The inventive genius

By 1983, Tesla's alternating current system was established as the preferred method of transmitting electrical power. After supervising the construction and installation of the first generators at Niagara Falls, Tesla turned his attention to an ambitious scheme for broadcasting power around the world.

by J. L. ELKHORNE

In 1886, Edward Dean Adams, head of the Cataract Construction Company, organised the International Niagara Commission. He asked Lord Kelvin to serve as chairman, to find a means of using the untapped power of the falls. Numerous ideas were studied and discarded: mechanical, hydraulic, and compressed air systems.

Lord Kelvin – William Thomson – had been engineer-in-charge of the first successful transatlantic cable. For this achievement, he was knighted. In 1890, his committee offered a $3000 prize for the best plan – of any kind – to utilise the power of Niagara. Some 20 plans were submitted, none by the large companies. Westinghouse demurred on the basis that the commission would get a hundred thousand dollars worth of value for a paltry prize.

By 1893, the commission had recognised that a businesslike approach was necessary and asked for bids from manufacturers. Also in that year, Westinghouse won the contract to light the Columbian Exposition. Originally planned as a celebration of the 400th anniversary of Columbus' discovery of the New World, the opening was delayed due to the extravagant plans made. The Building of Manufacturers and Liberal Arts spanned some 16 hectares, for example – the largest exposition building ever erected to that time. The Ferris wheel was invented for the occasion. The Exposition itself used more electricity than the city of Chicago – all produced by the Tesla system.

Tesla himself spent a week there, giving public demonstrations of his more unusual experiments. He had designed a graphic display of the rotating magnetic field, a modern-day parallel of the egg of Columbus. As Columbus was supposed to have stood an egg on end to challenge his critics, Tesla allowed a copper egg to stand on end and rotate around a platform, drawn by the invisible and revolving magnetic field created in the coils underneath.

He put on a veritable magic show of electrical technology, amazing thousands of onlookers with wireless lights, corona effects, high-frequency and high-potential wizardry – and culminated his performance by passing one million volts "through" his body. This feat, perhaps more than anything, convinced the doubting public that the horrors of alternating-current which Edison portrayed were greatly exaggerated.

Of course, Tesla had discovered early on that the nerves did not respond to frequencies above about 700Hz. He also became aware of skin effect – that a high-frequency current would pass across the body. And his megavolt had very little current behind it. Still, seeing a man grasp the high-tension terminal of a conical coil, reach out and vaporise a copper disc, was truly overwhelming.

Tesla's personal exhibit remained at the Exposition, as part of the Westinghouse Company display in Electricity Building. Untold numbers of people saw the marvels of Tesla's casual handling of greater voltages than any other man had ever produced.

His equipment represented 10 years' work. It included early polyphase motors, displays such as the "egg of Columbus," the 384-pole alternator, some of the "disruptive discharge" coils, fluorescent tubes, various forms of the "wireless" light, and the original oscillator.

By now, Edison's attempt at adverse influence having failed, an exchange of patent rights was arranged between the Westinghouse Electric Co and the General Electric Co. Lord Kelvin, having studied the proposals submitted for Niagara, reluctantly agreed that alternating current seemed to be the answer.

In October, the Westinghouse tender for two-phase generating equipment was accepted. Initially, three 5000 horsepower machines would be installed, and the first large-scale hydroelectric facility was born. The General Electric bid to build the transmission line found favour and the two bitter rivals collaborated on the largest electrical engineering project to that time.

Westinghouse completed Power House Number One in 1895, and the transmission system went on-line in 1896.

In 1885, three years after the opening of Edison's Pearl Street Station, several thousand power plants, supplying some 20 different direct current systems, operated throughout the United States. Most of them were steam plants, deriving their energy from coal-fired boilers.

Dr Charles F. Scott, of Yale University, commented that single powerhouses (now) supply more power than all of the thousands of central stations and isolated plants of 1890.

# of Nikola Tesla

Part 3

Power from the Niagara plant went to Buffalo, 22 miles away. The first industrial customer for Tesla electricity was the Pittsburgh Reduction Company. The aluminium plant, founded by Charles Hall in 1888, had been based on his discovery of a workable smelting process two years earlier. Cheap, long-distance power from Niagara turned the expensive novelty metal into commercial practicality.

The second industrial user connected to the Niagara system was Dr E. G. Acheson's carborundum plant. His artificial abrasive had been a commercial failure, until the advent of the Tesla polyphase electric system. Following these two modern industries came a whole host of other products that became commercially viable with cheap and efficient electricity: acetylene, nitric acid, explosives, fertiliser, artificial graphite, furnace electrodes, battery carbons, lubrication, ferrosilicon, ferrochromium, ferrotitanium chlorine, phosphorus, caustics and ammonia.

