The inventive genius

"The battle of the currents" — DC versus AC — raged throughout the 1880s. On one side was Edison, already famous, while on the other was an unknown newcomer, Nikola Tesla. Tesla's concepts of AC power generation and distribution eventually carried the day, but not without controversy.

While Tesla worked at the Hungarian Telegraph office thoughts of alternating current never left his mind. Every spare moment was used in creating his unique mental constructs. Eventually, the toll became too much and Tesla had a breakdown. Doctors professed themselves mystified by his weird symptoms.

Tesla wrote: "I could hear the ticking of a watch with three rooms between myself and the timepiece. A fly alighting on a table in the room would cause a dull thud in my ear . . . the roaring noises from near and far often produced the effect of spoken words which would have frightened me had I not been able to resolve them into their accidental components.

"In the dark I had the sense of a bat and could detect the presence of an object 12 feet away by a creepy sensation on my forehead. My pulse varied from a few to 260 beats."

The physicians' cures did nothing for him, but slowly the malady ebbed. Tesla was pleased that his memory had not been affected, for his ability to quote from the classics remained as sure as ever.

One afternoon in February, 1882, whilst walking in a park with his assistant, Szigeti, he spoke some lines from Goethe:

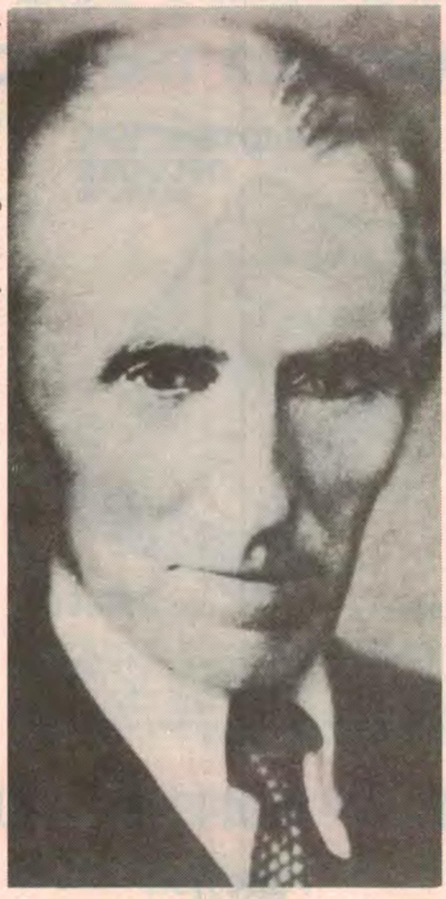
The glow retreats, done is the day of toil;
It yonder hastes, new fields of life exploring;
Ah, that no wing can lift me from the soil;
Upon its track to follow, follow soaring . . .

Suddenly he fell silent. There, before him, was the device he had thought about so long.

"Watch me reverse it," he told Szigeti. His assistant, naturally seeing nothing, feared that Tesla had had a relapse.

Impatiently, Tesla described the concept that had flashed into his mind when he quoted those lines of poetry: a two-phase circuit — two magnetic fields — that would create a rotating force to puli a rotor by induction. Quickly, he picked up a stick and sketched the circuit in the dust of the path. His exposition was so

Photo courtesy Westinghouse Electric Corp.



One of the few photographs of Tesla, taken late in life.

lucid that Szigeti immediately grasped the principle.

On his return to his job, however, other tasks awaited him and he had no time to devote to this marvellous discovery. It did not worry him, for he could build his mental constructs and set them running, to be examined at some future date. Soon, the telephone centrai office was completed.

In the spring of 1882, Tesla travelled to Paris, securing employment with the Continental Edison Co. After some design work, a power plant assignment took him to Strassburg. A physical example of the rotary field AC motor was constructed there in the summer of 1883. When not wasting time with the Germanic bureaucracy, he tried to raise interest and capital for his AC discovery but had no luck.

Returning to Paris early in 1884, he found the same situation. What is more, the large bonus he had been promised for earlier design work and his efforts as trouble-shooter in Strassburg never materialised. At that point, he determined to go to "The Land of Golden Promise" — America.

Armed with a letter from Charles Batchellor, a company director, and a personal friend of Thomas Edison, Tesla prepared to depart Europe, perhaps for good. On his way to the docks, someone picked his pocket. He convinced ship's personnel that he had booked a passage by quoting the ticket number. He arrived in the United States with a book of his poems, a couple of technical articles, some notes on a mathematical problem, a design for a flying machine — and four cents in his pocket.

