison Machine Works, and remained with the company even through its merger into General Electric. While Batchelor never made a name for himself in either invention or business, he was widely recognized as Edison's closest associate during the most creative years of Menlo Park.

John Kruesi (1843-1899)

Kruesi arrived in the United States in 1870, having been trained in his native Switzerland as a machinist. According to one of his coworkers, Kruesi "understood work in the drafting room and could decipher one of Edison's sketches no matter how crude it was." It was Kruesi who constructed the first experimental phonograph, following Edison's design. Like Batchelor, Kruesi worked for Edison before Menlo Park, and afterwards served as superintendent of the Edison Machine Works in Schenectady.

John Kruesi
S.I. Image #72-4116

The Light Bulb


Edison lamp
S.I. Image #13,369B

When, in 1878, Edison announced that he had the answer and knew how to make an incandescent light, gas stocks around the world fell. The only problem was that his answer was wrong, and a year of hard work lay between Edison and success.

The initial idea was to make a lamp with a platinum filament, a metal that was slow to oxidize and that had a high melting point. To keep the filament from overheating and burning out, Edison designed a complex regulating mechanism. The regulator would occasionally shunt current away from the filament, allowing it to cool off. Not only was this mechanism complicated to make and operate, but a light bulb that shut itself off every few minutes was hardly practical.

Experiments with platinum proved useful, however. Edison discovered that hot filaments released gasses trapped in the metal. One of the hurdles to overcome was the creation of a better vacuum pump, one that could produce the very high vacuum needed. While experiments progressed through late 1878 and into 1879, Edison initiated work on other components needed for a practical lighting system, items like meters, cables, generators. He also began an economic survey of gas lighting, the technology he had to compete against.

The light bulb effort was not the only project at Menlo Park; another was continuing work on improving Edison's telephone. The heart of Edison's transmitter (superior to Bell's by most accounts) consisted of a variable resistance carbon disk about the size of a button. Edison, like many of his competitors, had tried carbon as a lamp filament, but was discouraged by the material - it burned-out too quickly. Carbon had the highest melting point of any element, however. In the fall of 1879, experiments with carbon filaments resumed.

Edison and his men recorded designs and experiments in notebooks all around the lab. Edison knew these books would be invaluable for backing patent claims, but probably thought little about their value to historians. In October 1879, Batchelor recorded a series of experiments with carbon filaments made from a variety of materials. Much mythology surrounds these experiments, but according to the notebooks a carbonized filament of uncoated cotton thread operated for a total of 14½ hours on 22-23 October. While not the 40 hours of legend, this filament led the Menlo Park team to believe that they were on the right track.

By 2 November that belief was such that Upton reported in a letter home, "The electric light is coming up. ... I have been offered $1,000 for five shares of my stock." Under pressure from his investors, Edison announced a public demonstration of the new lamp for New Year's Eve. Though not completely satisfied with the newest lamp (containing a carbonized paper filament), Edison nevertheless invited the public to Menlo Park. Visitors from New York City arrived on special trains to see the laboratory, the grounds, and Sarah Jordan's boarding house illuminated with about 100 of the new lamps, one of which is seen above.

Promoting Edison's Lamp

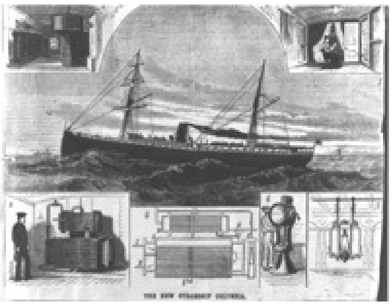
"Dispatch received this morning from steamer *Columbia* states she arrived safe in Rio and that the Edison light is all right."
(Charles Mott, 31 May 1880)

Edison's business sense has been questioned over the years. However, he understood well the need to promote new inventions, and displayed keen salesmanship. He was never too busy to talk to reporters or to demonstrate inventions to lab visitors. Edison Company representatives traveled around the country and the world participating in shows and expositions.

The New Year's Eve demonstration at Menlo Park (31 December 1879) became the first in a series of promotional events, all designed to link Edison's name with the new lighting technology in the public's mind.

S.S. *Columbia*

Oregon Railway and Navigation Company president Henry Villard attended the New Year's Eve demonstration and became an instant Edison enthusiast. (He later became president of Edison General Electric Company.) Villard boldly decided to purchase an Edison lighting system for a new steamship, the S. S. *Columbia*, then under construction for his company.

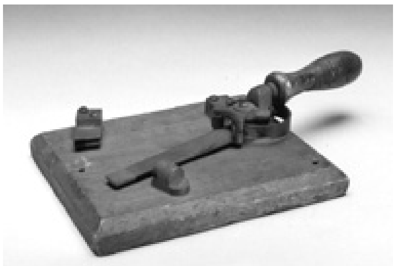


S.S. *Columbia*
S.I. image #79-2134

Not everyone believed that installing the new technology on the ship was prudent. Edison himself apparently showed some reluctance, wanting to concentrate on his idea of centrally generated power and not "isolated" power plants. Villard persisted however, and Edison came to view the job as an opportunity for promoting the new system. The *Columbia* installation became the first commercial order for Edison's light bulb.

The ship was launched in February 1880 and sailed to New York where the electrical equipment was installed. In May the ship took on cargo and sailed for Portland, Oregon, a trip of about 10 weeks around South America. The installation proved both technically and promotionally successful: the equipment functioned properly and the press reported the story. *Scientific American* published an extensive article about the system, including the illustration above.

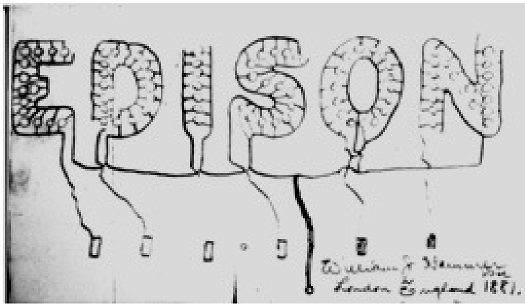
Hinds, Ketcham



Switch from Hinds, Ketcham & Co.
S.I. image #79-9466.12

Edison's first commercial installation on land was purchased by printers Hinds, Ketcham & Co. Like the *Columbia* installation, this was an "isolated" plant, meaning that the electricity came from a generator in the basement of the building, not a central power station. The New York City location permitted those interested in buying (or investing in) Edison equipment the opportunity to see the product in commercial use. The company's lights went on in January 1881. Around 1900 the installation was upgraded, and the switch seen here (and other objects) were donated to the Smithsonian.

Trade Shows & Expositions

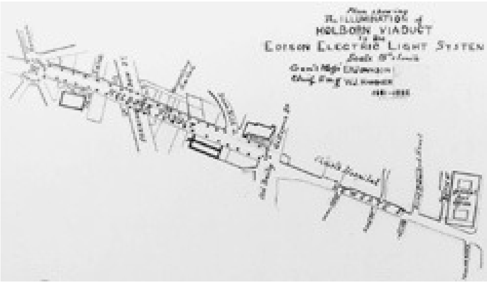


"Edison" electric sign
S.I. image #2003-35552

In the era before newsreels, radio, or television, large events such as world's fairs and technology expositions were important venues for promoting new inventions. Edison had shown telegraphic inventions at the 1876 Centennial Exhibition and knew the value of this type of product exposure. Edison exhibits appeared in American shows (Philadelphia, Cincinnati, 1888) and in European shows (Paris, London, 1881; Vienna, 1882).

William J. Hammer, one of Edison's Menlo Park assistants, played a major role in showing the Edison product in these expositions. The sketch seen here is his design for "the first electric sign," which he developed for the Crystal Palace Exposition in London.

Holborn Viaduct



Holborn Viaduct
S.I. image #79-2132

Edison modeled his lighting system on the existing system of gas lighting. This model featured a centrally located supply of energy which users tapped through a system of pipes. He believed this concept of centralized supply necessary to make his system economical, and envisioned an underground distribution system of cables to carry electricity from generating stations to end users.

Gaining permission to dig up city streets took time, especially with gas suppliers trying to keep the new competitor out of the lighting business. Edison's representatives in London, eager to demonstrate a central system, found a way around the issue by proposing to run electric lines under the Holborn Viaduct. The location had the added advantage of being near Fleet Street, home to various newspaper offices.

The temporary installation began service in January 1882 and operated until 1884–long enough to prove that the concept was technically feasible. It also provided a testing ground for Edison's first permanent station, planned for New York.

Pearl Street


Pearl Street Station model
S.I. image #10,501

Edison constructed a full-scale, central generating station in New York City as a focal point for further promotional efforts and a clear demonstration that his electric lighting system worked. In addition to the light bulb, he had invented numerous additional items necessary for the system, including especially a meter (to measure how much electricity the customer used) and an improved generator.

The site for Edison's generating station had to satisfy both engineering and business needs. Using 100 volt direct current to power the new light bulbs resulted in a practical limitation–customers could be no further than ½ mile from the generator. To promote the system, a high profile location was called for. Edison chose a site in the heart of New York's financial district, 255 and 257 Pearl Street. On 4 September 1882, he threw a switch in the office of one of his main investors, J. Pierpont Morgan, and initiated service to the area.

Financially, the station's performance was mediocre. Costs were higher than anticipated, and the station did not make a profit for about five years. The experience gained at Pearl Street served Edison's purposes well, however. Responding to high copper prices, for example, Edison designed a three-wire distribution system that brought substantial savings to subsequent installations.

As a technical demonstration that Edison's system could function, the station proved a resounding success. Edison's financial backers, content with growing sales of stand-alone "isolated" generating plants, urged caution in promoting central station power–they wanted to see Pearl Street in operation first. Satisfied with the station's performance, they began licensing central systems throughout the U.S. By the end of the 1880s, dozens of Edison companies were in business.

A fire caused extensive damage to the Pearl Street station in 1890, but Edison and his men worked around the clock for 11 days to restore service. The station was taken out of service and dismantled in 1895, and the building sold and later demolished. The New York Edison Company placed a commemorative plaque at the site in 1917.

Competition to Edison's Lamp

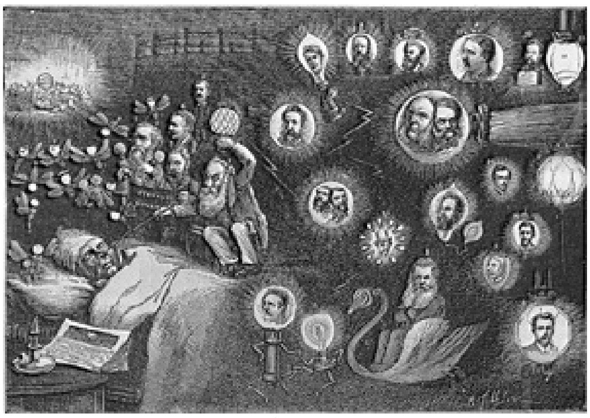
"If you want to succeed, get some enemies."
(Edison, as quoted in the *Ladies Home Journal*, April 1898).

Successful inventions spawn competition which, in turn, often stimulates new inventions. Edison's lighting system was no exception and competitors very quickly introduced similar products. Some copied what he had done; others used their own inventive talent to create new ideas and new devices. The competition provoked controversy and a great deal of activity.

By 1891 there were over 1,300 incandescent lighting central stations in the United States with a capacity of approximately three million lamps. Towns and cities across the country competed with each other for the privilege of being the first in their area to gain access to the new technology.

Gas Light

Developed in England in the 1790s, gas light technology spread quickly. In 1816 gas streetlights went into service in Baltimore, and by the time of Edison's 1879 lamp invention, gas lighting was a mature, well-established industry. The gas infrastructure was in place, franchises had been granted, and manufacturing facilities for both gas and equipment were in profitable operation. Perhaps as important, people had grown accustomed to the idea of lighting with gas.



"The Dream of a Gas Manufacturer," 1883
S.I. image #48,285C

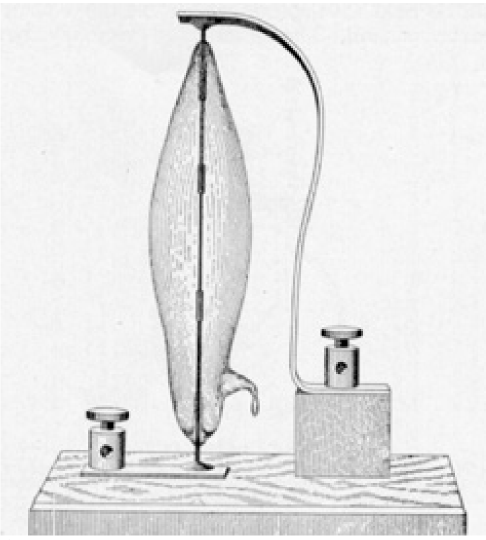
Edison consciously modeled his plans for an electric lighting system on the gas light technology. Instead of gas-making plants, he designed generators. Where pipes ran under the streets distributing gas to end users, he planned to place electrical "mains" (conductors) to carry current. Since people were able to have gas lamps in many rooms and control them individually, Edison intended his lamps to be capable of independent operation.

Even before Edison demonstrated a working lamp, gas stocks began to fall in price. In late 1879 he and his men began making detailed cost studies of gas light in order to determine price goals that the electric light would have to meet. After the lamp invention, promotions for the Edison system duly reported deaths and injuries due to gas.

Despite nightmares like the one depicted above, gas manufacturers responded to the challenge with two major advances. The first was better quality gas. The second was an incandescent mantle invented by Carl Auer von Welsbach of Austria (who later invented the first commercial metal filament light bulb). Both innovations resulted in more brighter, more efficient light.

Gas proved a tough competitor since infrastructure already existed, whereas electric light could not be used until generating plants were built and wires were strung. Also, gas could be used for heating and cooking as well as light. In 1910, GE's William Coolidge invented a tungsten-filament lamp capable of giving 10 lumens per watt. That invention, combined with the growing level of electrification in the country effectively eliminated competition from gas lighting.

Electric Light



Swan experimental lamp
S.I. neg. #2002-29339

Edison was neither the first nor the only person trying to invent an incandescent electric lamp. In the U.S., Moses Farmer, William Sawyer and Albon Man, and Hiram Maxim were all pursuing the goal, as were St. George Lane-Fox and Joseph Swan in England.

Swan demonstrated a working lamp of the design seen to the left in several early 1879 lectures. But his lamp (like those of the other contenders) used a carbon rod of relatively low electrical resistance. It was practical only if used in series (where the current flowed successively through several lamps that would turn and off together) or if it was close to the power supply (so that the lead wires would be short).

Swan had experimented with carbonized paper filaments for some years, however. Once he learned that a high resistance filament was needed, he quickly adapted it to his own lamps and established the Swan Electric Light Company. It should be noted that Swan had been granted several patents for various lamp features before Edison's breakthrough. Indeed Swan's patent position in England was strong enough that in mid-1882 a merger was arranged and the Edison & Swan United Company ("Ediswan") was formed.

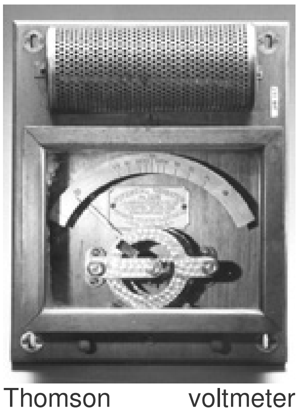
Hiram Maxim also quickly produced a lamp containing a high-resistance filament in 1880. One of the reasons Maxim was able to introduce a product so fast was that he had hired Ludwig Boehm (Edison's glassblower) away from Menlo Park earlier that year. Maxim soon moved on to other inventions (such as machine guns), but the United States Electric Lighting Company installed systems that used the Maxim lamp for several years. The company was purchased by George Westinghouse in 1888.

The company Elihu Thomson and Edwin Houston established in 1880 to sell arc lamp systems became quite successful and diversified into other electrical markets. In 1886 they purchased the Sawyer & Man Electric Co. and began making incandescent lamps under the Sawyer-Man patents. By 1890, Edison, Thomson-Houston, and Westinghouse were the "Big 3" of the American lighting industry. In 1892, J. Pierpont Morgan engineered a merger between the Edison interests and Thomson-Houston. The resulting company was named General Electric.

George Westinghouse's initial fame stemmed from his invention of an air-brake that vastly improved railroad safety. In the 1880s he too diversified into electrical equipment and then into electric lamps. At the time he bought U.S. Electric Lighting Co. and began making lamps, the company was being sued by Edison for patent infringement. In 1892 the courts decided in Edison's favor and forced Westinghouse to stop production. However, Westinghouse had obtained rights to the Sawyer-Man patents and quickly retooled to make non-infringing lamps based on those patents. He produced these "Stopper lamps" until Edison's patents expired in 1897.

Meters

Critical to any electrical system is the ability to measure at any moment the flow of electricity (the current) and the force on it (voltage). These techniques were well known, and it was a relatively simple matter to design instruments that could deal with the relatively high flow in lighting circuits (like the Elihu Thomson voltmeter shown here). For a commercial enterprise, it was also important to know how much energy the customer was using. Edison designed a chemical meter in which a portion of the current being supplied caused metal to be deposited on an electrode. The electrode could then be weighed to give a measure of the energy consumed. Later electromagnetic meters registered watt-hours directly by measuring the product of voltage and current over time.



Thomson voltmeter
S.I. Image #79-9469.13

AC Versus DC

Tesla AC motor
S.I. Image #79-94714

Both alternating and direct current had been used for arc lights, and both could be used for incandescent lamps. However, in the early 1880s motors could function effectively only on DC. There was an expectation that electricity could be stored in batteries during off-peak hours, and this was possible only with DC. Finally, there was evidence that at the same voltages AC was more dangerous than DC. All of this led Edison to prefer a DC system.

An important advantage for AC became apparent with the invention of the transformer in 1883. This meant that the voltage from an AC generator could be efficiently increased for transmission and then decreased at the other end for use in the home or factory. (Electrical energy is proportional to voltage times current, so that boosting the voltage means that the same amount of energy can be transmitted with less current flow. Since heat produced in the line is a function of the current and the resistance, so with less current the loses are less.) For short lines (of a mile or so) this made little difference. But for long distances it would be critical.

The Westinghouse and Thomson-Houston companies preferred AC, and their faith was justified when Nikola Tesla invented a practical AC motor in 1888 (an early example is shown in the picture). Additional Tesla polyphase patents made AC systems more efficient. These patents were used by Westinghouse at Niagara Falls in 1895.

During the 1880s a sometimes fierce–and not always logical–battle was waged between proponents of AC and of DC. Edison himself became less involved as he devoted more time to his new laboratory at West Orange, New Jersey, after 1886, and as he became more involved with his iron-ore project. The Edison and Thomson-Houston companies merged in 1892 to form General Electric.

Consequences of Edison's Lamp

"I have accomplished all I promised."
(Thomas Edison, to New York *Sun* reporter, 1882)

"Electricity is a modern necessity of life."
(Franklin Roosevelt, at Rural Electrification Administration celebration, 1938)

Edison's statement indicated his pleasure upon opening the Pearl Street station. But even he would have had difficulty predicting the consequences of his invention. It stimulated a lighting industry that quickly spread through cities and towns across the country. And it helped establish a need for large central stations, beginning with Niagara Falls. Ironically, since these stations would rely on alternating current for efficient long-distance transmission, they would lead to the abandonment of Edison's direct current systems in most applications.

Over the course of the next half century two especially significant social effects became clear. We gained control over light in homes and offices, independent of the time of day. And the electric light brought networks of wires into homes and offices, making it relatively easy to add appliances and other machines. As reflected by FDR's statement, low cost lighting and nationwide electrification became fundamental parts of twentieth century America.

Electric Power Plants & Transmission Grids

"Someday I'll harness that power."
(Nikola Tesla, as a young boy looking at a picture of Niagara Falls, according to a recollection in 1915)

The world's first large-scale central generating station opened at Niagara Falls in 1895, with some of its output transmitted twenty miles away to Buffalo. It employed two-phase AC techniques invented by Nikola Tesla and was thus more efficient than previous alternating current systems.

Aluminum samples
S.I. image #79-9468.25a

At first, most of the current from the Niagara generators was used locally. The production of aluminum (such as the ingot and trays shown here), and Edward Acheson's newly discovered abrasive "Carborundum" both required tremendous amounts of electricity. But some was transmitted to Buffalo, where it was used for lighting and for street cars. Here was practical proof that long-distance systems were indeed efficient.

In succeeding years, the construction of an interconnected system of large, central generating stations, high-voltage AC transmission lines, and lower voltage AC and DC distribution lines in cities and towns across the country resulted in the creation of a national grid. This was an integrated energy system that could make electricity and deliver it hundreds of miles to wherever it was wanted.

Interior Lighting

The electric lamp gave people complete control over lighting inside their homes and work places at the click of a switch. By the eve of World War II this was largely true, with the help of the Rural Electrification Administration (REA), even in rural areas.

Rambusch ceiling luminaire S.I. image #lar1-5a1

As more people turned to electricity for light, prices of both lamps and electricity fell. Older forms of lighting, such as candles and oil lamps, became used only for special occasions or emergencies like power "black-outs."

The consequence was to interrupt the normal, biological rhythms of life and to alter our schedules for work and leisure. Industrial plants could operate in shifts around-the-clock, for example, and the concept of "the city that never sleeps" became a reality.

Use of the new technology effected building architecture as daylight became only a supplemental source of light. Electricity for lights, elevators, and pumps allowed architects to design "skyscrapers" of unprecedented height. The "windowless building" was also an architectural design option by the 1930s.

The availability of more powerful light bulbs made controlling the light they emitted a necessity. Fixture makers combined both art and science in electrical luminaires that provided optical control and fashionable design. A Danish immigrant, Frode Rambusch, started a business in New York in the 1890s designing murals and stained glass windows for public buildings. He soon expanded activities to make special lighting fixtures, incorporating artificial light into the architecture. Above is a Rambusch fixture designed in 1939 for church illumination.

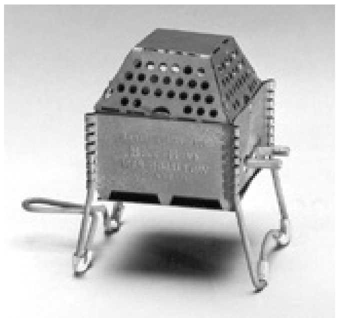
Decorative and novelty lights quickly found acceptance. Edison made small lapel lights which he gave to friends. The first Christmas tree known to use electric lights was trimmed in the home of Edison Company vice president Edward Johnson in 1882. Conrad Hubert and Joshua Cohen (founders of Eveready Battery and Lionel Trains, respectively) also produced miniature decorative lamps, but then put the lamps to practical use in 1898 with the hand-held flashlight.

The economic effect of electric lighting went far beyond increasing the workday. Profits generated by the electric lamp, in effect, paid for a network of generators and wires. This infrastructure then became available for a whole new class of inventions: appliances and equipment that by the 1930s had transformed the home and the workplace.

Appliances

"Use Your Electricity For More Than Light."
(Sears catalog, Spring 1917, p. 856.)

A major factor slowed the adoption of electric light–the need to install electric wiring. Nineteenth century construction materials and techniques often made this a very difficult and expensive process. The ability to use electricity for non-lighting tasks gradually became an important incentive for home and factory owners to make the investment.



Marshmallow toaster
S.I. image #79-9468.04a

Manufacturers developed a wide range of electric appliances for the home. Electric irons and washing machines made laundry day less labor intensive, while electric vacuums made cleaning carpets and furniture easier. Time spent doing domestic tasks didn't seem to decline, however, as standards of cleanliness rose and fewer families employed domestic servants.

Electric refrigerators presaged an end to ice boxes and home ice deliveries. Bread toasters, tea kettles, waffle irons, and marshmallow toasters (above) were only a few of the electric appliances introduced to kitchens. Many of these smaller devices sported elaborate and artistic designs, and were meant to be used at the dinning room table.

Electric climate control began with fans and radiant heaters that used special light bulbs. Personal care items like electric hair dryers, heating pads, and shaving mugs appeared. Electricity for telephones and radios brought users instantaneous personal communications and news and entertainment. Indeed, radios and lamps were the two electrical devices that sold steadily throughout the Great Depression.

Small electric motors freed factories from the need to arrange equipment based on power shafts and belts. Each machine, independently powered, could be arranged on the shop floor for efficient production flow. Electrified tools boosted industrial productivity, and many were eventually made available to domestic "do-it-yourselfers."

Electric power for transportation made subways practical and streetcars more efficient. These in turn provided central stations with daytime consumers of electricity. Electric cars and buses never overcame competition from the internal combustion engine, however, despite the best efforts of Edison, Samuel Insull, and others.

20th Century Invention Factories

Today's invention factories produce a range of lighting devices that Edison could hardly have imagined. Use of these modern lamps has fundamentally altered the way we live.

Modern lamp inventors have the advantage of building upon the work of Edison and his contemporaries, though they pay a price for this head start. Solving complex technical problems today often requires expertise and equipment beyond the reach of a single inventor. When individuals and small companies do create new lamps, they face the daunting task of competing with large corporations in a global market.

Preconditions to 20th Century Lamps

"I remember this circumstance very well because of the excitement and surprise and incredulity which he manifested at the time. He asked me over and over again what it was."
(William D. Coolidge, General Electric scientist, 1909)

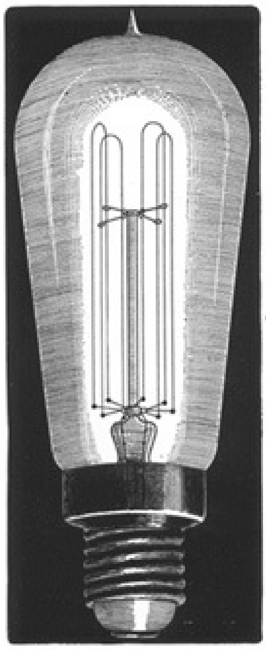
Coolidge was recounting Fritz Blau's reaction to a lamp made with bendable (or "ductile") tungsten wire. Blau, an Austrian, had helped invent a "non-ductile" tungsten lamp only a few years earlier and knew well the difficulty of working with this metal. Coolidge's lamp was not the first improvement in Edison's design, nor the last. It built on previous work (such as Blau's) and fueled new work (such as Irving Langmuir's).

Inventors in the late 20th century had access to technical information unknown in Edison's time. Some knowledge came from outside the industry–like phosphor work done for television. But lighting scientists and engineers made many discoveries in the first half of the century, especially in the new industrial laboratories inspired by Edison's Menlo Park and West Orange labs. Research into the physics of electrical discharges, the metallurgy of tungsten, and chemical properties of glass all played a role in creating lamps that became available in the 1930s.

As the technology matured however, the pace of major improvements slowed. Below are some of the major developments of the 1900-1950 era important to lamps in use today.

Incandescent Lamps: Exit Carbon–Enter Tungsten

By 1900 the carbon filament lamp was a mature product in mass production. Electrical efficiency (or "efficacy") remained very low at about 3.5 lumens per watt (lpw). Aside from wasting electricity, these carbon lamps simply did not provide strong light. Inventors, especially in Europe with its high energy costs, searched intently for new filament materials.



Non-ductile tungsten lamp
S.I. image #69,208

Though carbon has the highest melting point of any element, the operating temperature of carbon filament lamps had to be kept relatively low. Very high temperatures caused carbon to evaporate quickly from the filament and coat the inside of the bulb, dimming an already low light. Experiments with various metals were aimed at finding a material that could operate at a higher temperature without so much evaporation. Higher operating temperatures meant brighter, more energy efficient lamps.

Carl Auer van Welsbach of Austria (inventor of the gas mantle) developed the first commercially practical metal filament lamp in 1898 by making filaments with element # 76, osmium. The very brittle filaments gave 5.5 lpw, a significant improvement, but osmium lamps proved difficult and expensive to make. They were replaced in 1902 by lamps invented by Germans Werner von Bolton and Otto Feuerlien, who used element # 73, tantalum. Tantalum lamps produced 5 lpw, a slight drop from osmium that was more than offset by tantalum's greater strength.

Tantalum was in turn superceded by lamps made with element #74, tungsten. Another difficult metal to work with, tungsten lamps like the one seen above gave 8 lpw, and in 1904 three different tungsten lamps appeared on the European market almost simultaneously. American manufacturers licensed and sold both tantalum and first generation tungsten lamps in the U.S.

Many of Edison's carbon lamp patents were expiring around this time and competition was heating up. In 1904, Willis Whitney used the new electrical resistance furnace at GE's Schenectady lab to bake carbon filaments at very high temperatures. The resulting filaments exhibited metal-like properties and gave 4 lpw. Sold as the "General Electric Metallized" or "GEM" lamp, this lamp still achieved only half the efficacy of the new tungsten lamps from Europe.

William Coolidge, also at GE's research lab, began exploring the metallurgy of tungsten. The European lamps were almost as fragile as earlier osmium lamps because tungsten was too brittle to bend ("non-ductile"). Coolidge developed a process to make bendable ("ductile") tungsten wire, and in 1910 GE began selling lamps made with this filament. The lamps gave 10 lpw, and also gave GE strong new patents.

Coolidge's colleague, the future Nobel laureate Irving Langmuir, discovered that by coiling the tungsten filament and placing an inert gas like nitrogen inside the bulb he could obtain 12 lpw or better. Langmuir's lamp joined Coolidge's on the market in 1913, both selling under the "Mazda" trade-name.

Various improvements in both the tungsten lamps themselves and in production machinery occurred during the following forty years. These cut costs drastically but improved lamp efficacy only slightly. By 1950, tungsten lamp technology seemed at a dead-end, especially given the growth of discharge lamps like fluorescent tubes. Some older engineers began advising younger colleagues to avoid staking a career on incandescent research.

Discharge Lamps: Lightning in a Tube

Cooper Hewitt tube
S.I. image #lar2-1b1

An interesting curiosity of the 19th century were devices called Geissler tubes. German glassblower Heinrich Geissler and physician Julius Plücker discovered that they could produce light by removing almost all of the air from a glass tube and then sending an electric current through the tube as an arc discharge. Poor seals allowed air to seep back in and extinguish the light, but the work spurred research into discharge lighting.

In the first decade of the 20th century, two commercial discharge lamps gained modest popularity. One, invented by American D. McFarlan Moore, used carbon-dioxide or nitrogen filled tubes up to 250 feet long. Moore tubes were more efficient than carbon filament lamps but difficult to install and maintain. A second lamp, invented by American Peter Cooper Hewitt, passed an electric current through mercury vapor. Cooper Hewitt lamps (above) gave off much light and could be made portable, but the light was a garish blue-green suitable for few uses. These lamps contained about a pound of mercury each.

Coolidge's and Langmiur's tungsten filament lamps of the 1910s raised the efficiency standard for all lighting devices. Moore lamps, for one, soon disappeared from the market. Research indicated that very high efficacies might be attainable with discharge lamps however, so work continued.

Building on Moore's work, Georges Claudé of France developed neon tubes in 1910 and showed that a discharge lamp could give 15 lumens per watt–if one wanted red light. Additional European work resulted in a high-intensity mercury vapor lamp (from General Electric Company of England) in 1932. This lamp used a tiny fraction of the mercury needed for Cooper Hewitt lamps, had a screw base, and gave 40 lpw, though its color was still poor.

A collaboration of GEC in England, Philips in The Netherlands, and Osram in Germany produced a low-pressure sodium lamp also in 1932. The key to this lamp lay in a special glass that could withstand the corrosive effects of sodium. The light was a stark yellow suitable only for use in applications like street lighting, but efficacy started out at 40 lpw and reached about 100 lpw by 1960.

Reports began reaching GE and Westinghouse in the late 1920s and early 1930s of French experiments with neon tubes coated with phosphors. A phosphor is a material which absorbs one type of light and radiates another. A German patent in 1927 contained most of the features of a fluorescent tube, but the lamp was not produced.

American scientist Arthur Compton, a consultant to GE, reported seeing a green French lamp giving 30 lpw in 1934. An engineer at GE later wrote that they thought Compton had misplaced a decimal, that the true figure was 3.0 rather than 30 lpw.

