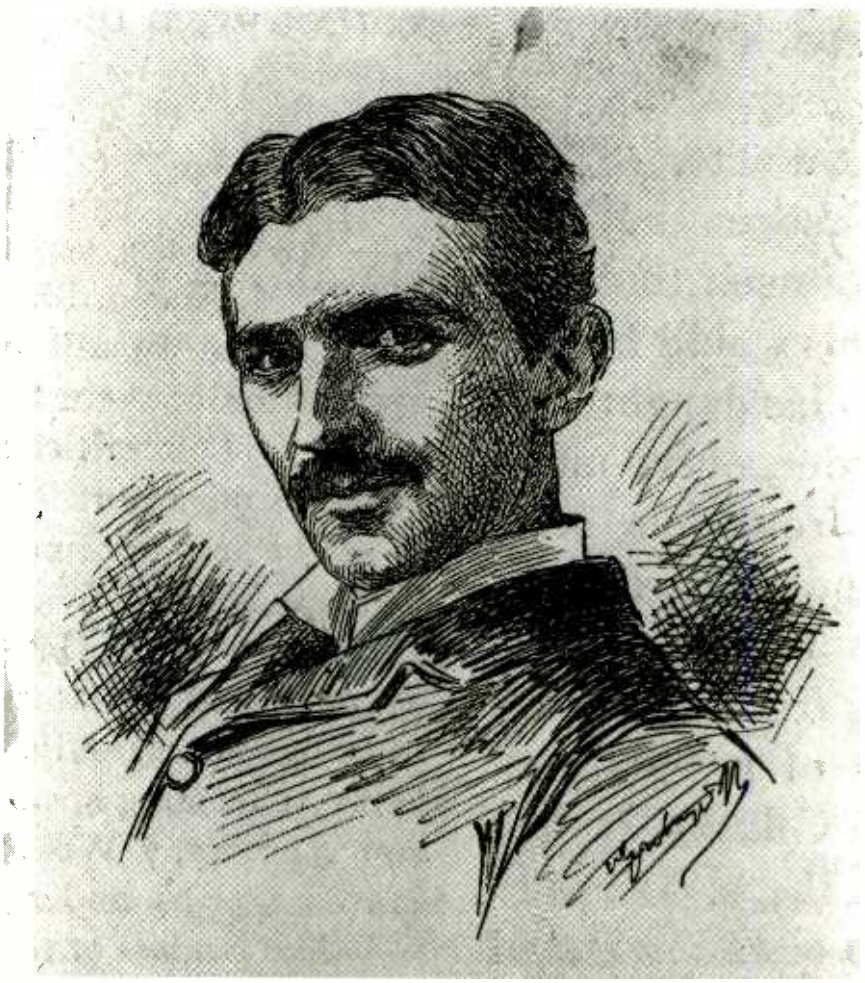
Nikola Tesla: Scientific Savant

Calling Tesla merely "an inventor" would be like referring to Frederic Chopin as simply "a piano player."

JAMES P. RYBAK



What would cause a person to refuse a Nobel Prize? A 1915 Reuters dispatch from London stated, albeit unofficially, that Nikola Tesla and Thomas Edison had been chosen to share that year's Nobel Prize in physics. Numerous magazines and newspapers throughout the world published this report as fact. However, the awards were never made either to Tesla or to Edison. The complete story is not known, but many believe that Nicola Tesla may have refused to accept the award.

Tesla was very much in need of the $20,000, which would have been his half of the cash award accompanying the Nobel Prize. His work had resulted in the creation of fortunes for many others; but he, himself, lived much of his later life in near poverty and he would die penniless. If Tesla did decline the Nobel Prize, it likely was a matter of principle that precipitated his decision to refuse this prestigious honor. From Tesla's perspective, Edison was merely an "inventor" who devised useful applications of science. Tesla, meanwhile, considered himself a "discoverer" of new scientific principles and only, incidentally, an inventor. In Tesla's mind, the importance of the discoverer far outweighed that of the inventor.

Others believe that it was Edison who refused the award. Perhaps he was still angry that Tesla had quit working for the Edison Company and had aligned himself with Edison's arch competitor, Westinghouse.