Nikola Tesla presented himself to Edison straight away. The famous Yankee inventor looked suspiciously at this dapper foreigner before him, but read the letter of recommendation from Batchellor:

"I know two famous men and you are one of them," it said. "The other is this young man."

On the strength of that, Edison offered the excellently educated and well-experienced engineer $18 a week — hardly more than he paid one of his mechanics. Tesla, for his part, was quite impressed by Thomas Alva Edison, almost a legend in his own lifetime.

He was to write: "The meeting with Edison was a memorable event in my life. I was amazed at this wonderful man who, without early advantages and scientific training, had accomplished so much. I had studied a dozen languages, delved in literature and art . . . and felt that most of my life had been squandered."

At first, Tesla was given very junior tasks but soon he had won Edison's confidence. On one occasion, Tesla was despatched to the steamship *Oregon,* which had missed its sailing date, due to a problem with Edison generating equipment on board. At five o'clock the next

# of Nikola Tesla *Part 2*

by J. L. ELKHORNE

morning, Tesla, with the assistance of the crew, had effected major repairs and was returning to the shop, when he met Edison and Batchellor, recently returned from Europe.

"Here is our Parisian running around at night," Edison commented. Tesla informed him that the repairs on the *Oregon* had just been completed. As he left, he heard Edison tell Batchellor: "This is a damn good man."

The good relationship would soon deteriorate, however. As soon as Tesla mentioned his ideas about alternating current, Edison silenced him. Then, in one of those little incidents that grow all out of proportion, Nikola Tesla would misunderstand a casual statement.

He had suggested some significant improvements to the Edison equipment. The American inventor remarked: "There's $50,000 in it for you, if it works."

Soon, Tesla had completed his calculations and tests. His improvements were put into practice. Time passed, and the reward he envisaged did not occur.

"The American inventor remarked: "There's $50,000 in it for you, if it works"

Finally, he questioned Edison about it, and learned that it was "a practical joke". Tesla could not laugh, however. He had designed 24 different types of machines, in a workday which went from 10.30 in the morning to 5am the next morning – without a day's exception – for nearly a year.

Tesla resigned.

His initial impression of Edison had been tempered by observation of the great man at work: "If Edison had a needle to find in a haystack, he would proceed at once with the diligence of the bee to examine straw after straw until he found the object of his search. I was a sorry witness of such doings, knowing that a little theory and calculation would have saved him 90% of his labour."

Edison relied on his "intuition" and trial-and-error methods. After 10,000 trials for a new type of storage battery had proved fruitless, Edison bragged that he had not failed. "I now know 10,000 ways that won't work," he said.

Unfortunately, Edison had the reputation – and the money to follow his own path. Tesla, only a year in America, had no money, no contacts, and no prospects. Still, a group of entrepreneurs approached him with an idea to start yet another street lighting company, still a money-maker in the big cities. Tesla worked for some time, designing new types of arc lights and regulators, and eventually found himself the possessor of a stock certificate of doubtful value.

Edison, bitter over their differences, told anyone who would listen that the foreigner was not to be trusted. Tesla went through such hardship during the next year that he seldom spoke of it afterwards. He did occasional electrical repair jobs and during the bitter winter of '86-7, worked as a common labourer. His foreman, a stockbroker who had lost everything in the market, maintained contacts in the business world. After listening to Nikola Tesla at length, he approached an executive, A. K. Brown, of the Western Union Telegraph Co.

Brown and an associate were favourably impressed by Tesla and financed a laboratory for the inventor, not far from the Edison works. The concepts Tesla had developed five years earlier were on file – in his head. His original motor lay forgotten in Europe; the later work had all been intellectual. By October of 1887, Tesla built his engine models. He filed for patent on an alternating current system, of which the motor was only a part.

Photo courtesy Westinghouse Electric Corp.

This tower was built on Long Island in 1904 while Tesla was experimenting with power distribution by wireless.

The inventive genius of Nikola Tesla

Just as Edison had foreseen that the electric light without a distribution system was of little import, so Tesla regarded his discovery of the rotating magnetic field. To him, the motor provided only a piece of a unified system. The US Patent Office, however, reacted with horror at his sweeping approach. They broke the original application down into seven sections, and by the end of the year, had issued 30 basic patents.

