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EDITORIAL

Nicola Tesla: Who Is Mr. 'T'? The Man Behind the Unit of Magnetic Field Strength

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Clinicians reading magnetic resonance imaging (MRI) reports routinely see the initial 'T' indicating the magnet field strength of the machine used to perform the study. Many do not realize the contributions of Nicola Tesla, the scientist and innovator represented by that initial. This article hopes to provide a brief summary of some of his accomplishments. (Journal of Surgical Orthopaedic Advances 29(4):191–194, 2020)

The unit of magnetic field strength designated as "T" is well known to those who order and interpret magnetic resonance imaging (MRI), and we commonly see the terms 1T, 1.5T, and 3T associated with these scans. In 1960, Nikola Tesla was posthumously honored by the International Bureau of Weights and Measures with the naming of the standard unit of Magnetic Flux Density as a Tesla Unit. He joins the pantheon of only 18 other scientists honored in this way. He is considered by the Institute of Electrical and Electronics Engineers (IEEE) to be one of the twelve apostles of electrical science.[1]

Around the turn of the 20th century, Tesla's name and face decorated newspapers and magazines; however, the man behind the unit of measure dropped into obscurity for many years. Only with the recent introduction of the Tesla Motor Car has his name returned to common usage (Fig. 1). Who was this remarkable man? Once hailed as the wizard of electricity, he died penniless and isolated, mocked by some who considered his claims to be pure science fiction, while other fringe enthusiasts elevated him to the status of alien.

Nikola Tesla was born in 1856 in the Austro-Hungarian village of Smiljan, now Croatia, to ethnic Serbian parents. His father was a respected Orthodox priest known for his gifts of poetry, political activism, and an encyclopedic knowledge of many subjects. Although his mother never learned to read, she could recite Serbian epic poems and long passages from the Bible from memory. Tesla attributed his aptitude for invention, prodigious memory, and unrelenting work ethic to her.

Upon his first encounter with static energy at age 3 while stroking his cat, Tesla became fascinated with electricity.[2] He was also captivated by all things mechanical, like waterwheels and turbines. He displayed his inventive nature at an early age. One of his first inventions echoed an idea he would use throughout his life – harnessing nature to do man's bidding. To this end, he employed the indefatigable June bug to power a primitive helicopter. This invention ultimately failed when another boy ate his June bugs alive. This ended his first experiments with flight and gave him a life-long aversion to bugs.[3] On entering the Real Gymnasium (high school), he was accused of cheating due to his ability to perform advanced calculus in his head. He was a polymath and a hyperpolyglot, fluent in nine languages. He also spoke the languages of mathematics and engineering. He was gifted with eidetic imagery, a skill which he perfected to envision and mentally perfect an idea before engaging in practical experimentation. He would use this ability to perform thought experiments throughout his life, at times to his detriment. Once he had perfected an idea in his mind, he frequently felt little need to confirm it in a practical model.

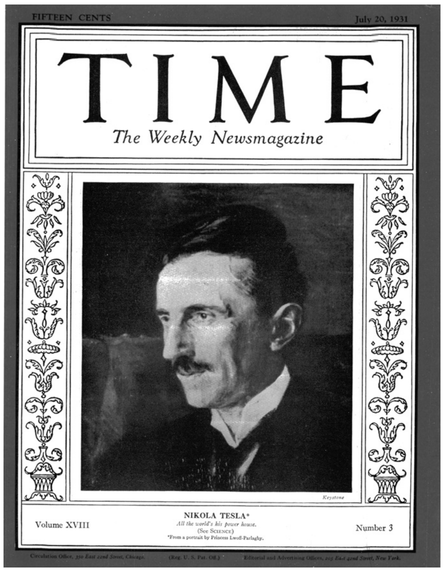

FIGURE 1. Time Magazine, 1933.

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Although Tesla was intended to follow his father into the priesthood, he persuaded his family to allow him to study engineering. He was enrolled at the Graz polytechnic in 1875 at the age of 19, studying physics and mathematics. In the course of his physics class, a Gramm Dynamo (a generator of direct current [DC]) was demonstrated. Tesla was bothered by the inefficiency of the sparking commutator. Those sparks from the commutator would be the spark of inspiration for the eventual development of a commutator-free alternating current (AC) motor. Tesla eventually completed his studies in Prague. He would later work for an Edison affiliate in Budapest leading to further work with the Edison Company in Paris and finally his move to America in 1884.

