Appendix 3

The logistics of the transition from invention to manufacture: the bamboo filament lamp

Abridged from
Chapters 67-69 and 81-83 of *Menlo Park Reminiscences* by Francis Jehl

Fig. a3.1 Iwashimizu-Hachiman-Gu, Shinto shrine at Yawata, Kyoto Prefecture, Japan near which William H. Moore found the best bamboo for Edison's incandescent lamp in 1880.

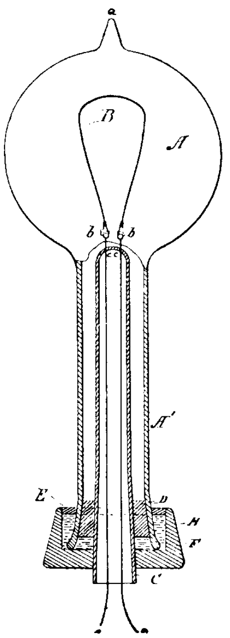
You have already heard how from time to time he himself [Edison] studied each operation in the making of his lamp, and how thoroughly he worked out the process of carbonization. First he formed his filaments from the raw material and then he carbonized them. Those that worked on the problem before Edison, took carbon already made from which to shape their light-giving elements. Some had their carbons made by Carré of Paris, an electric arc light carbon manufacturer; and these were in the shape of rods.

Thus we see distinctive methods of operation, with Edison following a different course from all the others in procuring and making his carbon filament.

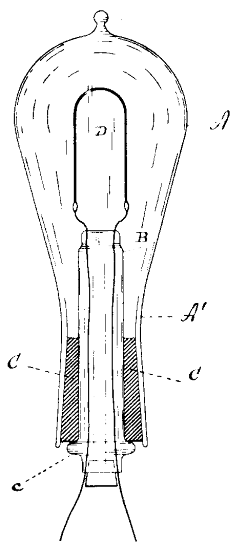
When at last he had concluded his investigations into carbon-making and began to make lamps in quantities, he assigned Lawson, Van Cleve and others to the job, instructing them in all the details. From that time forth it was more of a routine process than an experimental one. Likewise the newcomers whom the new-found light and dynamo lured to Menlo Park, Clarke, Howell, Hammer, Acheson, Holzer and others, were assigned places in this new activity. And each of the so-called 'departments' was given its own routine.

While the new lamp and its system were being exhibited at Menlo Park (and that continued for months), Edison made a final exhaustive search for a raw material that would be more dense and homogeneous. He said, 'In God's almighty warehouse there must certainly be such a material – we have only to hunt for it.' Books on botany and catalogs were studied; Hughes, our purchasing agent, was sent to New York with a list of materials to purchase. Day by day he brought back packages of samples. He called on wholesale drug companies agents of foreign firms, museums, colleges, and consuls of foreign nations in an effort to get almost everything in the vegetable kingdom. He also brought samples from the animal world, such as hoofs, hides, horns, and hair. Botany professors sent in contributions when it leaked out that Edison was making a last search for a better raw material.

It would be tedious to name the different kinds of woods, grasses, plants, and hair, human and animal, that were tried. Yes, we even plucked the red whiskers of a Scottish guest at Menlo Park and the black ones of a Swiss and made bets on which would prove the better filament. As the thousands of samples came to Menlo Park, Edison examined each under his old verdigris-covered microscope. Those found acceptable for further trials were laid aside, while others that did not possess the qualities he desired were consigned to the stove. Carbonizing, blowing the glass parts, exhausting the air, and testing, continued day and night.



US Pat 239373
Fig. a3.2 Edison rubber bung lamp (1880)



US Pat 251543
Fig. a3.3 Edison stopper lamp (1881)

Further experiments included treating carbonized filaments in hydrocarbon liquids and vapors while a current heated them. Dr. Haid made different kinds of gases and Edison studied their effects. I remember his saying that the gases tend to destroy the filaments gradually by a sort of air-washing, for strong currents are set in motion at the heated sides of the filament. Edison also repeated some of the old experiments of 1879, impregnating raw filaments with solutions of various hydrocarbons such as rock candy, whale oil, tar, turkey red oil, cotton oil and an endless number of others.

In the early part of 1880 Edison told Boehm to make some glass and rubber stopper lamps. In these the glass stopper served as the glass stem did in the other lamps: through it passed the lead wires to which the platinum clamps that held the carbon filaments were attached. These glass stoppers after grinding were inserted into an equally ground aperture in the lamp bulb. With the application of a little specially-prepared wax they made an air-tight joint. Edison hit upon that idea while watching the Geissler-Sprengel air pump with their ground glass connection joints. He also made lamps with stems that were forced through rubber stoppers, and they too gave quite satisfactory results.

Coming back again to the laboratory, we find Edison at work, and still in the main searching for a better material, sampling samples, making experimental lamps; and so time passed on. Then one day something happened, one of those rare paradoxical incidents that often mark the advent of a new period.

As I have said, the specimen upon specimen of raw material which were examined and tried cost a great deal of time and money to procure. And where at last was the prize sample found but in our very laboratory! In our laboratory, I say, lying on the tables and exposed to view all the time it was being hunted outside. We always had, just as you will find now in the restored Edison laboratory of The Edison Institute at Dearborn, palm leaf fans lying about on the tables upstairs; these fans were often used in the course of experiments, especially when we desired to evaporate some liquid in a shallow glass plate or dry some mixture. It thus happened sometime towards the latter part of April or May that Edison noticed, while doing some microscopic work with a filament of carbon, that one of these fans was lying near his instrument.

In his stooping position he noticed that a part of the binding rim of the fan was detached and was away from the fan leaf. He received the impulse to take the fan up and examine the rim: on closer examination it was found to be made from some sort of cane. He cut a piece of it, planed it and put it under his microscope: its structural characteristics were the most ideal thus far obtained. Batchelor was called to prepare a few raw filaments from the rim of the fan and carbonize them. The results were that Edison was satisfied that he now had a better carbon than that produced from the paper cardboard. Hughes was again sent to New York to pick up all kinds of cane wood, especially the various kinds of bamboo. Bamboo brought a cessation for awhile in the hunt for raw material that would be an improvement. Lamps made with bamboo filaments were exceedingly successful from a commercial point of view as regards manufacture. Now came the question of the kind of bamboo to use; for Edison soon found that there existed an endless variety of such tropical grasses. He also surmised that one kind would no doubt be better than another, and on this point he soon convinced himself. All the varieties that could be obtained in this country were soon under microscope, knife and fire at Menlo Park, and experimental lamps were constantly being tested. Edison was also busy thinking out ways and methods of manipulating the bamboo in the production of raw filaments.

Batchelor and Kruesi were kept busy designing and making various small apparatus to cut, plane, and finish the bamboo ready for the carbonizing mould. As we know, the ultimate object in all such pioneer work is to get results irrespective of the way of obtaining them. After the main purpose of the research has been fulfilled, then the secondary purpose of improvement in the art for the sake of obtaining the desired effect can be attended to. So it was with the gigantic industry that Edison created during 1879 and 1880 – not alone the lamp but everything relating to the distribution of electrical energy. Step by step improvements followed all along the line; and yet embedded in every improvement were the fundamentals that Edison expounded when he was first exploring the dark territories of a force called electricity.

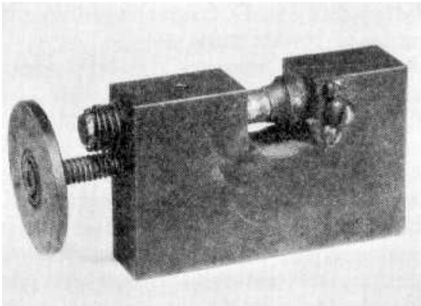


Fig. a3.4 Tool used for shaving bamboo

A pioneer system was gradually being evolved in the operation of handling the bamboo in all its stages, from the stem to the finished raw filament ready to be carbonized. As we know, the paper filaments as well as the bamboo ones were cut with shanks at their extremities, an expensive process but also one that limited the production of carbons in quantities.