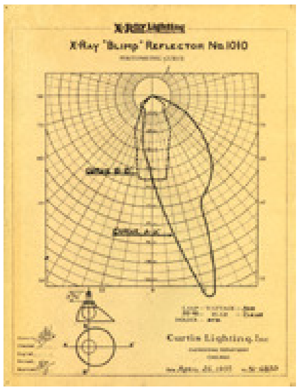
The figure, soon confirmed, sparked an intensive research program. In 1936, tubes using low-pressure mercury vapor and a coating of phosphors were demonstrated to the Illuminating Engineering Society and the U.S. Navy. In 1939, GE and Westinghouse introduced fluorescent lamps at both the New York World's Fair and the Golden Gate Exposition in San Francisco. Other lamp makers soon followed.

Despite resistance from some utilities fearing loss of electricity sales, the need for efficient lighting in U.S. war plants resulted in rapid adoption of fluorescent technology. By 1951 industry sources reported that more light in the U.S. was being produced by fluorescent lamps than by incandescent.

Research After Edison: "The Science of Seeing"

Thomas Edison's lamp research focused mostly on the chemistry and engineering of the light bulb itself and its interaction within an electrical system. As researchers began building on Edison's work, the topics broadened to include subjects like optics and the physics of light itself. Edison, intent on inventing, cared little for basic research, but new professional "illuminating engineers" explored the fundamental nature of light and lighting devices.

For example, as metal filament lamps began replacing carbon lamps, the problem of glare arose. Shades for the brighter tungsten lamps had to be designed to both protect eyesight and to more effectively channel light. New applications like automotive and aviation lighting required development of a host of new lamp designs with special electrical and optical characteristics.



Photometric curve
S.I. image #lar2-1c1

Researching human eye response to different colors and light levels became more important as electric lighting began to change people's lifestyles. Questions about the affect of lighting on productivity in both workplace and home carried great economic significance. Development of fluorescent lamps in the late 1930s led to experiments with "windowless factories."

The 1906 establishment of the Illuminating Engineering Society marked a formal recognition that lighting had moved from the realm of lone inventors to that of a profession. Corporate and academic researchers not only presented their work in the form of patents, but also wrote papers that appeared in scholarly journals. A prominent researcher, GE's Matthew Luckiesh described the field as "The Science of Seeing."

Researchers produced light distribution curves for fixtures (above), studied how different consumer groups used light, and developed deeper understandings of the fundamental nature of light. Expensive research equipment, needed to pursue these issues, made it difficult for smaller companies to compete. Lighting design emerged as a special field, distinct from architecture, just as lighting engineers diverged from electrical engineers.

Lighting and radio were the two electrical products that sold well throughout the Great Depression, justifying continued investment in research. The onset of World War II provided stimulated research for military uses of lighting, especially into materials like quartz and ceramics, while blackouts and materials rationing held back civilian purchases. Finally, the postwar economic boom released tremendous demand for lighting. The result proved to be a burst of lighting innovation.

Inventing Six Modern Electric Lamps.

"Genius is ninety-nine percent perspiration and one percent inspiration." (Thomas Edison)

Whatever the percentages, the concept is much the same for inventors today as for Edison. But circumstances have changed. Work is more often done in groups in large laboratories; scientific training is essential; equipment is complex and expensive. Here, we examine some of the differences and similarities between inventing Edison's lamp, and inventing six recent lighting devices.

Tungsten Halogen: teamwork	Metal Halide: scientific training	High Pressure Sodium: materials
Compact Fluorescent: manufacturing	Silica Carbide: lone inventor	Sulfur: opportunity

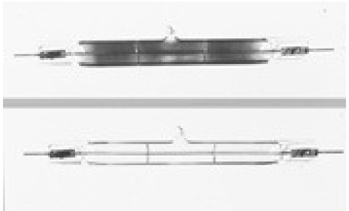
Tungsten Halogen: Working in a Modern Industrial Laboratory

Edison assembled a team of talented assistants for his Menlo Park "invention factory." But he remained the guiding force behind the light bulb effort. From the initial experiments, through design of production equipment, to selling the lamp and its electrical infrastructure, Edison ran the show. Today, most lamps pass from one specialist or group of specialists to another as the original idea becomes a commercial product. Rarely does one individual oversee the entire process.

In 1950, at General Electric's Nela Park facility, Alton Foote led an effort to design a new heat lamp using a small tube of fused quartz rather than a large glass bulb. Foote found that quartz could withstand high heat, but the lamps blackened too quickly to be of use. Tungsten evaporated from the filament and settled on the inside wall of the tube, darkening the lamp.

Machinist turned inventor Elmer Fridrich, with the help of Emmett Wiley, placed some iodine in a quartz lamp and "Eureka! we put it on and instant success ... it was just beautiful." As seen in the image below, iodine cleared the tungsten atoms from the tube wall and returned them to the filament. Despite the initial success, follow-up experiments proved frustrating as some lamps worked and some that appeared identical failed.

In early 1954 chemist Edward Zubler was assigned to find out just what was happening inside the lamps, and in 1955 engineer Frederick Mosby transferred into the project to begin designing a marketable product. Fridrich and Wiley began playing a reduced role. After about three years of experiments Zubler and Mosby worked out the unique chemical and structural requirements of the lamp, some of which called for new procedures. For example, the tungsten filament wire had to be unusually pure, and this required the participation of engineers at GE's "wire plant."


Lamp before & after halogen cycle
S.I. image #99-4111

A "pilot production" facility was set up to provide hand-made experimental lamps and by mid-1958 the team began to feel confident. As Mosby recalled, "Once management decided that we were ready to go beyond the piloting operation, we then called in our manufacturing people. They came in and looked at the lamp and decided what equipment we had to have in order to make this lamp at higher speeds–so prime responsibility went out of our hands at that time. We worked very closely with the manufacturing people, but it became their responsibility to get the equipment designed and made to put into our factories for expanded production."

In 1959, the tungsten halogen lamp was ready to emerge from the lab, bringing more new players into the process. Application engineers designed ways to use the lamps. Marketers began crafting sales pitches and researching needs that the new lamps might meet. This team approach has become typical of modern lamp invention.

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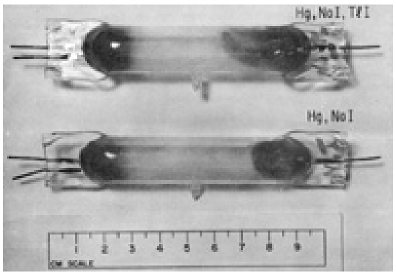
Metal Halide: The Value of Scientific Training

Edison never considered himself a scientist and cared little for theoretical studies. Trial and error experiments gave him the working knowledge he needed, and if some higher math was called for he had Francis Upton on the payroll. Modern lamp inventors have the knowledge inherited from people like Edison, but they have also inherited complex problems not given to easy solutions. Inventing a lamp today calls for advanced scientific and engineering training, both to define problems and to use the highly specialized equipment needed to find solutions.

As early as 1912 Charles Steinmetz had placed metal halide compounds in mercury lamps hoping to improve the lamps' blue-green color. Iodine, bromine and chlorine are all elements known as "halogens" and react chemically with metals to form salts. The physics of electrical discharges and the chemistry of metal halides turned out to be quite complex, and practical lamps were not made until the late 1950s.

By the 1950s, mercury vapor lamps were common and the subject of much research. In West Germany, Otto Neunhoeffer and Paul Schultz explored the use of halogens to combat electrode evaporation. Bernard Kühl and Horst Krense also tried halogens in a lamp and filed for a patent in August 1960. However, Osram had introduced an improved mercury lamp (designated H-33) without halides in 1959. The H- 33 lasted longer and was more efficient than older designs, and may have tempered commercial willingness to quickly introduce yet another improved mercury lamp.



Metal halide arc tubes
S.I. image #99-4074

At this same time, American physicist Gilbert Reiling was also experimenting with metal halides and mercury lamps. His work at General Electric's Research Laboratory involved a mix of theoretical studies and experimentation. Reiling was able to bring a high level of expertise to bear on the problem. "I had 11 years of college mathematics, from topography to matrices to tensor [states] - everything you could possibly mention in the field of mathematics, and you need that for the physics. I had made some thermodynamic calculations that showed that, with sodium iodide, the iodine was so powerful that sodium would not attack the quartz [envelope]. That's what so many people worried about, that these alkali metals were just going to chew up the envelope, but it turned out that the thermodynamics showed that it wouldn't, and it was that idea that really made this work."

Reiling's experiments with sodium and thallium (see lamps above) were promising enough that in June 1960 he reported to GE, "these lamps appear to have a higher luminous efficiency than the mercury lamp and the possibility for better color rendition." In September the lab's research director C. Guy Suits wrote to GE's Chairman Ralph Cordiner to tell him of the new lamp. Suits reported that, although the lamp produced white light "through a complex mechanism which our scientists are still studying in detail,... it now appears that little change will be required in manufacturing the new lamps other than simply adding a scientifically determined 'pinch' of the optimum compound." GE publicly announced the metal halide lamp in late 1962 and used it at the 1964 World's Fair.

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High Pressure Sodium: Studying Materials

Edison spent almost a year trying to develop a platinum filament for his lamp. The material would not burn up in air, but making it give light without melting proved difficult. Eventually Edison return to experimenting with carbon filaments, and he and his team baked hundreds of materials before settling on bamboo for their commercial product. The choice of materials is no less important today. Modern inventors simply have many more possibilities to chose from due to the great number of artificial materials unavailable a century ago.

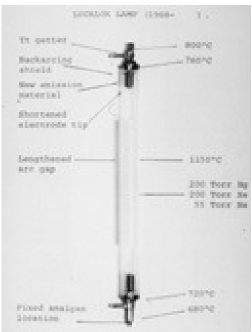
Low-pressure sodium (LPS) lamps were developed in Europe early in the 1930s. Because sodium was very corrosive, LPS lamps needed special glass and very stable temperatures to operate. These factors led to complex glass-work, Dewar-type housings, and large fixtures. Research in the 1920s indicated that increasing the sodium's pressure would improve the lamps' poor color, but no practical material could be found that resisted sodium corrosion at the higher pressures.

After World War II, the GE Research Laboratory in Schenectady began a program to explore the properties of ceramics. Under the direction of chemist Joseph Burke, the program was designed to provide an understanding of ceramic processes. There was no particular product goal in mind, just fundamental research into a little known area.

In 1955 Robert Coble, a recent graduate from M.I.T., joined the team. A series of experiments ensued with polycrystalline aluminum oxide (PCA). Coble added magnesium to the mix, making a material Burke described as "more nearly transparent than had ever been hoped for. Actually, it was more nearly translucent. ... the material appears similar to a slightly frosted glass–but light transmission is from 90-95%."

Metallurgists and ceramicists worked on improving processing techniques needed to produce the new material (now called "Lucalox" for Trans**luc**ent **Al**uminum **Ox**ide) consistently, mainly by determining the manufacturing parameters. George Inman, a senior manager of GE's Nela Park lighting works in Cleveland heard of the PCA research during a trip to Schenectady in 1956 and directed engineer William Louden to begin assessing the possibilities of making a new lamp. In late 1957, Inman sent chemical engineer Nelson Grimm to Schenectady to learn about Lucalox and its manufacture. Grimm returned to Nela Park and established a "pilot-plant scale operation" that began providing tubes of the translucent material to Nela's lamp designers in 1958.

Physical chemist Kurt Schmidt began experimenting with different fill-gasses and in August 1959 filed for a patent on "Metal Vapor Lamps" that included sodium. Still, the lamps were not ready for sale. A difficult problem lay in sealing the ceramic tubes, since they could not be pinched shut like hot glass. Few sealing materials would stick to the new ceramic, and those that did needed to withstand the high operating temperatures and pressures of the lamp.


Lucalox tube
S.I. image #99-4125

The task of designing the seals fell to Louden who later recalled, "The first seals that we made to Lucalox with metal were very short lived and we experimented for a long time with various methods of sealing. We got life out to 2000 hours, and at that point everybody began to recognize that we had something that might be commercially feasible." Niobium was chosen for the seal and made into a cap that expanded at nearly the same rate as aluminum oxide. However, niobium was a fairly exotic element, and new methods of working it had to be devised. Also, a material had to be found to serve as a "frit" (or caulking) between the niobium cap and the equally exotic ceramic tube.

In 1962 GE unveiled the new high-pressure sodium (HPS) lamp. A reporter covering the unveiling noted some bantering between Louden and Schmidt.
" 'He was destroying things as soon as they were made,' said the electrical engineer."
" 'He couldn't make them tough enough,' said the physicist."

Though reported as a joking exchange, the underlying situation was serious. The HPS lamp was not sold until 1965 and was redesigned in 1967. Continued materials research since that time has resulted in: clear ceramic tubes (Westinghouse & Corning, 1976); very high pressure lamps (Philips 1986); and "unsaturated lamps" (Philips, Sylvania 1993). In 1997, ceramic tubes were adapted to metal halide lamps.

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Compact Fluorescent: The Challenge of Manufacturing

Inventing a product often calls for inventing manufacturing equipment and processes. Many Edison patents described improved ways of making lamps. To achieve his price goals, Edison needed mass-produced light bulbs rather than a hand-crafted product. Desire to boost production machine efficiency has often motivated design changes in lamps. Conversely, new lamps requiring complex production techniques have often been shelved as uneconomical. In the 1970s, many inventors proposed designs for efficient compact fluorescent lamps (CFL). Most of these designs worked in the lab. However, most were considered too expensive to mass-produce.

Below are a few of those designs.

John Campbell (General Electric) "Sequential Switching Lamp," 1972. (See U.S. patent # 3,609,436.) Campbell's work on high-frequency fluorescent lamp ballasts in the 1950s led to this design. The lamp contained multiple electrodes, each activated in quick sequence in its own arc-path. The switching circuitry and the glass-work were deemed too complex for mass production.

William Roche (GTE-Sylvania) "Short Arc Lamp," 1974. (See U.S. patent # 3,849,699.) Roche described this lamp in a 1996 interview: "In some of the early days we were trying to develop a ballast-less fluorescent lamp. How could we compact the lamp and eliminate the ballast? [We thought] maybe the ballast wasn't all that bad if we could miniaturize it and tuck it away in the base. This lamp's construction had a filament running the length of the lamp to serve as an ignition aid. The problem is that they were not efficient, the shortness of the arc was one major problem. [In] the short-arc, high-current was required to generate the power, and the high-current in the ballast created losses within the electronics. It proved not to be feasible."

John Anderson (GE) "Solenoidal Electric Field Lamp" and Donald Hollister (Lighting Technology Corporation) "Litek Lamp," mid 1970s. Electrodes are responsible for much of the energy lost in a fluorescent lamp and are usually the first part of the lamp to fail. Both Anderson and Hollister designed small "electrodeless" lamps that operated with high-frequency radio waves instead of electrodes. The electronic components available at the time were expensive and generated too much heat, and neither lamp made it to market. However, in the 1990s, Philips, GE, and Osram-Sylvania all began selling electrodeless fluorescent lamps.

R. Gaines Young (Westinghouse), and Harald Whiting (GE) "Partitioned Lamps," late 1970s. Due to the physics of fluorescent lamps, longer tubes mean higher energy efficiency. One way around this is to create a maze-like path for the electrical arc using glass partitions within a short bulb. Young, Witting, and others patented many variations on this theme, but the glass-work for all proved too complex for high-speed manufacture.

Jan Hasker (Philips) "Recombinant Structure Lamp," 1976. (See U.S. patent #4,101,185). Hasker developed compact fluorescent lamps filled very loosely with glass fibers. These fibers altered the properties of the electrical current flowing inside the lamp, boosting light output without reducing energy efficiency. Though his experiments were promising, Hasker wrote that, "before any practical applications can be realized, technological problems concerning the manufacture of the recombination structure ... should be solved." Hasker's was only one of the CFL designs being developed by Philips, and the company chose not to pursue the lamp, partly due to manufacturing concerns.


Spiral CFL
S.I. image #lar2-2d1

Edward Hammer (GE) "Spiral Lamp," 1976. Hammer's idea (at left) was to take a long, thin fluorescent tube and bend it into a spiral shape. This not only allowed for a long electrical arc, but also simulated the optical properties of a frosted incandescent lamp. Existing lamp machinery had difficulty making the fragile spiral, and GE felt that new machinery would be too expensive, so they shelved the design. However, spiral lamps appeared on the market in 1995 as other manufacturers decided to see if the design could be competitive.

Leo Gross and Merrill Skeist (Spellman Electronics) "Magnetic Arc-Spreading Lamp," 1980. An energized coil of wire in the middle of a cylinder-shaped lamp generated a magnetic field. The field expanded the electrical arc inside the lamp, activating a greater area of phosphors. Prototypes included both cylindrical lamps and a hemispherical unit. According to Skeist, "we achieved 15% improved efficiency" over other CFL designs, at which point, "many companies expressed interest." But the glass envelope proved too expensive to make.

Successful designs from Philips and Westinghouse, and CFLs from other manufacturers that followed, required substantial investment in new production machinery. This was a major reason why the initial price of these lamps was rather high (about $15 in the early 1980s–which would be about $30 now). Large orders from governments and electric utilities, who then offered the lamps to customers at sharply reduced prices, gave producers an incentive to make the needed investments.

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Silicon Carbide: The Lone Inventor

Americans hold a special place in their hearts for the "garage inventor"–someone who, without an expensive laboratory or a large staff of assistants, proceeds to dazzle everyone with a marvelous new gadget. Edison and his team at Menlo Park really don't fit this image, and given the electrical equipment needed for lamp experiments neither did most others of that era. The training and equipment needed for inventing electric lights still serves as a hurdle that lone inventors must overcome. But a large lab is not required for inspiration; that can come from a high school project.

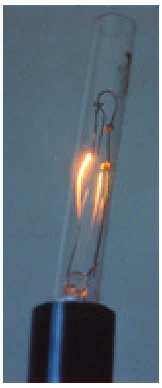
Research to find a better filament has been a part of incandescent lamp history since the beginning. Edison and many other inventors labored to find a suitable material. By the 1920s tungsten became the filament of choice and has remained so to this day. As production techniques became more sophisticated, most researchers turned to improving, rather than replacing, tungsten filaments.

In 1987, John Milewski, Sr. found himself with an interesting situation. His son, Peter, had decided to investigate the electrical properties of single crystal "whiskers" of silicon carbide (SiC) for a high school science fair. Peter's goal was to determine if the ceramic material would make good heating elements. His choice of projects was influenced by his father's career. The elder Milewski (with a Ph.D. in ceramic engineering) worked at Los Alamos National Laboratory, exploring the use of SiC whiskers as structural reinforcement for graphite objects.

John Sr. began assisting his son with some excess silicon carbide left over from lab experiments. SiC could withstand 1500-1600^{o}C, making it a good candidate for a heating element. As they increased the temperature, they found that the whiskers glowed, not totally unexpected since many materials radiate light at high temperature. What surprised them was how fast light production increased as temperature rose. They redirected the project from developing a heating element to evaluating SiC's potential as a lamp filament. Using surplus equipment purchased from Los Alamos, father and son began making light bulbs in their living room.

Though hampered by their inability to create a very high vacuum in their lamps, the comparison of SiC to tungsten yielded interesting results. Peter's project took third place at the science fair, but the consolation prize was U.S. Patent #4,864,186 issued to the Milewskis in 1989. By that time, Peter had entered North Carolina State University, and John Sr. had retired from Los Alamos and established Superkinetic Inc. with $83,000 ($30,000 for patents, $50,000 for equipment). John's goal was to improve the whiskers and seek "more perfect crystals" by initiating experiments with hafnium carbide (HfC). He moved the work out of his home and into a lab at the University of New Mexico.

Unlike corporate researchers, Milewski had to mix fund raising with experimenting. In April 1991, he submitted sample SiC lamps like the one at right to the National Institute of Standards and Technology (NIST) for evaluation and received a favorable review. Later that year he obtained funding from the Electric Power Research Institute (EPRI). The EPRI funds allowed Milewski to improve his equipment and make filaments 5 microns in diameter and 3 mm long.


Silicon carbide lamp
S.I. image #99-4100

However, SiC crystals take around 16 hours to grow, while HfC crystals take 35-40 hours. Problems arose in keeping oven conditions constant for that length of time, particularly with the surplus equipment being used. Milewski and company were building their own equipment or picking up surplus materials from Los Alamos and

Sandia National Labs. Crystal-growth processes became the main problem standing between them and success.

In 1993 the EPRI money ran out, but Superkinetic was able to land a $100,000 grant from the joint NIST-DOE Energy-Related Invention Program. This allowed production of filaments up to 7 micron diameter and 7mm length. The funding only lasted one year, however, and Milewski took a page from Edison's book by expanding research and development in his company to include more immediately marketable products. To date, the ceramic filament lamp remains in the laboratory.

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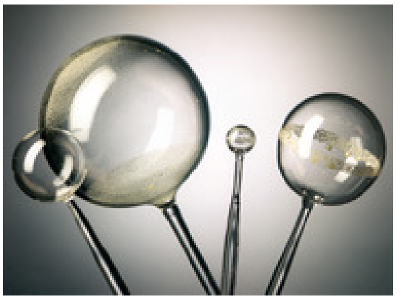
Sulfur: Opportunity in a Non-Lighting Company

George Westinghouse's company became the #2 lamp maker in the U.S., but he did not start out making lamps. Westinghouse invented a railroad air-brake in 1867 and then diversified into electrical railroad devices and more generalized electrical equipment including light bulbs. Invention still occasionally appears from an unlooked-for direction. A breakthrough may require an approach that runs counter to conventional wisdom. Sometimes an answer that requires a large mental leap from an inventor close to a technology may only be a small step for another inventor concerned with a different technology. The development of a microwave-powered light bulb provides a case in point.

In 1990 Fusion Systems was a small company with a successful, highly specialized product. Founded by "four scientists and an engineer," the company marketed an innovative ultraviolet (UV) lighting system powered by microwaves. Introduced in 1976, the system found favor with industrial customers who needed a fast and efficient way to cure inks. A major brewery, for example, purchased the system for applying labels to beer cans.

In 1980 and again in 1986, engineer Michael Ury, physicist Charles Wood, and their colleagues experimented with adapting their UV system to produce visible light. Discharge lamps have traditionally been hindered by the need for electrodes to support an electric arc. Tungsten electrodes are most common, so materials that might erode tungsten can't be used in the lamp and care must be taken to not melt the electrodes. Fusion's UV lamp side-stepped this problem by eliminating the electrodes entirely. Microwave energy was focused on the lamp to energize the discharge. This opened the way for experiments with non-traditional materials, including sulfur.

In 1980 Ury and Wood tried placing sulfur in their linear UV lamp without success. One lamp "blew up," and they shelved the idea. By 1986 they had improved the basic design of the UV lamp by replacing the linear tube with a rotating sphere. Ury decided to try making an electrodeless metal-halide lamp that might be useful in motion picture lighting. The design had color problems, and this project also was shelved.


Sulfur bulbs
S.I. image #lar2-2f1

Ury recalled the sulfur experiments in 1990 and directed engineer Jim Dolan to test the element in the spherical lamp. At 16:57:53 (4:57 pm) on 16 July 1990, a computer print-out showed the inventors what they hoped for: a good visible spectrum with little UV or infrared. They began setting up "crude" lamps in the Fusion production facility in order to learn more about the new light source. They also tested variations of the bulb, such as the different diameter spheres seen here.

After a year of tests, Ury learned of a new optical plastic based on the work of Lorne Whitehead at the University of British Columbia. "Light Pipes" with an internal coating of the plastic would be a perfect way to distribute the light produced by the sulfur bulb. But a demonstration of the technology would be needed.

Lee Anderson, lighting product manager at the Department of Energy heard about the sulfur bulb and saw the invention's potential as an energy saver. He arranged for two high profile public demonstrations of the new technology: outdoors at DOE's Washington headquarters, and inside the most visited museum in the world, the Smithsonian's National Air & Space Museum. Though he realized that failure would be impossible to hide, Ury agreed to the plan.

The installations proved successful, and the lighting industry began to take sulfur lamps more seriously. Commercial units have been placed on the market. While still not widely adopted, several fixture companies have produced designs that can use the lamp. Whitehead's light-pipe technology has seen a bit more success as several companies have coupled conventional metal halide lamps to them. The long term success or failure of both sulfur lamps and light pipes, of course, remains to be seen.

Promoting Modern Lamps

"It's one thing to develop a product, but somehow you've got to market it. We develop products now with specific market applications in sight." (William Roche, engineer, OSRAM SYLVANIA, 1996)

Most of Edison's inventions were also aimed at particular markets. He knew that products had to be promoted, and he knew how to use the media available to him– mainly newspapers, magazines, and live demonstrations. But, as he found out, sometimes even the best promotion couldn't guarantee success.

Some promotional tools available to the modern lamp inventor are little changed from Edison's time. Newspapers and magazines (especially trade and professional journals) are major promotional vehicles. And live demonstrations, whether at trade shows or in actual, high-profile installations, are still quite common.

Perhaps the biggest change lies in the institutionalization of promotion. Corporate lamp inventors today have little responsibility for promoting their invention to customers, aside from posing for photos at a press event. Sales and marketing departments design advertising campaigns and often define likely market targets. And this modern professional promoter has access to media undreamt of in the 1880s, some of which are reviewed below.

World's Fairs & Trade Shows

In the years since Edison's display at the Centennial Exhibition, world's fairs continued to play a role in the introduction of new products. Fluorescent tubes were introduced simultaneously at the New York World's Fair and the (San Francisco) Golden Gate Exposition in 1939.

Even more fruitful was the 1964 New York World's Fair. Both tungsten-halogen and metal-halide lamps were introduced to the public at this event. As seen on the cover of *Life*, national capitals were marked by tungsten-halogen lamps on the Unisphere. Special fixtures were used so that if a lamp failed, another would rotate into place.

Tungsten halogen demonstration
S.I. image #99-4081

Trade shows give lamp marketers the opportunity to introduce products to wholesalers and retailers, as well as to equipment manufacturers who might incorporate lamps into their products. Once shown as part of general electrical shows, there are now several trade shows devoted wholly to lighting.

Public Installations

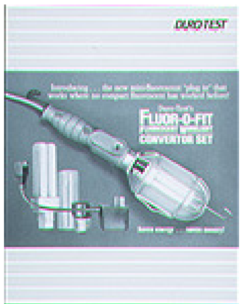
Metal halide demonstration
S.I. image #99-4120

Large public demonstrations, like the 1986 relighting of the Statue of Liberty, have also given makers an opportunity to show their product. A special metal-halide lamp was designed by GE inventor Gilbert Reiling for the Liberty project. Fusion Systems placed three demonstration Sulfur Lamps in the Space Gallery of the National Air & Space Museum in 1994.

These types of demonstrations are not limited to the U.S. In 1995, Dutch lamp-maker Philips installed their "QL" electrodeless compact fluorescent lamps behind the clock faces of London's Big Ben in 1995.

Print Media

Print ads have been a staple of the lighting industry since Edison's day. These ads may come directly from the lamp maker, like the one to the right, or from a wholesaler or retailer. Cooperative programs, in which manufacturers share advertising costs with retailers, is a common industry practice.



Ad for CFL conversion kit
S.I. image #99-4090

Broadcast Media

Radio became the new way to reach into homes during the 1930s. While print ads still predominated and door-to-door sales continued, the popularity of radio allowed corporate lamp makers to reach a broad audience. Television extended this reach in the 1950s and 60s.

The recent emergence of the World Wide Web as a popular medium has not gone unnoticed by lamp makers. Lamp makers are using the web to advertise and to disseminate technical information about their products.

Direct Mail and DSM

CFL rebate coupons
S.I. image #lar2-3a1

Direct mail advertising was a promotional staple of the 20th century. In the 1960s, some electric utilities mailed free, high-wattage light bulbs to customers as part of "load building" programs designed to boost electricity consumption.

This type of promotion turned completely around in the 1980s and 1990s, when many utilities gave away compact fluorescent lamps as part of "Demand Side Management" programs designed to slow the growth in demand for electric power.

The Halarc Adventure: When Promotion Fails

"All of a sudden it was a big project and we had all kinds of meetings and inventions-of-the-week and, ah, just terrible."
(Elmer Fridrich, former GE engineer, 1996)

"It was a disaster."
(Gilbert Reiling, former GE engineer, 1996)

"This was the first electric light to be sold with an instruction manual."
(Lee Anderson, Lighting Program Manager, Department of Energy, 1996.)

Sometimes, no amount of advertising will sell a product. At the time of the energy crisis of 1973, the metal halide lamp was being used successfully for outdoor lighting. Experiments with miniature metal halide lamps had been conducted by GE engineer (and tungsten halogen co-inventor) Elmer Fridrich for several years. Though Fridrich proposed making lamps for commercial and industrial customers, GE managers saw an opportunity to develop a low-intensity version for home use.


Electronic Halarc lamps
S.I. image #lar2-3b1

There were technical problems in making a residential metal halide lamp, some of which were due to basic limitations of physics. The lamp had a warm-up time of about three minutes, could only be used in an upright position, and did not produce a full, continuous spectrum like an incandescent lamp. As a result colors appeared slightly different under this light. But by 1980 GE had a lamp that achieved about 40 lumens per watt, double the energy efficiency of regular incandescent lamps.

GE introduced the "Electronic Halarc" lamp in 1981 to great fanfare. But consumers found the limitations of metal halide technology unacceptable, and also balked at the cost: about $15 (that would be about $30 today). Equally important, public concern about conserving energy had abated. For those still interested, an alternative product, compact fluorescent lamps, had by then reached the market. Despite the millions of dollars GE spent on promotion, the lamp was no longer available in 1984.

Competition for A Modern Lamp

"When you come out with a product, you need to give people choices." (Gilbert Reiling, former GE engineer, 1996)

If a product is successful, other companies inevitably will try to supply that product. Sometimes competitors come up with a different way of doing the same thing or at least make significant improvements. Sometimes they sign a licensing agreement.

In the wake of the energy crisis of the 1970s, public demand for an energy-efficient light bulb resulted in several new products. Several of these designs either stayed in the lab or enjoyed only modest success in the marketplace. Compact fluorescent lamps (CFLs) caught on, though. Twenty years of competition has led to refinements in the basic technology and a large variety of styles. Below, we will examine some of the early competitors to the CFL and a few of the variations on the theme.

Improved Incandescent Lamps

An early response to the problem of making a better light bulb was to keep as much of the incandescent technology as possible and to introduce specific refinements. This not only allowed researchers to draw on decades of existing knowledge to guide their work, but also meant that new designs could use existing production equipment.

One design, already on the market in small numbers, simply replaced the argon gas in a light bulb with krypton gas. Krypton does not conduct heat as well as argon and slows tungsten evaporation from the filament; both factors boost lamp efficacy. An advance in gas production technology lowered the price of krypton in the 1960s, leading to special designs like the "Superbulb" from Westinghouse.

Tungsten halogen lamps had been developed in the 1950s, and several designs intended to replace regular filament lamps went onto the shelf in the 1960s. Some of these designs came off of the shelf and are available today, though they are more expensive than regular lamps.

Another way to boost efficiency was to recycle some of the heat produced by a lamp. Dichroic coatings, developed in the early 1960s, allowed some wavelengths of light to pass, while reflecting other wavelengths. Duro-Test Corporation introduced a spherical lamp with an dichroic coating on the inside in 1980. This "heat-mirror" technique allowed visible light to pass but reflected infrared heat back onto the filament, raising the filament's temperature.

"Heat mirror" lamps
S.I. image #lar2-4a1

Higher filament temperatures meant better efficiency, but the lamp proved fragile and somewhat difficult to make. Duro-Test withdrew the "MiT-Wattsaver" lamp in 1988, but GE then adapted the technology by coating their tungsten halogen lamps with dichroic films. The resulting "Halogen-IR" lamps, though expensive, exceeded 30 lumens per watt.