Two years later, Tesla initially refused to accept the Edison Medal that the American Institute of Electrical Engineers (AIEE) planned to award him for his outstanding work in the development of alternating current theory and applications. Perhaps Tesla was miffed because it had taken the AIEE almost thirty years to recognize the significance of his work. Perhaps, too, Tesla was insulted to be given an award named after the person who had so strongly opposed the adoption of alternating current power distribution systems and who, Tesla believed, had reneged on a promise to pay him a large amount of money for solving important technical problems. In any event, it was clear that awards meant nothing to Tesla. It took an AIEE official several visits together with much coaxing and pleading before he could get Tesla to agree reluctantly to accept the Edison Medal. Tesla then almost failed to appear at the award ceremony.

Who was this man, this pioneer

whom many obviously have admired for the past century? Join us for a look at this savant's life and his accomplishments. As you'll see, forgetting Tesla is unforgivable for electronics activists. We owe him much.

Early Days. Nikola Tesla was born in 1856 to Serbian parents who lived in a Croatian village in the southern part of the Austro-Hungarian Empire. His father had abandoned a military career to become a priest in the Serbian Orthodox Church. Although Nikola's mother had received no formal education, she was bright and had an exceptional memory. Tesla always credited his mother as the source of his intellectual abilities.

Mathematics was Nikola Tesla's favorite subject in school and the one in which he truly excelled. When given a problem to solve, he needed neither a blackboard nor a sheet of paper. Tesla had the extraordinary ability to visualize in his mind all the steps needed to solve the problem, just as though he had written them down. The ability to visualize mathematical problems and engineering designs clearly in his mind was of great value to Tesla throughout his life

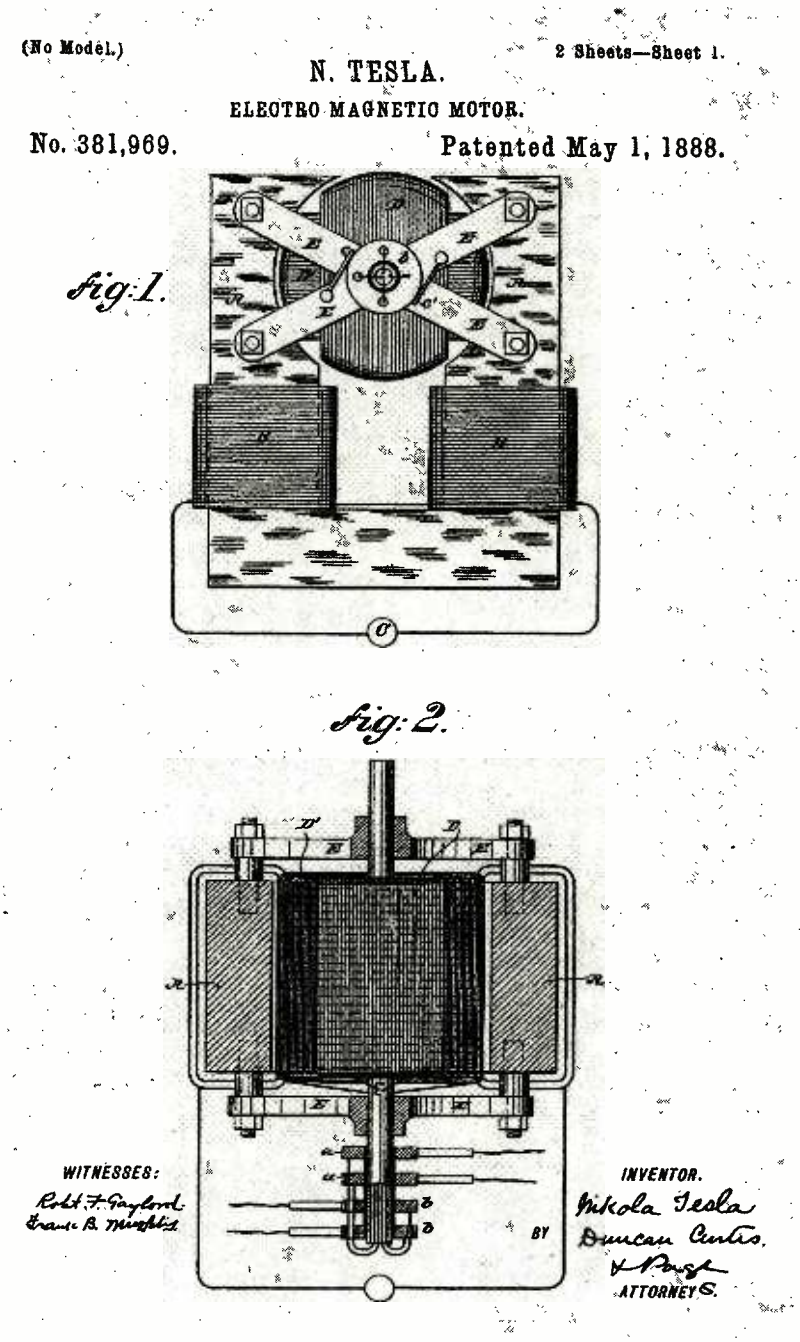
As a child, Nikola loved to read and retained knowledge extremely well. He also learned several foreign languages. This enabled him to read far more than what was written in his native Serbo-Croatian. Young Tesla loved to devise complex mechanical devices in his mind and then build them from whatever materials were at hand.