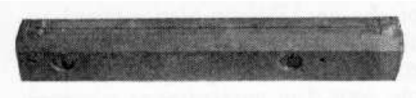


Fig. a3.5 Mould for cutting down bamboo strip to raw filament

Edison had also to work out a carbonizing mould for his bamboo filament. We few old-timers left from those days still remember the nickel ones that played such an important role in the beginning of the new industry. These were neat affairs having loose guide pieces in each end arranged so as to hold the bamboo filament in position, allowing at the same time for contraction. When put into the furnace these moulds, each holding one filament, were placed one upon the other like a pack of thick cards. The bamboo filaments having shanks at their extremities and being bent at the top were difficult to carbonize with more than one in a mould. Edison desired to have neat-looking filaments: the contrast between the earliest bamboo ones and those made later is quite marked. For some time at the beginning we were very liberal in the use of platinum wire and clamps, for the early filament was held just as the paper horseshoe one, with a platinum clamp. Later in this same year Edison plated the shanks of the filaments with copper and thus prevented much loss in breakage while they were being placed in the clamps.

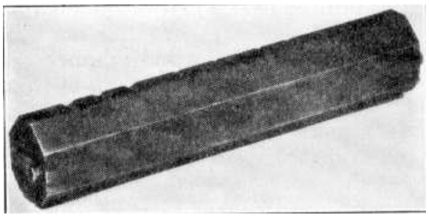


Fig. a3.6 Finishing tool for 8 candle power lamp filament

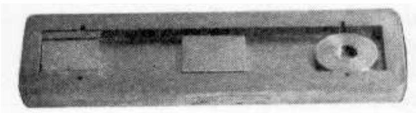


Fig. a3.7 Nickel carbonizing mould

A radical change soon took place; the platinum clamps were discarded and in their place was substituted a crude sort of copper clamp that was just sufficient to hold the shank of the filament. The stems with the copper clamps and filaments were then placed in a sulphate of copper bath in which the liquid only reached to the copper clamp The filament and clamp were then plated one on to the other, and so a secure electrical contact was obtained. It was a great advancement, for it cheapened the making of a lamp in many ways, as is evident. Later on, in 1886, another improvement was effected when filaments were made without shanks, being held to the lead wires by a carbon paste.

I well remember the time when we were conducting experiments in plating. We made experimental lamps in which the shanks were plated with silver, gold, copper and various other metals and then tested to see if one or another would show any advantage or disadvantage. The tests soon convinced us that it was immaterial whether the plating was done with gold, copper, or any other metal. The all-copper connection lamps were already in use during the second Edison demonstration in the winter of 1880-81.

Then, of course, the experimental lamps that exhibited good qualities were subjected to rigid tests electrically. They were tested for life and endurance under varying circumstances and at a sixteen candle power voltage. As we were in the pioneer stage of the art, Edison also wanted to ascertain whether the switching on or off of the current had any effect. Thus lamps were tested by interrupting the current thousands of times, in some tests the current was reversed thousands of times. At other trials Edison sought to determine whether the positive or the negative direction of the current had any influence on the corresponding side of the filament; that is, whether there existed some action akin to what takes place in electrolysis, though perhaps of a higher order. As a matter of fact he noticed what he termed an 'electrical carrying,' in which particles of carbon tearing themselves away from the negative side of the filament went over to the positive. He found that the amount of such transposition depended on the resistance of the filament, the voltage employed, the degree of incandescence and the state of vacuum.

Then there were series of experiments to overcome the blackening of the bulb and what Edison used to call 'molecular bombardment'; for he discovered that the filaments cast a shadow, leaving a line of no deposit inside the bulb. This line was in the direction of the plane of the whole filament.

Coming back to the bamboo lamp, I may say that its filament was longer than that of the paper horseshoe lamp and consequently its bulb was longer too. The paper horseshoe lamp had a round bulb while that of the bamboo lamp was made in pear form. Edison wanted to know how much greater the cubical contents of the pear-shaped bulb were than of the round bulb. He wanted to estimate whether it would take a much longer time to exhaust the air from the pear-shaped one than from the round one.

The following incident came up during the bamboo lamp experiments. I shall describe it by quoting myself in Dyer and Martin's work on *Edison and His Life and Inventions.*

> 'I was once with Mr. Upton calculating some tables which he had put me on, when Mr. Edison appeared with a glass bulb having a pear-shaped appearance in his hand. It was the kind that we were going to use for our lamp experiments; and Mr. Edison asked Mr. Upton to please calculate for him its cubical contents in centimeters. Now Mr. Upton was a very able mathematician, who after he had finished his studies at Princeton went to Germany and got his final gloss under the great master Helmholtz. Whatever he did and worked on was executed in a purely mathematical manner and any wrangler at Oxford would have been delighted to see him juggle with integral and differential equations, with a dexterity that was surprising. He drew the shape of the bulb exactly on paper, and got the equation of its lines with which he was going to calculate its contents, when Mr. Edison again appeared and asked him what it was. He showed Mr. Edison the work he had already done on the subject and told him that he would very soon finish calculating it. "Why," said Edison, "I would simply take that bulb and fill it with mercury and weigh it; and from the weight of the mercury and its specific gravity, I'll get it in five minutes, and use less mental energy than is necessary in such a fatiguing operation". Cases frequently arose in which Edison explained his common-sense methods to one or another of his assistants who was bungling along on some work that he was conducting in the so-called scientific way.'

Edison was an extremely practical and sensible worker, thinking all the time of what he was doing and accurately analyzing the results as he went along. I have already, stated that Hughes was to gather up samples of whatever varieties of bamboo could be obtained in this country. Edison, however, did not stop here, for after all the different kinds were analyzed he determined to go more fully into the matter and send a man to China and Japan in quest of the species most suitable for filaments.

Among the boys engaged at that time in the laboratory was William H. Moore. He had known Edison in 1875. He had traveled a lot and was once selling the Weston plating generators in England. While in England he had made many, friends among whom were some that had visited the East on business. Moore was an energetic and likewise tactful young man with an amiable disposition; he was what we would today call 'a good pal.' It was thus no wonder that Edison selected him to go to the land of 'Dai Nippon, the Sunrise Empire.' Before he went Edison plainly outlined his plan to him and took pains to instruct him in every detail of the work he was to do. With various bamboo samples that Hughes had already obtained in New York from Japanese merchants, Edison showed him what the desirable characteristics and qualities were that he was after; he instructed him how to proceed and how to test bamboo – of which there were over two hundred species, some reaching a height of 170 feet and a diameter of one foot. Edison also sent him into the library to look up and study Japan together with everything pertaining to it. He found a lot about that country in *Harper's New Monthly Magazine.* Edison also told him to make notes regarding the samples as he acquired them in Japan, specifying their age and the environs where found. When he was ready to start Edison provided him with various utensils and apparatus, among which was a good microscope. He was given letters and credentials to our political representatives in China and Japan, in addition to which he received letters of introduction to business houses in the East from friends of his own in England. A few of us boys gave him a quiet send-off. From that day he was called 'Japanese Moore.' To travel in those days was quite a different thing from what it is