Small Metal Halide Lamps


"Miniarc" lamp
S.I. image #lar2-4b1

Since the early 1960s, metal halide lamps have contributed to more energy efficient lighting of large areas. In the mid 1970s, General Electric and Sylvania both began experiments on miniaturized metal halide lamps for use in the home. Though Sylvania's "Mini-Arc" (at left) apparently never made it out of the lab, GE put their "Electronic Halarc" on the market in 1981.

With a high price and some operating characteristics that residential users found unacceptable, the lamp failed on the market. GE had shelved several compact fluorescent designs in favor of the Electronic Halarc, and the lamp's failure temporarily placed the company in a difficult competitive position.

Compact Fluorescent Lamps (CFL)

Fluorescent lamps represent one of the more efficient ways to make light, and attempts to make small fluorescent lamps date back to the 1940s. The internal physical properties make this more difficult than it sounds, however, and few practical designs emerged from the 1970s. As noted in our invention section, two designs that did appear on the market were the bent-tube "SL" and "Econ-Nova" designs, from Philips and Westinghouse respectively, and the bridge-welded "PL" design, also from Philips.

Other manufacturers also put bent-tube designs on the market in the early 1980s. Interlectric's "U-Lamp" had, like the Philips and Westinghouse lamps, been evaluated in a late 1970s program sponsored by the US Department of Energy. The Feit Electric Co. lamp from 1986 was a variation on the bent-tube theme.

These early designs used a magnetic ballast to operate the lamp, but magnetic ballasts were a major source of energy losses in fluorescent lamps. Advances in solid-state electronics allowed lamp makers to replace the magnetic ballast with an electronics package. This led to much more efficient lamps, both because the electronics wasted less energy than the magnetic ballast and because lamps operated more efficiently on high-frequency current.

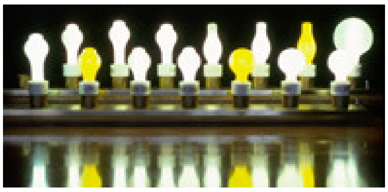
An early variation in compact fluorescent technology arose from a desire to reuse parts of the expensive lamp. Generally, the electrodes in a CFL would burn out long before either a magnetic or an electronic ballast. With one-piece or "integral" designs, this meant throwing away costly and still usable components. To address this issue, lamp makers produced multi-piece "modular" designs which allowed the user to replace only the failed component.

These modular designs typically used tubes with new, plug-style bases so that consumers could not accidentally couple a tube with an incompatible ballast. The plug-type bases also helped address another problem that became apparent in the late 1980s.

Many electric utilities, hoping to slow growth in electricity demand, distributed compact fluorescent lamps to their customers as part of "Demand Side Management" programs. Sometimes the lamps were given away free, sometimes the utilities used a mail-in rebate coupon. However, studies found that, for several reasons, many people used the CFL for a time and then removed it and returned to using an incandescent lamp in that socket–a phenomena called "snap-back."

Plug-type bases encouraged the sale of lighting fixtures with matching sockets. These "dedicated" fixtures would not accept filament lamps, ensuring that only efficient CFLs would be used. Of course many people were reluctant to replace entire fixtures, so designs with conventional screw bases continued to be produced.

A major optical difference exists between CFLs and the filament lamps they are intended to replace. CFLs emit light evenly along the entire tube surface. Filament lamps are considered "point sources," meaning that the light emanates from a small area. Fixtures for incandescent lamps are designed to focus the light from a point source, not from the broad radiating surface of a CFL, leading to light loss within the fixture.


CFL assortment S.I. image #lar2-4c1

Some designs compensate for this by including a reflector, other designs simulate the shape of an incandescent lamp as seen in this assortment of Duro-Test lamps at left. However, an advantage of dedicated CFL fixtures is that their optical properties are designed for CFLs, so little light is lost in the fixture.

Consequences of Modern Lamps.

"Lighting has finally arrived."
(Don Thomas, former Sylvania engineer, 1996)

Lighting considerations are now an integral part of the design of houses, offices, factories, museums, and other buildings. Architects and engineers consider not only light levels but also heat generation and long-term costs. And, increasingly, they consider energy conservation. In Thomas's words, they consider "the whole building as an energy-saving box."

The question for this exhibition is to what extent can this be considered a new "revolution"? In 19th Century Consequences we suggest that Edison's invention (with help from many others) led to two dramatic changes. One was our complete control over interior lighting. The second was the power infrastructure that brought electricity into homes and offices and made it economical to introduce a wide variety of electrical appliances and fixtures.

For 20th Century Consequences we would like you to consider two additional changes, still in process. One is the control we are achieving over exterior light. The second is the degree to which lighting is contributing to our understanding of the importance of energy conservation.

Exterior Lighting

"Some people want a lot of light and others don't."
(Robert Levin, OSRAM SYLVANIA scientist, 1997)

Highly efficient lamps have made it practical to convert night into day around shopping malls, football stadiums, parking lots, filling stations, and barnyards. Not everybody thinks all of this light is necessary or desirable, like the people living in the apartment building to the right. People inside and outside the lighting industry now weigh costs and benefits when considering exterior lighting. But for better or worse, the changes in our lives have been significant.

Example of "light trespass"
S.I. image #99-4118

On the side of benefits, traffic studies since the 1930s have indicated the safety value of street lighting. This includes well-lighted signs that can be read at a glance. Development of bright, reliable lights for use on vehicles has also advanced safety, though misaligned headlights sometimes create problems.

Lighting of large working areas like rail yards, docks, and quarries not only allows activity to proceed after dark but also aids in maintaining security. Airport lighting, with its many special devices, provides a prime example. Overnight delivery services like Federal Express and UPS could not function without night-capable airports.

The ability to illuminate stadiums, racetracks, and playing fields makes it possible for those who work during daylight hours to enjoy the diversion of night-time sports, either as a participant or as a spectator in person or on television. Evening concerts in large outdoor venues are also routine.

While some debate the actual effect of exterior lighting on criminal activity, most agree that people walking in well-lighted areas feel safer. Parking lots sprout lamp posts like trees. Many home owners mount powerful lights around their property, sometimes coupled to motion detectors, to deter crime–as well as smaller walkway and porch lamps to deter injuries.

Neon tubes, fluorescent signs, and lighted store-fronts and bill-boards have become advertising staples. Brilliantly illuminated "White Ways" once attracted shoppers to the downtown stores of major cities in the early 20th century. Now the lights of car dealerships, retail strip centers, and fast-food restaurants vie for attention along miles of major suburban routes.

The costs of exterior illumination began to be felt during the 1970s, when people questioned the amount of energy being used. Despite protests from businesses, illuminated advertising was curtailed for a time. Some streetlights were turned off. Engineers and designers started reevaluating both lighting standards and equipment designs. But as the energy crisis passed, the general public lost interest in the issue and the lights were turned back on.

Astronomers, however, began to feel pressure from increasing levels of "sky glow." Observatories built on top of remote mountains in the late nineteenth and early twentieth centuries found themselves trying to conduct sensitive research thru a haze of suburban lights. The problem became worse as more municipalities replaced older lamps with efficient metal halide and high-pressure sodium lamps. These lamps radiated many wavelengths of light rather than only one or two, making it difficult for astronomers to filter out the artificial light.

Environmental groups and campers also began to notice that night skies were fading into the haze. The term "light pollution" has been coined to describe the problem, and some local governments have enacted ordinances to address it. Wasted light, or light that does not provide illumination on the target surface, is a major cause of light pollution. Light that reflects off of the target surface into the sky is another.

While industry and interest groups debate the proper response, most agree that much of the problem stems from "bad lighting." Fixtures that throw light above the horizontal or that are misaligned are two of the culprits. Many people understand the annoyance of a streetlight that shines in the bedroom window.

New "full cut-off fixtures" have been developed that minimize "light trespass" by directing more light toward the target. Lower power lamps which provide adequate illuminance without excessive reflection are now commonly specified. Low-pressure sodium lamps, relatively easy for astronomers to filter out, are now used around most observatories.

These steps not only reduce light pollution but improve energy efficiency, an aspect of exterior lighting that is starting to attract attention once again.

Energy Conservation

"When the well's dry, we know the worth of water."
(Benjamin Franklin, in *Poor Richard's Almanac*, 1746)

As Franklin experimented with static and lightning, he could not have imagined a day when Poor Richard's truism would apply to electricity. We, however, are reminded of the worth of electric power whenever the lights suddenly go out. In 1998 nearly 70 percent of U.S. electricity was generated using nonrenewable fuels, and we've seen what happens to the worth of oil when wells go dry.


"North America from Space"
S.I. image #99-4114

The movement to conserve energy has been driven by several factors: the high cost of new electric generating plants, the oil crisis of 1973, and a moral desire to help conserve the world's limited resources. But in the United States, still a land of abundance, the impact of these factors on individuals is often short-lived.

Many manufacturers of electric appliances have tried to incorporate energy saving features into their designs, often with encouragement from agencies like the U.S. Department of Energy and the Environmental Protection Agency. More efficient refrigerators, clothes washers, and water heaters have been introduced into the market. Many computers sport an "Energy Star" label, attesting to efficient features.

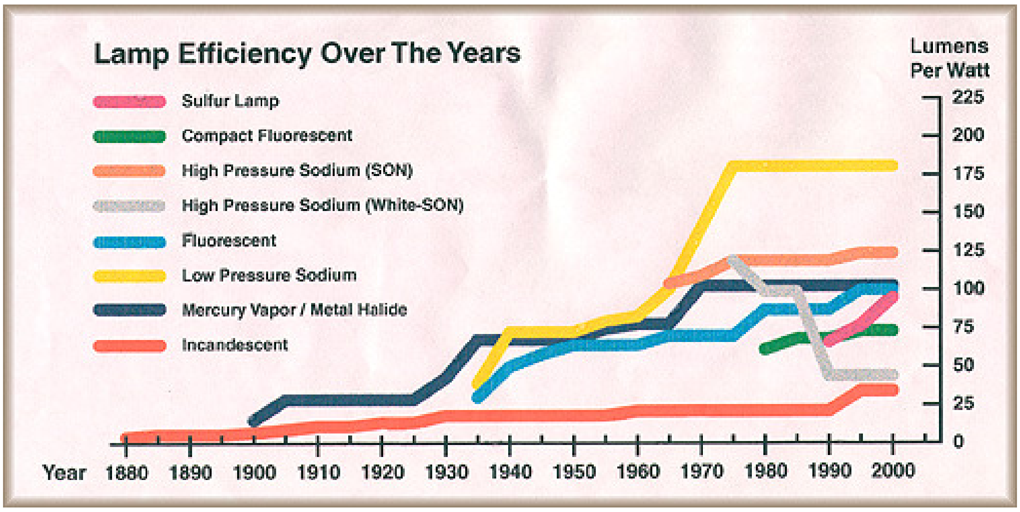
Two problems exist, however. First, major appliances, with design lives of 10 years or more, are only replaced when they break or wear out. Even if every person chooses an efficient replacement, making significant improvements will be slow. Since new, efficient designs are generally more expensive than older, less efficient designs, many people decide to buy the cheaper product–the second problem.

Perhaps what is needed is an appetizer. Might electric light, our most common and obvious use of energy, provide an example? Efficient lamps cost more to buy but save money in the long run because they use less energy and last longer. As people begin to make conscious choices about changing light bulbs in their homes, could they develop an instinctive understanding of conservation? If so, it may become second nature to weigh long-term energy savings against short-term costs.

Welcome to the Guest Lounge & Library

Please browse around and indulge your curiosity. We have posted technical references, historical overviews, scripts for the Lighting A Revolution exhibition, and much more. Don't miss the Curator's Choice -- how much can you guess about the mystery object?

Energy Efficiency:
Light Sources in the 20th Century



The 120 years since Edison's first commercial light bulb have seen tremendous improvements in the efficacy of light sources. That bamboo-filament lamp of 1880 gave about 1.6 lumens per watt (lpw). By contrast, today's common tungsten lamps are about ten times more efficient, and many discharge lamps give over 100 lpw.

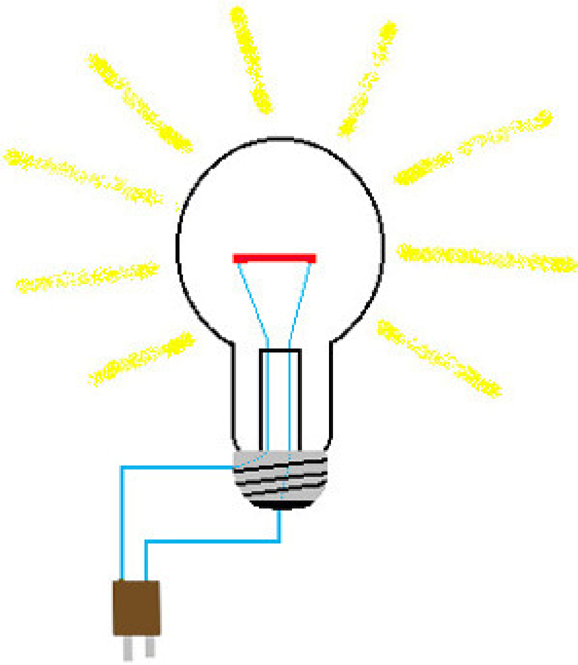
Much of the motivation for increasing efficacy stemmed from the low power of early lamps. From 1880 until the late 1910s, most common lamps gave a dim eight or sixteen candlepower (about the same amount of light as a modern 25-watt lamp). As the gas-filled tungsten lamp became more common in the 1920s, light levels began to rise in many homes. Gas lamps and candles became obsolete or were used only on special occasions.

Industrial users however, found even tungsten lamps too dim for many applications. They either had to install large numbers of fixtures or use higher power light sources like arc lamps or discharge tubes. These lamps were not easy to install or maintain and generally did not give the efficacy of the tungsten lamp, so they cost more to operate.

In the 1930s several efficient discharge lamps became available. Low pressure sodium (LPS), mercury vapor, and fluorescent lamps gave 40-50 lpw, lasted for thousands of hours, and were easy to maintain. Today, LPS lamps approach 200 lumens per watt while fluorescent tubes and metal-halide lamps both provide over 100 lpw.

Sometimes there are trade-offs. LPS, though efficient, gives a stark yellow light. High pressure sodium (HPS or, as it's known in the industry "SON") gives a somewhat better color, but at a lower efficacy. In the 1970s, an even better color HPS lamp (known in the industry as "white-SON") was developed, but the lamps' efficacy suffered still more.

Incandescent Lamps:
How They Work

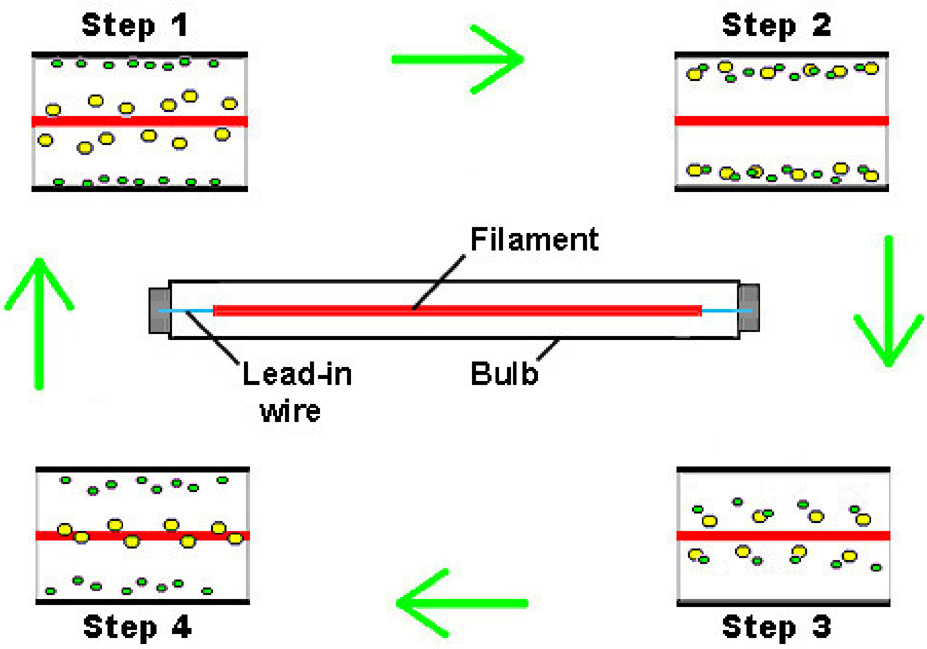


The glowing wire is called a filament. Filaments are made of materials that resist the flow of current.

Current flowing through a material of high resistance (like carbon or tungsten) generates heat and makes the material glow or become incandescent.

The power lines and lead wires are made with materials of low resistance like copper. Thus they do not get hot.

Tungsten Halogen Lamps:
The Halogen Cycle in an Incandescent Lamp



Step 1: Tungsten atoms evaporate from the hot filament and move toward the cooler wall of the bulb.

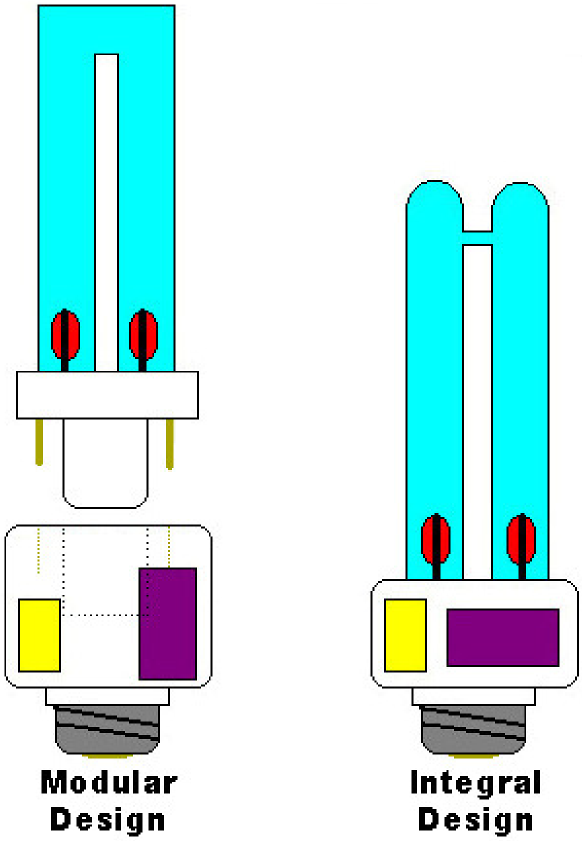
Step 2: Tungsten, oxygen and halogen atoms combine at the bulb-wall to form tungsten oxyhalide molecules.

Step 3: The bulb-wall temperature keeps the tungsten oxyhalide molecules in a vapor. The molecules move toward the hot filament where the higher temperature breaks them apart.

Step 4: Tungsten atoms are re-deposited on the cooler regions of the filament–not in the exact places from which they evaporated. Breaks usually occur near the connections between the tungsten filament and its molybdenum lead-in wires where the temperature drops sharply.

For more information about tungsten halogen lamps see Webnote 7-1.

Compact Fluorescent Lamps:
Good Things in Small Packages



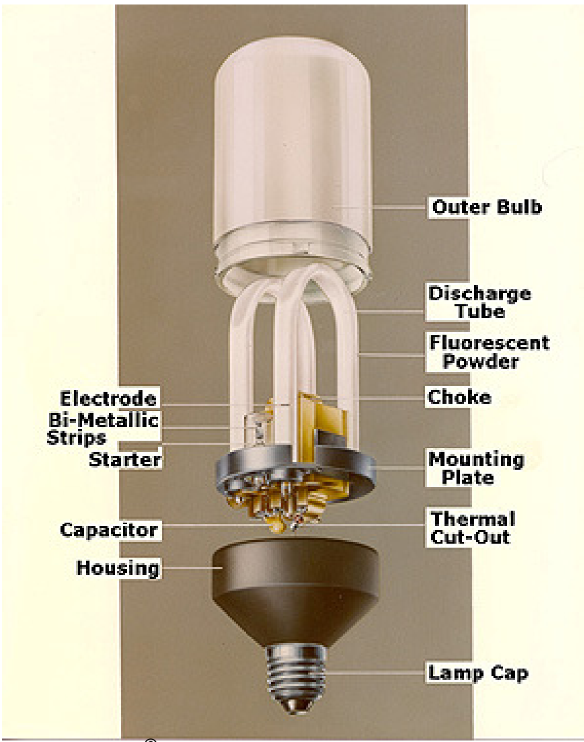
Compact fluorescent lamps (CFLs) operate in the same fashion as conventional fluorescent tubes. However, they did not become practical until the invention of rare-earth / aluminate phosphors in the late 1970s. Earlier phosphors could not stand the stress of being so close to the arc discharge.

CFLs also needed smaller electronic components. This was especially important for CFLs made to directly replace incandescent lamps in existing fixtures.

Some CFLs come as single-piece units. These are referred to as integral lamps. They easily replace incandescent lamps but when the electrodes in the tube fail, the entire lamp must be replaced. Also, it's equally easy to replace an integral lamp with an inefficient incandescent lamp.

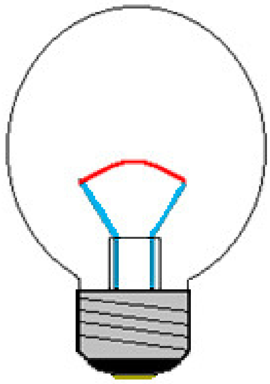
Modular designs come in two or more parts. When the electrodes fail, one needs only replace the tube section to reuse the expensive electronic package. Fixtures are being made to accept the modular tubes' unusual square bases so that an incandescent lamp cannot be used.

The image below is an exploded view of Philips' SL-18® integral lamp, introduced in 1980. The original part descriptions have been added to the photo electronically.



©1980 Philips Lighting Co.

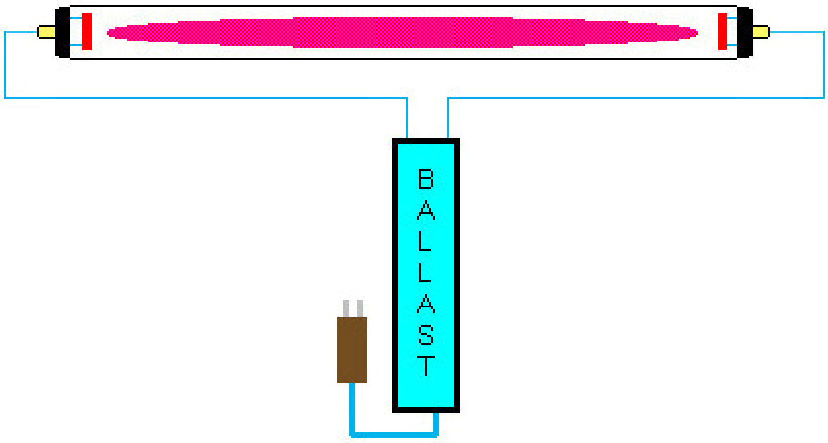
Silica Carbide Lamps:
Light From A Whisker



This incandescent lamp uses a single crystal of silica carbide for a filment rather than a tungsten wire. Another material, hafnium carbide, has also been tried in experiments.

The very thin "whisker" filament is stronger than tungsten, and has a high resistance that changes little during the lamp's operation. A major difficulty lies in growing the single crystals long enought to be useful. The crystals take time to grow and conditions in the oven must remain very stable.

Discharge Lamps:
How They Work

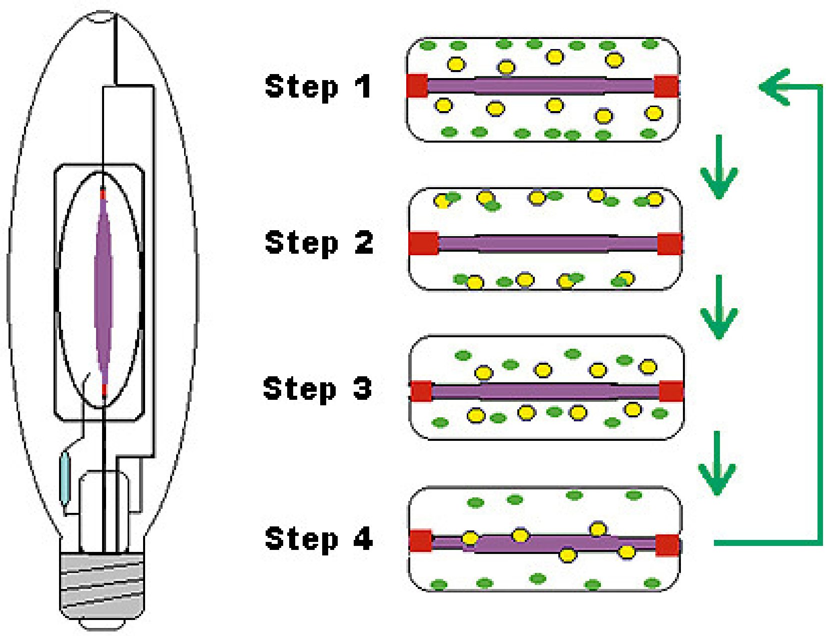


A current of electrons moving between the two ends gives energy to atoms of gas in the tube.

A ballast is needed to control the current flow. Often, a starter is needed to initiate the current flow through the gas.

Gasses commonly used in discharge lamps include neon, mercury and sodium. Fluorescent lamps are discharge lamps -- they use mercury.

Metal Halide Lamps:
The Halide Cycle in a Discharge Lamp



Step 1: Metal atoms move from the hot electric arc toward the cooler arc tube wall where the halides are.

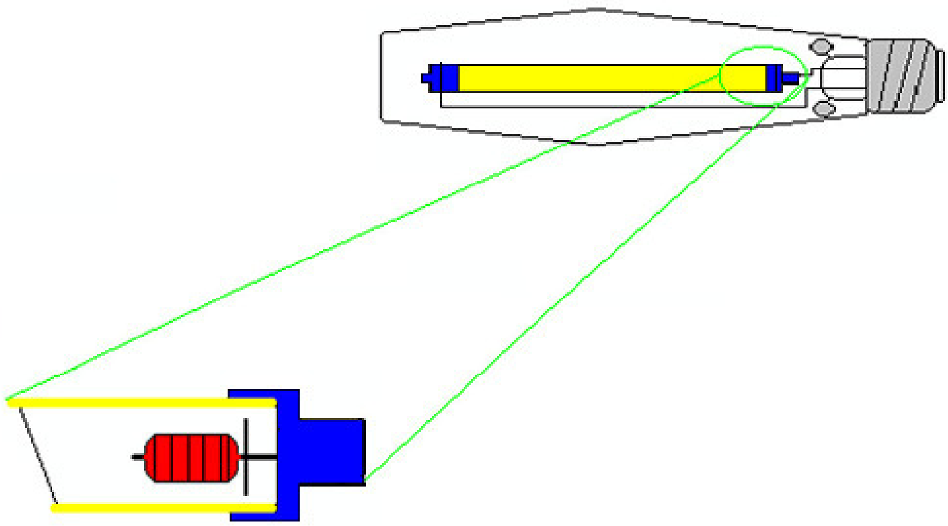
Step 2: Near the wall, the temperature and vapor pressure allow the metals and halides to form a stable molecule which will not corrode the arc tube.

Step 3: When the metal halides approach the hot arc, the molecule breaks apart.

Step 4: The halides move away from the arc, while the metals are energized and radiate light.

Sometimes a metal atom will not combine with a halide, but instead migrates through the arc tube. Over time, when enough metal atoms are lost, the lamp will fail.

High Pressure Sodium Lamps: Working With Exotic Materials

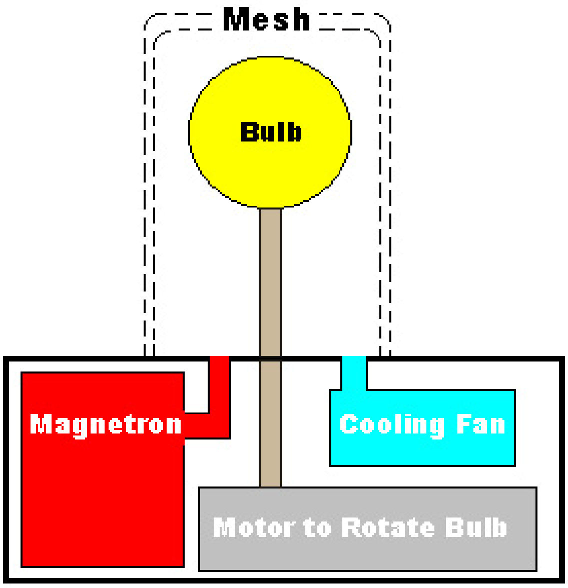


Development of this discharge lamp waited on the invention of a material which sodium would not corrode. A new type of alumina ceramic passed this test. Although the material appears milky white, it is actually 95% transparent.

Sealing the ends of the tubes proved difficult since few materials would stick to the new ceramic, and it would not melt like glass. Niobium seals were the answer.

Since the invention of this lamp in the 1960s, many seal styles have been developed as techniques for working these unusual materials have advanced. In the 1970s a clear alumina material was invented by Corning Glass and used in some lamps made by Westinghouse.

Sulfur Lamps:
Light from Microwaves

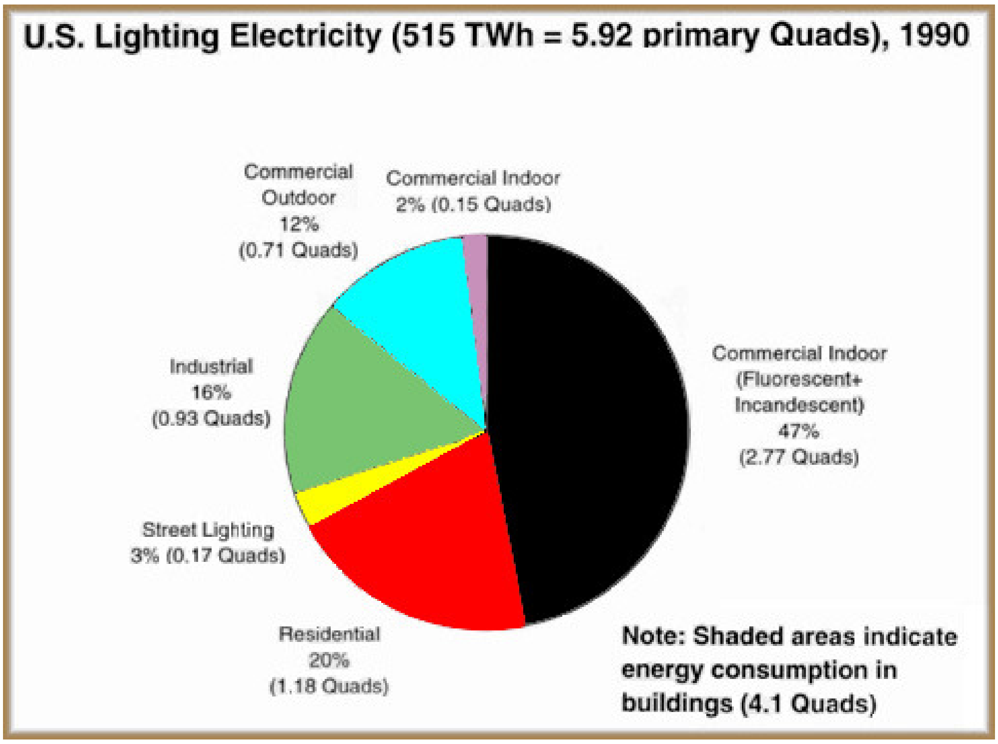


Microwaves give energy to sulfur atoms which emit then emit light.

A magnetron generates microwaves that are contained by a wire mesh screen. A fan cools the bulb and a motor sppins the bullb rapidly so that temperatures stay uniform over the bulb's surface.

There are no electrodes inside the bulb, and since the sulfur is very stable these golf ball-sized bulbs can last a very long time. In fact, in current models of the lamp the magnetron will fail before the bulb will.