Tesla had fulfilled that boyhood dream. His electricity and his motors – driven by the power of Niagara and harnessed to men's will – turned the wheels of industry as never before. And, as is so often the case, a host of claimants immediately sprang forth to announce loudly to the world that *they* were responsible for the new system. Von Dobrowolsky was one such – he claimed the invention of the rotary field motor, as used in a pioneer electrical transmission scheme in Frankfurt, Germany. After argument erupted in scientific journals, he reduced his claim. Even then, the chief engineer of the project published a statement: "The three phase current as applied at Frankfurt is due to the labours of Mr Tesla and will be found clearly specified in his patents."

Opponents of Tesla turned to obscure academic curiosities to prove priority. But even the authorities they quoted supported the Tesla patents. Finally, a judgment was rendered by Judge Townsend of the United States Circuit Court of Connecticut, on May 1, 1900. Townsend studied the state-of-the-art as of 1888, the year of the Tesla patents. "Prior to Tesla invention," he wrote, "no alternating-current motors were in use.

He referred to concepts of Siemens, Baily, and Bradley, and to the principle of the Arago rotation; and concluded:

"It remained to the genius of Tesla to capture the unruly, unrestrained and hitherto opposing elements in the field of nature and art and to harness them to draw the machines of man. It was he who first showed how to transform the toy of Arago into a engine of power; the 'laboratory experiment' of Baily into a practically successful motor; the indicator into a driver; he first conceived the idea that the very impediments of reversal in direction, the contradictions of alternations might be transformed into power producing rotations, a whirling field of force.

"What others looked upon as only invincible barriers, impassable currents and contradictory forces, he seized, and by harmonising their directions utilised in practical motors in distant cities the power of Niagara."

Tesla, when he left Pittsburgh, had vowed to work only for himself. His landmark lectures in 1891, 1892 and 1893, led him ever further into virgin fields of exploration. His closely coupled coils had been superseded by air coils and tuned circuits. By 1893, during his lecture before the Franklin Institute, he could speak with some assurance of the goal of his researches as "(to) transmit intelligible signals and perhaps power."

In 1895, when he was seeing the fruits of earlier efforts culminated in the Niagara Falls Power Plant Number One, a fire in his laboratory completely wrecked his progress. Every bit of apparatus he had built over the past six years was destroyed. His World's Fair display, numerous awards and personal mementos, all went up in smoke.

That fire at 33-35 South Fifth Avenue destroyed a unique site for the elite of New York City. Tesla, always an accomplished gourmet, had fulfilled social obligations with lavish dinners at the best of New York hotels. These feasts were followed by demonstrations of his latest work at the laboratory for some of the most famous people of the day.

Now, all was ashes.

With the support of Edward Adams and others, Tesla equipped a laboratory at 46 East Houston Street, taking about a year to duplicate what had been lost. A series of patents on the new technology began in April, 1896. These included various means of producing and regulating high-frequency and high-potential currents; techniques of tuning and selective signalling; wireless transmission of signals and energy; and control of moving vessels or vehicles. Some 30 patents were issued over a 15-month period.

His successful experiments in wireless telegraphy – over a distance of 20 miles – were announced in "Scientific American" for June 19, 1897.

Tesla had constructed a gigantic tank in Madison Square Garden, which his friend Stanford White, the eminent society architect, had designed. In this tank, Tesla placed the model boat which is specified in US Patent 613,809.

The inventor wrote: "When first shown in the beginning of 1898, it created a sensation such as no other invention of mine has ever produced. In November, 1898, a basic patent on the novel art was granted to me, but only after the Examiner-in-Chief had come to New York and witnessed the performance, for what I claimed seemed unbelievable."

This was the first of what Tesla called "telautomatons" – machines capable of

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carrying out operations at a distance, under the control of the operator. He built a larger example of this boat, with loop antennas, which was capable of operating as a submarine. He foresaw a whole new race of robots; machines which "would perform a great variety of operations involving something akin to judgment."

The boat was battery powered and used a number of tuned circuits controlling relays and servos. It had rudder control, forward and reverse, and could flash a pair of lights in response to questions from the audience, the answers being supplied by Tesla at the controls.