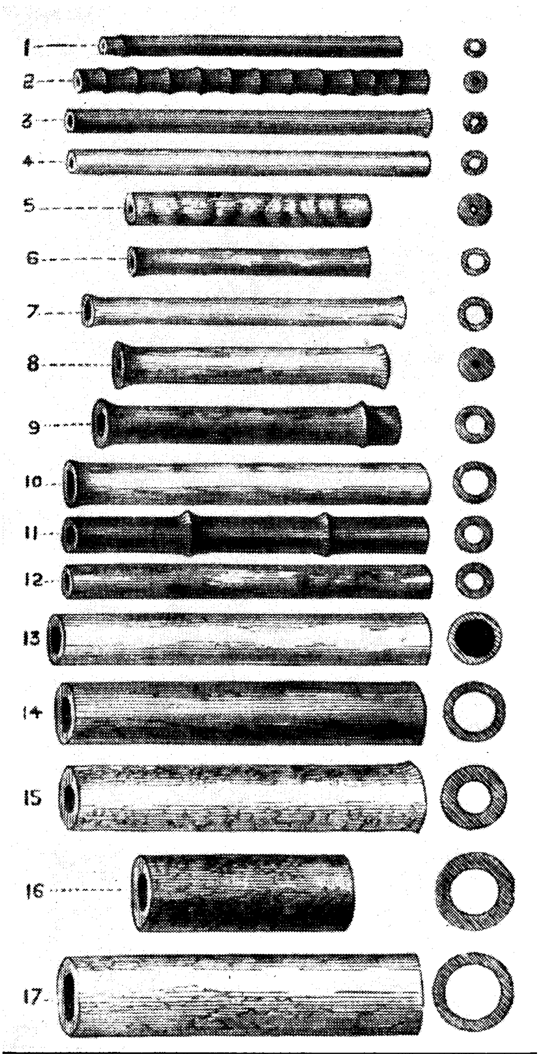


Fig. a3.8 Bamboo specimens

today. The world was, one might say, vastly larger and distant lands were further away. To be sent to Japan was far different and more thrilling than to be sent to Europe, as I was in 1882. Japan is the country of the great Rising Sun and has the oldest dynasty in the world. Even at that period it was considered a land of mystery and cherry blossoms. It was once a feudal empire ruled by shoguns (lords, as in early Europe). In 1853 Commodore M.C. Perry, of the United States Navy, forced his way pompously into Yokohama and in 1864 Japan emerged from seclusion and entered the family of nations. In 1868 the Mikado was restored to full power and shogunism abolished. An era of enlightenment followed, one which has had no parallel in history. The Emperor with the aid of Prince Ito and Prince Yamagata raised an empire from ancient medievalism into the status of a first-class nation in a little more than half a century. To the above names of Ito and Yamagata we must now add those of Togo and Nogi, all of whom together with the Emperor were the pillars upon which the new and modern Japan is founded (1867-1912). A great race, wrote Moore to me once, industrious, patient, disciplined, studious, polite and yet courageous, sincere if you are sincere, honest and clever. The same testimony was given by my friend Mr. Frazar, of Tokyo.

With such people to help him Moore's search made progress, and with the further aid of his diplomatic nature his results were eminent; for he succeeded in finding a bamboo that became the standard for making the Edison filaments during ten years. Moore's resolution when he was intrusted with the job was to get results, and he attacked the problem with the energy of a go-getter; he did not take photographic apparatus or a score of lead pencils and reams of paper with him to write the tale of his adventures for the delectation of the home office *à la* Jack Harkaway. He combed parts of China but did the greater part of his work in Japan, where he visited each of the four principal islands of the empire. Soon the laboratory at Menlo Park began to receive bales of bamboo. Each sample was put through several tests including use in experimental lamps, and the results were noted. In this manner examinations went on until Moore had ended his search. He was them informed which specimen Edison considered the best and was instructed to make a contract with the grower for periodical deliveries according to certain specifications. This bamboo grew near a Shinto shrine.

After an absence of about two years Moore returned and found a job with the Edison Company for Isolated Lighting and later with the Edison Machine Works. Edison did not yet, however, consider the search for the best fiber finished, for he sent P. Segedor, another of our Menlo Park boys, down to Cuba. Unfortunately Segedor was stricken with yellow fever and died. In December, 1880, a John C. Brauner, of Brooklyn, New York, was dispatched to search Brazil. Again in l887 Frank McGowan and C.F. Harrington, who were at that time employed at the Edison headquarters at 65 Fifth Avenue, in New York City, were sent to tour South America. In 1888 a school principal, James Ricalton, of Maplewood, New York, was engaged to make a world tour. He ended the fiber hunt.

The work of all the men that followed Moore resulted in no tangible results so far as a good or better lamp filament was concerned. Though some of them left us glowing tales copiously illustrated with photographs of thrilling jungle adventures, which are out of the scope of my articles, the fact remained that Japanese Moore did the work and found in Japan the satisfactory bamboo.

Coming back again to the work that was going on in the laboratory, it this time, we find Edison still busy examining and testing vegetable fibers of all kinds. A fair estimate calculated from his notes is that no fewer than six thousand different species passed through his hands. The principal reason for seeking something better than paper was that a material had to be procured that would enable him to obtain a still higher resistance in a filament and consequently to use a higher voltage, and which at the same time would be more adaptable to transportation, that is, not so fragile as the paper lamps. In bamboo Edison found the attainment of this object for the present. And thus when the prize bamboo of Japanese Moore arrived, work on bamboo began in earnest in every direction. We had a rubber stamp made which recorded the volts, ohms and foot pounds on each lamp tested; life endurance tests were added to this data. Of course, the number of lamps obtainable per horsepower was readily ascertained after the foot-pounds of energy required by the lamp at sixteen candles were known.

We knew even at that period that the economy of a lamp depended upon the amount of energy to which it was subjected. The higher a lamp was forced in candle power the less, we knew, were the watts per candle. We knew too, of course, that forcing the lamp up endangers its endurance, and so Edison sought the middle way.

A crude system of preparing the raw bamboo filaments was worked out by Edison at the laboratory. The sticks were sawed into appropriate lengths; these were then split into lesser sizes and passed through shaving tools. After having been shaved down to the required thickness, the ribbon-like pieces were placed in a finishing tool where the shanks and filament were cut out.

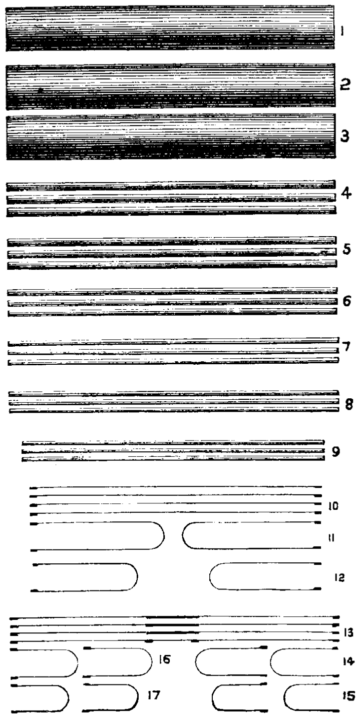


Fig. a3.9 Stages in preparing the bamboo filament

The carbonizing department had added two more muffle furnaces, so that we now had three in working order and the work there kept a few of the newly engaged boys busy day and night.

In the little glass house Holzer spent a great deal of time working out the details of making glass parts in a practical and commercial manner. Holzer was not only an expert in glass blowing but a practical business man who had been owner of a glass-blowing establishment in Philadelphia before

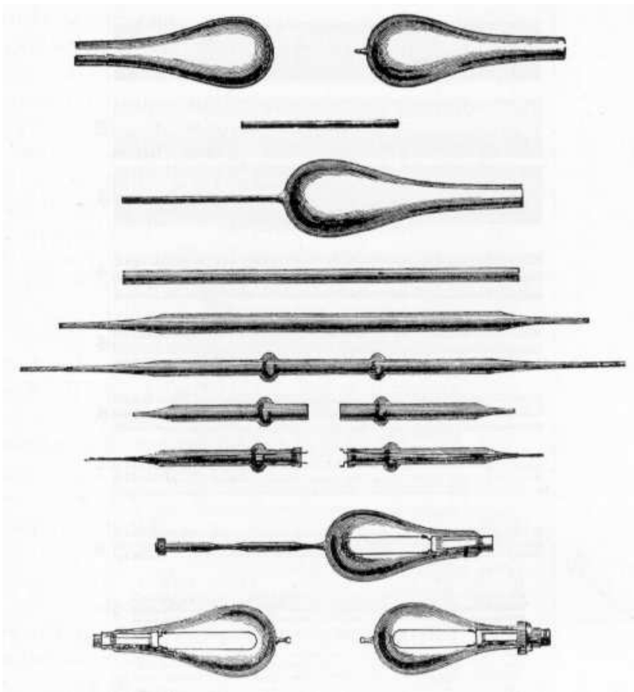


Fig. a3.10 Stages in making glass components of a lamp

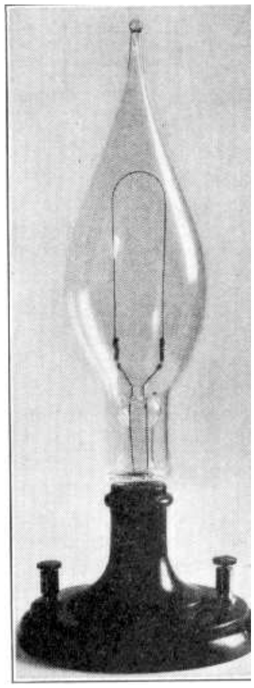


Fig. a3.11 Bamboo filament lamp

coming to Menlo Park. He received a good offer from Edison to sell out his business and join us. It gave Boehm the jitters to see Holzer degenerate the noble art of 'scientific glass blowing' into a new art of mass production.