Lighting Energy:
Who Turns-on the Lights



Almost half of U.S. lighting energy goes into commercial indoor lighting. This sector includes stores, offices, and schools. This explains why lamp makers have committed so much of their research resources to improving fluorescent lamps--the most common lamp in the commercial sector.

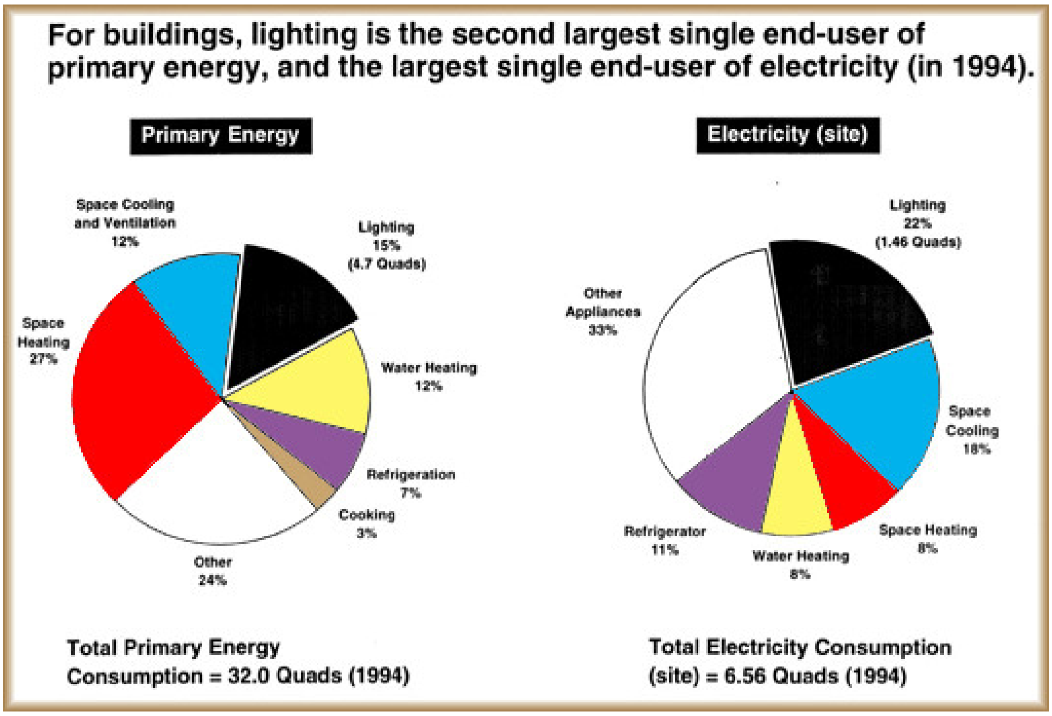
While residential lighting energy seems small in comparison (only 20%), this is a bit misleading. Most homes and apartments are lighted by incandescent lamps that are cheap and easy to use, but very inefficient. As there are so many residential users of light, even small gains can mean big savings if enough people adopt the more efficient product.

To read the chart above, a few definitions are needed. Electricity consumption is measured in "watt-hours" which is simply the number of watts used times the number of hours the electricity flows. A common unit of measure for home owners is the "kilowatt-hour." One kilowatt-hour is equal to 1000 watt-hours. Measuring electricity on a national scale calls for even larger increments, though. "TWh" in the chart stands for terawatt-hours. One TWh is equal to one billion kilowatt-hours.

Electricity is not the only form of energy, however. A common measurement of energy is the British Thermal Unit or BTU. A BTU is the quantity of heat needed to raise the temperature of one pound of water one degree Fahrenheit. "Quad" in the chart stands for one quadrillion BTUs, and is a measure often used in energy industries.

Chart by Lee R. Anderson, compiled from information in "Analysis of Federal Policy Options for Improving U.S. Lighting Energy Efficiency: Commercial and Residential Buildings," December 1992, Lawrence Berkeley National Laboratory, U.S. Department of Energy.

Energy In Buildings:
Lighting and Other Uses

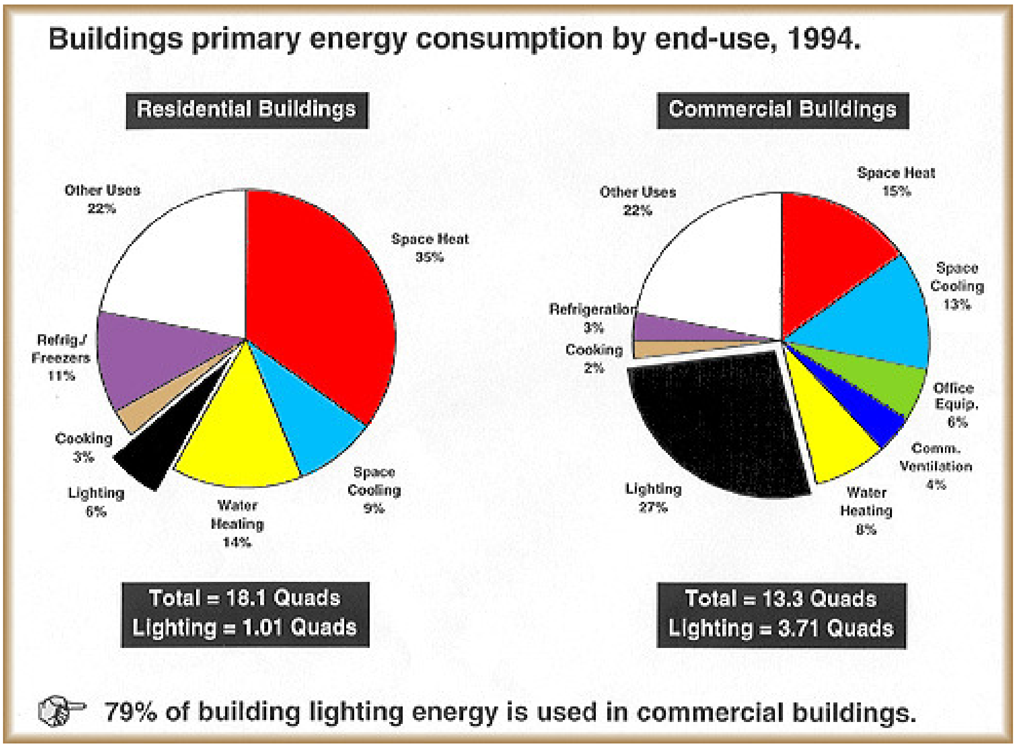


Primary energy includes power derived from steam, oil, natural gas, and coal in addition to electricity. Environmental conditioning (space heating and cooling) represents the largest energy load in most buildings. It is interesting that boosting the efficacy of lamps can help save some of this energy. Most lamps waste energy by generating heat. If lighting efficiency increases, less heat is generated easing the load on air conditioning units.

To read the chart above, a definition is needed. A common measurement of energy is the British Thermal Unit or BTU. A BTU is the quantity of heat needed to raise the temperature of one pound of water one degree Fahrenheit. "Quad" in the chart stands for one quadrillion BTUs, and is a measure often used in energy industries.

Chart by Lee R. Anderson, compiled from information in "DOE Core Databook," 7 June 1996, U.S. Department of Energy.

Energy In Buildings:
Home and Work



Primary energy includes power derived from steam, oil, natural gas, and coal in addition to electricity. The difference in lighting energy consumption in homes and in commercial buildings is significant. The planning process for constructing commercial buildings now generally includes detailed lighting designs. In the past, such planning often lumped the lighting design in with the overall electrical installation or handled by the architect, if there was a lighting design at all.

Today, trained professionals evaluate not only the optimum levels of illumination in various spaces, but also how lighting will affect the energy consumption of a building. Many local governments are adopting building codes that place an upper limit on the amount of energy a new commercial building can use per unit area of floor space.

To read the chart above, a definition is needed. A common measurement of energy is the British Thermal Unit or BTU. A BTU is the quantity of heat needed to raise the temperature of one pound of water one degree Fahrenheit. "Quad" in the chart stands for one quadrillion BTUs, and is a measure often used in energy industries.

Chart by Lee R. Anderson, compiled from information in "DOE Core Databook," 7 June 1996, U.S. Department of Energy.

Script & Webnotes: 19th Century

The complete text of the labels mounted in Lighting A Revolution's 19th century section are available through the links below. Webnote links are included in each of the five label sections, or you can go directly to the webnotes index with the link below. We have also posted lists of the objects and graphics that are included in this section of the show.

The objects and graphics lists are large and may take time to load.

Listed below are the objects displayed in the 19th century section of *Lighting A Revolution*.

Section 1: Preconditions

Catalog #	Object Name	Date	Dimensions	Source
181,343	Henry "Yale" Magnet	1831	*	Yale University
323,886	Voltaic Pile	1805	*	Canisius College
315,114	Cruickshank Trough Battery	1801	*	Joseph Priestly
322,934	J. Frederik Daniell Cell	1836	*	Columbia University
315,801	Grenet Cell	1840	*	Middlebury College
337,158	Georges Leclanche Cell	1868	*	*
252,644	Thomas Davenport Motor (Patent model)	1837	*	U.S. Patent Office
318,743	Charles G. Page Motor	1821	*	Colgate University
180,034C	Charles G. Page Motor	*	*	B&O Railroad
181,577	Gardiner Colton Motor	1847	*	A.J. Davis
252,635	Moses Farmer Motor	1856	*	*
308,567	W. Vergnes Motor (patent model)	1860	*	U.S. Patent Office
327,899	Antonio Pancinotti Motor (reproduction)	1861	*	Chicago Museum of Science & Industry
252,568	Edward Weston Motor (patent model)	1876	*	U.S. Patent Office
323,353	Hippolyte Pixii Generator	1832	*	University of Virginia
326,309	Edward Clarke Generator	1837	*	University of Georgia
181,550	Charles Page Generator	1845	*	*
*	Brevete Magneto (Frederick Holmes type)	1850s	*	from Union College

323,429	Charles Wheatstone Dynamo	1866	*	King's College, London
322,249	Zenobe Gramme Dynamo	1874	*	*
252,659	Edward Weston Dynamo	1878	*	U.S. Patent Office
319,413	Leopoldo Nobili Galvanometer	1820s	*	*
319,741	Leopoldo Nobili Galvanometer	1830s	*	*
326,132	Demonstration Galvanometer	mid-1800s	*	Mount St. Mary's College
315,113	Gauss Galvanometer	mid-1800s	*	*
314,473	Edward Weston Electrodynamometer	mid-1800s	*	Weston Instrument Co.
322,995	Tangent Galvanometer for telegraphy	mid-1800s	*	Western Union
332,099	Tangent Galvanometer	mid-1800s	*	Wabash College
181,739	Henry iron magnet core	1827	*	Mary Henry
181,740	Henry iron magnet cores	1827	*	Mary Henry
315,310	Henry iron magnet core	1832	*	Bowdoin College
315,523	Henry iron magnet core	1827	*	Mary Henry
181,458	Henry iron magnet core	1827	*	Mary Henry
323,887	Electromagnet demonstration	mid-1800s	*	*
252,673	Charles Page Induction Coil	1838	*	*
325,969	Edward Ritchie Induction Coil	1868	*	*
335,588	Telegraph Relay by Charles T. & J.N. Chester	1850s	*	Janet Lewis
327,945	Thomson-Houston Arc Lamp	1870s	32H x 18W x 9D	*
251,235	William Wallace Plate Arc Lamp	1877	10.5H x 9W x 5.25D	U.S. Patent Office
308,584	William Sawyer Incandescent Lamp (patent model)	1878	12H x 4DIA	U.S. Patent Office
320,900	William Wallace Plate Arc Lamp	1877	13H x 12.5W x 3D	IBM, William J. Hammer Collection
181,977	Moses Farmer Incandescent Lamp	1878	9.5H x 6DIA	Sarah Farmer
251,230	Charles Brush Arc Lamp	1870s	49H x 24W x 12D	U.S. Patent Office
252,655	Hiram Maxim Arc Lamp	1878	23H x 7.5DIA	U.S. Patent Office
315,717	Jules Duboscq Arc Lamp	1860	19H x 9W x 9D	U.S. Military Academy
252,646	Paul Jablochkoff "Candle"	1877	12.5H x 6DIA	US Patent Office
181,644	William Wallace Dynamo	1877	*	Coe Brass Manufacturing Company
181,717	Thomson-Houston Dynamo	1879	*	General Electric Company

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Section 2: Invention

Catalog #	Object Name	Date	Dimensions	Source
310,582	Edison Bust by J. Beer, Jr., for the Phrenological Society of America	1878	*	Frank Wardlow, Jr. and Frank Wardlow
*	Caveat, "Acoustic Transfer Telegraph"	10 July 1876	*	*
*	U.S. Patent #266,022 to Thomas Edison	1882	*	*
*	U.S. Patent #208,013 to Thomas Edison	1878	*	*
*	U.S. Patent #272,034 to Thomas Edison	1883	*	*
*	Assignment, Edison to Samuel Mills	23 April 1877	*	*
*	Document, "Case 118, Acoustic Telegraph"	16 May 1876	*	*
*	Preliminary Statement, "Case 118, Acoustic Telegraph"	17 August 1876	*	*
*	Admission of Priority, Interference case between Edison and Elisha Gray	*	*	*
*	Caveat #79, Acoustic Telegraph	10 July 1876	*	*
*	Assignment, Jay Gould to Atlantic & Pacific Telegraph Co.	19 July 1875	*	*
252,622	Carbon-resistance telephone transmitter (patent model)	1878	*	U.S. Patent Office
318,576	Improved Phonograph	1878	*	Princeton University
*	Notebook open to "Test Table" drawing	1880	*	*
*	"Notebook #3, Miscellaneous, Notes, Figures, &c"	*	*	*
*	Notebook open to page 188 - 189, "At E.M. Co."	*	*	*
*	Notebook open to "Coutinuous Alternate Current Dynamo Machines"	1882	*	*
*	Notebook open to page 30 -31, drawing of Johnson bevel-ring lamp	6 July 1881	*	*
*	Vacuum pump drawing	8 July	*	*

		1880		
262,377	Assortment of experimental filament coatings	1879	*	Mrs. George F. Barker
320,526	Assortment of experimental filaments	about 1885	*	IBM, William Hammer collection
*	Bristol-board filaments (2)	1880	*	U.S. Park Service
320,509	Bamboo filaments in a bundle	1880	*	IBM, William Hammer collection
314,259	Bamboo plane	about 1881	*	Vannevar Bush
*	Glassblower's caliper	1880	*	Corning Glass Works
*	Glassblower's paddy	1880	*	Corning Glass Works
310,578	New Years Eve Lamp	1879	*	Frank Wardlow, Jr. and Frank Wardlow
181,798	Wooden mogul-screw based Lamp, 16cp.	1880	*	General Electric Co.
180,932.02	Wooden mogul-screw base socket	1880	2" L x 2.75" DIA.	IBM, William Hammer Collection
318,629	Wooden mogul-screw based Lamp, 8cp.	1880	*	Princeton University
181,799	Wooden Johnson bevel-ring lamp	1881	*	General Electric Co.
180,934	Plaster Johnson bevel-ring lamp	1881	*	J. E. Hinds
320,735	Johnson bevel-ring socket	1881	*	IBM, William Hammer Collection
318,664	Plaster collared lamp	1881	*	Princeton University
318,677	Medium-screw base with plaster insulator lamp	1884	*	Princeton University
na	Edison notebook pages (reproductions)	August 1879	*	Edison National Historic Site

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Section 3: Promotion

Catalog #	Object Name	Date	Dimensions	Source
160,081	Painting of SS Columbia	*	*	John Roach and Son
318,717	Knife Switch	1880s	5H x 14W x 5.5D	Princeton University
262,476	Edison Chemical Meter	about 1882	15H x 13.5W x 5.5 or 17D	The Easton Gas & Electric Co.
331,146	Edison Ammeter	1880s	12.75H x 9.5W x	Western Union

			4.5D	
337,118	Edison fan motor	1880s	10H x 7W x 8.5D	James M. & Reathie L. McKee
314,919	Edison cable sample	about 1885	23.5H x 2DIA	Consolidated Edison Co., New York
314,917	Edison junction box	about 1885	13H x 36W x 10D	Consolidated Edison Co., New York
318,726	Wooden Knife Switch	*	11H x 12W x 5D	Princeton University
318,719	Wooden Knife Switch	*	7H x 9.5W x 2D	Princeton University
318,718	Wooden Knife Switch	*	7H x 11.5W x 2.5D	Princeton University
328,092	Rotary Switch	1880s	4H x 6.5DIA	George C. Maynard
273,182	Rotary Switch	1880s	4H x 4W x 4D	Charles H. Newton
181,754	Bergmann Rotary Switch & Cover	1887	4.5H x 5DIA	George C. Maynard
309,605	Model of Pearl Street Station	1928	*	The New York Edison Co.
180,944	Dynamo switch	1881	6H x 10W x 2D	Hinds, Ketchum Co.
180,942	Dynamo switch	1881	4.5H x 5.5W x 2.5D	Hinds, Ketchum Co.
180,943	Fuse	1881	4H x 5W x 1.5D	Hinds, Ketchum Co.
180,946	Fuse	1881	10H x 7W x 5.5D	Hinds, Ketchum Co.
180,934	Plaster Johnson Bevel-ring lamp	1881	5.25H x 2.25DIA	Hinds, Ketchum Co.
180,940.01	Johnson Bevel-ring socket and fixture	1881	20H x 2DIA	Hinds, Ketchum Co.
180,940.02	Mogul Screw-base socket and fixture	1881	18H x 2.5W x 3.5D	Hinds, Ketchum Co.
180,941	Resistance coil	1881	14.75H x 6.5W x 7D	Hinds, Ketchum Co.
180,939	Johnson Bevel-ring printer's luminaire	1881	24H x 5W x 15D	Hinds, Ketchum Co.
*	Luminaire with two medium screw-base sockets	about 1890	11H x 14W x 11D	National Park Service
10,175	Combination gas / electric luminaire	about 1890	10H x 11W x 10D	National Park Service
*	Two converted gas luminaires with lamps	about 1890	11.5H x 12.5W x 8D	Mt. Vernon Museum of Incandescent Lighting

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Section 4: Competition

Catalog #	Object Name	Date	Dimensions	Source

327,831	Sawyer-Man lamp	1885	*	Chicago Museum of Science & Industry
323,557	Swan lamp	1881	*	*
181,804	Edison lamp	1886	*	General Electric Co.
327,785	Edison lamp	1888	*	Chicago Museum of Science & Industry
1997.0388.80	Westinghouse "Stopper" lamp	about 1894	6.75 L x 3 DIA	from General Electric Lighting Co.
1997.0388.79	Thomson-Houston Decorative lamp	about 1890	5.5 L x 2.75 DIA	from General Electric Co.
327,839	Sterling carbon lamp	about 1900	*	Chicago Museum of Science & Industry
327,830	Fostoria carbon lamp	about 1900	*	Chicago Museum of Science & Industry
318,641	Brush-Swan carbon lamp	about 1885	*	Princeton University
181,980	Maxim carbon lamp	1881	*	Sarah J. Farmer
318,666	New Type Edison lamp	about 1890	*	Princeton University
311,930	Westinghouse carbon lamp	about 1890	*	Newark College of Engineering
318,674	Vitrite-Luminoid carbon lamp	1890	*	Princeton University
320,675	Columbia "USONA" carbon lamp	about 1905	*	*
327,856	United Electric Improvement Co. carbon lamp	about 1894	*	Chicago Museum of Science & Industry
318,749	Columbia carbon lamp	about 1890	5.75 L x 2.75 DIA	Colgate University, Dept. of Physics & Astronomy
230,836	Phelps twist-style Hy-Lo carbon lamp	about 1895	*	General Electric Co.
325,794	Perkins carbon lamp	about 1890	*	Thompson Equipment Company
335,363	Peerless carbon lamp	about 1890	*	Robert F. Hoke
318,634	Weston carbon lamp	about 1887	*	Princeton University
320,673	Maxim carbon lamp	about 1881	*	IBM, William Hammer collection
327,811	Ediswan carbon lamp	about 1885	*	Chicago Museum of Science & Industry
323,559	Elblight carbon lamp	about 1890	*	*
318,642	Weston carbon lamp	1882	*	Princeton University
313,320	Imperial carbon lamp	about 1900	*	Chicago Museum of Science & Industry
327,853	Sunbeam carbon lamp	1900	*	Chicago Museum of

				Science & Industry
327,829	United Electric Improvement Co. lamp	about 1894	*	Chicago Museum of Science & Industry
318,607	Shelby carbon lamp	about 1905	*	Princeton University
314,289.16	Knowles carbon lamp	about 1895	*	C. Locklin
314,289.17	Pond carbon lamp	about 1895	*	C. Locklin
314,289.18	K&W carbon lamp	about 1895	*	C. Locklin
327,840	McNutt carbon lamp	about 1895	*	Chicago Museum of Science & Industry
327,796	Capital carbon lamp	about 1900	*	Chicago Museum of Science & Industry
327,800	Independent carbon lamp	about 1895	*	Chicago Museum of Science & Industry
327,792	Buckeye carbon lamp	about 1895	*	Chicago Museum of Science & Industry
320,761	Ediswan socket	about 1890	*	IBM, William Hammer collection
327,857	United Electric Improvement Co. socket	about 1894	*	Chicago Museum of Science & Industry
320,763	Swan socket	*	*	IBM, William Hammer collection
320,748	Insulite Thompson-Houston socket	about 1895	*	IBM, William Hammer collection
320,746	Westinghouse socket	about 1899	*	IBM, William Hammer collection
214,331	Nernst lamp with Westinghouse plug	1902	*	Nernst Lamp Company
*	Book by Latimer: "Incandescent Electric Lighting"	*	*	*
*	C.S. 825 - "The Edison Electric Light"	*	*	*
*	C.S. 825 - "The Edison System of Incandescent Lighting"	*	*	*
*	Booklet: "Westinghouse Co. Infringements of the Edison Patents"	*	*	*
*	List of Edison "Z" dynamos"	*	*	*
*	Columbia College, lit by Edison Co.	1884	*	*
*	Booklet: "The United Electric Light & Power Co."	*	*	*
*	Booklet by Sprague: "Electric Lighting; Its State and Progress,	1878	*	*

	1878"			
*	Booklet: "A Warning from the Edison Electric Light Co."	*	*	*
*	Booklet: "Street Lighting by the Edison Municipal System"	*	*	*
*	Book by Johnson: "Safeguards Against Fire"	*	*	*
*	Catalog with colored drawing on cover: "The Edison Electric Light"	*	*	*
*	Book by Levey: "Electric Light Primer"	about 1890	*	*
*	"Financial & Commercial Success of Electric Lighting"	1885	*	*
*	U.S. Circuit Court: "The Edison Incandescent Lamp Case"	1891	*	*
*	Book: "The Edison Electric System: Light and Power" (2nd Edition)	*	*	*
*	Catalog: "The Columbia Incandescent Lamp Co."	*	*	*
*	Catalog: "The Nernst Lamp"	*	*	*
*	Book: "Electric Lighting" (open to pages 18 & 19)	*	*	*
*	Catalog: "Sawyer-Man Electric Co."	*	*	*
*	Catalog: "Brush-Swan System"	*	*	*
*	Catalog: "Das Edison-Licht"	*	*	*
*	Catalog: "La Lumiere Edison"	*	*	*
*	Catalog: "The Mather System"	*	*	*
*	Catalog: "Stanley Transformer" (open to illustration on page 15)"	*	*	*
*	Catalog: "Facts About the Sprague Electric Stationary Motor"	*	*	*
*	Picture: Factory of the U.S. Electric Lighting Co., Newark, N.J.	*	*	*
*	Catalog: "Adams-Bagnall Electric," Cleveland	*	*	*
*	Catalog: "Sprague Motor Operating Elevator" (open to illustration on page 9)	*	*	*
*	Catalog: "Brush Electric Co.," Cleveland	*	*	*
*	Catalog: "Schuyler Electric Light Co."	*	*	*

318,351	Thomson voltmeter	about 1891	*	Princeton University
322,811	National Electric ammeter	*	*	State University of NY, Buffalo
318,376	Slattery ammeter	*	*	Princeton University
313,670	Edison "Kennelly" ammeter	*	*	Weston Electrical Instrument Corp.
317,692	Hartmann & Braun ammeter	*	*	Iowa State University
319,238	Weston ammeter	about 1890	*	Daystrom Inc.
219,027	Thomson-Houston voltmeter	about 1890	*	Potomac Electric Power Co.
318,356	Thomson-Rice ammeter	*	*	Princeton University
334,396	GE Thomson voltmeter	about 1903	*	American Museum of Electricity
314,968	Norton voltmeter	*	*	E. P. Custis
318,320	Westinghouse ammeter	*	*	Princeton University
319,443	Gardiner electro magnetic meter	*	*	Mrs. Donald Bliss
314,411	Stanley phase-indicator ammeter	*	*	Weston Electrical Instrument Corp.
313,286	Edison General Electric ammeter	1890	*	Weston Electrical Instrument Corp.
314,459	Stanley static ground detector	about 1896	*	Weston Electrical Instrument Corp.
318,350	Ft. Wayne "Wood" Ammeter	about 1890	*	Princeton University
326,483	Ft. Wayne "Wood" Meter	about 1895	*	General Electric Co.
326,921	Biddle wattmeter	about 1895	*	Trinity College
336,453	Weston voltmeter	about 1900	*	Donald Hoke
1998.0112.01	Ft. Wayne "Wood" Voltmeter for AC	about 1890	4 D x 11.5 DIA	Vincent King
*	Western Electric voltmeter	*	*	National Park Service
318,301	Thomson Wattmeter	about 1887	*	Princeton University
334,385	Western Electric ammeter	*	*	American Museum of Electricity
*	Interactive display with transformer, meters, and lamps	*	*	*
311,853	Gaulard & Gibbs transformer	1883	*	Westinghouse Electric Manufacturing Co.
322,808	Stanley transformer (reproduction)	1886	*	*

327,571	Ferranti transformer	*	*	Sabastian de Ferranti
318,553	Westinghouse transformer	1887	*	Princeton University
334,376	Thomson wattmeter	1890s	*	American Museum of Electricity
334,416	Sangamo DC wattmeter	1890s	*	American Museum of Electricity
322,183	Westinghouse wattmeter	about 1894	*	Massachusetts Institute of Technology
334,377	Westinghouse wattmeter	about 1889	*	American Museum of Electricity
318,349?	Stanley Watthour meter	1890s	*	American Museum of Electricity
334,389	Stanley wattmeter	1890s	*	American Museum of Electricity
327,571	Ferranti generator	1883	*	Sabastian de Ferranti
315,075	Brush generator	1884	*	Massachusetts Institute of Technology
181,720	Thomson-Houston generator	1885	*	General Electric Co.
319,260	Edison 6kw motor	about 1883	*	Brown University
311,854	Tesla AC motor	1888	*	Westinghouse Electric Manufacturing Co.
313,044	C&C sewing machine motor	1886	*	Crocker - Wheeler Electric Manufacturing Co.
320,572	Edison Z-type generator, rated at 60 lamps (52 amps at 110 volts)	about 1888	*	University of Minnesota
305,262	Edison Voltmeter	1880s	*	Roller-Smith Company
*	Edison Voltmeter	1880s	*	*
318,717	Edison porcelain fuse-block	1880s	*	Princeton University
314,474	Edison Bergmann ammeter	1880s	*	Weston Electrical Instrument Company
*	Rheostat (Edison Type)	1880s	*	*
318,252	Westinghouse single-phase generator (220 volts, 40 amps)	about 1888	*	Cornell University
322,556	Exciter generator	1880s	*	Princeton University
318,277	Westinghouse Voltmeter	1880s	*	Princeton University
*	Fuse (Westinghouse System)	1880s	*	*
*	Fuse (Westinghouse System)	1880s	*	*

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Section 5: Consequences

Catalog #	Object Name	Date	Dimensions	Source
322,844	Westinghouse dynamo nameplate	1897	*	Niagara - Mohawk Power Co.
*	Power Station generator model	*	*	NMAH Construction
315,850	Power Station turbine model	1892	*	Niagara - Mohawk Power Co.
320,523	cable section	1895	*	IBM [Hammer collection]
318,344	porcelain insulator	1895	*	*
*	Carborundum sample	*	*	Mrs. Edward Acheson
*	Carborundum sample-wheel on card	*	*	*
51690	Aluminum sample - face	*	*	Pittsburgh Reduction Co.
51690	Aluminum sample - owl	*	*	Pittsburgh Reduction Co.
51629	Aluminum sample - ingot	*	*	Pittsburgh Reduction Co.
51679	Aluminum sample - "faucet handles"	*	*	Pittsburgh Reduction Co.
51688	Aluminum sample - sheet	*	*	Pittsburgh Reduction Co.
*	Booklet: "The Wonders of Niagara"	*	*	Warshaw Collection of Business Americana, NMAH
*	Ink-blotter and advertisement: "Triscuit"	*	*	Warshaw Collection of Business Americana, NMAH
*	Two ink-blotters and advertisement: "Shredded Wheat"	*	*	Warshaw Collection of Business Americana, NMAH
330,674	General Electric Heater	about 1893	*	Phillip Klien
330,997	Hoover vacuum cleaner	1908	*	The Hoover Company
330,712	American Electrical Heater tea kettle	1904	*	Lawrence R. Friel
1991.0410.02	Spot Reducer massager	*	3.5 L x 3.5 W x 6 H	Bernard S. Finn
333,893	Egg-stirrer	*	10 H x 6 DIA x	Alfred T. Giller
330,718	Manning Bowman cigar lighter	1911	*	Mrs. Walter Lindquist
1990.3115	Cigar lighter figurene	*	7 L x 2.25 W x 4.5 H	Bernard S. Finn
330,714	Shaving mug	1914	*	LeRoy Halsey
330, 721	Daniel Woodhead glue pot	*	*	Thomas J. Kliminiski

314,346	Appliance wattmeter	*	*	Weston Electrical Instrument Co.
1989.0643.02	Weller soldering-iron prototype	1941	*	Carl Weller
330,665	GE Hotpoint heating pad	*	*	General Electric Co.
1990.0401	Kimco electric socks	*	9 L x 6.5 W x 4 H	Bernard S. Finn
330,770	Simplex waffle iron	about 1910	*	Mrs. Ted Bussman
1979.1044.02	Universal kitchen set	1926	13 L x 9.5 W x 9 H	Marabeth S. Finn
329,791	Iron	1906	*	*
330,776	Marshmallow toaster	about 1909	*	Mr. and Mrs. Samuel F. Hunter
1991.0410.03	Kenmore hair-dryer	about 1949	7.5 L x 4 W x 9 H	Bernard S. Finn
330,647	Curtis & Crocker fan	1886	*	Chicago Museum of Science & Industry
330,673	General Electric fan	about 1892	*	General Electric Company
328,749	Edison Electric fan	1880s	*	Dept. of Physics, Amherst College
1997.0387.25a and .25b	Hunter ceiling fans (2)	about 1897	*	Mt. Vernon Museum of Incandescent Lighting
1979.1044.01	Lyhne Desk Lamp	about 1911	*	Marabeth S. Finn
70.37	"Solar" lamp converted to electricity (with small shade)	about 1920	13 H x 7 DIA	Clara B. Blackmar
65.180	Kerosene lamp converted to electricity (with bird shade)	about 1920	21.5 H x 11 DIA	Mrs. Fielding Pope Meigs
*	1840s gas lighting fixture converted to electricity around 1895	about 1895	*	Mt. Vernon Museum of Incandescent Lighting
*	Combination electric and gas lighting fixtures	about 1895	*	Mt. Vernon Museum of Incandescent Lighting
1981.595.02	Wall-mounted sconce	about 1920	15 H x 7 W x 4.5 D	*
1991.837.01	"Watchdog Nite-Lite"	about 1950	6 L x 6.25 H x 3.5 W	*
1995.0340.01	Sign from U. S. Patent Office	*	18 L x 9 W x 2.5 H	Robert C. Reed
1992.0284.02	Rambusch church wall-fixture	*	18 L x 16.5 W x 4 H	Rambusch
1992.0284.01	Rambusch church wall-fixture	about 1908	14.5 L x 11 W x 1/16 [1] H	Rambusch
1990.136.02	Table lamp with	1907	20 H x 12 DIA	*

	Emeralite shade			
*	Flashlights	about 1940	*	Eveready Battery Co.
1994.0219.01	Ever Ready Flashlight Cane	about 1910	*	Lawrence N. Ravick
350,649	Electric Table lamp	about 1910	14 H x 5 W x	Miss M.H. Avery
x-93-1	Photographic pendant lamp	about 1899	16 H x 16 DIA	(prop)
1992.0284.03	Rambusch ceiling fixture	about 1939	27 L x 27 DIA	Rambusch
329,287	General Electric model D-12 toaster	1910s	*	*
334,586	Universal model E945 toaster	about 1920	7.5 L x 4.25 W x 9.5 H	Edmond Chenette
1991.1.1	Universal / LFC model E9410 toaster	about 1928	14cm D x 21.5 W x 22 H	gift of Richard J. & Fannie V. Beall
1992.338.19	Waters-Genter model 1A1 toaster	about 1926	12cm D x 26 W x 19 H	Gift of Joyce Barth & Florence E. Scuderi from the Belford Giberson Collection
1992.338.28	Universal / LFC model E7212F toaster	about 1930	7.5 L x 5 W x 8 H	Gift of Joyce Barth & Florence E. Scuderi from the Belford Giberson Collection
336,530	Sunbeam model B toaster	about 1925	12 L x 7 W x 5 H	from Mr. & Mrs. Harry Failing
1992.338.2	Estate Electric model 77 toaster	about 1925	7.5 L x 7.5 W x 7 H	Gift of Joyce Barth & Florence E. Scuderi from the Belford Giberson Collection
1988.227.01	Toast-O-Lator model J toaster	about 1940	30cm L x 11.5 W x 24.5 H	*
8010	T.A. Edison "Edicraft" toaster	about 1929	12 L x 6.5 W x 8 H	from the National Park Service
1987.0368.01	Toastmaster model 1A5 toaster	about 1950	10 L x 4.5 W x 7 H	Bernard S. Finn
1992.338.04	Universal / LFC model E7222 toaster	about 1925	13cm D x 21.2 W x 20 H	Gift of Joyce Barth & Florence E. Scuderi from the Belford Giberson Collection
MN7891-A	Electric coal-cutter	*	*	Jeffery Manufacturing Co
1980.0405.02	AC control board	*	*	Consolidated Edison Co. of New York, Inc.
1980.0405.03	Group switch and circuit breakers	*	*	Consolidated Edison Co. of New York, Inc.
1980.0405.04	DC feeder selector switch assembly	*	*	Consolidated Edison Co. of New York, Inc.