Once in the United States, Tesla continued his work for the Edison Company. He later said "meeting with Edison was a memorable event in my life. I was amazed at this wonderful man who, without any early advantages and scientific training, had accomplished so much…."[3] Some of his later comments about Edison were less flattering. For example, "If he [Thomas Edison] had a needle to find in a haystack, he would not stop to reason where it was most likely to be, but would proceed at once with the feverish diligence of a bee, to examine straw after straw until he found the object of his search. … Just a little theory and calculation would have saved him ninety percent of his labor."[1] Tesla worked for Edison in New York for 6 months, still thinking about perfecting an AC motor, but relegated to improving the DC system of electrical transmission of energy that the Edison Company was developing. He became disillusioned by the lack of recognition for his work and ideas and left Edison, determined to complete and perfect an AC motor. This was the start of his career as an independent inventor, a career that would change the world and would pre-conceive ideas that were more than 100 years ahead of their time. In the ensuing years, he would obtain close to 300 patents issued in 26 countries.[4]

The underlying theme behind Tesla's ideas and inventions was to harness nature to do the work of mankind utilizing renewable energy sources. He explored solar, geothermal, and hydroelectric sources of power, wanting to provide power through "the wheelwork of nature." His ideas and inventions were disruptive technologies that strove to relieve mankind from the burden of manual labor. They ranged from the use of energy to enrich soil with nitrogen to promote crop growth to electrical energy to promote health. Through his understanding of electricity and capacitance of the earth, he achieved the wireless transmission of signal and power. His use of the earth's conductivity preceded and predicted the later use of sonar. He developed practical applications of remotely controlled machines and tried to sell the United States Navy on the idea of remotely controlled torpedoes and the use of radar to identify and locate the position of ships. He predated Rutherford and Bohr with his description of the atom.[1] He envisioned electric cars, trains, and airplanes, powered wirelessly. He accurately predicted that rapid air travel would not be achieved by propeller planes and anticipated the jet engine. One of his patents in 1928 was for a vertical take-off and landing (VTOL) aircraft.[1,4] Tesla's concept of his wireless transmitter anticipated the world-wide web and the cell phone.[1,5] The clarity of his writing and his dramatically demonstrated lectures inspired many future pioneers in the field of electrical innovation.

Some of His Most Renowned Inventions

AC Motor

Tesla first encountered the Gramm Dynamo during his university physics course. Troubled by the inefficient and sparking commutators that transformed AC power into DC, Tesla began to focus his imagination and energies on eliminating the commutator and developing an AC motor. In 1882, he conceived the idea of the rotating magnetic field and developing a polyphase AC induction motor. He did not formally patent the motor until May 1888. His presentation to the IEEE in the same year introduced both his polyphase induction motor and a system for the generation and distribution of power, emphasizing the benefits of alternating current. A dominant advantage of alternating current was that the voltage could be stepped up with the aid of a transformer, allowing power transmission over long distances, whereas direct current was limited to a 1 to 2-mile range. On arriving at its site of use, the voltage could then be stepped down again to the requirements of the load. Tesla's creation of an AC motor and his promotion of AC current helped win the "War of the Currents" between the Westinghouse corporation on the side of AC power transmission and the Edison Company on the side of DC power transmission. With the development of an AC motor, current could provide more than light; it could now power industries. When Westinghouse won the contract to build the power plant at Niagara Falls, the die was cast and the AC system was adopted. The hydroelectric power plant at Niagara first powered the city of Buffalo and later New York City. Completed in 1895, this plant set the standard for modern hydroelectric power plants. Today, electric motors utilize 45% of the power consumed worldwide.[6]

Phosphorescent (Fluorescent) and Neon Lighting

Edison was not the only inventor to develop an efficient and commercially viable lightbulb. Tesla's first patent in the US in 1886 was for an improvement in arc lighting. When the Westinghouse corporation won the contract to provide electrical power to the 1893 Chicago World's Fair, they had to provide both power and lighting that did not infringe on the Edison patents. Tesla not only created new bulbs, but also created new shapes for bulbs, forming them into geometrical shapes and writing out words and names of famous scientists, similar to neon lights of today. He later experimented with phosphorescent materials, laying the foundation for fluorescent lighting. He recognized the inefficiency of incandescent lights that burned with 6% efficiency. Some of Tesla's initial investigations into high frequency high potential power sources (the spark gap oscillator and the Tesla coil) were aimed at developing a new lighting system. His high voltage – high energy system could wirelessly light up his rarefied gas tubes at up to 120 feet from the power source.[7,8]

Tesla Coil

Perhaps the most visually dramatic invention associated with Nikola Tesla is the Tesla coil. The coil was a resonant transformer capable of generating high voltage, high amplitude, and low current electrical force. By tuning the primary and secondary coils, extremely high voltages could be generated. If the electrical potential generated in the secondary coil is not put to work, the potentials boil off as a corona of bluish light or as sparks and streamers that jump to nearby conductors. By attaching the secondary coil to an aerial, the Tesla coil becomes a powerful radio transmitter. In the early days of radio, most transmitters used Tesla coils. For Nikola Tesla, larger or smaller versions of this coil enabled him to conduct experiments with high voltage. He used versions of his coil to investigate phenomena such as fluorescence, x-rays, and radio transmission. This was the foundation for his idea for the wireless transmission of power. Today, the Tesla coil has limited uses, other than creating spectacular special effects (Fig. 2).