The glass bulbs for the bamboo filament lamp were at first blown by hand and of course were very irregular in form like an elongated egg or pear. Edison soon had Kruesi make some iron moulds with which to blow the bulbs in a regular shape. Towards the end of 1880 we received pot-blown bulbs from some of the outside glass works, and about this same time Holzer proposed the flat seal for the platinum lead wires. This type of seal has been employed ever since because it not only produced an infinitely better seal but saved lots of time.

For some months the platinum clamp method was still used for attaching the bamboo filament to the lead wires. This, as I may have already mentioned, was followed by copper plating of the shanks, which not only saved breakage but provided a more secure contact. Following up rapidly this idea of plating, Edison next made a copper clamp with which the shanks of the filament were copper plated together.

Such complete lamps were already in use during the second and larger demonstration given by Edison during the winter of 1880-81. I may also state that at first Edison made bamboo filament lamps of 16 candle power and then of 8 candles.

Experiments with the bamboo lamps were conducted at the laboratory for some time, and when the principal obstacles were subdued, Edison thought the time had arrived to start manufacture on a commercial basis. This was about the middle of the summer of 1880. Plans were made to utilize the old neglected clapboard building in which he had once made his electric pens.

During 1879, I often strolled over in the evening to this building. It fascinated my romantic soul because in it the Edison Electric Pen was once made, the pen with which I was so familiar, and which I operated before I joined Edison. When Edison passed over its manufacture to the Western Electric Company of Chicago, the building stood unoccupied for a few years.

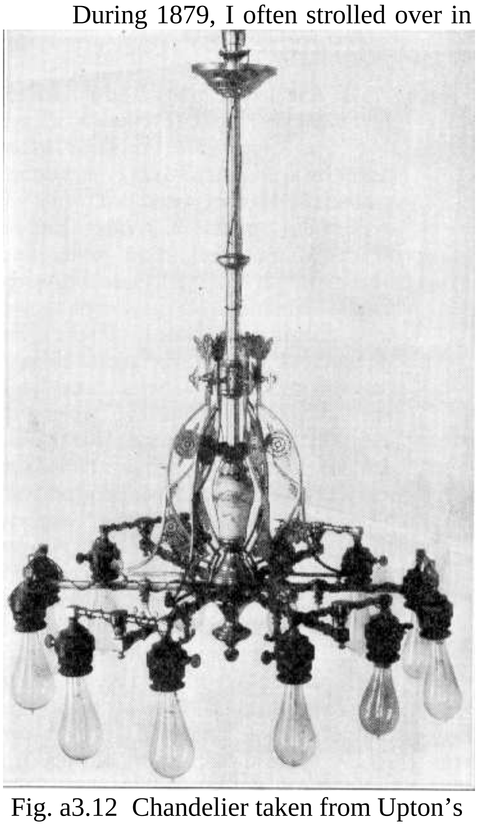


Fig. a3.12 Chandelier taken from Upton's house

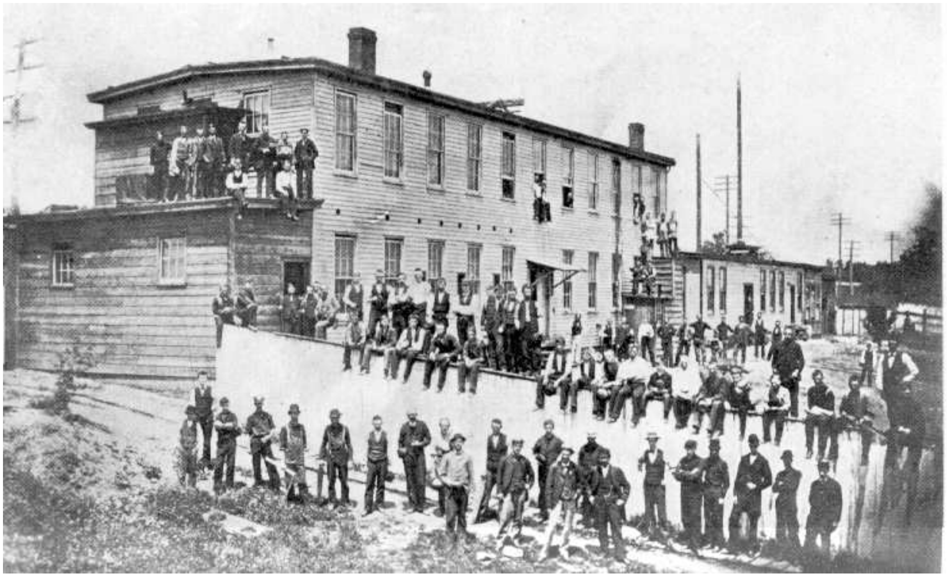
I say it was unoccupied, meaning for any legitimate purpose; but it served as a night shelter to bands of hobos who were 'pounding' the road between Jersey City and Philadelphia.

Edison's first move to fix this building was to send over a gang of carpenters and make it tenantable, as roof, floors, etc., were in a dilapidated condition. While Kruesi's carpenters, Moffett, Campbell and their aids, were at work, Edison with Upton, Batchelor and Kruesi began to draft plans and regarding the various departments of the future lamp factory.

It must not be forgotten that no precedent existed, that an entirely new art had to be taught to unskilled men and boys, mostly hired from around Menlo Park. Then again, Edison had to construct many pieces of new apparatus better adapted to a factory than those we used in the laboratory. In brief, he had to systematize the art of making incandescent lamps from the laboratory method into one of commercial manufacture.

After he had about finished the laboratory researches, he had to begin new ones on a practical scale for manufacturing. Also, Kruesi and his men were kept busy with the construction of utensils and apparatus deemed necessary in getting the lamp factory started Edison seemed to like this work of transforming laboratory methods into practical ones. In fact, the lamp factory had a tender spot in his heart and in its growth and development he entertained great hopes. The lamp and his dynamo were his greatest inventions up to that period, and he knew that in their future was a gigantic industry and system of current distribution for all purposes. The lamp factory was his pet hobby; he visioned it as a purely Edisonian affair always to be retained as such. The work that he had done in that connection and the recollections and reminiscences of those days formed one of the brightest chapters of his life.

As we know, The Edison Electric Light Company was the parent, with control of all Edison's electric light patents. That company did not desire to enter into manufacturing, but wished only to grant licenses. In its contract with him, he was obligated to sell his manufactured products at a certain price, from which the company received a part of its royalties.



Edisonia 1904

Fig. a3.13 The first lamp factory at Menlo Park

So it happened that Edison with Batchelor, Upton and Johnson raised the money to install the first incandescent lamp works. Edison, of course, had the controlling interest, about 80 cent; his share was greater than the combined shares of the others.

Edison, Batchelor and Upton were the active members who devoted their time in building up the lamp works, while Johnson was the outside man. He was active at that time in pushing the Edison system in England. Where did they obtain the money for this investment? Well, Edison had received a certain number of shares from the parent company for his work in creating his system. He in turn distributed some of these to his loyal assistants, and as the shares stood very high on the market at that time, some were sold. From the proceeds, the capital was procured to set up the lamp works. It also was said that some of the money Edison received for his European telephone patents was invested here.

After Kruesi's carpenters had set the old building somewhat in order, it was divided into different departments, and ways and means were sought to make each as efficient as possible. Of course, Edison knew that as, time went on many changes would take place in the process of manufacturing. The problems of first importance were the processing of the bamboo, the carbonizing outfit, and setting up an efficient glass-blowing and vacuum pump department.

The necessary power for operating the various motors, etc., was to be obtained from the laboratory machine shop on the hill. The line was erected by Hammer and Force under the supervision of Upton.