1998.0162.01	Elevator	1902	*	Cooper-Hewitt Museum of Decorative Arts & Design
321,385	Westinghouse street-car controller	1910	*	Robert M. Vogel

Listed below are the graphics displayed in the 19th century section of the exhibition. Copyright belongs to the source unless otherwise noted.

Graphics permanently removed from the exhibition during the 2003 renovation are noted below in red font.

Section 1: Preconditions

Negative #	Image Title	Date	Source	Comments
46,790-O	Morse Telegraph Sounder, 1850s	1908	*	Drawing of a Morse Telegraph Sounder
78-17711	Edison Generator, 1870s	1885	*	Drawing of a Edison Generator
46,890E	Froment Motor, 1870s	1883	*	Drawing of a Froment Motor
46,957A	Foucault Arc-lamp, 1870s	1864	*	Drawing of a Foucault Arc-lamp
47,037	Bell Magneto Telephone, 1880s	1908	*	Drawing of a Bell Magneto Telephone
44,454A	Westinghouse Transformer, 1880s	about 1885	*	Drawing of a Westinghouse Transformer
80-16511	Edison (age 59) in front of his lab bench in West Orange Laboratory	1906	*	*
*	Edison at age 14	1861	*	p.42 L.A.R. Catalog
*	Edward Weston (1850 -1936)	*	*	Weston emigrated from England to Newark, New Jersey, in 1870. He established the Weston Electric Instrument Company there in 1888. Its meters gained a reputation for accuracy and reliability.
*	Zenobe-Theophile Gramme (1826 - 1901)	*	*	Gramme, a Belgian, used Pacinotti's armature design to make efficient magneto generators in the 1860s and self-excited dynamos in the 1870s.
*	Antonio Pacinotti (1841 -1912)	*	*	Born in Pisa, Italy, Pacinotti became professor of physics at the University of Bologna at age 23. There he developed a ring armature design that was used by Gramme in motors

				and generators.
*	George F. Barker (1835 -1910)	*	*	A professor of Physics at the University of Pennsylvania from 1835 to 1900, Barker was Edison's closest friend in the academic community. His interest in electric lighting was an influence on Edison in 1878.
78-17840	Brush arc lamps at the Military Academy, West Point	1879	*	*
45,394a	Arc lighting in Dublin	1849	*	*
46,957g	Arc lighting in Paris	1878	*	*
47,038n	Arc lighting inside the Hippodrome in Paris	1880	*	*
80-16568	Paul Jablochkoff (1847 -1894)	18	*	Born in Russia, Jablochkoff spent his career in Paris. There he invented an "electric candle" arc light in 1877, which was sensational in demonstrations in theaters and opera houses.
*	Charles F. Brush (1849 -1929)	18	*	Trained in chemistry at the University of Michigan, Brush established himself in Cleveland. There he built his first dynamo in 1875 and an arc light in 1876. His company eventually became part of General Electric.
*	Edwin J. Houston (1847 -1914)	18	*	Houston was born in Alexandria, Va., but spent most of his life in Philadelphia teaching at Central High School. With Elihu Thomson, he designed an arc-light generator. He left the Thomson-Houston Company in 1882 to devote his time to teaching.

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Section 2: Invention

Negative #	Image Title	Date	Source	Comments
15,390	Matthew Brady photo of Edison (age 31) with phonograph	1876	*	p.8 L.A.R. Catalog*
49,474g 80-16718	Edison with his team inside the Menlo Park lab	1880	*	*
80-18655	Edison as the Wizard, from the New York Graphic	1877	*	*
*	Photo of Edison's drawing of an air bubble in platinum wire	January 19, 1879	Edison National Historic Site	*
80-18680	Photo of the patent for Edison's platinum	*	*	*

	filament lamp			
47,961c	Photo of an Edison assistant operating the new vacuum pump	*	*	*
70,672	Menlo Park during the New Year's Eve Demonstration	31 December 1879	*	*
*	Front steps of Menlo Park laboratory with Edison holding straw hat	1880	Edison National Historic Site	*
80-16529	Laboratory compound in winter of 1880 as sketched by R. F. Outcault. Center building is laboratory, front right is library, and at rear is machine shop	1880	Edison National Historic Site	*
80-16540	Formal view of Edison and staff at laboratory	1880	Edison National Historic Site	*
49474g	Inside the laboratory	1880	Edison National Historic Site	*
*	Sarah Jordan's Boarding house at Menlo Park	1880	Edison National Historic Site	*
87-1592	Laboratory building at Menlo Park	about 1879	Edison National Historic Site	*
80-16528	Photo of the electric railway at Menlo Park	about 1879	*	*
80-18648	Drawing of Edison's telegraphs: Duplex, Quadruplex, and Autograph	about 1879	*	*
*	Edison's motor patent #228,617	8 June 1880	*	*
87-1711	Edison and C. P. Steinmetz	1922	*	Label id: A
*	Mary Stilwell Edison (first wife) at about 28	1888	*	Label id: AA
*	Edison around 1900	around 1900	*	Label id: B
*	Edison at "Glenmont" home	1917	*	Label id: BB
80-16532	Edison in West Orange Laboratory library, with model of concrete house he was producing in background	1911	*	Label id: C
87-1670	Edison resting in West Orange Laboratory	1911	*	Label id: D
*	Samuel Edison Jr. (father)	*	*	Label id: E
*	Nancy Elliott Edison (mother)	*	*	Label id: F
*	Railway station where Edison learned telegraphy	*	*	Label id: G
*	Edison at time clock	about 1921	*	Label id: H
*	Last photo taken of Edison	1931	*	Label id: I
*	Announcement of intention to be an inventor	1869	*	Label id: J

*	Naval Consulting Board, with Franklin Roosevelt at left end of first row, Edison third from left	1915	*	Label id: K
87-1594	Mina Miller Edison (second wife), about time of wedding	about 1886	*	Label id: L
*	Edison and Mina	1906	*	Label id: M
80-16546	Edison and motion pictures	1912	*	Label id: N
15,390	Matthew Brady photo of Edison with phonograph	1876	*	Label id: O
*	Edison with dictaphone	1893	*	Label id: P
87-1671	Edison in West Orange Laboratory	1893	*	Label id: Q
80-16538	Edison in West Orange Laboratory	about 1886	*	Label id: R
*	Edison at about four	about 1851	*	Label id: S
*	Edison at age ten	1857	*	Label id: T
87-1629	Edison "Glenmont" home.	*	*	Label id: U
87-1604	Edison with staff at West Orange	1893	*	Label id: V
*	Edison at about 34	1880-1881	*	Label id: W
*	Edison at 31	1878	*	Label id: X
*	Edward Hurley, John Burroughs, Edison, Henry Ford, Harvey Firestone, R. J. H. Deloach at start of camping trip	1918	*	Label id: Y
87-1605	Edison with improved phonograph	1888	*	Label id: Z

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Section 3: Promotion

Negative #	Image Title	Date	Source	Comments
*	Emil P. Spahn photo of Edison at age 33	1880	*	p.3 LAR catalog
78-17751	Display of Edison equipment at Cincinnati Exposition	1885	*	*
79-4883	Display of Edison equipment at Paris Centennial Exposition	1889	*	*
87-1631	Display of Edison equipment at Paris Centennial Exposition	1889	*	*
79-4884	Display of Edison	1889	*	*

	equipment at Paris Centennial Exposition			
*	William J. Hammer with some of his collections	about 1904	*	*
80-16564	Francis Jehl (1860 - 1941)	*	*	Born in New York City, Jehl had little schooling. He became an assistant to Edison at Menlo Park and went to Europe in 1882 to promote the Edison System. On his return he helped reconstruct the Menlo Park laboratory at Dearborn, Michigan.
80-16690	Francis R. Upton (1852 -1921)	*	*	As a graduate of Bowdoin, with graduate work at Princeton and in Germany, Upton was the best-educated of Edison's assistants. Nicknamed Culture by his colleagues, worked on the light bulb, the generator, and other projects.
80-16685	Charles W. Batchelor (1845 - 1910)	*	*	Batchelor was born in London and trained as a mechanic. He came to the U. S. at age 22 and soon joined Edison, becoming his closest associate. Batch went to Europe in 1881 to promote the Edison system, returning to head up the Edison Machine Works.
69,231	Distribution area of Pearl Street Station	*	*	*
80-18686	Page from Edison lighting patent #239,147	*	*	*
80-16509	Front of Edison Manufacturing Co.	*	*	*
78,928h	"The Regulator," "Test Battery of 1000 Lamps," and "The Dynamo Room"	1882	*	Lithograph showing Pearl Street Station components.
78,927e	Lithograph: "The Switch"	1882	*	Pearl Street component.
*	"Junction box for coupling length of tubing"	1882	*	*
78-17702	Cutaway view of underground junction box.	1882	*	*
47,962g	"New Enterprises in New York City"	1882	*	Laying underground conduit for Pearl Street Station.
80-16522	Lithograph of Hinds - Ketcham & Co. Plant	*	*	*

79-2132	Drawing: layout of Holborn Viaduct	1881	*	*
79-6564	Edison Co. building near Holborn Viaduct	*	*	*
79-6571	Holborn Viaduct street corner	around 1882	*	*
79-6567	Holborn Viaduct from below	around 1882	*	*
79-6570	Holborn Viaduct street corner	around 1882	*	*
80-16697	Lithograph of Bergmann Co. showroom	1882	Sigmund Bergmann & Company catalog	Bergmann, a longtime friend and business partner of Edison's, had an exclusive agreement to make fixtures for Edison lamps.
78-17756	Drawing: illuminated Victorian parlor	*	Sigmund Bergmann & Company catalog	*
78-17741	Drawing: curved wall bracket	*	Sigmund Bergmann & Company catalog	*
78-1	Drawing: moderately ornate chandelier	*	Sigmund Bergmann & Company catalog	*
78-1	Drawing: room with ornate chandelier	*	Sigmund Bergmann & Company catalog	*
78-1	Drawing: highly ornate chandelier	*	Sigmund Bergmann & Company catalog	*
78-1	Drawing: illuminated dining room	*	Sigmund Bergmann & Company catalog	*
78-17740	Drawing: 3-lamp pendant luminaire	*	Sigmund Bergmann & Company catalog	*
78-17747	Drawing: 10-lamp globe luminaire	*	Sigmund Bergmann & Company catalog	*
78-16734 80-16734	Drawing: illuminated art gallery	*	Sigmund Bergmann & Company	*

			catalog	
78-17745	Drawing: electric flowers	*	Sigmund Bergmann & Company catalog	*
78-17746	Drawing: angled wall bracket	*	Sigmund Bergmann & Company catalog	*
78-16740	Drawing: combination wall brackets	*	Sigmund Bergmann & Company catalog	*
78-17742	Drawing: combination wall bracket	*	Sigmund Bergmann & Company catalog	*

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Section 4: Competition

Negative #	Image Title	Date	Source	Comments
80-16526	Kreidler photo shows Edison (age 48) seated at Ogden Mine	1895	*	*
48,285C	Lithograph "The Dream of a Gas Manufacturer"	1883-84	La Nature, v.12, p.96	There are 26 people shown. Note Wilhelm and William Siemens (6, 7), Joseph Swan (8), Edison (12), Hiram Maxim (13), Paul Jablochkoff (18).
79-10114 79-10115 78-17694 79-10112 78-17727 80-18694 * 79-10118 79-10117 *	Lighting company advertisements panel montage (10 ads)	1880s and 1890s	*	C&C Electric Motor Co. Sawyer-Man Electric Co. Western Electric Co. German Electric Belt Agency Thomson-Houston Electric Co. Edison United Manufacturing Co. General Electric Weston Standard Volt & Ammeters Edison Lamps, 16cp Westinghouse Electric Co.
80-16549	Schematic of an electric light bulb	about 1885	*	*
*	Joseph W. Swan (1828 -1914)	*	*	Swan had a varied inventive career, with early contributions to photography. His carbon filament lamp anticipated Edison's by several

				months, but it had a low resistance and was unsuitable for commercial use. Swan's 1883 cellulose filament became an industry standard.
*	Walther H. Nernst (1836 -1941)	*	*	Nernst, a professor of physics at Göttingen and Berlin, received a Nobel Prize in Chemistry in 1920 for work in thermodynamics. As a sidelight, in the 1890s he invented an efficient lamp in which the filament heated rare-earth salts, which then glowed. The lamp was very efficient, but too expensive to be practical.
*	Lewis H. Latimer (1848 -1928)	*	*	An African American, born in Chelsea, Mass., Latimer trained as a draftsman at a Boston patent law firm. There he made drawings for Alexander Graham Bell, among others. He joined the Maxim company in 1880 and invented a means of producing improved carbon filaments. In 1884 he moved to Edison's Lamp Works and had a distinguished career as a draftsman.
*	Oliver B. Shallenberger (1860 -1898)	*	*	A graduate of the U. S. Naval Academy, Shallenberger left the Navy in 1884 to join the Westinghouse company. In 1888 he invented an induction meter for measuring alternating current, a critical element in the Westinghouse AC system.
*	Nikola Tesla (1856 -1943)	*	*	Born of Serb parents in Croatia, Tesla was educated in Europe. He came to New York in 1884 and worked briefly for Edison. He patented a practical AC motor in 1888. Other AC patents were used in the Westinghouse generators at Niagara Falls. He is also known for high-frequency experiments and inventions in the field of radio.

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Section 5: Consequences

Negative #	Image Title	Date	Source	Comments
*	Falk photo of Edison at age 57	1904	*	free-standing cutout
80-17028	Niagara Falls: Pittsburgh Reduction Co. plant	*	*	*
79-9341	Niagara Falls	*	*	*
79-2144	Niagara Falls:	*	*	*

	Exterior of the powerhouse			
79-2147	Niagara Falls: Interior of the powerhouse	*	*	*
79-2142	Niagara Falls: Line Crew	*	*	*
79-2148	Niagara Falls: Transmission Lines	*	*	*
79-9335 79-9337 79-9336 79-9346	Niagara Falls industrial company photos (4)	*	*	Aerial diagram of Niagara Falls Diagram of Falls and plants Industrial generator at plant Interior of industrial plant at Niagara
99-4080	GE National Mazda advertisement, "She Doesn't Like Dim Light"	1920	*	National Mazda full-page advertisement clipped from The Saturday Evening Post. [4 December 1920, p. 44]*
99-4121	Photo of lighting engineer Matthew Luckiesh's living room	1939	General Electric Lighting Co.	photo from "A Decade of Watts in my Home, 1929-1939," reprint from the Magazine of Light, p.4*
99-4076	Lighting a Drawing Room	1927	*	photo from "Modern Electrical Illumination," p.270*
99-4071	Another view of lighting engineer Matthew Luckiesh's living room	1939	General Electric Lighting Co.	photo from "A Decade of Watts in my Home, 1929-1939," reprint from the Magazine of Light, p.4*
99-4078	"One Corner of a Dining-Room Converted into an Attractive Nursery"	1927	*	photo from "Modern Electrical Illumination," p.274*
99-4130	Office with makeshift electrical installation	about 1912	General Electric Lighting Co.	photo showing office with cords running from converted gas chandeliers*
99-4072	"Layout of Outlets for a Typical Small House"	1922	General Electric Lighting Co.	wiring diagram from "Edison Lamp Works Lighting Data Bulletin #137: Residence Lighting," p.31*
99-4077	"Lighting a Bed Room"	1927	*	photo from "Modern Electrical Illumination," p.271*
99-4079	GE National Mazda advertisement, "Restful Light"	1925	General Electric Lighting Co.	National Mazda advertisement from "The Four-Star Book," 1925, p. 3
80-16701	Lithograph of electrified kitchen	*	*	*
78-17750	Advertisement of Hotpoint Electric Appliances	*	*	*

99-4075	Miners Using Electric Coal Cutter	1906	*	photo from "The Romance of Modern Electricity" p.270
*	Sydney H. Short (1858 -1902)	*	*	Short was born in Columbus, Ohio. After graduating from Ohio State University, he became professor of physics and chemistry at the University of Denver. He held over 500 patents, many in the field of streetcar railways.
*	Charles J. Van Depoele (1846 - 1892)	*	*	A native of Belgium, Van Depoele came to the United States in 1869 and settled in Detroit. He invented an arc lamp in 1870, but is especially known for developing a form of electric railway using overhead wires.
*	Frank J. Sprague (1857 -1934)	*	*	A graduate of the U. S. Naval Academy, Sprague covered the Paris (1881) and London (1882) electrical exhibitions for the Navy. He worked briefly for Edison and later developed a constant-speed motor and an overhead trolley pickup device important for street railways.
*	Leo Daft (1843 - 1922)	*	*	Born in Great Britain, Daft came to the United States in 1866. In 1879 he joined the New York Electric Light Company and transformed it into the Daft Electric Company, which became a major competitor in the street railway business.

Webnote 1-1

The museum has long held significant lighting collections. Some of the most interesting items are from William J. Hammer, who came to work at the Menlo Park laboratory in 1879 and stayed on to be responsible for many of Edison's early promotional displays (his picture appears prominently in the third section of the exhibition). A collection of his personal and professional papers is preserved in the museum's Archives Center. Other material assembled by Hammer, most notably a large light bulb collection, are housed at the Henry Ford Museum and Greenfield Village)

Other objects have been obtained from manufacturers and individuals over the years. Included is a substantial number of light bulbs from GE in the early years of the twentieth century.,

At the time when preparations were being made for this exhibition, however, the museum's collections of material objects, photos, and documents related to post-World War II developments were very thin. A major research project was therefore undertaken to learn about this period and to collect pertinent items. The files and artifacts that were obtained are available to scholars and other interested parties in the Electrical Collections unit in the Division of Information Technology and Society at the National Museum of American History.

The basic structure of the exhibition is described in the label associated with this webnote (innovation broken down into five steps, which are then described for lighting in Edison's period and then again in the late twentieth century). The form chosen for most of the labels is a quote from someone who participated in the inventive / innovative process, followed by a curatorial commentary. This was done for two reasons: 1) to make the inventors and their contemporaries more intimately a part of the exhibit, and 2) to make the labels more interesting. Paul Israel, whose biography of Edison appeared the year before the exhibit opened, was of great assistance in identifying pertinent quotes from Edison.

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Webnote 1-2

Credit is given to donors of individual items where those items appear in the script.

Paul Israel (primarily for the first part) and Terry McGowan (primarily for the second part) read the script and made some important suggestions for changes. They of course bear no responsibility for any errors that may appear. We hope (and expect) that readers will let us know if they feel we have made mistakes (you can contact us via the link below). Corrections to the exhibit itself are sometimes difficult and take time; but one of the advantages of a website is that they can be made easily and quickly.

Email: Electricity Collections

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Webnote 1-3

Sources of information about batteries.

- Bretton, M. G., "A Century of Lead-Acid Accumulators, " in *Fisica e Technologia* 5 (July-Sept 1982), pp. 191-9.
- Dibner, Bern, *Alessandro Volta and the Electric Battery* (New York: Franklin Watts, Inc., 1964).
- King, W. James, "The Development of Electrical Technology in the 19th Century: 1. The Electrochemical Cell and the Electromagnet," in *Contributions from the Museum of History and Technology, United States National Museum Bulletin 228* (Washington: Smithsonian Institution, 1962), pp. 231-271.
- Schallenberg, Richard H. "The Anomalous Storage Battery: An American Lag in Early Electrical Engineering," in *Technology and Culture* 22 (1981), pp. 725-52.
- Schallenberg, Richard H., *Bottled Energy: Electrical Engineering and the Evolution of Chemical Energy Storage* (Philadelphia: American Philosophical Society, 1982).

Schallenberg's extensive notes and other material collected for his battery research were given to the Smithsonian and are available in the Archives Center of the National Museum of American History.

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Webnote 1-4

Sources of information about motors.

- Alger, Phillip, and Robert Arnold, "The History of Induction Motors in America," in *IEEE Proceedings* 64 (1976), pp. 1380-1383.
- Body, J. H. R., "A Note on Electro-magnetic Engines," *Transactions of the Newcomen Society* 14 (1933-34), pp. 103-107. An account of early 19th-century devices.
- King, W. James, "The Development of Electrical Technology in the 19th Century: 1. The Electrochemical Cell and the Electromagnet," in *Contributions from the Museum of History and Technology, United States National Museum Bulletin 228* (Washington: Smithsonian Institution, 1962), pp. 231-271.
- Michalowicz, Joseph, "Origin of the Electric Motor," in *Electrical Engineering* 67 (1948), pp. 1035-40.

See also biographies of Nikola Tesla, listed under the general bibliography.

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Webnote 1-5

Sources of information about generators.

- King, W. James, "The Development of Electrical Technology in the 19th Century: 3. The Early Arc Light and Generator," in *Contributions from the Museum of History and Technology, United States National Museum Bulletin 228* (Washington: Smithsonian Institution, 1962), pp. 333-407.
- Lamme, Benjamin G., "Development of a Successful Direct-Current 2000 KW Uni-Polar Generator," in *AIEE Transactions* (1912). An account of a generator developed by Lamme at Westinghouse in 1906.
- Walker, Miles, "Dynamo-Electric Machinery, 1878-1916," in *Electrician* 77 (1916), pp. 817-21.

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Webnote 1-6

Sources of information about meters.

- Brown, C. N., "Charging for Electricity in the Early Days of Electricity Supply," in *Institution of Electrical Engineers Proceedings* 132 Pt. A (Dec. 1985), pp. 513-24.

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Webnote 1-7

Sources of information about electromagnets.

King, W. James, "The Development of Electrical Technology in the 19th Century: 1. The Electrochemical Cell and the Electromagnet," in *Contributions from the Museum of History and Technology, United States National Museum Bulletin 228* (Washington: Smithsonian Institution, 1962), pp. 231-271.

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Webnote 1-8

Sources of information about arc lamps:

- Bowers, Brian, *Lengthening The Day*, (New York: Oxford University Press, 1998).
- Bright, Arthur A. Jr., *The Electric-Lamp Industry: Technological Change and Economic Development from 1800 to 1947*, (New York: MacMillan Co., 1949).
- Brush, Charles F., "The Arc-Light," in *The Century Magazine*, May 1905, V.70, #13, p.110.
- Carlson, W. B., *Innovation as a Social Process, Elihu Thompson and the Rise of General Electric, 1870 - 1900*, (Cambridge: Cambridge University Press, 1991).
- Fleming, J. A., *Electric Lamps and Electric Lighting*, 2nd ed., (London: The Electrician Printing & Publishing Co., Ltd., 1899).
- International Correspondence Schools, *A Textbook on Electric Lighting and Railways: Electric Transmission & Electric Lighting*, (Scranton, PA: International Textbook Co., 1901).
- King, W. James, *The Development of Electrical Technology in the 19th Century: 3. The Early Arc Light and Generator*, United States National Museum, Bulletin 228, (Washington, DC: Smithsonian Institution, 1962).
- Schivelbusch, Wolfgang, *Disenchanted Night: The Industrialization of Light in the Nineteenth Century*, trans., Angela Davies, (Berkeley: Univ. of California Press, 1988).

Archival material.

- Sarah J. Farmer Collection, 34,583. Electricity Collections, National Museum of American History.
- William J. Hammer Collection. Archives Center, National Museum of American History.
- Lighting Reference Collection. Electricity Collections, National Museum of American History.
- Potomac Electric Power Company Collection, 40,913. Electricity Collections, National Museum of American History.
- US Patent Office Collections, 48,865; 49,064; and 89,797. Electricity Collections, National Museum of American History.

- William Wallace Collection, 35,164. Electricity Collections, National Museum of American History.

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Webnote 1-9

Biographical information for featured players:

- **George F. Barker** (1835-1910)
  A professor of Physics at the University of Pennsylvania from 1835 to 1900, Barker was Edison's closest friend in the academic community. His interest in electric lighting was an influence on Edison in 1878.
- **Charles W. Batchelor** (1845-1910)
  Batchelor was born in London and trained as a mechanic. He came to the U. S. at age 22 and soon joined Edison, becoming his closest associate. Batch went to Europe in 1881 to promote the Edison system, returning to head up the Edison Machine Works.
- **Charles F. Brush** (1849-1929)
  Trained in chemistry at the University of Michigan, Brush established himself in Cleveland. There he built his first dynamo in 1875 and an arc light in 1876. His company eventually became part of General Electric.
- **Leo Daft** (1843-1922)
  Born in Great Britain, Daft came to the United States in 1866. In 1879 he joined the New York Electric Light Company and transformed it into the Daft Electric Company, which became a major competitor in the street railway business.
- **Zenobe-Theophile Gramme** (1826-1901)
  Gramme, a Belgian, used Pacinotti's armature design to make efficient magneto generators in the 1860s and self-excited dynamos in the 1870s.
  - Chauvois, Louis, *Histoire merveilleuse de Zénobe Gramme, inventeur de la dynamo*, (Paris: Librairie scientifique et technique A. Blanchard, 1963)
- **Edwin J. Houston** (1847-1914)
  Houston was born in Alexandria, Va., but spent most of his life in Philadelphia teaching at Central High School. With Elihu Thomson, he designed an arc-light generator. He left the Thomson-Houston Company in 1882 to devote his time to teaching.
  - Houston, Edwin J., *Electricity in Every-Day Life* Three volumes, (New York: P. F. Collier & Son, 1904)
- **Paul Jablochkoff** (1847-1894)
  Born in Russia, Jablochkoff spent his career in Paris. There he invented an "electric candle" arc light in 1877, which was sensational in demonstrations in theaters and opera houses.
- **Francis Jehl** (1860-1941)
  Born in New York City, Jehl had little schooling. He became an assistant to Edison at Menlo Park and went to Europe in 1882 to promote the Edison System. On his return he helped reconstruct the Menlo Park laboratory at Dearborn, Michigan.
  - Jehl, Francis, *Menlo Park Reminiscences* Three volumes, (Kila, MT: Kessinger Publishing, 2002)
  - Simonds, William Adams, *A boy with Edison*, (Garden City, N. Y.: Doubleday, Doran & company, inc., 1931)
- **Lewis H. Latimer** (1848-1928)
  An African American, born in Chelsea, Mass., Latimer trained as a draftsman at a Boston patent law firm. There he made drawings for Alexander Graham Bell, among others. He joined the Maxim company in 1880 and invented a means of producing improved carbon filaments. In 1884 he moved to Edison's Lamp Works and had a distinguished career as a draftsman.