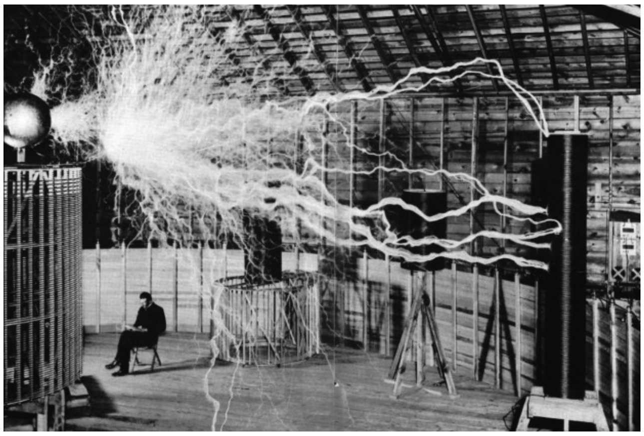

FIGURE 2. Multiple exposure image from 1899 during his high-voltage experiments while in Colorado Springs.

Wireless Signal Transmission

Who was the father of radio? Like many inventions, the answer is not simple. Tesla demonstrated short-distance signal transmission as early as 1893; however, his notes and research apparatus were lost in a fire in 1895. In 1897, he transmitted a signal from his lab in lower Manhattan to West Point, a distance of 30 miles. Tesla built on the work of others in wireless signal transmission, yet his innovations advanced the field in unique and transformative ways. He recognized the importance and developed the means of creating signals and receivers tuned to specific frequencies. He identified and reported on the observation that vacuum tubes could detect radio waves. The patent office initially upheld Tesla's patent priorities and rejected Marconi's patent application, stating, "Marconi's pretended ignorance of the nature of a 'Tesla Oscillator' being little short of absurd … the term 'Tesla Oscillator' has become a household word on both continents."[9] Only with the retirement of John Seymore from the patent office in 1903 was Guglielmo Marconi able to obtain a patent in 1904. Through the infringement of Tesla's patents Marconi successfully achieved long-distance signal transmission. After a long legal battle filled with treachery and interrupted by two world wars, the 1943 United States Supreme court decision resolved the question of patent priority awarding the patent to Tesla. Sadly, it occurred five months after Tesla's death and 34 years after Marconi received the Nobel Prize for achievements in wireless signal transmission based on the patents of Nikola Tesla.

Robotics

Tesla is considered by some to be one of the pioneers in robotics, both in vision and in practice.[10] In 1898 at an electrical exhibition, Tesla demonstrated his "teleatomaton," a radio-controlled boat that used coded pulses of electromagnetic waves to change direction or flash lights. The boat was operated at a remote distance by Tesla. The boat demonstrated how wireless technology could be used to command ships and missiles from a distance. Although Tesla proposed to develop this for the Navy, they did not appreciate the value of such a device at the time.[11,12] Tesla further recognized the value of a feedback loop for the ability of a machine to "learn." He later worked on a vehicle that would have the ability to learn from past experience to avoid obstacles.[10]

Shadowgraphs

During the course of Tesla's investigations into lighting sources, he began working with a photographer to use his lights to reduce photographic exposure times. During that same period, he was also experimenting with cathode rays. He and his photographer noted that there were unaccountable marks and defects on the unexposed photographic plates stored in the laboratory. Other unexplained "ruined photographic plates" were not further investigated, although Tesla speculated that the effects may have been produced by the cathode ray. Only after Roentgen's 1895 publication did Tesla's photographic collaborator realize that the damage to the photographic plates had been caused by these x-rays. Thereafter, Tesla rushed to produce radiographic images using his high-voltage, high-frequency oscillating transformers.[1,11] He was neither the first to accidentally nor deliberately produce x-rays in the United States, but he did produce very high-quality images with his powerful beams[11,13,14] (Fig. 3). He was also the first to warn against the negative effects of x-rays, initially attributing these effects to the production of ozone. He later recognized the danger of the rays themselves and wrote about the damaging health effects of the rays, particularly the skin effects. He provided recommendations for reducing risks by shielding and maintaining a minimum of 14 inches from the tube to the subject.[11,15]