During the day two of the dynamos at the laboratory machine shop were connected in series, while another supplied current for the field magnets. At the lamp factory, the power was used by electric motors which drove the blower or glass blowing, in the carbonizing furnaces, for rotating the glass annealing machines, by the saw which cut up the bamboo, for lifting mercury in the pump room and for lighting and testing purposes.

The laboratory machine shop continued to deliver current to the lamp factory until March, 1881. Then Edison built a separate power plant at the factory. A house was erected, and a steam engine and boiler were installed. The former supplied power for driving six Edison dynamos, and the current thus generated supplied the motors, lighting, etc. Steam from the boiler was used also for heating purposes.

It may be mentioned that the transmission of electric energy from the laboratory machine shop to the lamp works in 1880 was not only unparalleled at that date, but historically it was the first example of a commercial factory using solely electrical power in its operation. It demonstrated the Edison system for the transportation of light, heat and power.

The lamp factory was also equipped with a large gas manufacturing plant for use in the glass-blowing department, and in the carbonizing furnaces.

The best quality [bamboo] had been discovered by Moore in Japan. Near the Iwashimizu-Hachiman-Gu shrine in the Kyoto Prefecture, he found the bamboo that Edison considered best for his filament. At first which the bamboo arrived at Menlo Park, it was placed in a storeroom, sawed into the required lengths, and later split it gradually into splints. The splints were then planed down to a ribbon, after which they were cut out in separate apparatus into raw filaments.

It must not be forgotten that Edison, Upton and Batchelor went to great pains in instructing unskilled labor in the art of working the bamboo into filaments. At the same time Kruesi had to make and devise many of the small bamboo planers and apparatus with knives, for cutting it down. Of course, in order to obtain systematic results, gauging apparatus was also used. It must be evident that the starting of the work in the various departments, getting them into an operative condition, was a difficult and tedious task, requiring infinite patience. After that, when everything was set going, it was much easier to improve the apparatus and system of procedure whenever necessary.

After the raw filaments were finished, they were passed on for carbonization. That system also passed through many changes. The first bamboo filaments had been cut out with shanks at their ends so that more surface contact was obtained when they were inserted into the platinum or nickel clamps. These first clamps also had a tiny screw to tighten the contact surfaces of the clamp and carbon shank of the filament, and thus make a better contact. This operation was expensive in more than one way, the metal was expensive, the making of the delicate clamps and screws was costly, and many carbon filaments were broken when they were inserted into the clamps.

Edison remarked that the shanks on the carbon filaments were an expensive affair, and that we must try to get rid of them. He knew the small clamps were not ideal for contact making, and for that reason devoted much thought to the subject at the laboratory. The filaments with shanks were also expensive in another way. In carbonizing them, each filament was put into a separate small mould. At first iron moulds were tried, then Edison made them of nickel and plumbago. Later he tried some of fire-clay.

However, the nickel moulds were the ones we used when the Edison Lamp Works were first started, and were the ones to receive the most attention at the time. Large numbers were fabricated. Costly also was the process of placing the raw filament in the mould. The outside dimensions of these nickel moulds were as follows: length 3-23/32. inches, width 1-3/16 inches, and depth 3/16 inch. They were hollowed out in an oblong fashion, having a length of 3-3/8 inches, width of 11/16 inch, and depth of 1/8 inch. The ends of the mould on the outside were rounded. Edison was particular at that time to have the carbonized bamboo filaments appear neat and straight; that was one reason the raw bamboo filaments were carbonized individually, each in a nickel mould and kept straight during the process of carbonization by having guide pieces inside the mould.

The mean shrinkage of the bamboo filament was about 2-5 percent during the process of carbonization. The nickel guides in the mould permitted this, and at the same time kept the filament legs straight.

The preparation of the bamboo raw filament was costly because it was necessary to cut out the shanks at the end of their legs for contact purposes. Without the shanks, the finished raw ribbon of bamboo could have been cut up into more than one filament.

Then again, the raw bamboo filament had to be bent into a hairpin form. In taking account of the grain, the shanks came at right angles to its legs, and this prevented placing more than one filament into the little nickel carbonizing mould. After each filament was individually carbonized in a mould, the moulds were piled one upon another and placed into a large plumbago container, packed with carbon dust. The container was then inserted in the carbonizing furnace. Incidentally, the moulds had no covers, but were simply piled one upon another like a pack of cards.

In order to prevent any rupturing of the grain of the wood, the raw filaments were at first steamed and later on a hot burnished round iron was used to bind them over.

Edison, of course, was well aware of these various disadvantages, but a start had to be made, knowing that time would soon bring many improvements.

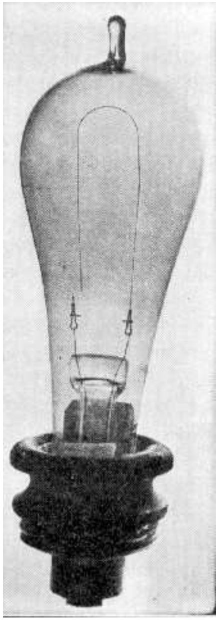


Fig. a3.14 Lamp with platinum filament clamps

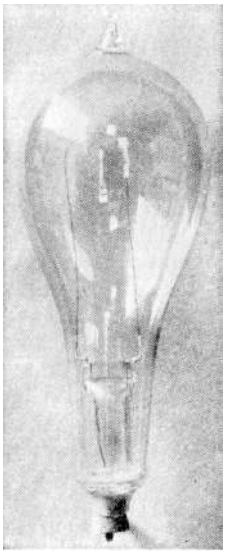


Fig. a3.15 Lamp with copper-plated filament contacts

Another disadvantage shanking caused was that it prevented the sorting of the carbonized filaments into lengths for voltages. Thus, when the finished lamps were tested, they varied in voltage considerably and had to be segregated into lots of different voltages. They were then supplied to different plants which operated at different voltages. Many of these obstacles were soon obviated, for in the same year, 1880, Edison commenced to plate the shanks with copper, thus making them rigid and thereby reducing the breakage when inserting them into the tiny platinum clamps.

The copper plating of the shanks soon led Edison to the idea of making a simple copper holder and copper plating the filament to the holder. The latter consisted of a copper wire, one end of which was fused to the platinum lead wire of the lamp; the other was flattened out and lapped sidewise to form a temporary sort of clamp or holder. After the filament legs or shanks were inserted into these holders, that part was placed in a copper bath and plated together.

This developed toward the end of 1880. In the early part of 1881, the Edison Lamp Works employed this system of filament attachment. In fact, the lamps used in the demonstrations of the Edison system during the early part of 1881 were of the bamboo filament type, in which the filament was copperplated onto the lamp leads.

Copper plate filament attachment continued until 1886, when carbon paste superseded it. The copper plating method resulted in a great saving in the cost of manufacturing the first pioneer commercial lamps. We saved the cost of making the tiny platinum clamps with their tiny screws, and there was considerable saving in the cost of platinum. The platinum leads that passed through the glass stem were gradually shortened so that by the latter part of 1881, employment of that metal had almost ceased. Thus the copper plating method did away with all platinum in the lamp except that used through the glass stem as leads.

The method of copper plating was simple. It consisted merely of small wooden troughs, in the bottom of which bevel perforations were cut; bevel-shaped rubber corks with a center aperture fitted into the bevel holes; into these the glass stems with their filaments were inserted, and these were then pushed down so that the top part of the copper holders were just about immersed in the plating solution. All the copper leads of the stems were connected to one of the proper terminals of a galvanic battery, while the other pole of the battery terminated in a strip of pure copper immersed in the plating bath. The current deposited enough copper in a few minutes to insure a good contact between filament and holder.

The part subjected to the plating process was next gently rinsed with warm water and thoroughly dried. The stems were taken to the glass-blowing department, and sealed into bulbs. From there they passed on to the pump room, where the occluded gases were expelled.

I have mentioned, the pear-shaped bulbs were at first blown from glass tubing. When Holzer came, Edison had him experiment with bulbs blown from an iron mould. About the time the Edison Lamp Works were ready to start, the bulbs were ordered from the Corning Glass Works in New York, although I remember Edison had sample bulbs made elsewhere. The Corning bulbs were handmade, and blown from molten glass taken from the furnace.