  - Janet M. Schneider, Bayla Singer, *Blueprint for change : the life and times of Lewis H. Latimer*, (Jamaica, NY: Queens Borough Public Library, c1995)
  - Turner, Glennette Tilley, *Lewis Howard Latimer*, (Englewood Cliffs, N.J.: Silver Burdett Press, c1991)
  - Rayvon Fouche, *Black Inventors in the Age of Segregation: Granville T. Woods, Lewis H. Latimer, and Shelby J. Davidson*, (Baltimore: Johns Hopkins University Press, 2003)
- **Walther H. Nernst** (1836-1941)
  Nernst, a professor of physics at Göttingen and Berlin, received a Nobel Prize in Chemistry in 1920 for work in thermodynamics. As a sidelight, in the 1890s he invented an efficient lamp in which the filament heated rare-earth salts, which then glowed. The lamp was very efficient, but too expensive to be practical.
  - Diana Kormos Barkan, *Walther Nernst and the Transition to Modern Physical Science*, (Cambridge: Cambridge University Press, 1999)
  - Mendelssohn, K., *The world of Walther Nernst; the rise and fall of German science, 1864-1941*, (Pittsburgh: University of Pittsburgh Press, 1973)
- **Antonio Pacinotti** (1841-1912)
  Born in Pisa, Italy, Pacinotti became professor of physics at the University of Bologna at age 23. There he developed a ring armature design that was used by Gramme in motors and generators.
  - Pacinotti, M. A. Telo, *Mio padre Antonio Pacinotti : con documenti inediti*, (Pisa: Sala delle stagioni di Fernando Vallerini editore, 1962)
- **Oliver B. Shallenberger** (1860-1898)
  A graduate of the U. S. Naval Academy, Shallenberger left the Navy in 1884 to join the Westinghouse company. In 1888 he invented an induction meter for measuring alternating current, a critical element in the Westinghouse AC system.
- **Sydney H. Short** (1858-1902)
  Short was born in Columbus, Ohio. After graduating from Ohio State University, he became professor of physics and chemistry at the University of Denver. He held over 500 patents, many in the field of streetcar railways.
- **Frank J. Sprague** (1857-1934)
  A graduate of the U. S. Naval Academy, Sprague covered the Paris (1881) and London (1882) electrical exhibitions for the Navy. He worked briefly for Edison and later developed a constant-speed motor and an overhead trolley pickup device important for street railways.
  - Passer, Harold Clarence, *Frank Julian Sprague, father of electric traction, 1857-1934*, (Cambridge, Mass.: Harvard University Press, 1952)
  - Sprague, Harriet Chapman Jones, *Frank J. Sprague and the Edison myth*, (New York: William-Frederick Press, 1947)
- **Joseph W. Swan** (1828-1914)
  Swan had a varied inventive career, with early contributions to photography. His carbon filament lamp anticipated Edison's by several months, but it had a low resistance and was unsuitable for commercial use. Swan's 1883 cellulose filament became an industry standard.
  - Swan, Mary E., *Sir Joseph Wilson Swan, F.R.S. : a memoir*, (London: Ernest Benn, 1929)
- **Nikola Tesla** (1856-1943)
  Born of Serb parents in Croatia, Tesla was educated in Europe. He came to New York in 1884 and worked briefly for Edison. He patented a practical AC motor in 1888. Other AC patents were used in the Westinghouse generators at Niagara Falls. He is also known for high-frequency experiments and inventions in the field of radio.
  - Tesla, Nikola, *My inventions : the autobiography of Nikola Tesla*, (Williston, Vt.: Hart Bros., 1982)
  - Tesla, Nikola, *The complete patents of Nikola Tesla*, (New York: Barnes & Noble Books, 1994)
  - Hunt, Inez, *Lightning in his hand; the life story of Nikola Tesla*, (Denver: Sage Books, 1964)

    - Seifer, Marc J., *Wizard : the life and times of Nikola Tesla : biography of a genius*, (Secaucus, N.J.: Carol Pub., c1996)
    - O'Neill, John J., *Prodigal genius; the life of Nikola Tesla*, (New York, N.Y.: I. Washburn, Inc., 1944)
- **Francis R. Upton** (1852-1921)
  As a graduate of Bowdoin, with graduate work at Princeton and in Germany, Upton was the best-educated of Edison's assistants. Nicknamed Culture by his colleagues, worked on the light bulb, the generator, and other projects.
- **Charles J. Van Depoele** (1846-1892)
  A native of Belgium, Van Depoele came to the United States in 1869 and settled in Detroit. He invented an arc lamp in 1870, but is especially known for developing a form of electric railway using overhead wires.
- **Edward Weston** (1850-1936)
  Weston emigrated from England to Newark, New Jersey, in 1870. He established the Weston Electric Instrument Company there in 1888. Its meters gained a reputation for accuracy and reliability.
    - Woodbury, David Oakes, *A measure for greatness; a short biography of Edward Weston*, (New York: McGraw-Hill, 1949)

Webnote 2-1

Sources of information about Edison and the Menlo Park lab:

- Baldwin, Neal, *Edison: Inventing The Century*, (New York: Hyperion, 1995).
- Friedel, Robert, and Paul Israel, with Bernard S. Finn, *Edison's Electric Light: Biography of an Invention*, (New Brunswick, NJ: Rutgers Univ. Press, 1986).
- Israel, Paul, *Edison : A Life of Invention*, (New York : John Wiley, c1998).
- Jeffrey, Thomas E. et. al. (eds.), *Thomas A Edison Papers: A Selective Microfilm Edition* Part 1 (1850-1878) and Part 2 (1879-1886) (Bethesda, MD: University Publications of America, 1985-)
- Jehl, Francis, *Menlo Park Reminiscences*, three volumes, (Dearborn, MI: Edison Institute, 1936, 1938, 1941).
- Jenkins, Reese V., et. al., *The Papers of Thomas A. Edison*, volume 3, *Menlo Park: The Early Years, April 1876 - December 1877*, (Baltimore: The Johns Hopkins University Press, 1994).
- Millard, Andre, *Edison and the Business of Invention*, (Baltimore, MD: The Johns Hopkins University Press, 1990).
- Pretzer, William S. (ed.), *Working at inventing: Thomas A. Edison and the Menlo Park Experience* (Dearborn, MI: Henry Ford Museum and Greenfield Village, 1989
- Reich, Leonard S., *The Making of American Industrial Research: Science and Business at GE and Bell, 1876 - 1926*, (Cambridge: Cambridge Univ. Press, 1985).
- Rosenberg, Robert A., et. al. (eds.), *The Papers of Thomas A. Edison*, volume 4, *The Wizard of Menlo Park: 1878*, (Baltimore: The Johns Hopkins University Press, 1998).

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Webnote 2-2

Portions of Edison's notebooks can be found in both the microfilm and book editions of *The Papers of Thomas A. Edison*. See more complete citation in webnote 2-1 above.

Webnote 2-3

The drawing of an air bubble in the platinum filament, which Edison observed under a microscope, is significant because it led him to believe that he could increase the strength of the wire if he could remove the bubbles. This, he reasoned, could be done if he kept the filament in an evacuated bulb. He then developed a very efficient vacuum pump, which later became critical for his experiments with carbon.

Sources of information about Edison's electric lamp invention:

- Bright, Arthur A. Jr., *The Electric-Lamp Industry: Technological Change and Economic Development from 1800 to 1947*, (New York: MacMillan Co., 1949).
- Friedel, Robert, and Paul Israel, with Bernard S. Finn, *Edison's Electric Light: Biography of an Invention*, (New Brunswick, NJ: Rutgers Univ. Press, 1986).
- Jehl, Francis, *Menlo Park Reminiscences*, three volumes, (Dearborn, MI: Edison Institute, 1936, 1938, 1941).
- Howell, John W., and Henry Schroeder, *History of the Incandescent Lamp*, (The Maqua Co., 1927).
- Rosenberg, Robert A., et. al., *The Papers of Thomas A. Edison*, volume 4, *The Wizard of Menlo Park: 1878*, (Baltimore: The Johns Hopkins University Press, 1998).
- Schroeder, Henry, *History of Electric Light*, (Washington: Smithsonian Institution, 1923).
- "The Story of the Evolution of the Edison Incandescent Lamp, I," and "The Columbia Incandescent Lamp Company Case," in *Electrical World*, 22 April 1893, V.21, #16, p.291.
- "The Story of the Evolution of the Edison Incandescent Lamp, II," in *Electrical World*, 29 April 1893, V.21, #17, p.315.
- "The Oconto Incandescent Lamp Case," in *Electrical World*, 15 July 1893, V.22, #3, p.45.
- United States Patent #223,898 to Thomas A. Edison, 1879.

Webnote 3-1

William J. Hammer had worked briefly for Edwin Weston before he came to Menlo Park in December, 1879, at the age of 22. He stayed for several years and was especially effective at setting up displays of the Edison system at various industrial exhibitions. With Edward Johnson he organized the Holborn Viaduct demonstration in 1882. The electric sign invention gives some evidence of his interest in exhibits. Hammer went on to be a consulting engineer, and like many others of his generation became fascinated with the discovery of x-rays and of natural radiation. He corresponded with some of the well-known scientists and engineers of his day. These letters, photographs, and other documents are preserved at the American History Museum's Archives Center.

Webnote 3-2

The best source of information about the Pearl Street station is Francis Jehl's *Menlo Park Reminiscences*, three volumes, (Dearborn, MI: Edison Institute, 1936, 1938, 1941). However, it should be used with some caution, since Jehl was writing more than fifty years after the events and his memory cannot always be trusted. Other sources include the Edison biographies and the publications of the Edison Papers Project, cited in webnote 2-1.

Webnote 4-1

Sources of information about gas lighting:

- Bowers, Brian, *Lengthening The Day*, (New York: Oxford University Press, 1998).
- Bright, Arthur A. Jr., *The Electric-Lamp Industry: Technological Change and Economic Development from 1800 to 1947*, (New York: MacMillan Co., 1949).
- Schivelbusch, Wolfgang, *Disenchanted Night: The Industrialization of Light in the Nineteenth Century*, trans., Angela Davies, (Berkeley: Univ. of California Press, 1988).
- Duncan, Robert Kennedy, "Some Rare Elements and Their Application," in *Harper's*, August 1906, V.113, #675, p.417.
- The Henry Ford Museum and Greenfield Village, Dearborn, Michigan.

Webnote 4-2

Sources of information about electric lamp competition in the 19th century:

- Bowers, Brian, *Lengthening The Day*, (New York: Oxford University Press, 1998).
- Bright, Arthur A. Jr., *The Electric-Lamp Industry: Technological Change and Economic Development from 1800 to 1947*, (New York: MacMillan Co., 1949).
- Fleming, J. A., *Electric Lamps and Electric Lighting*, 2nd ed., (London: The Electrician Printing & Publishing Co., Ltd., 1899).
- Hammond, Robert, *The Electric Light in Our Homes*, (New York: R. Worthington, 1884).
- Jones, Robert, and Oliver Marriott, *Anatomy of a Merger: A History of G.E.C., A.E.I., and English Electric*, (London: Jonathan Cape Ltd., 1970).
- McCarthy, Thomas E., *The History of GTE: The Evolution Of One Of America's Great Corporations*, (Stamford, CT: GTE Corporation, 1990).
- Passer, Harold C., *The Electrical Manufacturers, 1875-1900*, (Cambridge, MA: Harvard Univ. Press, 1953).
- Stocking, G. W., and M. W. Watkins, *Cartels in Action: Case Studies in International Business Diplomacy*, (New York: The Twentieth Century Fund, 1946; reprint, Millwood, NY: Kraus Reprint Co., 1975).
- *The Electrical Age*.
- *The Electrical Engineer*.
- *Electrical Merchandising*.
- *Electrical Review*, (New York).
- *Electrical Review*, (London).
- *Scientific American*.
- *Western Electrician*.
- Anderson, John M., and John S. Saby, "The electric lamp: 100 years of applied physics," in *Physics Today*, October 1979.
- Halbertsma, N. A., "The Birth of a Lamp Factory in 1891," in *Philips Technical Review*, February/March 1962, V.23, #8/9, p.222.
- Oetting, R. L., "Electric Lighting in the First Century of Engineering," in *Proceedings of The American Institute of Electrical Engineering*, November 1952, V.71, pt.2, p. 269.
- Reich, Leonard S., "Lighting the Path to Profit: GE's Control of the Electric Lamp Industry, 1892-1941," in *Business History Review*, v.66, Summer 1992, p. 305-34.

- Staff, "Scientific Research of Philips' Industries from 1891 to 1951," in *Philips Technical Review*, July/August 1951, V.13, #1, p.3.
- Electricity Collections, National Museum of American History.
- The William J. Hammer Collection, Henry Ford Museum and Greenfield Village, Dearborn, Michigan.
- Archives and Collections of the Mt. Vernon Museum of Incandescent Lighting, (Baltimore, MD).
- GE NELA Park Files. Electricity Collections, National Museum of American History.
- The William J. Hammer Collection. Archives Center, National Museum of American History.
- Lighting Research Files. Electricity Collections, National Museum of American History.

Webnote 4-3

As indicated in the text, alternating and direct current co-existed as practical sources of electricity for arc lighting in the 1870s and were seen as viable alternatives for incandescent lighting in the 1880s. That is, as long as the AC frequency wasn't so low that the light would visibly flicker.

Until 1888 the arguments from both sides were based on the various practical and economic merits. But in the fall of 1887 a proposal was made to substitute electrocution for hanging in New York State as a more humane form of execution. Edison supported this view, emphasizing that alternation current would be more effective. In 1888 he allowed Harold Brown, an electrician who had developed strong feelings about the dangers of AC, to perform experiments in his laboratory. And Edison was a tacit advocate of inflammatory arguments that Brown and others made.

The success of Tesla's motor, and the failure to discover a means of storing electricity, made the arguments in favor of alternating current overwhelming for central stations and by 1890 Edison had reversed his stand and was beginning to develop his own AC system. The merger of the Edison company with Thomson-Houston in 1892, and the adoption of AC at Niagara Falls (the first generator was installed in 1895) determined the future direction. However, direct current would remain necessary for electrochemical processes and also for street railroads.

For more on the AC-DC controversy see

- Thomas Hughes, "Harold Brown and the Executioner's Current: An Incident in the AC-DC Controversy," *Business History Review* 32, pp. 143-65.
- Terry Reynolds and Theodore Bernstein, "Edison and the Chair," IEEE *Technology and Society Magazine* 8 (1989), pp. 19-28.
- W. Bernard Carlson and A. J. Millard, "Defining Risk within a Business Context: Thomas A. Edison, Elihu Thomson, and the AC-DC Controversy, 1885-1900," in B. B. Johnson and V. T. Covello (eds.),
- *The Social and Cultural Construction of Risk* (Boston: Reidel, 1987), pp. 275-93.
- Paul Israel, *Edison: A Life of Invention* (New York: John Wiley, 1998) especially pp. 321-337.

See also other biographies of Edison and biographies of Tesla listed in Bibliography section.

Webnote 4-4

Sources of information about transformers:

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Webnote 5-1

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Webnote 6-3

"Different Ways to Make Light" was designed by Thomas M. O'Brien, Interactive Exhibit Developer, National Museum of American History. Materials for the display were provided by OSRAM-SYLVANIA Inc. and Maurice Electric Co. This interactive display consists of five activities that explore the relation between lamps, light, color, and energy. Four different, but common, light sources are compared: tungsten-filament incandescent, fluorescent, mercury-vapor, and low-pressure sodium.

A persistent question asks, "Isn't it true that manufacturers know how to make a light bulb that will never burn out, but refuse to make it because it would put them out of business?" As Roberts noted in the quote above, the answer to the first part of the question is yes. However, the reason manufacturers do not make a "forever lamp" has little to do with corporate survival.

Energy efficiency (or "efficacy"), color output, and the life-rating of an incandescent lamp are determined by the operating temperature of the filament. At higher temperatures the color improves and the efficacy increases, but the life-rating drops as tungsten evaporates faster from the filament. Professional photographers use special light bulbs for studio portraits that give very good color at high efficacy -- each bulb lasts from 3 to 20 hours.

Running a lamp on reduced voltage will lower the filament temperature and extend lamp-life since tungsten evaporates more slowly. But the color of the light will be noticeably red-orange and the efficacy will drop sharply. The money spent on extra electricity to run the bulb would quickly add up to more than the cost of putting in another bulb. (Think of driving a car that never needs a tune-up, but runs only 2 miles on a gallon of gasoline.) Only in situations where changing a bulb is difficult or dangerous do extended-life incandescent lamps make economic sense.

The activity "White-Hot Light, Red-Hot Light" demonstrates how energy and color are related in an incandescent lamp. An incandescent lamp is mounted in the display. When the filament is at full power and very hot it emits the full range of rays that we see as white light. By turning a knob, the visitor reduces voltage to the lamp and the filament's temperature drops. As the voltage falls, the filament cools and the blue and green colors fade (as seen on a diffraction grating mounted behind the lamp). Only the red remains directly visible. The lamp still produces invisible heat (infrared energy), however. Seen through a special camera similar to night-vision goggles, the lamp glows brightly in the infrared.

Blue and green light require much more energy to make than does red light and infrared heat. As the voltage falls, the higher energy colors fade away.

In the activity "Seeing Infrared," the infrared camera also shows how little heat emanates from three discharge lamps. The camera is sensitive to both visible light and infrared energy, allowing one to compare the energy coming from each lamp. All four lamps glow brightly in visible light. But after adjusting the camera, only the incandescent lamp remains bright. However, the other three lamps almost disappear. The mercury-vapor lamp's arc-tube can be seen, as can the electrodes in the fluorescent and low-pressure sodium lamps. Nothing else in these lamps generates enough heat to be detected by the camera.

We can feel infrared energy as heat but we cannot see it directly, so for lighting a room it is wasted energy.

The activity "Feeling Light" asks one to touch the panel in front of each lamp and compare how warm they feel. The incandescent panel feels warmest, the mercury-vapor panel a bit less so, and the fluorescent and sodium panels feel cool. Much of the energy going into the incandescent lamp is radiated as infrared (heat). The low-pressure sodium lamp emits four times more visible light and uses only half the energy of the incandescent lamp, which is why it feels cooler. The other two lamps also produce more light than heat.

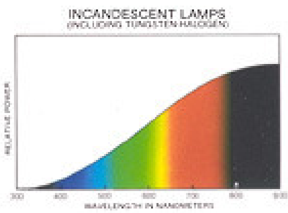
We judge the efficiency of a lamp by the amount of visible light it produces from the energy it consumes.

In "Light and Color" one slides a photograph under each of the four lamps in the display to see how its appearance changes when viewed under different light sources. Different lamps emit different combinations of color. The photograph can only reflect the colors produced by each lamp. Low-pressure sodium does not produce blue light, so the sky in the photo appears gray.

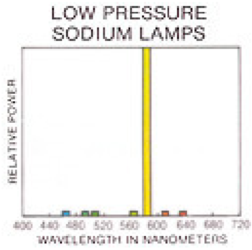
The 1962 photo to the right demonstrates the same effect. All three models are identically dressed and are in identical surroundings, but they appear different because each is illuminated by a different type of lamp. In this instance, mercury vapor, metal halide, and incandescent (left to right).

Because of color characteristics, a lamp may be ideal for one use and not for another. Low-pressure sodium street lamps would not be welcome inside most homes, for example.

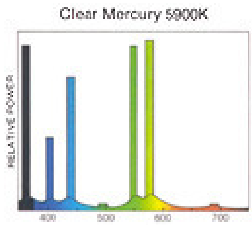
The final activity, "Making Color," displays the different combinations of colors produced by each of the four lamps. Spectral charts (below) are mounted under each lamp, allowing one to see which color lines appear in more than one. Atoms and molecules in each lamp emit distinctive colors. The graphs indicate that the same atoms and molecules may be present in different lamps. Strong blue lines, for instance, come from the element mercury while sodium produces a strong yellow line. Your eye and brain merge these lines to "see" an overall color.



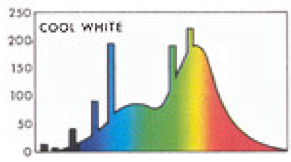
Incandescent



Low Pressure Sodium



Clear Mercury Vapor



Cool White Fluorescent

The color a lamp produces depends on the materials used and how those materials are energized. Inventors keep this in mind when choosing materials for their lamps.

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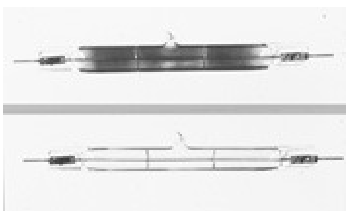
Webnote 7-1

About the halogen cycle:

The halogen cycle describes a complex chemical interaction between tungsten, oxygen and a halide that makes tungsten halogen lamps possible. Incandescent lamps operate by using an electric current to heat a filament so that it glows. Edison and later inventors needed to cope with material that evaporated from the hot filament since this material would build-up on the inner bulb-wall and darken the lamp. This "lamp blackening" becomes even more severe when the filament is situated near the bulb-wall, as in thin tubular lamps. The halogen cycle prevents lamp blackening but does not, by itself, make these lamps more energy efficient.



The same lamp before and after operation of the halogen cycle

S.I. image #99-4111

In brief, the cycle works like this:

Step 1: Tungsten atoms evaporate from the hot filament and diffuse toward the cooler bulb wall. The filament temperature is about 3030° Celsius (or about 5480° Farenheit). The temperature at the bulb wall is about 730° C (or about 1340° F).

Step 2: Tungsten, oxygen and halogen atoms combine on or near the bulb-wall (exactly where is still uncertain) to form tungsten oxyhalide molecules. Originally, iodine was the halogen used but today bromine is more common. Chlorine is used in some special photocopying lamps that operate only for brief intervals. Fluorine has been researched extensively for many years but is not used in commercial lamps.

Step 3: Tungsten oxyhalides remain in a vapor phase at the bulb-wall temperatures and this vapor moves toward the hot filament. A combination of diffusion and convection currents are responsible for the movement.

Step 4: High temperatures near the filament break the tungsten oxyhalide molecules apart. The oxygen and halogen atoms move back toward the bulb wall and the tungsten atoms re-deposit on the filament. The cycle then repeats.

It is important to note that the tungsten does not return to the exact spot from which it evaporated, but rather re-deposits on cooler areas of the filament. Breakage usually occurs where the filament connects to the molybdenum lead-in wire, as the temperature drops sharply at that point. (The halide fluorine can return tungsten to the hottest parts of a filament, holding the promise of a true regenerative cycle. Unfortunately, fluorine also attacks the cooler areas of the filament. Experiments to resolve that problem continue.)

Because tungsten is cleaned from the inner bulb-wall, halogen lamps can be operated at higher temperatures than ordinary incandescent lamps. Energy efficiency (or "efficacy") is due to the higher temperature–the hotter an incandescent lamp operates the more efficacious is becomes. Likewise, the longer life ratings of tungsten halogen lamps stem not from the presence of halogens but rather are a function of the higher pressures at which these lamps operate.

For a diagram of the halogen cycle, see Tungsten Halogen Lamps in our Technology Files.

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Webnote 9-2

"Out of the Blue" and "Two-Stage Light" were designed by Thomas M. O'Brien, Interactive Exhibit Developer, National Museum of American History. These activities are intended to demonstrate how a fluorescent lamp works.

"Two-Stage Light" provides a look inside fluorescent tubes. Two tubes are shown, each with only a partial coating of phosphor (the white, powdery material on the inside of the tube). One tube is operating and the other is off. Tiny drops of mercury are seen condensed on the inner bulb-wall of the unlighted tube. An electric current passing between two electrodes in the lighted tube heats a gas that vaporizes the mercury.

Fluorescent tubes make white light in two stages. Stage 1: ultraviolet rays radiate from mercury atoms excited by the electric current. Stage 2: the tube's phosphor coating absorbs the ultraviolet and emits visible light.

It takes very little energy to maintain the current through the mercury vapor and make lots of ultraviolet rays for the phosphors to convert to visible light. This is why fluorescent lamps are so energy-efficient.

"Out of the Blue" shows how the phosphors work. A special fluorescent lamp in the display produces ultraviolet rays that give energy to phosphors coated on each of three panels. Each panel is coated with a different phosphor, and thus radiates a different color light. These colors can be combined to create white light by sliding the panels so that they overlap.

A fluorescent lamp emits white light because it has a carefully formulated mixture of phosphors coated on the inside of the tube.

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Preconditions to Edison's Lamp: Script

Bracketed information [xxx] does not appear on the label.

[Label xL1 - Henry Magnet]

[Curator's note, March 2003: The Henry magnet was not originally part of *Lighting A Revolution*, but instead served to introduce visitors to the three exhibitions that made up the Hall of Electricity in 1979. In addition to *Lighting*, these were *Person To Person* (telephone history) and *First Views* (static electricity). As *Person To Person* had closed in 1989 and we knew that *First Views* would be closing in 2002, we decided to refurbish the area around the Henry magnet and tie it more closely to *Lighting*.]

[Curator's note, November 2003: The area around the Henry magnet was again refurbished in mid-2003 during work associated with the exhibition *America On The Move*.]

"With this magnet I can lift a thousand pounds."
Joseph Henry, describing this electromagnet that he constructed for Yale University, 1832

Joseph Henry pioneered the development of powerful electromagnets, which turned out to be central to the practical use of electricity in the 19th century. They were essential for the development of motors, generators, the telegraph, the telephone, and many measuring instruments. Henry became the first Secretary of the Smithsonian in 1846, a post he held for 33 years.

Object:

- Magnet and supporting apparatus, 1832 [181,343], from Yale University

Graphics:

A. Telegraph receiver, 1850s
B. Generator, 1870s
C. Motor, 1870s
D. Arc lamp, 1870s
E. Telephone receiver, 1880s
F. Transformer, 1880s

[Curator's note, November 2003. The following text was added to this label during the 2003 renovation.]

Electrical Collections at the Smithsonian

To document the history and social influences of electrical science and technology, this museum has preserved thousands of objects, pictures and documents. These are available for research purposes and for exhibitions, both here and through loans to other museums. Currently, two electrical topics are treated in this museum–lighting (to your left) and communications (in the Information Age exhibition elsewhere on this floor). More can be found on the museum's website.

[Label xL105 - Title header]

LIGHTING A REVOLUTION

[xLOT2: hanging sign]

[Curator's note, March 2003: *First Views* was de-installed in May 2002 as part of the space-preparation process for the exhibition *America On The Move*.]

FIRST VIEWS

The Study of Frictional Electricity

[xLOT3: hanging sign]

[Curator's note, November 2003. This sign was removed during the 2003 renovation.]

LIGHTING A REVOLUTION

<= The Edison Era   A Century Later =>

[xLOT4: hanging sign]

[Curator's note, November 2003. This sign was removed during the 2003 renovation.]

Exit from

LIGHTING A REVOLUTION

[Label xL5 - Introduction to Exhibit]

"Well, I'm not a scientist, I'm an inventor."
Thomas Edison, as quoted by his private secretary, A. O. Tate

Of course, some scientists are also inventors. But there is a difference. A person acting scientifically is trying to understand the natural world, whether or not that understanding is economically useful. An inventor tries to create something new that will have practical application. In both cases there is a sense of challenge in the pursuit and a sense of achievement in the result.

In this exhibition we will see how inventors work, and whether they act today the way Edison did a century ago. We will look at

1) **Preconditions** for invention
2) **The inventive process**
3) **Promotion** of the invention
4) How success brings **competition**
5) Some of **the consequences** of an important invention

We will look first at Edison's work on the incandescent light in the late 19th century, and then at several other lighting inventors a hundred years later.

We will also see how concepts of efficiency have come to dominate the lighting field.

Edison at his West Orange laboratory in 1906 at age 59.

[xL5.1: introduction to webnotes]

An expanded version of this exhibit can be found on-line. Webnotes refer to specific places on the website for citations and more detailed information. To use them, go to the website and click on the Webnotes link.

The URL for this site is
americanhistory.si.edu/lighting

Webnote: 1-1

[Label xL6 - Exhibition Credits]

This exhibition is a collective effort by staff of the National Museum of American History and the Smithsonian Institution. Historical exhibitions are complex undertakings, and the history they present is an interpretation of historical evidence informed by knowledge and experience.

This exhibit opened originally in 1979 and featured only Edison's activities. In 2000 it was modified to include recent developments and to make comparisons -- to see how invention has changed, and how it has stayed the same.

The original Lighting a Revolution exhibit was curated by Bernard Finn with assistance from Robert Friedel and Cathy Zusy; the designer was David Ellis; editing was by Michael Fruitman; production was by the Museum's Exhibits staff. Funding came from a major grant from the International Committee for the Centennial of Light of the Thomas A. Edison Foundation and General Electric's Lighting Business Group.

The additions and revisions were inspired by the vision of Dr. Lee R. Anderson (1936-1998), Lighting Program Manager at the Department of Energy.

The new section was curated by Bernard Finn with assistance from Harold Wallace; the designers were David Ellis, Marcia Powell, Constantine Raitzky, and Russell Cashdollar; editing was done by Nancy Growald Brooks; project managers were Patrick Ladden and Andrew Heymann; production was by outside sources; and the website was produced by Harold Wallace. Funding came from a major grant from the United States Department of Energy, and additional grants from a fund in memory of Carl Weller, and from Eveready Battery Co. Inc. Lighting fixtures provided by Lightolier, lamps provided by OSRAM SYLVANIA Inc.

Webnote: 1-2

[Label xL7.1 - Section #1 introduction - Edison free-standing cut out]

Step 1: Preconditions

[Label xL7.2 - Section #1 introduction - Edison free-standing cut out]

"Mr. T. A. Edison has resigned his situation in the Western Union office, Boston, Mass., and will devote his time to bringing out his inventions."
Edison announcement in the *Telegrapher*, January 1869

Edison had very little formal education, but he read extensively. A practicing telegrapher from 1862 to 1868, he gained hands-on experience with electrical apparatus. This gave him the confidence he needed to strike out on his own.

Edison in 1861 at age 14.

[Label xL8 - Batteries]

Batteries

Italian Alessandro Volta announced in 1800 that he could produce electricity by chemical means. His pile or "battery" stimulated a wide number of scientific and technical experiments. Note in particular the early voltaic pile (1) and the early trough battery (2) designed by William Cruickshank in England following Volta's principles. Modifications of the Daniell cell were widely used in American telegraphy.

1. Voltaic pile, about 1805 [323,886], from Canisius College
2. Cruickshank trough battery, 1801 [315,114], from Joseph Priestley
3. J. Frederik Daniell (England), 1836 [322,934], from Columbia University
4. Grenet cell, 1840 [315,193], from Middlebury College
5. Georges Leclanché (France), 1868 [337,158]

Webnote: 1-3
[information about batteries]

[Label xL9 - Motors]

Motors

In 1821 in England, Michael Faraday discovered a way to change electrical energy into the continuous motion of a motor in 1821 Others followed with their own variations. Note in particular the design (6) by Thomas Davenport, a Vermont blacksmith, who in 1834 had all the essential elements of the classic motor -- a rotating armature, field magnets, and a commutator.

6. Thomas Davenport, patent model, 1837 [252,644], from U. S. Patent Office
7. Charles G. Page (U.S.),1838, [318,743], from Colgate University
8. Charles G. Page, 1845, [180,034C], from B&O Railroad
9. Gardiner Colton (U.S.), 1847 [181,577], from A. J. Davis
10. Moses Farmer (U.S.), 1856 [252,635]
11. W. Vergnes (U.S.), patent model, 1860 [308,567], from U.S. Patent Office
12. Antonio Pacinotti (Italy), reproduction, 1861 [327,899], from Chicago Museum of Science and Industry
13. Edward Weston (U.S.) patent model, 1876 [252,568], from U.S. Patent Office

Webnote: 1-4
[information about motors]

[Label xL10 - Generators]

Generators

Working at the Royal Institution in London, Michael Faraday felt certain that somehow magnetism could produce electricity. After a decade of searching, he found the answer in 1831. It was a simple matter of having a conducting wire move across the "lines of force" that Faraday imagined coming out of the end of the magnet. Early machines were very weak because they depended on permanent magnets.

Note in particular the early Pixii machine (14), with a commutator (to change alternating to direct current) designed by A. M. Ampere. The Holmes-type machine (17), with its several large permanent magnets, was inefficient but still strong enough to light arc lamps for special applications. In 1866 Charles Wheatstone and Werner Siemens independently invented the self-excited generator (18), where the magnetic field is produced by an electromagnet using electricity from the generator itself. In just a few years very efficient generators were being designed, most notably by Zenobe Gramme (19).

14. Hippolyte Pixii (France), 1832 [323,353], from University of Virginia
15. Edward Clarke (England), 1837 [326,309], from University of Georgia

16. Charles Page (U.S.), 1845 [181,550]
17. In the manner of Frederick Holmes (England), 1850s, from Union College
18. Charles Wheatstone (England), 1866 [323,429], from King's College, London
19. Zenobe Gramme (England), about 1874 [322,249]
20. Edward Weston (U.S.), patent model, 1878 [252,659], from U.S. Patent Office

Webnote: 1-5
[information about generators]

[Label xL11 - Meters]

Meters

It is necessary to measure electrical effects in order to perform scientific and technical experiments. All of these meters operate on the principle that a magnet will move when affected by an electric current. Note in particular the Nobili galvanometers (21, 22). There are two magnetized needles attached to the vertical string, parallel to each other but magnetized in opposite directions, which means that the combination is not affected by the Earth's magnetic field. One you can see above the coil, and the other is inside the coil. When current flows in the coil, the needle inside is affected more, and it twists the string. You can see how much it twists by looking at the upper needle.

21. Leopoldo Nobili (Italy), late 1820s [319,413]
22. Leopoldo Nobili, 1830s [319,741]
23. For lecture demonstrations, mid-19th century [326,132], from Mount St. Mary's College
24. According to design by Carl F. Gauss (Germany), mid-19th century [315,113]
25. Edward Weston (U.S.). with a second coil instead of a magnet, mid-19th century [314,473], from Weston Instrument Company
26. For telegraphy, mid-19th century [332,099], from Western Union
27. Tangent Galvanometer, [322,995] from Wabash College

Webnote: 1-6
[information about meters]

[Label xL12 - Electromagnets]

Electromagnets

The electromagnet was arguably the most important electrical invention of the 19th century. It concentrated the magnetism produced by electricity and made it possible to build effective telegraphs, telephones, generators, and motors. William Sturgeon constructed the first practical electromagnet in 1824 in England. Joseph Henry, an American, perfected the design.