Bladeless Turbine

Tesla's "powerhouse in a hat" was a new design for power generation. Turbines convert kinetic energy from a moving liquid or gas to mechanical energy. Tesla's bladeless turbine used the adhesion properties of fluids and gases (boundary layer drag) to spin a series of metal disks connected to a central rotor. As fluid (or gas) entered from the periphery, the fluid would spin more rapidly toward the center, like a whirlpool, generating mechanical energy. If the flow was reversed from the center to the periphery, then the turbine functioned as an efficient pump. The advantages of the bladeless turbine included easier manufacture, fewer moving parts, and higher efficiency with less energy lost to heat. In one of his earlier prototypes, he was able to generate 30 horsepower with a 10-pound machine.[11,16] As the rotor gained higher speeds greater power was produced, but the metal disks began to deform. Although Tesla claimed efficiencies of 60–97%, subsequent studies have found only a 40% efficiency.[17] By the time Tesla was able to develop a commercially practicable model, the internal combustion engine was entrenched in the power mechanics of the day. As material science has evolved, some companies have resumed experimentation with these designs.[11]

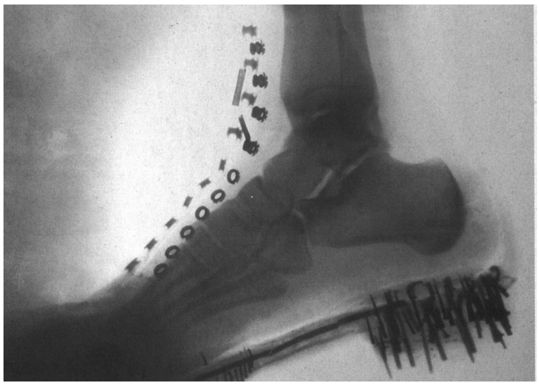

FIGURE 3. Shadowgraph image of Tesla's foot in a boot, 1896.

Magnifying Transmitter (Wireless Transmission of Power)

As early as 1893, Tesla was able to wirelessly transmit power within his laboratory. As he continued to experiment with high frequency power, he began to envision not only long-distance signal transmission, but also long-distance power transmission. He moved his experimentation to Colorado Springs, working on concepts of high-frequency standing waves transmitted through the earth. When he returned to New York in 1900, he convinced J.P. Morgan to invest in his plans for a trans-Atlantic signal transmission. The property for the first station was in Shoreham New York, named Wardenclyffe. A second station was to be built in England. Tesla had been given freedom of design but a fixed budget. Consumed by his vision of wireless power transmission, he over-designed his signal station and was soon out of money. His dream of Wardenclyffe would eventually be his downfall. After he lost financing, he never recovered financially or emotionally. He could not bring his dream to a practical and commercially profitable application. Today's engineers do not think that the scale of wireless power transmission would have functioned as Tesla envisioned, but it was an idea ahead of its time.

Drifting into Obscurity

It is noteworthy that many electronic experimenters and electrical engineers of the post-World War II had never heard of Nikola Tesla. Advances in technology and the introduction of the transistor were relevant to this historic omission. However, patent disputes and personal agendas also played a role in this oversight. References to Tesla's work were deliberately removed from standard text books,[1] and other scientists would blatantly take credit for Tesla's work.[9]

Tesla's personality played a part in his passage into obscurity. Given his ability to visualize projects and perform thought experiments, he frequently failed to follow through with practical experimentation or independent verification of his findings. He enticed financial support for commercial development for one project, but would use those funds to pursue other interests, principally, his vision of the wireless transmission of power. Tesla never recovered from the loss of the Wardenclyffe Magnifying Transmitter. He did continue to work on projects and consulting work with the hope of gaining sufficient funds to reclaim and complete Wardenclyffe. In his later years, his public interviews made fantastic claims that sounded like the work of science fiction. To the press, he became an eccentric avuncular figure who told tall tales.

As noted in Walter Isaacson's book *The Innovators. How a Group of Hackers, Geniuses, and Geeks Created the Digital Revolution*, "Innovation is driven by people who have both good theories and the opportunity to be part of a group that can implement them."[18] Tesla was a loner and either through a fluke of his personality or distrust of others he did not have the resources as an individual to develop his ideas and experiments into commercial production and practical application.

The range and depth of the ideas and inventions of Nikola Tesla are beyond the scope of a small article. Multiple books and websites attest to the brilliance of this man out of time. There is no doubt that Nikola Tesla stood upon the "shoulders of giants," yet he is still one of the giants upon whom scientists and engineers stand today. So the next time you see the magnet strength on the MRI report, you will have some appreciation of the man behind the initial.

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