The type of vacuum pumps used at the Edison Lamp Works at first was a simplified variety of the Sprengel. They were worked out at the laboratory for commercial purposes and used for many years here and abroad in all Edison Lamp Works.

I will now review briefly our work in producing a commercial vacuum at the laboratory. Early in 1879, while Edison was still experimenting with high fusible metals, such as platinum, iridium and others known at the time, he began by placing them in a vacuum produced by a mechanical air pump. I have already described the result. He found that metals and other substances were packed with occluded gases, which could be driven out by heating in a vacuum. It was a great discovery, and paved his way to success when he began his work on the carbon filament lamp. He then saw the need of obtaining a better vacuum and asked Upton to borrow a Sprengel mercury air pump from Princeton University.

Of the many attempts to produce a handy, good vacuum pump, only those of Geissler and Sprengel were successful. With either of these, scientists were at last able to obtain a high vacuum. Geissler invented his pump in 1858, while Sprengel followed in 1864. Both were made entirely of glass and employed mercury.

It was our opinion that with the Sprengel pump a higher degree of attenuation could be attained, and more easily than with other equipment. Its action is based upon the fall of mercury into a drop tube, there forming at first small cylinders of mercury that take with them small columns of air. As the mercury descends into the drop tube it finally falls into a glass jar, and the air is liberated. The contents of the glass jar are poured from time to time back into the mercury reservoir that feeds the pump from the top. As the pump operates, the mercury cylinders and air columns grow smaller and smaller, until the fall of the mercury into the drop tube makes a hammering metallic clink. The cylinder formation ceases. The mercury carries out particles of the highly attenuated air that look like specks, and these too finally disappear. At this stage, the vacuum was considered sufficient for our purpose. About five hours were required to exhaust the air and occluded gases from a lamp bulb.

The principle upon which the Geissler mercury air pump operated was more intermittent. The operator lifted a mercury-filled bottle, which was connected by a rubber tube to a glass tube that emptied into a glass chamber. When the bottle was lifted, the mercury flowed into the glass chamber, filling it. A stopcock was turned and the bottle was placed on the floor, so that the mercury could flow back into it. Thus a Torricellian vacuum was created in the glass chamber, and when another stopcock was turned to open the passage leading to the lamp bulb, the air in the latter became so rarefied that the vacuum was considered sufficient.

Of course, both these pumps were so constructed and operated that account could be taken of the barometric influence. The Sprengel pump, with some modifications made by Edison, was used in all our lamp experiments. When Edison wanted to give a demonstration of his system in 1879, he needed a large quantity of lamps, and to obtain them used a combination of the Sprengel and Geissler air pumps, that is, he had a Sprengel pump connected to a Geissler. His object was to pump out most of the air by means of the Geissler, and then finish the job by letting the Sprengel pump perform the higher exhaustion. We made three such combination sets. Because of the Geissler, an attendant was required for each set.

With these three sets and three men operating them, we commenced the production of incandescent electric lamps in quantities. We could make about twenty to twenty-four lamps in twenty-four hours, and that was considered good for a product of which the world still had but a hazy idea. The lamps were of the paper horseshoe type of filaments. With these combination air pumps we later exhausted many experimental bamboo filament lamps, although special experiments were always made with the Sprengel.

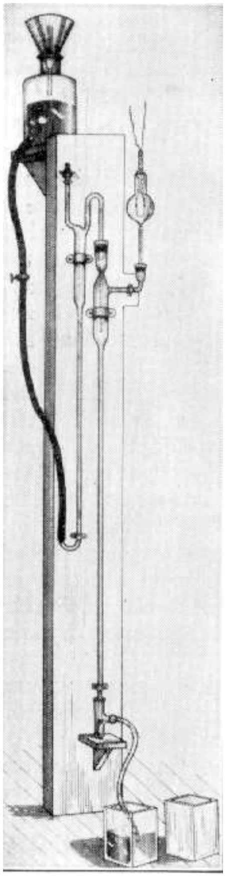
Here I might mention that when we first commenced working with the Sprengel, in 1879, Edison had our glass blower insert a small chamber just under the place where the tubulating tube of the lamp was connected to the pump. In it Edison placed phosphoric anhydride, to absorb the moisture contained in the air.

As in the experimental days, Edison always heated the bulb with an alcohol lamp, and this rule was always followed when lamps were on the pump for exhaustion. I must also note that when Edison made the combination of the Geissler and Sprengel pumps, he added a McLeod gauge to measure the state of the vacuum, a spark gap by means of which, with the aid of an induction coil, the state of the vacuum could be estimated. To these he added two more chambers, one to absorb the moisture and the other, containing gold leaf, to absorb the mercury vapor. As will be seen, this combination was a rather complicated affair, difficult and expensive to make. It will also be noticed that this combination air pump, with its different absorption chambers and connecting tubes, inclosed a great deal of air space, which always had to be exhausted when new lamps were put on the pump.

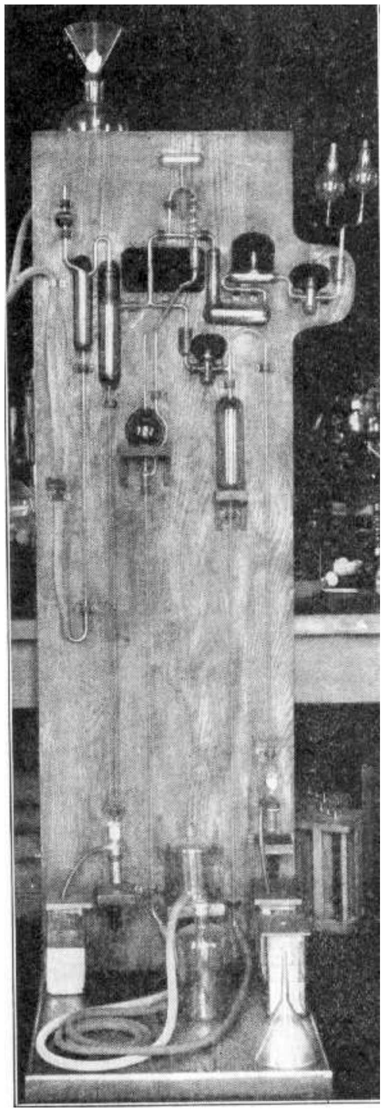
Connections and stopcocks were all of ground glass, and some had mercury seals which, with a mercury reservoir for the Sprengel and two others working the Geissler pump and McLeod gauge, completed the outfit. What I have so far described gives the reader an idea of the methods used in the laboratory in exhausting air and gases from the lamp bulbs.

When Edison had finished his laboratory work on the bamboo filament lamp, and believed the time had come to produce lamps on a commercial scale, he had to commercialize his lamp-making laboratory methods. One of the problems at this stage was the simplification of the vacuum pump system Edison was convinced that the pumps so far used were too elaborate and complicated to be adapted successfully in the new work.

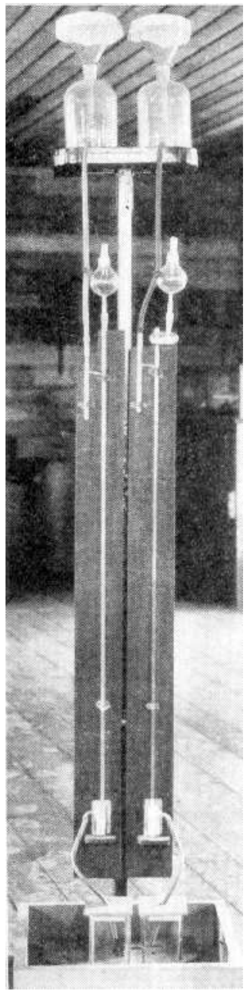
Edison entrusted me, as well as W. S. Howell and W. Hammer, with this task, telling us to do away if possible with the ground glass stopcocks, joint connections, mercury seals and glass tubes in general.



[1937] Jehl
Fig. a3.16 Sprengel pump initially used by Edison



[1937] Jehl
Fig. a3.17 Combination Sprengel-Geissler vacuum pump



[1937] Jehl
Fig. a3.18 Simplified vacuum pump designed by Jehl

'Start,' he said, 'with the Sprengel or continuous drop principle, for it presents the most favorable chances for improvement.'