Note in particular the magnet Henry constructed for Yale University at the entrance to this hall, as well as the cores for some of his earlier magnets shown here (28, 29, 30)

28. Joseph Henry (U.S.) magnet core, 1827 [181,739], from Mary Henry
29. Joseph Henry, magnet core, 1827 [181,740], from Mary Henry
30. Joseph Henry, magnet core from Bowdoin College magnet, 1832 [315,310], from Bowdoin College
31. Used by Joseph Henry, mid-19th century [315,523], from Mary Henry
32. Used by Joseph Henry, mid-19th century [181,458], from Mary Henry
33. Demonstration magnet, mid-19th century [323,887]
34. Charles G. Page (U.S.), induction coil, 1838 [252,673], from U.S. Patent Office
35. Edward S. Ritchie (U.S.), induction coil, c1868 [325,969], from Wofford College
36. Telegraph relay by Charles T. and J. N. Chester, 1850s [335,588], from Janet Lewis

Webnote: 1-7
[information about electromagnets]

[Curator's note, November 2003. New label added during 2003 renovation]

Faces of Invention

Many people shared Edison's ambition and passion to invent. Amid fierce competition, the achievements of one provided new foundations on which the work of others could be constructed. Here and elsewhere throughout the exhibition are portraits of some of Edison's fellow inventors.

Webnote 1-9

[Label sL1 - Weston]

Edward Weston (1850 -1936)

Weston emigrated from England to Newark, New Jersey, in 1870. He established the Weston Electric Instrument Company there in 1888. Its meters gained a reputation for accuracy and reliability.

[Label sL2 - Gramme]

Zenobe-Theophile Gramme (1826 -1901)

Gramme, a Belgian, used Pacinotti's armature design to make efficient magneto generators in the 1860s and self-excited dynamos in the 1870s.

[Label sL3 - Pacinotti]

Antonio Pacinotti (1841 -1912)

Born in Pisa, Italy, Pacinotti became professor of physics at the University of Bologna at age 23. There he developed a ring armature design that was used by Gramme in motors and generators.

[Label sL4 - Barker]

George F. Barker (1835 -1910)

A professor of Physics at the University of Pennsylvania from 1835 to 1900, Barker was Edison's closest friend in the academic community. His interest in electric lighting was an influence on Edison in 1878.

[Label sL6 - Brush]

Charles F. Brush (1849 -1929)

Trained in chemistry at the University of Michigan, Brush established himself in Cleveland. There he built his first dynamo in 1875 and an arc light in 1876. His company eventually became part of General Electric.

[Label sL7 - Houston]

Edwin J. Houston (1847 -1914)

Houston was born in Alexandria, Va., but spent most of his life in Philadelphia teaching at Central High School. With Elihu Thomson, he designed an arc-light generator. He left the Thomson-Houston Company in 1882 to devote his time to teaching.

[Label xL13 - arc lamp information and credits]

Arc Lamps

"The intense light had not been subdivided so that it could be brought into private houses."
Edison, notebook entry, September 1878

In an arc light, vaporized carbon particles are heated electrically to the point where they glow brightly--too bright in fact for use in the home. Edison proposed to use electricity to heat a wire. The brightness of this "incandescent" lamp could be made dim enough for use indoors.

Electricity does not flow freely through materials. This resistance to the flow can vary, depending on what is in the circuit, or path, of the flow of electricity. Arc lights had low electrical resistance. In a circuit several were linked together in electrical series, and their total resistance was high compared to the resistance of the conducting wires. Thus more energy was used in the lights and not wasted as heat in the wires. Edison s successful incandescent lamp had a relatively high resistance and could be controlled individually.

1. Thomson-Houston (U.S.), arc lamp, 1870s [327,945]
2. William Wallace (U.S.), arc lamp, patent model, 1877 [251,235], from U.S. Patent Office
3. William E. Sawyer (U.S.), incandescent lamp, patent model, 1878 [308,584], from U.S. Patent Office
4. William Wallace arc lamp, 1877 [320,900], from IBM, William J. Hammer Collection
5. Moses Farmer (U.S.), incandescent lamp, 1878 [181,977], from Sarah Farmer
6. Charles Brush (U.S.), arc lamp, patent model, 1870s [251,230], from U.S. Patent Office

Webnote: 1-8
[information about arc lamps]

[Curator's note, November 2003. This label was changed during the 2003 renovation. The following is the original text of the label.]

Arc Lamps

"The intense light had not been subdivided so that it could be brought into private houses."
Edison, notebook entry, September 1878

In an arc light, particles of vaporized carbon are heated electrically to the point where they glow brightly--too bright for use in the home. Edison proposed to use electricity to heat a wire (he was thinking of platinum or some other metal but eventually settled on carbon). The brightness of this incandescent lamp could be made dim enough for use indoors.

Furthermore, arc lights had low electrical resistance (a few ohms). In a circuit several were linked together in series so that their total resistance was appreciable compared to the resistance of the conducting wires; thus more energy was used in the lights and not wasted as heat in the wires. Edison s successful incandescent lamp had a relatively high resistance (about 100 ohms) and could be controlled individually.

[Label xL14 - Arc-lamp generators]

"Hurry up the machine, I have struck a bonanza."
Edison to Wallace, September 13, 1978

Edison had ordered a generator, like the one in the smaller case behind you, from William Wallace the previous week. He was anxious to use it in his experiments.

The development of efficient electric generators in the early 1870s made the commercial use of arc lamps possible. The first large-scale application occurred in Paris in 1878, with lamps designed by Russian inventor Paul Jablochkoff and generators by the Belgian Zenobe Gramme. In America, Wallace (with Moses Farmer), Charles Brush, and the firm of Elihu Thomson and Edwin Houston soon followed with their own systems.

But bright arc lamps were not suitable for use inside. Edison thought he saw a way to make smaller lights. He called this idea his "bonanza."

At left:

7. Hiram Maxim (U.S.), arc lamp, 1878 [252,655], from U.S. Patent Office
8. Jules Duboscq (French), arc lamp, 1860 [315,717], from U.S. Military Academy
9. Paul Jablochkoff (Russian), arc lamp, patent model, 1877 [252,646], from U.S. Patent Office

Graphics:

A. Arc lighting in Paris (1878)
B. Military Academy at West Point (1879).

[Curator's note, November 2003. This label was changed during the 2003 renovation. The following is the original text of the label.]

"Hurry up the machine, I have struck a bonanza."
Edison to Wallace, September 13, 1978

Edison had ordered a generator like the one in the large case to your left from William Wallace the previous week. He was anxious to use it in his experiments. The "bonanza" was his notion that he would subdivide the brightness of the arc light and have many separately controlled lamps.

Arc lamps became practical with the development of machines that could function as stable power-sources machines like the Thomson-Houston generator in the case behind you. The first commercial form of electric lighting, arc lamps are very bright and well suited for lighting large areas.

[Label sL5 - Jablochkoff]

Paul Jablochkoff (1847 -1894)

Born in Russia, Jablochkoff spent his career in Paris. There he invented an "electric candle" arc light in 1877, which was sensational in demonstrations in theaters and opera houses.

[Label xL102 - Wallace generator]

Generator by William Wallace, 1877 [181,644], from Coe Brass Manufacturing Company

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[Label xL103 - Thomson-Houston generator]

Generator by Elihu Thomson -Edwin Houston, 1987 [181,717], from General Electric Company

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[Curator's note, November 2003. This label was removed during the 2003 renovation, along with the London and Paris Hippodrome images.]

[L15 - arc lamp photos label]

"I believe I can beat you making the electrical light."
Thomas Edison to electrical inventor William Wallace, 1878

By the mid-1870s Americans William Wallace, Charles Brush, and other inventors had made small-scale arc light demonstrations. The first large-scale application occurred in March 1878 when Jablochkoff arc lamps, powered by Gramme generators, lit the streets of Paris. Edison proposed to make an incandescent lamp that was not as bright and could be operated individually.

Photos on right, top to bottom, show arc lighting in London (1879), in Paris (1878), and inside the Hippodrome in Paris (1880); on right, Military Academy at West Point (1879).

Inventing Edison's Lamp: Script

Bracketed information [xxx] does not appear on the label.

[Label xL16.1 - Section #2 introduction - Edison free-standing cut out]

Step 2: Invention

[Label xL16.2 - Section #2 introduction - Edison free-standing cut out]

"Aren't you a good deal of a wizard, Mr. Edison?"
(New York *Daily Graphic* reporter interviewing Edison, 1878)

Edison established a laboratory in 1876 in rural Menlo Park, New Jersey, 20 miles from New York. He was determined to invent things, and he was very successful at doing so. In 1877, while working on an improved telephone, he invented the phonograph. Even he was surprised. Others were astounded to hear the human voice reproduced, and he quickly became a celebrity. He used this popularity to his advantage, to gain support for further inventions.

Matthew Brady photograph shows Edison in 1878 at age 31.

[Label xL104 - Menlo Park]

"Edison made your work interesting. He made me feel that I was making something with him. I wasn't just a workman."
(John Ott, long-time Edison associate)

When Edison began work on the light bulb, he had a large advantage over his competitors--his laboratory at Menlo Park and a dozen assistants. An important part of his success was his ability to work with these men and to inspire them

Menlo Park Laboratory in 1880; Edison is in the middle. Note that light bulbs have replaced gas lights overhead.

Webnote: 2-1

[label xL18 - timeline]

An Edison Chronology

1847: Born February 11, Milan, Ohio

1859-63: Sells newspapers and sundries on train between Port Huron, Michigan, and Detroit

1864-67: Years as a traveling telegrapher

1868: Patents first invention, Boston

1869: Works on stock ticker and printing telegraph, New York

1870: First substantial income from an invention (stock ticker)

1871: Marries Mary Stilwell

1874: Quadruplex telegraph (sending four messages over a wire at the same time)

1876: Carbon-resistance telephone transmitter

1877: Phonograph

1879: Incandescent lamp

1882: Pearl Street Station, New York

1883: Discovers and experiments with electrical discharge inside lamp (called Edison Effect; later basis of vacuum tube)

1884: Wife Mary dies

1886: Marries Mina Miller

1887: Newer, larger laboratory, West Orange, New Jersey

1888-: Motion pictures

1889-95: Concentrated activity on electromagnetic ore-separation work, Ogdensburg, New Jersey
- More work on phonograph
- Development of storage battery

1923-: Attempts to find alternative sources of rubber

1929: Inauguration of Menlo Park laboratory as a museum, Dearborn, Michigan

1931: Dies October 18, West Orange, New Jersey

[Label xL24 - credit label near bust of Edison]

Bust of Edison, made by J. Beer, Jr., for the Phrenological Society of America, 1878 [310,582], from Frank Wardlaw, Jr. and Frank Wardlaw

"Wizard" cartoon appeared in *New York Graphic* in 1877.

[Label xL19 - filaments]

"Your trip to China and Japan on my account to hunt for bamboo or other fiber, was highly satisfactory ... you found exactly what I required."
Edison letter to William Moore, about 1885

Carbonized vegetable fibers made the strongest filaments. As part of a world-wide search, Edison sent William Moore to the Far East. He collected thousands of samples of bamboo to be tested. The best were from a grove in Yawata, near Kyoto, Japan. This became the standard for Edison lamps for the next ten years.

Edison had begun his search for an electric light in September 1878, using electricity to heat a thin wire until it glowed. He knew he needed a material that was a conductor with a high melting point and tried a number of different metals and metal oxides, but their low resistance made them inefficient. In September 1879, he experimented with thin filaments of carbon, and by the end of the year he had a practical lamp.

The carbon filament was thin enough so that it had a relatively high resistance--much higher than the wires leading from the generator. This meant that most of the energy would be used in the light bulb and not in the distribution system, a critical factor that distinguished Edison s invention from all others.

Edison got his carbon filaments by baking vegetable fibers, which he reasoned would leave the carbon atoms strongly linked together. Thread worked, cardboard was better, and even better was bamboo. He also made improvements in other parts of the lamp.

At right:

1. Platinum filaments and other experimental materials used for lighting elements, 1878 and 1879 [262,377], from Mrs. George F. Barker.
2. Development of carbon filament material 1879 [320,526], from IBM (William J. Hammer collection)

In case at lower right:

3. Cut cardboard before being baked, from U.S. Park Service
4. Bamboo strips, from IBM (William Hammer collection)
5. Plane for making thin bamboo strips [314,259], from Vannevar Bush
6. Caliper for judging size of hand-blown bulbs, from Corning Glass Works
7. "Paddy" for shaping glass bulb, from Corning Glass Works

A. Photo of Edison drawing of air bubble in platinum wire, January 19, 1879, from Edison National Historic Site

Webnote: 2-3

[Label xL20 - Books and bulbs]

"In 1877 ... I commenced the practice of placing notebooks all over my laboratory."
Edison testimony, 1880

Recording notes is a critical element of the inventive process, especially when several people are involved. Notes are also valuable in patent cases and, eventually, to historians. In the case below are several of Edison's notebooks.

In case at right:

1. New Year's Eve lamp with cardboard filament, 1879. Notice the tip, which shows where the lamp was sealed at the point where the vacuum pump was attached. [310,578], from Frank A. Wardlaw, Jr. and Frank A. Wardlaw
2. Lamp with bamboo filament, 1880. Also, a screw base has been added, and the glass is pressed against the lead-in wires, making a simpler seal.

[181,798], from General Electric Co.
2a. Socket, 1880 [320,503], from IBM, William Hammer collection.
3. Lamp with filament copper-plated to leads, 1880 [318,629], from Princeton University
4. Lamp with new screw base, 1881 [181,799], from General Electric Co.
5. Plaster-based lamp that was easier to form than wood, 1881 [180,934], from J. E. Hinds
5a. Socket, 1881 [320,735], from IBM (William J. Hammer collection)
6. Screw base lamp with thread-pitch and diameter still in use today, 1881 [318,664], from Princeton University
7. Screw base lamp with lip removed, due to improved bond between glass and plaster, 1884 [318,677], from Princeton University

Webnote: 2-2

[Label xL22 - credit label]

Notebooks from Edison s Laboratory:

Case at lower left:
In fifth notebook notice argument about AC vs DC (1882)
Drawing in seventh notebook is of apparatus to evacuate bulbs (1879)

This case:
Reproductions of notebook pages below show Edison's speculations about his lighting system (August, 1879).

from Edison National Historic Site

[Label xL106 - New Year's Eve]

"On December 31, 1879, special trains brought thousands of people out from New York to see this spectacular display."
Francis Jehl, Edison assistant, in his recollections, 1939

By early December 1879, Edison was convinced that he had developed a practical carbon-filament incandescent lamp. As soon as he could produce enough of them, he strung them around his Menlo Park compound for others to see.

[Label xL23 - credit label]

The Menlo Park Gang

A. Front steps of Menlo Park laboratory with Edison holding straw hat, 1880
B. Laboratory compound in winter of 1880 as sketched by R. F. Outcault. Center building is laboratory, front right is library, at rear is machine shop.
C. Formal view of Edison and staff at laboratory, 1880; inside laboratory, 1880.
D. Boarding house at Menlo Park; laboratory building, about 1879.

Photos from Edison National Historic Site

Left:
1. Patents obtained by Edison while he was at Menlo Park, some of them assigned to others.

Far left:
2. Two patents and the electric railway at Menlo Park, 1880.

Case:
3. Carbon-resistance telephone transmitter (patent model) 1878 [252,622], from U.S. Patent Office;
4. Improved phonograph, 1878 [318,576], from Princeton University

Webnote: 2-4

[Label xL107 - photo gallery]

"Billie darling you shouldn't write so meanly about your being a small part of my life, etc, that is all nonsense; You & the children and the laboratory is all my life. I have nothing else."
Edison to his wife, Mina, August 8, 1898

Edison's first wife, Mary Stilwell, died in 1884. She was sixteen when they married and, she was never able to compete with his inventive life. Mina Miller, though only nineteen when she married the forty-year-old widower in 1886, was much more successful in keeping him at home. But even she had her difficulties.

[first row:]

A. Edison and C. P. Steinmetz, 1922
B. Edison, about 1900
C. Edison in West Orange Laboratory library, with model of concrete house he was producing in background, 1911
D. Edison resting in West Orange Laboratory, 1911
E. Nancy Elliott Edison (mother)
F. Samuel Edison, Jr. (father)

G. Railway station where Edison learned telegraphy.

[Second row:]

H. Edison at time clock, about 1921
I. Last photo taken of Edison, 1931
J. Announcement of intention to be an inventor, 1869
K. Naval Consulting Board, with Franklin Roosevelt at left end of first row, Edison third from left, 1915
L. Mina Miller Edison (second wife), about time of wedding in 1886
M. Edison and Mina, 1906
N. Edison and motion pictures, 1912.

[Third row:]

O. Matthew Brady photo of Edison with phonograph, 1878
P. Edison with dictaphone, 1893
Q. Edison in West Orange Laboratory, 1893
R. Edison in West Orange Laboratory, about 1886
S. Edison at about four, about 1851
T. Edison at age ten, 1857; Edison "Glenmont" home.

[Fourth row:]

U. Edison with staff at West Orange, 1893
V. Edison at about 34, 1880-81
W. Edison at 31, 1878
X. Edward Hurley, John Burroughs, Edison, Henry Ford, Harvey Firestone, R. J. H. Deloach at start of camping trip, 1918
Y. Edison with improved phonograph, 1888
Z. Mary Stilwell Edison (first wife) at about 28, about 1883
AA. Edison at "Glenmont" home, 1917.

Photos from Edison National Historic Site.

Promoting Edison's Lamp: Script

Bracketed information [xxx] does not appear on the label.

[xL26.1 - Section #3 introduction label - third Edison free-standing cut out]

Step 3:Promotion

[xL26.2 - Section #3 introduction label - third Edison free-standing cut out]

"Mr. Edison's exhibition is the wonder of the show."
London *Standard* describing an international electrical exhibition in 1882

Edison had a fine sense of the value of promotion. His own renown as an inventor--especially of the phonograph and of an improved telephone-- helped him get money from investors. But he also took care to have impressive exhibits at the international fairs. Many of these exhibits were organized by William J. Hammer, one of his Menlo Park employees. Edison also pressed ahead quickly with some highly- publicized lighting installations.

Emil P. Spahn photograph shows Edison at 33 in 1880.

[xL25 - information and credit label]

"... the first electric sign which was ever made [I] constructed in December, 1881, and hung up in the Crystal Palace in London, England. It flashed the name "Edison" by means of a huge lever spring switch."
William Hammer, in a lecture to the New York Electrical Society, 1913

Hammer's flashing "Edison" signs appeared in several European venues and attracted much notice. In an age before movies or television, live demonstrations at fairs and expositions were important promotional opportunities for cutting-edge technologies.

Below left:
display at Cincinnati Exposition, 1885

Three pictures in center
Paris Centennial Exposition, 1889

Below right:
William J. Hammer with some of his collections.

Webnote: 3-1

[Label sL8 - Jehl]

Francis Jehl (1860 -1941)

Born in New York City, Jehl had little schooling. He became an assistant to Edison at Menlo Park and went to Europe in 1882 to promote the Edison System. On his return he helped reconstruct the Menlo Park laboratory at Dearborn, Michigan.

[Label sL9 - Upton]

Francis R. Upton (1852 -1921)

As a graduate of Bowdoin, with graduate work at Princeton and in Germany, Upton was the best-educated of Edison's assistants. Nicknamed Culture by his colleagues, worked on the light bulb, the generator, and other projects.

[Label sL10 - Batchelor]

Charles W. Batchelor (1845 -1910)

Batchelor was born in London and trained as a mechanic. He came to the U. S. at age 22 and soon joined Edison, becoming his closest associate. Batch went to Europe in 1881 to promote the Edison system, returning to head up the Edison Machine Works.

[xL27 - information and credit label]

S.S. *Columbia*

"Dispatch received this morning from steamer Columbia states she arrived safe in Rio and that the Edison light is all right."
Charles Mott, Edison assistant, writing in his diary, May 31, 1880

The first practical application of the Edison lighting system was on a steamship bound from New York to San Francisco. All 115 cardboard-filament lamps survived the two-month voyage. The original system continued to operate (with replacement bulbs) for another 15 years.

Painting of Columbia [160,081], from John Roach and Son

[label xL32 - Pearl Street map]

Attracting Investors

In a twinkling, the area bounded by Spruce, Wall, Nassau, and Pearl Streets was in a glow."
New York Herald, 5 September 1882

The site for Edison s first U.S. central generating station had to satisfy both engineering and business needs. Use of direct current at 100 volts to power the new light bulbs resulted in a practical limitation customers could be no further than « mile from the generator. To promote the system, a high profile location was called for. Edison chose a site in the heart of New York s financial district, 255 and 257 Pearl Street, as seen on the map at right. On September 4, 1882, he threw a switch in the office of one of his main investors, J. Pierpont Morgan, and initiated service to the area.

A major factor in Edison s success lay in his ability to attract large amounts of money to fund research and development. Financing for Edison s initial light bulb experiments had mainly come from telegraph businessmen who knew him and had faith in his abilities. In 1878, they and the banking house of Drexel-Morgan paid $50,000 for 1/6 share in the Edison Electric Light Co. Edison held the other 5/6 share.

To finance Pearl Street Station, more money was needed and this same group established the Edison Electric Illuminating Co. in December, 1880. While raising $750,000 new money, both Edison s share and his control of the company declined. The other investors were cautious about engaging in manufacturing and marketing activities, but Edison was anxious to move ahead and sold some of his stock in order to finance new activities. These included:

- Edison Lamp Company (October 1880), to manufacture light bulbs
- Edison Machine Works (1881) to produce generators
- Edison Tube Works (1881) to make underground connectors
- Edison Company for Isolated Lighting (1884) to promote small generating stations for individual businesses and homes.

In 1884, although he no longer controlled the Edison Electric Light Company, Edison persuaded the other investors, notably Morgan, to support a more vigorous program of expansion. By 1886, total capitalization reached $1.5 million, and Edison moved to West Orange, New Jersey, to set up his new laboratory

He kept controlling interest in the machine and lamp works, but sold these after the several companies combined to form Edison General Electric in 1889. Though Edison was cool to the idea, this new company merged with the rival firm of Thomson-Houston in 1892 to form General Electric Co.

[xL31.1 - information label]

Pearl Street

"...my system of lighting having been perfected should be promoted."
Edison, as quoted in the Electrical World, August 1883

Edison's financial backers would have been content for him to license his invention for others to use. But Edison was not just an inventor. He was also an entrepreneur he wanted to make sure that his invention was used and that it was used correctly. He therefore constructed at Pearl Street in New York City a full-scale central station that began operations on September 4, 1882.

A focal point for further promotional efforts, the station gave a clear demonstration that his electric lighting system worked. By then, in addition to the light bulb, he had invented many additional items necessary for the system. These included a meter (to measure how much electricity the customer used) and an improved generator.

Edison went on to develop manufacturing plants for light bulbs, generators, and other system components. Beginning in 1886, these were consolidated in Schenectady, N.Y.

[Curator's note. This label was changed during the 2003 renovation. The following is the original text of the label.]

Pearl Street

"...my system of lighting having been perfected should be promoted."
Edison, as quoted in the *Electrical World*, August 1883

Edison s financial backers would have been content for him to license his invention for others to use. But Edison was not just an inventor; as an entrepreneur he wanted to make sure that his invention was used and that it was used correctly. He therefore constructed a full-scale central station at Pearl Street in New York City that began operations on September 4, 1882. It was a focal point for further promotional efforts, a clear demonstration that his electric lighting system worked. By now, in addition to the light bulb, he had invented numerous additional items necessary for the system, including especially a meter (to measure how much electricity the customer used) and an improved generator.

Edison went on to develop manufacturing plants for light bulbs, generators, and other system components. These were consolidated in Schenectady, N.Y., beginning in 1886.

[xL31.2 - credit label]

Pearl Street

1. Knife switch, 1880s [318,717], from Princeton University
2. Chemical meter, about 1882 [262,476], from Easton Gas & Electric Co.
3. Ammeter, 1880s [331,146], from Western Union

4. Edison fan-motor, [337,118], from James M. and Reathie L. McKee.
5. Cable sample, about 1885 [314,919], from Consolidated Edison Co. of New York
6. Junction box, about 1885 [314,917], from Consolidated Edison Co. of New York
7. Knife Switch, 1880s [318,726], from Princeton University
8. Knife Switch, 1880s [318,719], from Princeton University
9. Knife Switch, 1880s [318,718], from Princeton University
10. Rotary switch, 1880s [328,082], from George C. Maynard
11. Rotary switch, 1880s [273,182], from Charles H. Newton
12. Rotary switch (with cover), 1887 [181,754], from George C. Maynard

Opposite wall: Pearl Street Station, model [309,605], from New York Edison Co.

Webnote: 3-2

[xL30 - information label]

Testing The System

"Last week we lighted up the Lithograph Establishment of Messrs. Hinds & Ketcham in N. Y."
Edison letter, February 11, 1881

"There is only one system, and that is Edison's"
London Daily News, 1882

Prior to the opening of Pearl Street Station, Edison tested his lighting system and gained practical experience with smaller-scale installations.

Holborn Viaduct

William Hammer and other Edison associates established a demonstration central power system at Holborn Viaduct in London. It started operation January 12, 1882. By the time it closed down early in 1884, it had a capability of lighting over 3000 lamps.

The map above shows the location of Holborn Viaduct in London. Photographs at the left show the Viaduct area as it appeared a few years later.

from William J. Hammer.

[Curator's note. This label was changed during the 2003 renovation. The following is the original text of the label.]

Holborn Viaduct

"There is only one system, and that is Edison's"
London *Daily News*, 1882

William Hammer and other Edison associates established a full-scale demonstration system at Holborn Viaduct in London. It started operation January 12, 1882, and by the time it closed down early in 1884, it had a capacity of over 3000 lamps.

Photographs show the Holborn Viaduct area as it appeared a few years later, from William J. Hammer.

[xL24 - information and credit label]

Hinds-Ketcham

This was the first commercial installation of the new electric light. The power came from a stand-alone "isolated plant" rather than a central station, but still served to test system components in everyday use.

1. Dynamo switch, 1881 [180,944]
2. Switch, 1881 [180,942]
3. "Safety plug" fuse, 1881 [180,943]
4. "Safety plug" fuse, 1881 [180,946]
5. Light Bulb, 1881 [180,931]
6. Lamp fixture with socket, 1881 [180,940]
7. Lamp fixture with socket, 1881 [180,940]
8. Resistance coil, 1881 [180,941]
9. Printer's Lamp, 1881 [180,939]

All items from Hinds-Ketchum & Co.

[Curator's note. This label was changed during the 2003 renovation. The following is the original text of the label.]

Hinds-Ketcham

"Last week we lighted up the Lithograph Establishment of Messrs. Hinds & Ketcham in N. Y."
Edison letter, February 11, 1881

This was the first commercial installation of the new electric light.

1. Dynamo switch, 1881 [180,944]
2. Switch, 1881 [180,942]
3. "Safety plug" fuse, 1881 [180,943]
4. "Safety plug" fuse, 1881 [180,946]
5. Light Bulb, 1881 [180,931]

6. Lamp fixture with socket, 1881 [180,940]
7. Lamp fixture with socket, 1881 [180,940]
8. Resistance coil, 1881 [180,941]
9. Printer's Lamp, 1881 [180,939]

All items from Hinds-Ketchum & Co.

Competition to Edison's Lamp: Script

Bracketed information [xxx] does not appear on the label.

[xL34.1 - Section #4 introduction label - fourth Edison free-standing cut out]

Step 4:Competition

[xL34.2 - Section #4 introduction label - fourth Edison free-standing cut out]

"If you want to succeed, get some enemies." Edison, as quoted in the *Ladies Home Journal*, April 1898

Success produced rivals. The gas companies improved their lighting systems, and other electrical inventors came out with their own systems, many of them borrowing heavily from Edison's work. Edison himself was spurred on to make further improvements.

Some of Edison's rivals are represented in these displays of light bulbs, meters and generators.

Kreidler photograph shows Edison at 48 in 1895.

[xL35 - credit label]

Gas Light

"If I had had my wits about me when your telegram came announcing your discovery, I might have made you a clean million as it played the very devil with stocks all over the country."
George Gouraud in a letter to Edison, from London, October 1878

While Edison s initial announcement of his discovery was premature, his reputation served to cause a sharp drop in the price of gas company stocks. Edison used gas lighting as the model for his electric lighting system, and his success began a commercial rivalry between the two technologies. Notice Edison, Joseph Swan, and other electric lamp makers haunting *The Dream of a Gas Manufacturer* in the 1884 drawing at right. Improvements in gas quality and Carl Auer von Welsbach s gas mantle invention were two factors that kept gas lighting competitive with electricity for 30 years.

Case at left:

1. Electric lamp fixture, about 1890, from National Park Service
2. Lighting fixture with both gas & electric burners, about 1890 [10,175], from National Park Service
3. Electric lamp fixtures converted from gas, about 1890, from Mt. Vernon Museum of Incandescent Lighting

Large photo at far left:
from Sigmund Bergmann & Company catalog, 1882

Large image at right, *The Dream of a Gas Manufacturer* is from *Punch*, 1884. Note Wilhelm and William Siemens (6, 7), Joseph Swan (8), Edison (12), Hiram Maxim (13), Paul Jablochkoff (18).

Webnote: 4-1

[xL36 - credit label]

Electric Light

"You are aware that a seizure was made by us of the Maxim lamp at the Paris Exposition. Suit was commenced immediately on the seizure." Report of Messrs. Puskas and Bailey to the Edison Electric Light Co. of Europe, 1882.

Competition to Edison's lamp came quickly. Some inventors, like Joseph Swan of England, were already working on the problem and soon produced their own lamps. Others, like George Westinghouse, brought existing companies into the new field. As a result, Edison often found himself in court, defending his lamp patents and filing for injunctions.

The lamps in this case show a variety of designs that appeared within about twenty years of Edison's first commercial lamp.

1. Sawyer-Man, about 1885 [327,831], from Chicago Museum of Science & Industry

2. Swan, 1881 [323,557]
3. Edison, 1886 [181,804], from General Electric Company
4. Edison, 1888 [327,785], from Chicago Museum of Science & Industry
5. Westinghouse "stopper", about 1894 [1997.0388.80], from General Electric Lighting Co.
6. Thomson-Houston decorative, about 1890 [1997.0388.79], from General Electric Lighting Co.
7. Sterling, about 1900 [327,839], from the Chicago Museum of Science & Industry
8. Fostoria, about 1900 [327,830], from the Chicago Museum of Science & Industry
9. Brush-Swan, about 1885 [318,641], from Princeton University
10. Maxim, 1881 [181,980], from Sarah J. Farmer
11. New Type Edison, about 1890 [318,666], from Princeton University
12. Westinghouse, about 1890 [311,930], from Newark College of Engineering
13. Vitrite-Luminoid, 1890 [318,674], from Princeton University
14. Columbia "USONA", about 1905 [320,675]
15. United Electric Improvement Co., about 1894 [327,856], from the Chicago Museum of Science & Industry
16. Columbia, about 1890 [327,842], from the Chicago Museum of Science & Industry
17. Phelps "Hy-Lo", about 1895 [230,836], from General Electric Company
18. Perkins, about 1890 [325,794], from Thompson Equipment Company
19. Peerless, about 1890 [335,363], from Robert F. Hoke
20. Weston, about 1887 [318,634], from Princeton University
21. Maxim, about 1881 [320,673], from IBM (W. J. Hammer collection)
22. Ediswan, about 1885 [327,811], from Chicago Museum of Science & Industry
23. Elblight, about 1890 [323,559]
24. Weston, 1882 [318,642], from Princeton University
25. Imperial Bryan-Marsh, about 1900 [327,799], from Chicago Museum of Science & Industry
26. Sunbeam, 1900 [327,853], from Chicago Museum of Science & Industry
27. United Electric Improvement Co., about 1894 [327,829], from Chicago Museum of Science & Industry
28. Shelby, about 1905 [318,607], from Princeton University
29. Knowles, about 1895 [314,289], from C. Locklin
30. Pond, about 1895 [314,289], from C. Locklin
31. K&W, about 1895 [314,289], from C. Locklin
32. McNutt, about 1895 [327,840], from Chicago Museum of Science & Industry
33. Capital, about 1900 [327,796], from Chicago Museum of Science & Industry
34. Independent, about 1895 [327,800], from Chicago Museum of Science & Industry
35. Buckeye, about 1895 [327,792], from Chicago Museum of Science & Industry
36. Ediswan socket, about 1890 [320,761], from IBM (W. J. Hammer collection)

37. United Electric Improvement Co. socket, about 1894 [327,857], from Chicago Museum of Science & Industry
38. Swan socket [320,763], from IBM (W. J. Hammer collection)
39. Insulite socket for Thomson-Houston lamp, about 1895 [320,748], from IBM (W. J. Hammer collection)
40. Perkins socket for Westinghouse lamp, about 1899 [320,746], from IBM (W. J. Hammer collection)
41. Nernst lamp, 1902 [214,331], from Nernst Lamp Company

Webnote: 4-2

[Label sL11 - Swan]

Joseph W. Swan (1828 -1914)

Swan had a varied inventive career, with early contributions to photography. His carbon filament lamp anticipated Edison's by several months, but it had a low resistance and was unsuitable for commercial use. Swan's 1883 cellulose filament became an industry standard.