As his work began to receive publicity, he was hailed as the scientific genius of the age. On invitation, he delivered a lecture before the American Institute of Electrical Engineers on May 16, 1888. The theory and practice he presented are the basis of the system we still use today. Improvements have been made, to be sure, but offer no radical departures to his central concept. In one stroke, he accomplished an engineering breakthrough of such magnitude that no comparable development has been presented since – especially by a single individual.

The group of patents included single and multi-phase motors, polyphase distribution and transformers, alternating current generators, AC to DC conversion, condensers, insulators and meters.

Five years before, Edison had electrified New York City, a remarkable achievement – with remarkable limitations. Even with his feeder-and-main distribution system, there was about a 30 volt drop overall. The nominal 110 volt adopted by Edison was compensated for by generating at 120 or even 130 volts. Those closest to the central station had brighter light – and quicker burnouts; those people at the far end had light that left much to be desired. The Edison system was predicted on an arrangement of a power house every mile or so. Although men had actually made DC generators that emitted as much as 6kV, outside the laboratory such machines were not practical, nor was long-distance transmission feasible with them. Line loss remained a significant factor of DC operation.

With Tesla's polyphase system, however, power could be generated anywhere, transformed, sent down a transmission line, and then stepped down at the point of use, all with a very high efficiency.

Fortunately for Tesla – and for mankind – a man of commerce who could bring this scientific feat out of the laboratory and to the world of everyday engineering practice made his approach. George Westinghouse, inventor and head of his own company, had succeeded after the American Civil War in marketing a portable device for getting derailed cars back on the tracks.

His invention of the railroad air brake though, established him as one of the giants of American business. He went on to become a pioneer of the gas-distribution and lighting industry. When Edison's electric distribution system began making itself felt, Westinghouse knew he needed to get involved in electricity to remain competitive. He swiftly mastered the state-of-the-art and bought the patent rights of various inventions. He designed a transformer, after study of the recent Gaulard-Gibbs unit, in three weeks. Having invented one of the first steam turbines in the world, he was quick to realise that a practical AC motor would be the key to a new and profitable system.

"I will give you a million dollars for the use of your AC patents."

When he heard of the Tesla patents in the latter part of 1887, he had already organised the Westinghouse Electric Company. He saw the importance of the rotating magnetic field concept. He approached Tesla in 1888 with an offer that could not be refused: "I will give you a million dollars for the use of your AC patents," he told the gaunt inventor, 10 years his junior. Tesla later admitted that such an astounding figure shocked him speechless. After a long pause, he replied, "Accepted – if you will also offer a royalty on manufacture."

At this point legend appears to take over from known fact. A popular story has it that Tesla and Westinghouse agreed on certain sum per horsepower of equipment sold; a sum which varies – apparently depending on the re-teller of the story – from one dollar to two dollars fifty. And, according to the story, it was a handshake agreement.

Whether this was ever ratified by a formal contract is not known, and no such contract has ever been found. But the story goes on to tell how the Westinghouse board, who had provided most of the money, refused to honour the agreement and threatened to withdraw their support on the basis that it would bankrupt the company.

At this stage Tesla reputedly tore up the contract rather than see the company, and his work fail.

By all accounts, including that of Westinghouse historian Charles A. Ruch, this legend is just that; a legend arising out of a royalty discussion which was documented but which never went beyond that stage.

At any rate, the initial payment for patent rights (which one writer states was only $200,000) was split with Tesla's backers. With a small fortune at his fingertips, Tesla found himself eager to pursue remarkable new areas on the frontier of science. Westinghouse, however, convinced him that immediate practical work on the problem at hand was necessary.

Edison, extremely worried over his two million dollar investment in the New York City generating system, launched a vitriolic attack on the new system. With his usual publicity machine in action, he raised the horrors of imminent electrocution of the general public exposed to the AC system.

He wrote: "Just as certain as death Westinghouse will kill a customer within six months after he puts in a system of any size. He has got a new thing and it will require a great deal of experimenting to get it working practically. It will never be free from danger."

Edison men distributed pamphlets, warning the populace that it would be a matter of taking one's life in his hands to merely walk the streets, constantly at the mercy of the lethal high-tension wires. The fact that a lineman a month on the Edison system was killed was ignored. Convinced by their boss's propaganda the DC was inherently safe, they failed to take adequate safety precautions.