In those days it was thought that a perfect air-tight joint or stopcock could only be attained by having its parts well-ground and greased and to make them still more certain, they were inclosed sometimes in mercury seals. Edison said he thought too much fuss was made about this, and he was sure things could be pared down considerably. I felt highly honored in being entrusted by him with this work, and immediately set about the task of trying to eliminate first the ground glass stop cocks, joints and mercury seals. Edison told Glass Blower Boehm to make anything we requested, but when the latter learned what we were trying to do, he shook his head sadly and said that it would be impossible to simplify the Sprengel in any way, that we could not do away with ground glass cocks or joints in vacuum work.

I had acquired a good deal of knowledge about air pumps during 1879, and as I was always at Edison' s side from the start when he was personally conducting some air pump experiment, I had gained valuable experience in this line of work.

As I also had charge of the testing and photometer room, I began my work there and kept it under lock and key so that the other boys would not 'get wise' to what I was doing Edison would come in occasionally to see how far I had gone and to offer suggestions. After working on various ideas it happened one day that I was talking to Dr. Haid in his chemical den next door to the photometer room, and noticed on his side table various Eimer and Amend's conical rubber corks with a hole through the center. I was well aware of these rubber corks, for we too used them upstairs in research work, but now the idea struck me to try them in connection with the vacuum pump work. When Edison heard about the idea he encouraged me to go ahead and try it. I went over to the little glass house and had Boehm blow a cone-shaped glass receptacle, into which the rubber cork fitted. This was then fused to the stem whose other end terminated in the, ground glass stopper inserted into the air pump. It was our custom in those days to seal the tabulating tube of the lamp onto a glass stem whose other end had a ground glass stopper that was inserted in the air pump and so made connection with it. Inserting the tabulating tube of a lamp, whose bulb was to be exhausted from air and occluded gases, into the central hole of the rubber cork, I placed the whole onto the Sprengel pump and set it into operation. I poured some mercury over the rubber cork to act as a seal. The progress of the Sprengel air pump soon indicated that it was working satisfactorily, and in a few hours the vacuum had arrived at which we were ready to drive out the occluded gases from the filament. When the gases had been driven out the lamp was sealed off and the experiment clearly demonstrated the ground glass connections were not necessary in a commercial vacuum pump. I also found the mercury seal was not necessary, for if the rubber cork had leaked the pressure of the atmosphere would have driven it through into the pump. However, on the other hand it served as a telltale, indicating either a good or bad connection. Edison came in often and watched the experiment and was pleased, while Boehm would not believe it.

Then I tried another experiment by inserting, instead of a lamp, a spark gap so that the state of the vacuum could be estimated approximately, and that experiment, too, made it clear that the rubber cork held the vacuum just as well as the ground glass connection one. Then smaller and smaller rubber corks were tried and the end results were that rubber tubing was equally as efficient as the corks. A piece of thin, pure rubber tubing about one-half inch in length was slipped over the end of the lamp's tabulating tube and then placed on the pump. It was found that it was well to grease the rubber tubing connection a little as it facilitated the operation of putting it on the tube and taking it off.

The next work was to cut down the glass tubing, etc. of the Sprengel air pump to such a degree that would not impair its practical usefulness. These experiments in eliminating all the unnecessary glass tubing add other parts of the Sprengel air pump were so successfully reduced that a simple, efficient and practical mercury Sprengel form of pump was made for commercial purposes. The pump took up less space; it did not require an expert glass blower to make it, also it was inexpensive. The cubical volume of space in the inside of the glass tubes was reduced to a minimum. From the illustrations shown of the Sprengel-Geissler combination, the Sprengel alone and the end results of the eliminating experiments, these three cases are well presented in a pictorial manner that speaks more than words. Each of these three pumps could create a high vacuum, that was necessary for the production of lamps; yet the simplified one was the easiest, safest and most practical one to manipulate. Boehm was disconsolate, for he said that the art of glass blowing in general had slipped into a factory process.

We tried these simplified pumps for a few weeks. Edison, finding them all right, ordered Holzer to make a few hundred for the lamp works. Holzer was assisted in this work by Hipple whom Holzer had taught glass blowing at the little glass house. For the drying chamber of the pump we tried sulphuric acid, sodic hydrate and the phosphoric anhydride that I have already mentioned as the moisture absorbent that we had used in all former pumps. This latter chemical was then definitely selected by Edison for the pumps in the lamp works. The Edison Lamp Works here and abroad used this type for pump for many years. Small changes were made but fundamentally they remained the same; the chamber containing the phosphoric anhydride was later made separately and connected to the pump by a separate connection so that the chemical could be easily removed or renewed.

The vacuum pumps in the first lamp factory at Menlo Park were mounted in aisles and one attendant could take care of many, for it was not necessary to replace the mercury in the reservoir as it flowed into a jar, as we used to do in the laboratory. Edison obviated this procedure by connecting each pump to an iron pipeline by means of a piece of rubber tubing, while likewise the mercury that flowed out of the pumps passed into another iron pipe, and was collected into an iron reservoir from which it was raised to the upper feeding reservoir by an Archimedes screw pump.

The piece of rubber tubing that connected the vacuum pump to the upper iron feeding pipe had an iron clamp with a screw by means of which the flow of mercury into the vacuum could be regulated. I may also mention that the short glass tube of the vacuum pump to which the rubber tubing was attached had a contraction to prevent too much mercury from flowing into the vacuum pump, but it was soon found that the iron clamp could do all the regulating. Other little tricks were tried such as placing a tiny small glass funnel into the bore of the glass tube at the top where it was connected to the rubber tubing, but that did not prove of much value in regulating the flow of mercury. Of course, great care had to be taken in keeping the mercury clean and it was also necessary to clean the vacuum pumps from time to time. As time went on and more practical experience was acquired, small changes or additions were made that facilitated the operations and made the production less expensive and the lamps more efficient. At first when the Edison Lamp Works were started at Menlo Park it was the custom to heat the lamps from time to time with an alcohol lamp, and likewise the lamps, when exhaustion was finished, were sealed off by means of an alcohol lamp and blow pipe. More practical improvements followed these methods of operation and it was not until about 1896 that the General Electric Company introduced a new system of exhaustion – a mechanical chemical one – that produced radical changes in the art of creating a vacuum in lamps.

In the first lamp factory at Menlo Park, the lamps went from the pumps to the glass-blowing department to receive the finishing touches. They were then inspected and sent to the socketing room.

Old-timers of those days will remember the plaster of Paris base, with a bevel brass ring and screw as the contact pieces. This form was soon found not to be practical. When the base was screwed into a socket, the resulting strain on the plaster of Paris resulted in constant breakage. Things were in a quandary for a while.

After Edison and Bergmann got together, the lamp base – such as it still persists to this day – was born. Instead of the bevel contact ring, a small brass cap at the bottom of the base was adopted. This made a compression strain on the plaster, obviating the breakage.

Edison sent Bergmann to the lamp works at once to see Upton and have him change the construction of the lamp base accordingly. This happened in June, 1881, and from that day to this the same base has remained in principle.

In basing the lamps, metal moulds made in halves were placed together in bevel apertures bored out in narrow strips of wood that formed a stand. The metal screw and cap were placed in the mould, which was oiled a little. The stem of the lamp was then inserted, with care that the copper lead wires were properly led, one to the screw and the other to the cap contact pieces. The lamp bulb was held by iron prongs attached to a rod that could be slid up and down. Thus the lamp could be properly regulated into position, into the moulds.

Next a composition of plaster of Paris was poured into the moulds and allowed to set. The screw ring and cap contact pieces were held together onto the lamp stem. The copper lead wires were then soldered onto their respective contact pieces. The work in basing the lamps was done in rows. The lamps were so arranged that the plaster of Paris composition could be poured successively from one mould to another.

After the lamps had been inspected and tested for voltage at sixteen candle power, they were segregated in lots of equal voltages and labeled. The lamps that passed the inspection test were sent to the packing department to be shipped. In the early days, the lamps that were sent out from the Edison Lamp Works were well-wrapped in paper and packed in light barrels.