[Label sL12 - Nernst]

Walther H. Nernst (1836 -1941)

Nernst, a professor of physics at Göttingen and Berlin, received a Nobel Prize in Chemistry in 1920 for work in thermodynamics. As a sidelight, in the 1890s he invented an efficient lamp in which the filament heated rare-earth salts, which then glowed. The lamp was very efficient, but too expensive to be practical.

[Label sL13 - Latimer]

Lewis H. Latimer (1848 -1928)

An African American, born in Chelsea, Mass., Latimer trained as a draftsman at a Boston patent law firm. There he made drawings for Alexander Graham Bell, among others. He joined the Maxim company in 1880 and invented a means of producing improved carbon filaments. In 1884 he moved to Edison's Lamp Works and had a distinguished career as a draftsman.

[xL43 - credit label]

Meters

These meters represent some of the many companies that competed in the electric light business.

Left:

1. Thomson voltmeter, about 1891 [318,351], from Princeton University
2. National Electric ammeter, [322,811], from the State University of New York, Buffalo
3. Slattery ammeter [318,376], from Princeton University
4. Edison ammeter [313,670], from Weston Electrical Instrument Corp.
5. Hartmann & Braun ammeter [317,692], from Iowa State University
6. Weston ammeter, about 1890 [319,238], from Daystrom Inc.
7. Thomson-Houston voltmeter, about 1890 [219,027], from Potomac Electric Power Co.
8. Thomson-Rice ammeter [318,356], from Princeton University
9. General Electric voltmeter, about 1903 [334,396], from the American Museum of Electricity
10. Norton voltmeter [314,968], from E. P. Custis
11. Westinghouse ammeter [318,320], from Princeton University
12. Gardiner "Electro Magnetic Meter", [319,443], from Mrs. Donald Bliss
13. Stanley phase indicator [314,411], from Weston Electrical Instrument Corp.

Right:

14. Edison General Electric ammeter, 1890 [313,286], from Weston Electrical Instrument Corp.
15. Stanley static ground detector, about 1896 [314,459], from Weston Electrical Instrument Corp.
16. Ft. Wayne ammeter, about 1890 [318,350], from Princeton University
17. Ft. Wayne ammeter, about 1895 [326,483], from General Electric Company
18. Biddle wattmeter, about 1895 [326,921], from Trinity College
19. Weston voltmeter, about 1900 [336,453], from Donald Hoke
20. Ft. Wayne volt-meter, about 1895 [1998.0112.01], from Vincent King
21. Western Electric voltmeter, from the National Park Service
22. Thomson wattmeter, about 1887 [318,301], from Princeton University
23. Western Electric ammeter, [334,385], from the American Museum of Electricity

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[Label sL14 - Shallenberger]

Oliver B. Shallenberger (1860 -1898)

A graduate of the U. S. Naval Academy, Shallenberger left the Navy in 1884 to join the Westinghouse company. In 1888 he invented an induction meter for measuring alternating current, a critical element in the Westinghouse AC system.

[xL48 - credit label]

Generators

From the beginning, many of Edison s rivals used alternating current generators.

1. Ferranti generator, 1883 [327,571], from Sebastian de Ferranti
2. Brush generator, 1884 [315,075], from Massachusetts Institute of Technology
3. Thomson-Houston generator, 1885 [181,720], from General Electric Company

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[xL44 - information label]

The Alternating Alternative

"It will never be free from danger."
Edison in a memorandum concerning the Westinghouse AC system, 1886

"Tell your father I was wrong."
Edison to George Stanley, son of William Stanley who had invented an AC transformer for Westinghouse, 1908

In the long term, Edison was certainly wrong in assessing the problems of alternating current. But at the time, he had good reasons for sticking with direct current. The reason for using AC was that it could be easily converted to high voltage, transmitted over long distances with low losses, and then converted back to low voltage to be used by the customers. But even at low voltage, there was evidence that AC was more dangerous than DC, and there was the possibility that the transformer might break down and deliver high voltage to the home. Even a few such accidents could be very harmful to the growth of this new industry.

Although both arc and incandescent lights could use AC, existing motors (especially important for the growing street railway industry) and meters could not.

Early AC transformers were inefficient.

Electrochemical processes used DC.

Batteries could store DC during periods of low demand.

Edison also may have been influenced by the commitment he had made to his own DC system and by the difficulty of visualizing the operation of AC.

Webnote: 4-3

[Label sL15 - Tesla]

Nikola Tesla (1856 -1943)

Born of Serb parents in Croatia, Tesla was educated in Europe. He came to New York in 1884 and worked briefly for Edison. He patented a practical AC motor in 1888. Other AC patents were used in the Westinghouse generators at Niagara Falls. He is also known for high-frequency experiments and inventions in the field of radio.

[xL45 - information label]

Transformers

The first practical AC transformer was developed by Frenchman Lucien Gaulard and Englishman John Gibbs; improvements were made at the Ganz company in Budapest and, in the United States, by William Stanley who was working for George Westinghouse.

Motors

A practical AC motor was invented by Nikola Tesla in 1888 (see example in the case behind you).

Webnote: 4-4
[information about transformers]

[xL46/47 - information and credit label]

Push the button to your right for a demonstration of a transformer in action. The input is at 125 volts. The transformer steps the electric voltage down by using the principle of **induction** -- 125-volt alternating current in one coil induces 3-volt AC in a second coil.

Cases below, right to left:

1. Westinghouse transformer, 1887 [318,553], from Princeton University
2. Ferranti transformer [327,571], from Sebastian de Ferranti
3. Stanley transformer, reproduction, 1886 [322,808]
4. Gaulard & Gibbs transformer, 1883 [311,853], from Westinghouse Electric Manufacturing Co.

[xL108 - information and credit label]

Watt-hour meters measure the amount of electrical energy consumed. These examples are from the 1890s.

1. Thomson [334,376], from American Museum of Electricity
2. Sangamo [334,416], from American Museum of Electricity
3. Westinghouse Shallenberger, [322,183], from Massachusetts Institute of Technology
4. Westinghouse, [334,377], from American Museum of Electricity
5. Stanley, [334,389], from American Museum of Electricity
6. Stanley, [334,399], from American Museum of Electricity

Consequences of 19th Century Lighting: Script

Bracketed information [xxx] does not appear on the label.

[xL50.1 - Section #5 introduction label - fifth Edison free-standing cut out]

Step 5: Consequences

[xL50.2 - Section #5 introduction label - fifth Edison free-standing cut out]

"I have accomplished all I promised."
Thomas Edison, to New York *Sun* reporter, 1882

This statement indicated Edison's pleasure upon opening the Pearl Street station. But even he would have had difficulty predicting the consequences of his invention. It stimulated a lighting industry that quickly spread through cities and towns across the country. And it helped establish the need for large central stations, beginning with Niagara Falls. Ironically, since these stations would rely on alternating current for efficient long-distance transmission, they would lead to the abandonment of Edison's direct current systems in most applications.

Over the course of the next half century two broad social effects developed that seem especially significant. 1) We now had complete control over light in homes and offices, independent of the time of day. 2) The electric light brought networks of wires into homes and offices, making it relatively easy to add appliances and other machines.

Photo by Falk shows Edison at 57 in 1904.

[xL109 - information and credit label - engines platform]

By the end of the 1880s three firms dominated the lighting field: Edison, Westinghouse, and Thomson Houston. Edison stayed with direct current, the others used alternating current. In 1892, the Edison company and Thomson Houston merged to form General Electric.

Right side of platform:

1. Edison Z-type generator, rated at 60 lamps (52 amps at 110 volts), about 1888, [320,572] from University of Minnesota
2. Voltmeter, 1880s, [305,262] from Roller-Smith Company
3. Voltmeter, 1880s
4. Fuse, 1880s, [318,717] from Princeton University
5. Bergmann ammeter, 1880s, [314,474] from Weston Electrical Instrument Company
6. Rheostat, 1880s

Left side of platform:

7. Westinghouse single-phase generator (220 volts, 40 amps), about 1888, [318,252] from Cornell University
8. Exciter generator, 1880s, [322,556] from Princeton University
9. Voltmeter, 1880s, [318,277] from Princeton University
10. Fuse, 1880s
11. Fuse, 1880s

[xL117 - information label]

"Someday I'll harness that power."
Nikola Tesla, as a young boy looking at a picture of Niagara Falls, according to a recollection in 1915

The world's first large-scale central generating station opened at Niagara Falls in 1895, with some of its output transmitted twenty miles away to Buffalo. It employed two-phase AC techniques invented by Nikola Tesla and was thus more efficient than previous alternating current systems.

In succeeding years, large centralized AC generating stations would eventually link together the many local systems (DC and AC) in cities and towns across the country into a national grid.

Webnote: 5-1
[information about Tesla and Niagara Falls]

[xL110 - credit label]

1. Westinghouse dynamo nameplate, 1897, [322,844] from Niagara-Mohawk Power Co.
2. Turbine model, 1892, [315,850] from Niagara-Mohawk Power Co.
3. Generator model
4. Cable section, 1895, [320, 523] from IBM (W. J. Hammer collection)
5. Porcelain insulator, 1895, [318,344] from Princeton University

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[xL54 - information and credit label inside case]

Much of the current from the Niagara generators was used locally.

1. Carborundum sample, from Mrs. Edward Acheson
2. Carborundum sample-wheel
3. Aluminum samples [MT2373-2389], from Pittsburgh Reduction Co.

Webnote 5-2
[information about aluminum and Acheson]

[xL111 - credit label inside free-standing case]
Edison 6kw motor, about 1883 [319,260] from Brown University

[xL112 - credit label inside free-standing case]
Tesla AC motor, 1888, [311,854] from Westinghouse Electric Manufacturing Co.
C&C sewing machine motor, [313,044] from Crocker-Wheeler Electric Manufacturing Co.

[xL113 - credit label inside free-standing case]

1. General Electric model D-12 toaster, about 1910, [329,287] from Priscilla Griffin de Mauduit
2. Universal model E945 toaster, about 1920, [334,586] from Edmond Chenette
3. Universal / LFC model E9410 toaster, about 1928, [1991.1.1] gift of Richard J. & Fannie V. Beall

[xL114 - credit label inside free-standing case]

1. Waters-Genter model 1A1 toaster, about 1926, [1992.338.19] Gift of Joyce Barth & Florence E. Scuderi from the Belford Giberson Collection
2. Universal / LFC model E7212F toaster, 1930s, [1992.338.28] Gift of Joyce Barth & Florence E. Scuderi from the Belford Giberson Collection
3. Sunbeam model B toaster, about 1925, [336,530] from Mr. & Mrs. Harry Failing

[xL115 - credit label inside free-standing case]

1. Estate Electric model 77 toaster, about 1925, [333,743] from Mrs. William Josten
2. Toast-O-Lator model J toaster, about 1940, [1988.227.01]

[xL116 - credit label inside free-standing case]

1. T.A. Edison "Edicraft" toaster, about 1929, [8010] from the National Park Service
2. Toastmaster model 1A5 toaster, about 1950, [1987.0368.01]
3. Universal / LFC model E7222 toaster, about 1925, [1992.338.04] Gift of Joyce Barth & Florence E. Scuderi from the Belford Giberson Collection

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[xL55 - information and credit label - appliance case - left hand section]

Interior Lighting

The electric lamp gave us complete control over lighting of homes and work places. By the time of the Roosevelt quote this was true (with the help of the REA) even in rural areas. The consequence was to interrupt the normal rhythms of life and to alter for all time the schedules we have for work and leisure.

A Danish immigrant, Frode Rambusch, started a business in New York in the 1890s designing murals and stained glass windows for public buildings. He soon expanded activities to make special lighting fixtures, incorporating artificial light into the architecture. At right (9) is his first fixture. It was designed in 1908 to shield the eyes while illuminating a mural he had created. The overhead lamp (1939) is also by Rambusch.

Objects:

1. Lyhne desk lamp, about 1911, [1979.1044.01] from Marabeth S. Finn
2. "Solar" lamp converted to electricity, about 1920, [70.37] from Clara B. Blackmar
3. Kerosene lamp converted to electricity, about 1920, [65.180] from Mrs. Fielding Pope Meigs
4. 1840s gas lighting fixtures converted to electricity around 1885, from the Mt. Vernon Museum of Incandescent Lighting
5. Combination electric and gas lighting fixture, about 1895, from the Mt. Vernon Museum of Incandescent Lighting
6. Wall-mounted sconce, about 1920, [1981.595.02]
7. "Watchdog Nite-Lite", about 1950, [1991.837.01]
8. Sign from U. S. Patent Office, 1930s, [1995.0340.01] from Robert C. Reed
9. Rambusch church wall-fixture, about 1909, [1992.0284.01] from Rambusch Decorating Co.
10. Rambusch church wall-fixture, [1992.0284.02] from Rambusch Decorating Co.
11. Table lamp with Emeralite shade, 1907 [1990.136.02]
12. Flashlights, 1930s, from Eveready Battery Co. Inc.
13. Ever Ready Flashlight Cane,1910, from Lawrence N. Ravick
14. Electric table lamp, 1910s, from Miss M.H. Avery
15. Photographic pendant lamp, about 1899 [x-93-1]
16. Rambusch ceiling fixture, 1939, [1992.0284.03] from Rambusch Decorating Co.

Graphics:

A. GE National Mazda advertisement, 1920
B. Photo of lighting engineer Matthew Luckiesh's living room, 1939, General Electric Lighting Co.
C. Lighting a Drawing Room, 1927
D. Photo of lighting engineer Matthew Luckiesh's living room, 1939, General Electric Lighting Co.
E. "One Corner of a Dining-Room Converted into an Attractive Nursery," 1927
F. Office with make-shift electrical installation, about 1912, from General Electric Lighting Co.

G. Diagram "Layout of Outlets for a Typical Small House," 1922, General Electric Lighting Co.
H. Lighting A Bed Room, 1927
I. GE National Mazda advertisement, 1925, from General Electric Lighting Co.

Webnote: 5-4
[information about Rambusch, lighting designers]

[xL56 - information and credit label - appliance case - right hand section]

Electrification

"Electricity is a modern necessity of life."
(Franklin Roosevelt, at Rural Electrification Administration celebration, 1938)

The electric lamp, in effect, paid for a network of generators and wires. These were available for a whole new class of inventions--appliances and equipment that by the 1930s had transformed the home and the workplace.

17. General Electric heater, about 1893, [330,674] from Philip Klein
18. Hoover vacuum cleaner, 1908, [330,997] from The Hoover Company
19. American Electrical Heater tea kettle, 1904, [330,712] from Lawrence R. Friel
20. Spot Reducer massager, [1991.0410.02] from Bernard S. Finn
21. Egg stirrer, [333,893] from Alfred T. Giller
22. Manning Bowman cigar lighter, 1911, [330,718] from Mrs. Walter Lindquist
23. Cigar lighter, [1990.3115] from Bernard S. Finn
24. Shaving mug, 1914, [330,714] from LeRoy Halsey
25. Daniel Woodhead glue pot, [330, 721] from Thomas J. Kliminiski
26. Appliance wattmeter, [314,346] from Weston Electrical Instrument Co.
27. Weller soldering-iron prototype, 1941, [1989.0643.02] from Carl Weller
28. GE Hotpoint heating pad, [330,665] from General Electric Co.
29. Kimco electric socks, [1990.0401] from Bernard S. Finn
30. Simplex waffle iron, about 1910, [330,770] from Mrs. Ted Bussman
31. Universal kitchen set, 1926, [1979.1044.02] from Marabeth S. Finn
32. Iron, 1906, [329,791]
33. Marshmallow toaster, about 1909, [330,776] from Mr. and Mrs. Samuel F. Hunter
34. Kenmore hair dryer, about 1949, [1991.0410.03] from Bernard S. Finn
35. Curtis & Crocker fan, 1886, [330,647] from Chicago Museum of Science & Industry
36. General Electric fan, about 1892, [330,673] from General Electric Company
37. Edison Electric fan, [328,749] from Dept. of Physics, Amherst College

    Above, outside case

38. Hunter ceiling fans, 1897, [1997.0387.25.01 and .02] from the Mt. Vernon Museum of Incandescent Lighting

Webnote 5-3
[reference to electrification]

[xL57 - electric coal cutter label]

"It is curious to watch two men entering what is little more than a crack in the earth, and taking with them a powerful machine which is receiving power from the surface by means of an electric cable."
Charles R. Gibson, reporting on the use of electricity for mining in 1906.

Gibson wrote a book-length survey of the state of the electric arts entitled, The Romance of Modern Electricity. The title reflected his sense of wonder at the marvellous [sic] difference that the advent of electricity has made in everyday life. That difference became practical through the development of an interconnected system of large, central generating stations, high-voltage AC transmission lines, and lower voltage AC and DC distribution lines. An integrated system that could make electricity and deliver it hundreds of miles to wherever it was wanted -- be that in tall buildings or deep mines as seen in the image to your right.

Coal Cutter

The machine below literally undermined a coal-seam by cutting a slot about 4 feet deep along the base of the seam. Gravity or, if necessary, explosives would then bring the seam down. Automating this part of the job doubled each miner s daily output, according to Gibson.

Electric coal-cutter, [MN7891-A], from Jeffery Manufacturing Co.

[label xL57.2]

Switch Panels

Opened in 1889 as a central generating station, the 26th Street Station in New York City provided direct current power to the surrounding area. When the Waterside generating station began providing alternating current service to all of Manhattan about 10 years later, rotary converters and the necessary control equipment were installed at 26th Street. Used as a substation, its operators converted 3-phase, 6600-volt, 25-cycle AC from Waterside to 120 / 240 DC needed by customers. The panels to the left were removed from 26th Street after it ceased operation in 1977.

Left to right:
AC control board, Group switch and circuit breakers, and DC feeder selector switch assembly, [1980.0405.02, .03, .04] from Consolidated Edison Co. of New York, Inc.

[label xL57.1]

Elevator

The elevator to your left was installed in the Carnegie mansion at 2 East 91st New York, in 1902. While this installation could be considered a luxury (it stopped at five floors and the basement), elevators were essential to the new skyscrapers.

Elevator, 1902, [1998.0162.01] from the Cooper-Hewitt Museum of Decorative Arts & Design.

[label xL57.3]

Street Car Controller

Aside from lighting, the most important early use of electric power was for street railways. The first practical system was installed by Frank Sprague in Richmond in 1888, and others quickly followed. Within 15 years over 20,000 miles of street railway lines had been built in American cities, almost completely replacing horse-drawn cars.

Shown here is a Westinghouse streetcar controller of about 1910 [321,385], from Robert M. Vogel.

Webnote: 5-5

[Label sL16 - Short]

Sydney H. Short (1858 -1902)

Short was born in Columbus, Ohio. After graduating from Ohio State University, he became professor of physics and chemistry at the University of Denver. He held over 500 patents, many in the field of streetcar railways.

[Label sL17 - Van Depoele]

Charles J. Van Depoele (1846 -1892)

A native of Belgium, Van Depoele came to the United States in 1869 and settled in Detroit. He invented an arc lamp in 1870, but is especially known for developing a form of electric railway using overhead wires.

[Label sL18 - Sprague]

Frank J. Sprague (1857 -1934)

A graduate of the U. S. Naval Academy, Sprague covered the Paris (1881) and London (1882) electrical exhibitions for the Navy. He worked briefly for Edison and later developed a constant-speed motor and an overhead trolley pick-up device important for street railways.

[Label sL19 - Daft]

Leo Daft (1843 -1922)

Born in Great Britain, Daft came to the United States in 1866. In 1879 he joined the New York Electric Light Company and transformed it into the Daft Electric Company, which became a major competitor in the street railway business.

An Edison Timeline

1847:	Born, 11 February, Milan, Ohio
1859-63:	Sells newspapers and sundries on train between Port Huron, Michigan, and Detroit
1864-67:	Years as a traveling telegrapher
1868:	Patents first invention, Boston
1869:	Works on stock ticker and printing telegraph, New York
1870:	First substantial income from an invention (stock ticker)

1871:	Marries Mary Stilwell
1874:	Quadruplex telegraph (sending four messages over a wire at the same time)
1876:	Carbon-resistance telephone transmitter
1877:	Phonograph
1879:	Incandescent lamp
1882:	Pearl Street Station, New York
1883:	Discovers and experiments with electrical discharge inside lamp (called "Edison Effect;" basis of the vacuum tube)
1884:	Wife Mary dies
1886:	Marries Mina Miller
1887:	Newer, larger laboratory, West Orange, New Jersey
1888- :	Motion pictures
1889-95:	Concentrated activity on electromagnetic ore-separation work, Ogdensburg, New Jersey
	More work on phonograph
	Development of storage battery
1923- :	Attempts to find alternative sources of rubber
1929:	Inauguration of Menlo Park laboratory as a museum, Dearborn, Michigan
1931:	Dies October 18, West Orange, New Jersey

Script & Webnotes: 20th Century

Editor's note, June 2004. The 20th century section of *Lighting A Revolution* has been reopened following renovation in the museum. None of the objects or graphics were permanently removed, however the interactive display "Out of the Blue" was removed. One graphic (an images of the New York skyline) was added to the exhibition.

The complete text of the labels mounted in Lighting A Revolution's 20th century section are available through the links below. Webnote links are included in each of the five label sections, or you can go directly to the webnotes index with the link below. We have also posted lists of the objects and graphics that are included in this section of the show.

The objects and graphics lists are large and may take time to load.

Photo Gallery #1:
Lamp Inventors 1950-1990

Below are seen a few of the people whose lamp inventions are profiled in Lighting A Revolution's 20th century section.

An enlargement with additional information is linked to each photo.

"Some people said it had been tried
- putting halogens in lamps -
but it didn't work."
-- Elmer Fridrich

Elmer G. Fridrich, co-holder of
US Patent #2,883,571
(tungsten-halogen lamp).
Photo ©General Electric.

"I felt that if we ever got to the point
where we knew how to control things
and make it, we would replace
standard incandescent lamps."
-- Frederick Mosby

Frederick Mosby (seated),
Edward Zubler, Stanley Ackerman
& Alton Foote, (standing r-l)
with the tungsten halogen lamp.
Photo ©General Electric.

"I knew what the lighting goals were,
everybody wanted more efficiency,
and they wanted white light,
and they wanted something economical."
-- Gilbert Reiling

Gilbert H. Reiling demonstrating
his metal halide lamp.
Photo ©General Electric.

"He was destroying things
as soon as they were made."
-- William Louden

William Louden, Kurt Schmidt
& Ernest Martt (l-r) standing
in front of a vacuum machine
for the "Lucalox" lamp.
Photo ©General Electric.

"The use of the new phosphors is not restricted to 40W T12 lamps."
-- Louis Vrenken

Louis Vrenken &
Johan B.J. van Overveld (r-l)
testing compact fluorescent lamps.
Photo ©Philips Lighting.

"I don't see any technical barriers, just financial ones."
-- John Milewski

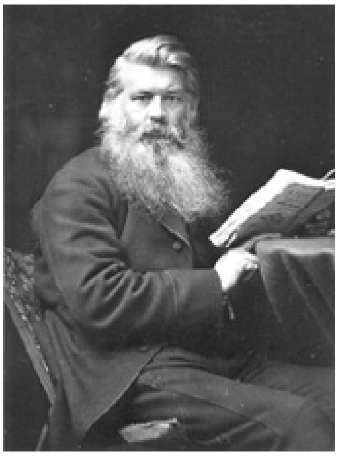
Peter & John Milewski (l-r)
near their home in New Mexico.
Photo ©Drs. John & Peter Milewski.

"That was the longest five minutes of my life."
-- Michael Ury

Michael Ury (r) with Lee Anderson
& 5 demonstration Sulfur lamps.
Photo ©Fusion Lighting.

"If I didn't invent the incandescent lamp, I never invented anything."
-- Thomas Edison, 1892

Thomas Alva Edison
© National Park Service

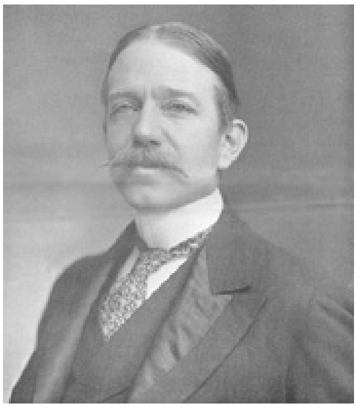


"I had the mortification one fine morning
of finding you on my track and in
several particulars ahead of me
-- but now I think I have
shot ahead of you, . . ."
-- Joseph Swan, 1880

Joseph Swan
from Tyne & Wear County Council Museums

"It's too small, too hot, and too red."
-- D. McFarlan Moore

Daniel McFarlan Moore photographed by the light of a Moore Lamp.
from the Moore Electrical Company



". . . for the economy of operation will much more than compensate for the somewhat unnatural color given to illuminated objects."
-- Peter Cooper Hewitt, 1902

Peter Cooper Hewitt.
from *The Electrical Age*

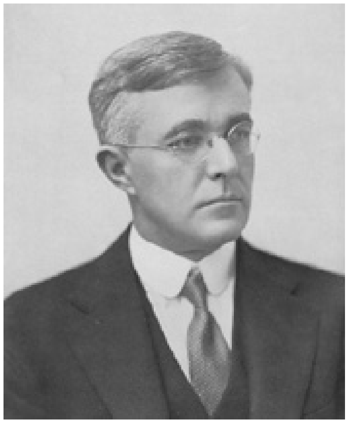
"It is bad engineering to assume
that a thing is perfected."
-- Willis R. Whitney, 1935

Willis Whitney.
from General Electric

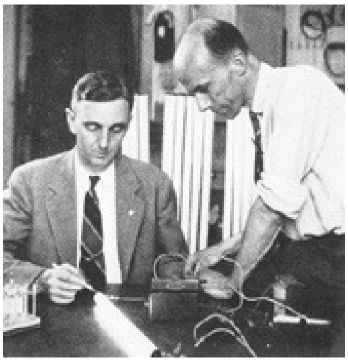
"I remember this circumstance very well because of the excitement and surprise and incredulity which he manifested at the time. He asked me over and over again what it was."
-- William Coolidge, 1909

William D. Coolidge.
from General Electric

"It seemed that an investigation, . . ., might possibly open the way to the discovery of methods by which the efficiency could be greatly improved."
-- Irving Langmuir, 1913



Irving Langmuir.
from General Electric



". . . at one time in development, rival cathode designs . . . necessitated the intervention of a neutral physicist."
-- Richard Thayer, 1989

George Inman & Richard Thayer

Curator's Choice for Spring 2003:

This object is in the collections of the National Museum of American History. What is it? Click the image for the answer.

Links for Lighting Information on the Web

Activating any of these links should open the target site in a new browser window. Just close that new window to return to **Lighting A Revolution**.

Other Smithsonian Sites:

- Lighting The Way
  -- Collecting History on the World Wide Web
  americanhistory.si.edu/lightproject
- Science Service At The Smithsonian
  -- images of electrical technology including electric lighting
  scienceservice.si.edu/
- Celebrating Thomas Alva Edison's 150th birthday at the Lemelson Center
  http://invention.smithsonian.org/centerpieces/ilives/edisonil.html
- Edison After Forty: The Challenge of Success
  -- what Edison did after the phonograph and light bulb
  americanhistory.si.edu/edison
- Powering A Generation of Change
  -- an exploration of electric power deregulation
  americanhistory.si.edu/powering

Please note:
The links below will take you to sites that are not on the Smithsonian server. Activating any of these links should open the target site in a new browser window. Just close that new window to return to **Lighting A Revolution**.

These links are provided for educational purposes and for the convenience of those visiting Lighting A Revolution. Listing of a link does not constitute an endorsement of a site or its content by the Smithsonian Institution.

Academic Lighting Site:

- Rensselaer Polytechnic Institute
  -- Lighting Research Center:
  www.lrc.rpi.edu

Government Lighting Sites:

- U.S. Department Of Energy
  -- Office of Building Technology, State and Community Programs:
  www.eere.energy.gov/
- U.S. Environmental Protection Agency
  -- Energy Star Program:
  www.energystar.gov
- Lawrence Berkeley National Laboratory
  -- Lighting Research Group
  eetd.lbl.gov/btp/lsr
- Sandia National Laboratory
  lighting.sandia.gov/

Professional Lighting Organizations:

- International Association for Energy-Efficient Lighting:
  www.iaeel.org
- Entertainment Services and Technology Association:
  -- A History of Theatrical Lighting and Its People
  www.esta.org/history/index.html
- Illuminating Engineering Society of North America:
  iesna.org
- International Dark-Sky Association:
  www.darksky.org/index.html
- National Electric Manufacturers Association:
  www.nema.org/
- National Lighting Bureau:
  www.nlb.org/index.html

Commercial Sites:

- General Electric Lighting:
  www.ge-lightingsystems.com/*.*/gelhome.jsp
- Lightolier:
  www.lightolier.com/
- Philips Lighting North America:
  www.lighting.philips.com/nam
- Osram Sylvania Inc.:
  www.sylvania.com/

Museums & Historic Sites:

- The Baltimore Museum of Industry: Baltimore, MD:
  http://www.thebmi.org/

- Thomas Edison Birthplace & Museum: Milan, OH:
  www.tomedison.org/index.html

- The Edison-Ford Winter Estates: Ft. Myers, FL:
  www.efwefla.org/

- Thomas Edison National Historic Site: West Orange, NJ:
  www.nps.gov/edis/home.htm

- Edison Memorial Tower and Menlo Park Museum: Menlo Park, NJ:
  www.menloparkmuseum.com/

- The Henry Ford Museum & Greenfield Village: Dearborn, MI:
  www.hfmgv.org/exhibits/edison/

- The Schenectady Museum, Hall of Electrical History: Schenectady, NY:
  www.schenectadymuseum.org/

Lamp Collectors & Special Lamp Sites:

- Livermore's Centennial Lamp:
  www.centennialbulb.org/index.htm/
  Includes "Bulb Cam," live from Station #6 of the Livermore-Pleasanton Fire Department.
- The Antique Christmas Lights Museum:
  www.oldchristmaslights.com/
- The Museum of Historic Discharge Lamps:
  www.lamptech.co.uk//
- Don's Lighting Info Center:
  www.misty.com/~don/light.html
- Kilokat's Antique Light Bulb site:
  www.bulbcollector.com/

Lighting Search Engines and Site Listings:

- The inter.Light Lighting Search Tool:
  www.lightsearch.com

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- Thomas Edison Birthplace & Museum: Milan, OH
- The Edison-Ford Winter Estates: Ft. Myers, FL
- Thomas Edison National Historic Site: West Orange, NJ
- Edison Lamp Tower: Menlo Park, NJ
- The Henry Ford Museum & Greenfield Village: Dearborn, MI
- The Schenectady Museum, Hall of Electrical History: Schenectady, NY
- Smithsonian Institution, National Museum of American History: Washington, DC