Half a mile from his estate at West Orange, New Jersey, Edison had built a large laboratory, replacing the facilities at Menlo Park. As part of his propaganda campaign, he and his associates regularly electrocuted "stray" cats and dogs in public demonstrations.

Animals were purchased at 25 cents a head from local schoolboys. Immediately after their acquisition, they were thrown onto a contrivance powered by a 1kV alternator, possibly manufactured by the Westinghouse Electric Company. The pet population of the New Jersey community was nearly wiped out.

Charles Batchellor, who had unleashed Tesla on Edison and America, suffered an unfortunate experience while helping his boss in these enlightenments. One large dog, having deduced no good was about to be done him, wriggled out of Batchellor's grasp, knocking the man

In one stroke, he accomplished an engineering breakthrough of such

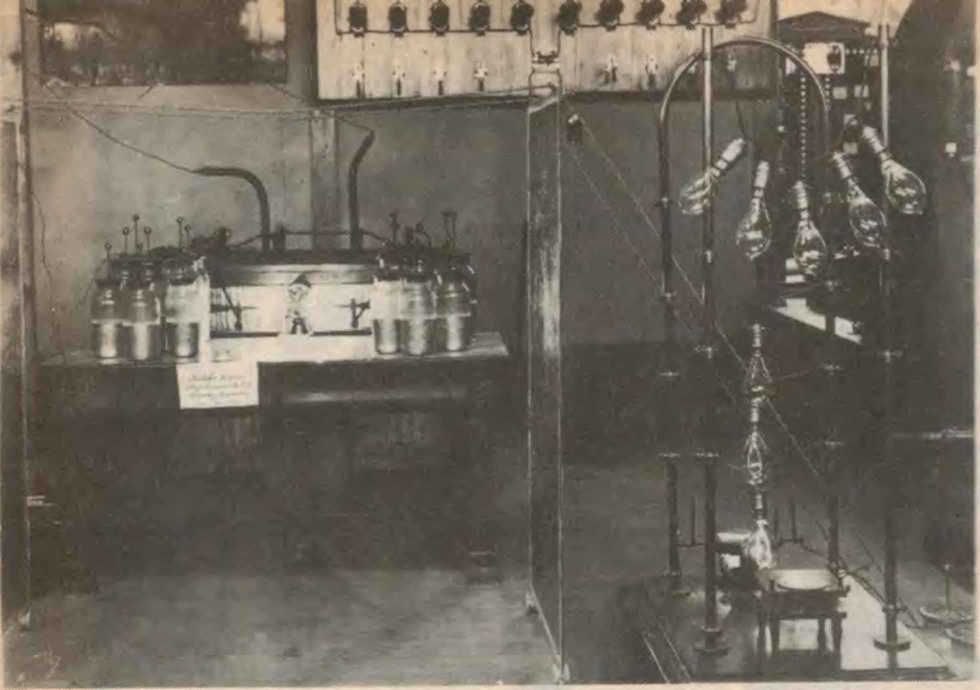


Photo courtesy Westinghouse Electric Corp.

A high voltage, high frequency set-up at Tesla's Westinghouse Laboratory.

himself onto the electrocution platform. Although he was not killed, he described the sensation: "(as) the sensation of an immense rough file thrust through the quivering fibres of the body."

Edison published an article defending his cruelty to animals, saying: "I have taken life – not human life – in the belief that the end justifies the means."

H. P. Brown, who had been a laboratory assistant at West Orange, himself began public execution of cats and dogs. He claimed to be demonstrating that such a death was "instantaneous, painless and humane." He became a lobbyist and independant consultant to the New York State legislature, helping to usher in a bill allowing capital punishment by electrocution. As soon as the statute became law, he made a well-publicised purchase of Westinghouse equipment, which was installed at Sing Sing Prison.

Westinghouse appealed to common sense, issuing a public statement that no deaths by electrocution had previously been caused by his company's equipment. He managed to counter a suggestion that the term "to Westinghouse" be used to refer to electrocution of condemned criminals.