I have already mentioned in former articles how we carbonized the raw paper horseshoe form of filaments in 1879, putting them into iron or fire-clay boxes, separating them by tissue or tracing paper, filling the box with carbon dust and then subjecting it to a gradually increasing heat in a muffle furnace. When Edison began his bamboo filament he had to modify the process of carbonizing on account of their shanks. This has already been explained.

At first Edison tried to carbonize a few filaments in a narrow mould, but they contracted into different shapes unsuitable for his purpose. Then he began to carbonize them separately in small individual moulds. It was in June, 1880, when he made some experiments with a specially designed oven made of fire-clay, in which he used gas and compressed air to supply the heat. The gas and air were conducted into the four sides of the oven, and the graphite container, into which the filaments, each in a separate mould, were packed, was placed inside. To prevent the oxygen that liberated during carbonization from acting on the filaments, a separate tube was led into the oven and placed in connection with the graphite filament box. Before starting the fire and also while it was burning, hydrogen gas or hydrocarbon was introduced to take up the oxygen and prevent it from damaging the hot filaments.

In July, 1881, a young man named John W. Howell was put to work by Edison in the lamp works. He had just graduated from the Stevens Institute of Technology in Hoboken, New Jersey, and had written a fine thesis on the Edison System.

His one objective was to better the lamp commercially, and through all its transitions in the Edison Lamp Works, the Edison General Electric Company and finally the General Electric Company, he remained steadfast at his post as an expert lamp engineer. When he first came to the Edison Lamp Works at Menlo Park in 1881 the bamboo filaments were placed in carbon boxes, but he adds:

'We soon learned to pack them in peat moss which was first roasted. This shrunk the same amount as the bamboo and kept the fibers in shape. When we left off the shanks, everything was simpler and we packed large numbers in peat and carbonized them. We carbonized them in two operations, the first was done in iron boxes – up to 600º Fahrenheit. These were heated very slowly, for if we went too fast the tar which was distilled out of the bamboo and peat would come too fast and stick all the carbons together. The first heat took from six to eight hours. The second carbonizing was done in graphite boxes and they were run up as fast as possible to a white heat. The first was called the preliminary and the second the final heat. All the shrinkage took place in the first heat, the mass of peat and fibers shrunk away from the box leaving an empty space all around. This mass of peat and fibers was put bodily in the graphite crucible or box. Many thousands could be put in one box.'

When John W. Howell joined the Edison Lamp Works, they were making two kinds of lamps, one of sixteen candle power and one of eight. Manufacture of the sixteen candle power lamps was divided into two sorts, one being rated at eight lamps per horse power and the other sort at ten lamps per horsepower. According to Howell, the raw bamboo filament dimensions of the eight per horsepower were .008 x .017 inches, while those of the ten per horsepower were .008 x .0135. Their length, not including the shank, was six inches, for both kinds. The raw filament dimensions of the eight candle power lamp had the same cross section as the sixteen candle power ones, but were three inches long. The object, of course, was in one case to produce lamps that possessed a long life, while in the second they had a better efficiency but less life.

I have already mentioned elsewhere the splendid work William Holzer did in organizing the glass-blowing department of the Edison Lamp Works and placing it on a commercial basis. The art of blowing glass objects from glass tubes, using a table or bench supplied with gas and air bellows, was considered at that early date an exotic profession. Few such artisans could be found in America, and now the call came to transform that art into a factory process for mass production. Holzer had the ability to do that kind of work, for he was not only an efficient glass blower, but also practical. He gathered about him farmer boys and others from the neighboring villages, and gradually made out of them good glass blowers. Some even rose to become masters of the art.

Francis R. Upton, Batchelor's successor as general manager of the Edison Lamp Works, gave a terse description of the Menlo Park Lamp Works in 1883, as follows:

'In April, 1880, the manufacture of the lamps was commenced at the laboratory in Menlo Park with a payroll and organization separate from the experimental work then being carried on there. Previous to this time no distinction had been drawn between manufacturing and experimental work in the division of labor, though a large number of lamps had been made.

'In the summer of 1880, Mr. Edison bought the building at Menlo Park where at one time Mr. Batchelor and Mr. Kruesi had made the Edison electric pens. Early in the fall Mr. Batchelor gave his entire time to the manufacture of lamps, and under him a large amount of money was expended in making the various tools and in experimenting on the best method of manufacture. Mr. Batchelor deserves much credit, because under his management the most discouraging obstacles were encountered. Everything was new when the attempt was made to change from laboratory methods to manufacturing processes, and from use of skilled labor to the instruction and-employment of unskilled men and boys.

'In January, 1881, I took charge of the factory; Mr. Batchelor's health having given out.'

'Up to March, 1881, all the power used at the factory was carried on a wire from the laboratory – a distance of about a half mile – by means of electricity, using Mr. Edison's machines for generating and receiving the power. In March, 1881, an engine and boiler were procured for the lamp factory in order to free the engine on the hill from extra draughts on it and to make the establishment separate.'

'Trouble was soon met with in Menlo Park of procuring suitable labor, especially light labor as boys and girls. Mr. Edison wishing to be secure, in the summer of 1881 purchased the present factory at Harrison, or East Newark, so as to provide against any emergency.'

'This factory was partly burned before purchasing it, bringing it into the market at very advantageous terms.'

'The Menlo Park lamp factory was thought to be a good place for trial of experiments before starting in the new place so as to save expense in fitting.'

‘On Apri1 1 1882, all manufacturing ceased at Menlo Park as it was decided that the process of making lamps was sufficiently settled to warrant the large investment required in fitting up the new place.

The Harrison factory was formerly occupied by the Peters Manufacturing Company, makers of oilcloth. The buildings are in a yard which takes an entire block. There are three four-story buildings standing and the ruins of another, besides boiler room, office, stables, dwelling house, sheds, etc. The main buildings have about ten times the floor space of the Menlo Park factory, and without building additional buildings more than ten times as many lamps can be made a day.’

In the early winter of 1880-1881, Dr. E. L. Nichols was transferred from the laboratory to the lamp works to undertake the organization of the lamp testing department. He worked out a more practical method of measuring candle power of lamps in the photometer room than that used at the laboratory. He made two electro-dynamometers which could be used more handily in sorting lamps for voltage. They did the work fairly well, but of course were discarded as soon as ammeters and voltmeters of strong field type made an appearance.

The Menlo Park Edison Lamp Works was started on October 1, 1880. The unskilled workers were first instructed, and the first regular payroll commenced on November 11, 1880. There were about 135 men employed. At Menlo Park about 80,000 lamps were shipped, while about 50,000 lamps were in the stockroom. The lamp works were moved to Harrison (then East Newark) April 1, 1882, and got started there on June 1, 1882, with about 150 men. The capacity at that time was about 1,200 lamps per day.

In starting this new industry, the [initial] cost of production was much greater than the stipulated selling price. Naturally, Edison lost money. However, he was confident that as factory facilities were improved and experience was obtained, the price of production per lamp would gradually decrease, until eventually he could make a profit. It was four years before he began to break even. Then again followed that soon redeemed the previous losses.

When I was in Europe for Edison, I remember selling thousands of American-made lamps at $1.00 per lamp. That price, of course, brought a profit, divided between the American and French companies. The latter owned the Edison rights for Europe.

Edison himself said that the cost of production during the first years was about $1.10 per lamp, while he had to sell them at $0.40 apiece. During the second year the cost went down to $0.70. The third year it sank to $0.50 and the fourth to $0.37. The profits in that year made up for all that he had lost in previous years.

Finally Edison got it down to $0.22 per lamp, and as they were made by millions and sold at the stipulated price of $0.40 a lamp, the Edison Lamp Company was making big money. It is on record that they paid a fat dividend every Saturday night. Frank L. Dyer wrote me that Edison frequently told him with great glee about declaring a dividend every Saturday night. It opened the eyes of Wall Street when they got wind of it and they coveted the concern. Edison sold out for $1,085,000.

In this series of articles on the lamp works, I have told how and with what facilities the first incandescent lamp factory began the production of lamps for commercial purposes. No new revolutionary changes came into effect during the succeeding ten years, yet during these years many decided improvements were made in the art of producing lamps.