While in what we would call high school and the first years of college, Tesla studied so intensely that his health was seriously affected. His father feared that engineering, which required many years of intense study and to which young Nikola aspired, would further jeopardize his son's well being. The elder Tesla urged the boy to enter the ministry because that profession required a less demanding program of study. Periodic episodes of severe illness due to overwork would plague Tesla throughout his life.

Although further weakened when he contracted malaria, Nikola successfully completed the four-year Higher Real Gymnasium (college) program in Croatia in only three years. It was during this time that Tesla became unalterably determined that he wanted to devote his life to electrical experimentation.

Upon his return home, Tesla's parents were alarmed by their son's demanding career choice and by the unrelenting pace at which he continued to pursue his studies. His health was still very much at risk, and they again insisted that he become a priest, not an engineer. Very quickly, Nikola experienced the additional discouragement of contacting cholera and receiving his draft notice for army service.

Tesla now became despondent and was almost at death's door. He knew that if he survived the cholera, he would have to serve time in the army and then study for the priesthood. He felt he had nothing to live



Tesla's second AC patent, granted in 1888, was for a then-groundbreaking induction motor.

for. Upon realizing this, Nikola's father relented and gave permission for his son to study electrical engineering.

Tesla slowly began to regain his health. His father then sent him off for a year's rest to further recover his health. During this time, the elder Tesla used the influence of relatives to get his son's military obligation cancelled.

Committed to Developing AC. In 1875, Tesla went to the city of Gratz, Austria to study electrical engineering. There he still continued to overwork himself and again jeopardized his health. It was at this time that Tesla realized the inherent limitations of DC motors and generators due to the sparking associated with commutator action (the switching of current polarity in a motor to keep the armature coil moving). This discovery clearly convinced Tesla of the need to develop alternating current motors and generators that would not need commutators.

Developing the details of how this goal could be accomplished occupied much of Tesla's time for the next several years. He rejected the claim of his professor who taught the courses on motors and generators that the development of AC motors and generators was an "impossible idea."

It was "instinct" that told Tesla his professor was wrong. Tesla's instincts were almost always correct when it came to solving scientific problems. Nonetheless, progress toward his goal did not come quickly.

Following some additional engineering study in Prague, Tesla went to Budapest in 1881 where a family friend had offered him a job at the new telephone central station that was being started. Tesla's design, computational, and estimating abilities soon attracted the attention of his supervisors. When the telephone exchange was completed, Tesla was placed in charge of its operation. Once again, Tesla worked excessively and his health rapidly declined. Exhaustion soon forced him to quit his job.

The Key AC Concept. In February of 1882, shortly after recovering his health, the solution to the alternating current problem came to Tesla. He now could visualize clearly in his mind how he would use alternating currents to create a rotating magnetic field. This was the key concept needed to produce a practical AC motor.

Tesla created the rotating magnetic field by using two circuits in which the currents were out of phase with each other. Others had tried to develop AC motors using only one circuit, but their approach could not produce continuous rotation of the motor. Nikola Tesla's two-phase system successfully eliminated the need for a commutator.

The work Tesla had begun was far from completed, however. He now developed designs for dynamos (generators), motors, transformers, and the other devices needed for alternating-current power systems. Tesla extended his rotating magnetic field idea to include currents of three, four, and six different phases. Nikola Tesla had developed in his mind a true polyphase power system. He also believed that he could even build a successful single-phase AC motor.

The telephone company in Budapest where Tesla had worked prior to his illness and to which he had hoped to return was sold. The same family friend who had helped Nikola get his job in Budapest now helped him obtain a job in Paris with the Continental Edison Company, which was licensed to make DC motors, generators, and lighting equipment under Edison's patents.

Tesla tried to interest every likely person he could find in Paris to help him develop his polyphase AC system. He did not have to worry about people stealing his ideas as no one showed any real interest in them at all.