Over strenuous objections by Westinghouse and his associates, the authorities finally decided to give the new statute – and equipment – a test. On the night of August 6, 1890, convicted wife murderer, William Kemmmler, was led from his cell. Moments later, he found himself vibrating to a jolt of Westinghouse alternating current. To the chagrin of the prison officials, the shock did not kill him – the voltage was too low. He was unstrapped from the chair, marched back to his cell, and the electric chair examined. A wiring fault was found. (The electrician was probably another Edison man – fearful of his proximity to such a devilish machine.)

Hasty modifications were effected – and William Kemmler brought once again to face his punishment. This time, death was instantaneous, but called by one observer "an awful spectacle, far worse than hanging." Apparently, the optimum high-tension had been far exceeded . . .

Tesla found himself fighting Westinghouse engineers in Pittsburgh during the year 1889. He had selected 60 Hertz as the best compromise frequency for commercial power applications. Westinghouse engineers (or company accountants) had decided that 133 cycles a second would be the standard –

"He built an alternator with 384 poles which generated 10,000 Hertz."

it would decrease the cost of core materials. Even though George Westinghouse offered Tesla a $24,000 per annum salary to stay, the younger man argued he wasted his time in minor design work, disagreements, and was not free for creative work.

"At the close of 1889, my services in Pittsburgh being no longer essential, I returned to New York and resumed experimental work in a laboratory on Grand St." Tesla later wrote.

Back in New York City, he began spending lavishly. He embarked on a program of research into a number of areas simultaneously. Familiar with the work of James Clark Maxwell and Heinrich Hertz, he proceeded to research apparatus working on higher and higher frequencies. He built an alternator with 384 poles which generated 10,000 Hertz. Although he finally achieved a stable rotary machine working at 30,000 Hertz, he abandoned such equipment for new apparatus capable of far higher frequencies. At the same time, he delved into the areas of mechanics, pneumatics, hydraulics and resonance phenomena.

His first high-frequency experiments culminated in a lecture at Columbia College on May 20, 1891. In it, he demonstrated the high-frequency alternator, as a power source for induction coils of his own design. He showed many curious electrostatic effects, so-called bush discharges, unique forms of incandescent lamps, and the first demonstration of wireless lighting. He achieved the phenomenon of stationary waves in a large copper bar, lighting various types of lamps at the maximum potential nodes of what seemed in conventional terms to be a short-circuit.

From the mundane world of low-frequency alternations, he had leaped into a strange, new frontier where each discovery was more unbelievable than the last – except for the fact that he was able to show experimental proofs to an astounded audience.

These investigations were the predecessor to the development of the Tesla coil. At this time, he was working with closely-coupled coils, sometimes cored, and immersed in oil or insulated with paraffin to prevent arc-over.

One of the more curious effects he demonstrated was the illumination of a carbon filament lamp, in which the globe itself was incandescent, whilst the filament remained dark! He also developed a lamp with a single button of ruby which emitted light.

His unique research so fired the imagination of scientific men that he was invited to England. In February, 1892, he gave a more advanced lecture before the Institution of Electrical Engineers, London, titled "Experiments with Alternate Currents of High Potential and High Frequency." Work he had done the previous year had been added to considerably. He had worked with Crookes tubes, precursors of the cathode ray tube. As the electron was not yet known to scientists, a great many puzzles manifested themselves in this research. Tesla was still working with relatively small, oil-insulated coils, but had made considerable advances in the types of sparkgaps employed. Dozens of fantastic luminescent effects were displayed: A group of incandescent lamps that had solid buttons of various materials instead

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magnitude that no comparable development has been presented since –

Nikola Tesla . . . ctd from p25

of filaments – the forerunners of modern fluorescent lamps – of much greater efficiency than the Edison lamp.

This lecture was so successful that Sir James Dewar called on Tesla and asked him to repeat it before the Royal Institution. Tesla replied that he never duplicated his lectures, preferring to always present new and original material. Sir James then escorted Tesla to a room, pushed him into a chair and "poured out half a glass of a wonderful brown fluid which sparkled in all sorts of iridescent colours and tasted like nectar."

"Now," the Scotsman said, "you are sitting in Faraday's chair and you are enjoying whiskey he used to drink."

This singular honour convinced Tesla to accede and he repeated the lecture before the Royal Institution the next evening. Following that, he gave other lectures in Paris and Berlin. On his return to the United States, he became actively involved in the realisation of a boyhood dream – the harnessing of Niagara Falls.