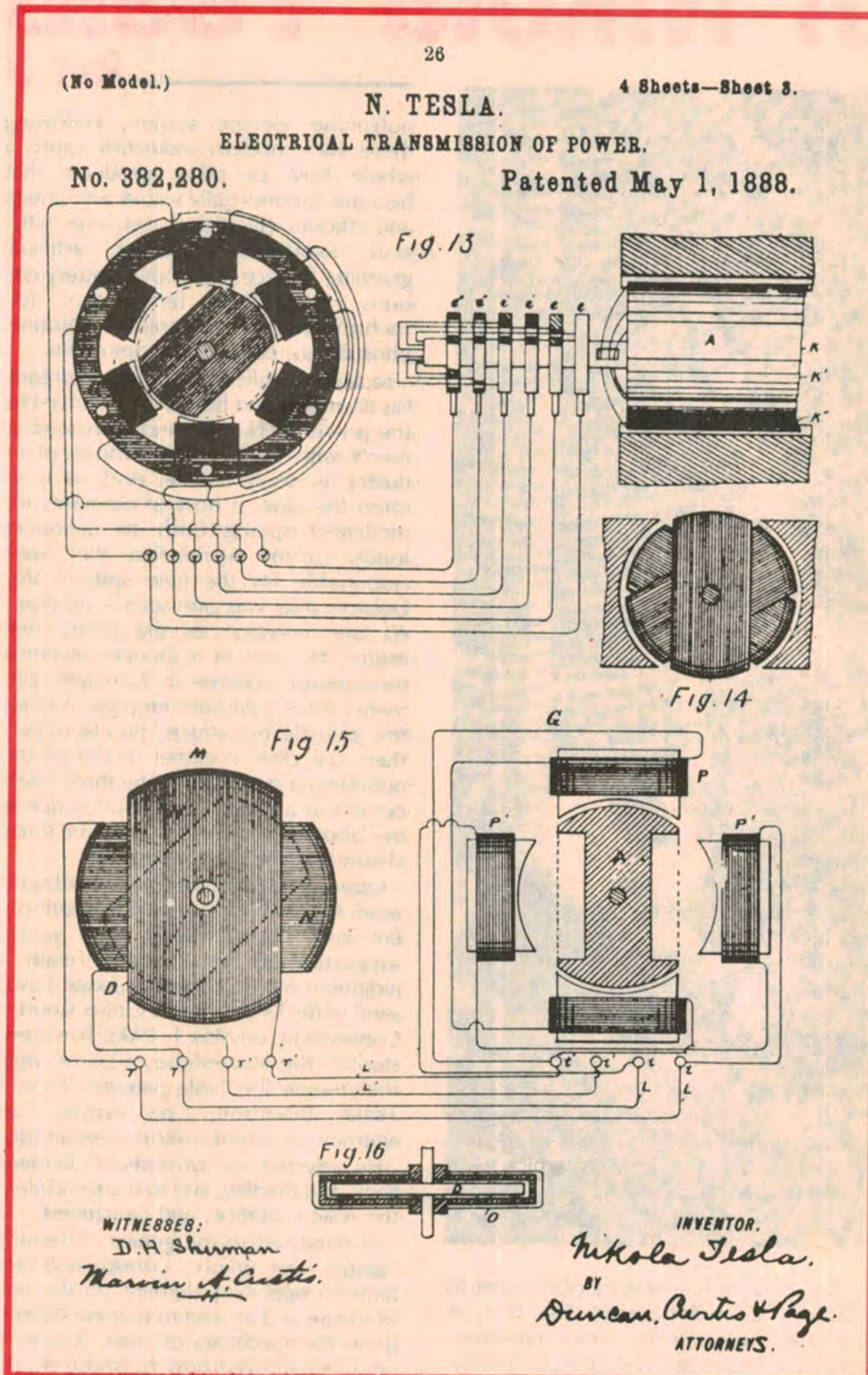
As a result of this exhibition, he was invited to organise a wireless reporting of an international yacht race, by Lloyds of London. Even though he could well have used the generous amount of money offered, he was too deeply engrossed in his researches to take the time and effort – or to allow anyone else to work with apparatus which he had, as yet, not wholly protected by patent. In any case, short distance signalling seemed insignificant to him.

His use of inductive coupling and multiple-tuned circuits to allay interference seems to predate work by Marconi, Lodge, and other fathers of wireless. Yet he did not pursue this area and put into solid engineering practice the discoveries he had made. If he had devoted himself or confined himself to this one area for even a year, he might well be known today as the father of radio.

One of the side issues he researched concurrent with high-frequency work was mechanical resonance. Some of this study had led to the "mechanical and electrical oscillator" first demonstrated in 1893. Another of the devices was an offshoot of air compression experiments. His goal in this area is not known.

One of the little toys he developed during this period was the scalp massager, often used by barbers in future years. Another item was a vibrating platform. Samuel Clemens, a good friend, used to regularly call on the inventor at the Houston Street laboratory, and is shown in one photograph holding one of the wireless lamps Tesla had developed.

The author – better known to the world as Mark Twain – once tried out the vibrating platform. He found the sensation quite soothing and refused to get off when advised to do so. After a couple more minutes of this gentle shaking, he leaped down and asked the way to the toilet. The laxative qualities of this machine were well known . . .



Tesla had a steel link delivered one day, and set up on sawhorses. It was two feet long and two inches thick. He attached a mechanical vibrator, powered by his special air compressor. This device was described later as "small enough to put in your pocket" and apparently had to be tuned by the operator. Once it achieved resonance, it reinforced the vibration until that steel link, capable of supporting tons of weight, snapped.

Next, Tesla found the 10-storey framework of a steel building going up on Wall Street. He attached his vibrator and set it going.

"In a few minutes," he wrote, "I could feel the beam trembling. Gradually, the trembling increased in intensity and extended through the whole great mass of steel. Finally, the structure began to creak and weave, and the steel-workers came to the ground panic-stricken, believing that there had been an earthquake . . . if I had kept on 10 minutes more, I could have laid that building flat in the street. And, with the same vibrator, I could drop Brooklyn Bridge into the East River in less than an hour."

If this seems unlikely, study the newsreel film of the collapse of the Tacoma Narrows bridge. The third longest suspension bridge in the US in 1940, it achieved resonance during a gusting storm – with a wave motion of 10 metres along its length. The 200 metre central span dropped into the Narrows after about four hours, followed a short time later by the 300 metre end spans.

"It is a fortunate circumstance," Tesla had written in his 1893 lecture, "that pure resonance is not producible, for if it were, there is no telling what dangers might not lie in wait for the innocent experimenter."

The main thrust of his research, though, was still toward the wireless transmission of power. He had reached a safe limit, he felt, of four million volts in his Houston Street laboratory. He organised finance for the building of an experimental laboratory at Colorado Springs, Colorado, in 1899 and began developing the next phase of his work, which he called a "magnifying transmitter."

In a large, barn-like structure, he constructed an enormous Tesla coil. The primary was 17 metres in diameter, of only a few turns. This coil was beneath the floor of the building, and many researchers have been misled by examination of photographs from that period.

The secondary of the system, of the same diameter, was connected to a coil centrally mounted, six metres in diameter and some 10 metres high. This third coil was tuned, at least in one instance, to 100 kilohertz. Tesla achieved an output of 12 million volts, which was not duplicated until 1976.

From this latter coil, a cable led to a copper sphere on a mast almost 200 feet tall. At full power of about 300 kilowatts, Tesla noted sparks in excess of 30 metres, until the system stabilised. He recorded peak antenna currents of 1100 amperes in his diary of that period.

Although modern engineers claim that Tesla attempted the impossible, it appears that he did prove the transmission of 10 kilowatts to a circuit 35 kilometres away – at a fraction of full power. He also recorded detection of signals from the magnifying transmitter some 1000 kilometres distant.

In electromagnetic radiation, the inverse square law holds – when the distance is double, the energy received is quartered, as it were. Yet, Tesla himself wrote of the principle being "the diametrical opposite of ... electromagnetic radiation." He seemed to be pursuing the goal of altering the natural electrostatic equilibrium of the globe.

On July 3, he had established, using one of his unique devices for recording lightning strikes, which are plentiful in Colorado, that stationary waves occurred in the Earth.

He also commented: "I never saw fire balls, but as a compensation for my disappointment I succeeded later in determining the mode of their formation and producing them artificially."

This latter statement, almost an aside, prompted Robert K. Golka, of Brockton, Massachusetts, to duplicate the Tesla magnifying transmitter in 1976. Ball lightning is now accepted as a plasma phenomenon – and the creation of a stable plasma is one of the keys to fusion power. Golka rejects completely the Tesla theory of power transmission, believing that the abnormal ground conductivity in Colorado influenced Tesla's results.

Tesla, however, returned to New York City in 1900, published some articles and filed for a patent on his magnifying transmitter. This was finally granted in 1914. On the strength of his results thus far, he received some money from J. P. Morgan and other financiers. At Shoreham, on Long Island, a monster tower began to grow. W. D. Crow, an associate of Stanford White, designed this 200-foot tower which would have been topped by a 68-foot copper hemisphere.

This plant was designed to transmit 10,000hp, in the form of power, radio broadcasts, time and navigation signals, facsimile, and private messages to individual receivers. The grand plan was never finished, however, for the money ran out. Despite rumours that the US government destroyed the tower in World War I, the fact is that Tesla surrendered the property as payment of outstanding debts and a contractor dismantled the wooden tower for scrap. The laboratory building remains today as a sort of national trust site.

By 1911, Tesla was flogging a radical new turbine he had designed. Although Allis-Chalmers Co put some effort into it, Tesla's inability to work with other people doomed the project to failure. From then on, he declined into obscurity.

He died, alone and virtually forgotten, in the world he had helped create, in New York City. He was 86.

His legacy remains in the power system we use today, a host of patents – over 700, worldwide, credited to him – and diverse articles in magazines. And, perhaps, a hint toward the power generation system of the future.