Tesla was assigned to a special project in Germany. Here he used his spare time to build a two-phase generator and a two-phase motor. Tesla did the close tolerance machining work himself. There were no working drawings on paper. Tesla had all the details clearly fixed in his mind. When he first tested the AC machines in 1883, they functioned extremely well. His theory was correct.

Upon returning to Paris after successfully completing the project in Germany, Tesla became dissatisfied with his immediate supervisors. He had been promised a generous bonus for his successful work in Germany but that bonus was never given. Indignant, Tesla decided not to show the Company officials his two-phase system in operation and resigned his position.

Tesla Meets Edison. Continental Edison's manager, Charles Batchelor, was an associate and good friend of Thomas A. Edison. Batchelor was impressed with Tesla and urged him to go to the United States to work directly with Edison.

Tesla welcomed this suggestion together with a letter of introduction to Edison that Batchelor is said to have written for him. Batchelor's

SUGGESTED READINGS

Cheney, Margaret; *Tesla—Man Out of Time*, Dorset Press, New York, NY, 1989.

Gernsback, Hugo; "Nikola Tesla and His Inventions," *The Electrical Experimenter*, January 1919, p. 614.

Glenn, Jim (editor); *The Complete Patents of Nikola Tesla*, Barnes & Noble Books, New York, NY, 1994.

Hunt, Inez and Draper, Wanetta W.; *Lightning in His Hand – The Life Story of Nikola Tesla*, Omni Publications, Hawthorne, CA, 1964.

O'Neil, John J.; *Prodigal Genius—The Life of Nikola Tesla*, Ives Washburn, Inc., New York, NY, 1944.

Secor, H,. Winfield; "The Tesla High Frequency Oscillator," *The Electrical Experimenter*, March 1916, pg. 614.

Seifer, Marc J.; *Wizard: The Life and Times of Nikola Tesla*, Birch Lane Press, Secaucus, NJ, 1996.

Tesla, Nikola; "The Problem of Increasing Human Energy," *The Century Magazine*, June 1900, p. 175.

Tesla, Nikola; "My Inventions," *The Electrical Experimenter*, February 1919, p. 696; March 1919, p. 775; April 1919, p. 864; May 1919, p. 16; June 1919, p. 112; October 1919, p. 506. Also reprinted in edited form with an introduction by Ben Johnston; *My Inventions*, Barnes & Noble Books, New York, NY, 1995.

letter to Edison reportedly stated "I know two great men and you are one of them; the other is this young man." Tesla sold his personal possessions to pay for the train and ship tickets he needed and left for New York in 1884.

Because his wallet and extra clothes were lost during his travels, Tesla arrived in the United States with little more than the four cents in his pocket and the clothes on his back. Fortunately, Tesla had a friend in New York with whom he could stay temporarily.

While Tesla was very favorably impressed with Edison when the two men first met, the reverse was not true. Edison had very little formal education and did his inventing by trial and error experimentation, whereas Tesla solved all his technical problems mentally and did virtually no experimentation. Perhaps an even greater barrier was that Edison was an unshakable proponent of DC power systems and was strongly opposed to the development of AC systems. Tesla was firmly convinced of the superiority of AC. Despite these fundamental differences, Edison gave Tesla a job, likely on the basis of Batchelor's recommendation.

Edison quickly saw that Tesla consistently put in long hours and made many valuable contributions. When Tesla suggested that he could improve the efficiency and lower the operating cost of the DC dynamos the Edison firm manufactured, the plant manager reportedly told him "There's fifty thousand dollars in it for you if you can do it."

During the following months, Tesla designed twenty-four new types of DC dynamos. He replaced the previously used long field magnets with more efficient shorter ones and added some important automatic controls. The machines performed as Tesla had promised and the Edison firm took out numerous new patents.

In the spring of 1885, when Tesla asked for the fifty thousand dollars he believed he had been promised and had earned, Edison's reply was "Tesla, you don't understand our American humor." Furious because he received not an extra dime beyond his $18 per week salary for all the successes he had produced, Tesla immediately quit his job with Edison.

The Tesla Electric Company. Tesla now was unable to find an engineering job and was forced to work as a laborer. In early 1887, Tesla's abilities and stories about his AC developments attracted the attention of the foreman of the labor crew on which Tesla worked. The foreman also was working far below his own level of training and was sympathetic to Tesla's situation. He introduced Tesla to A. K. Brown of the Western Union Telegraph Company. In April of 1887, Brown and a friend provided the money to create the "Tesla Electric Company." By coincidence, Tesla's new laboratory was located within sight of Edison's facility.

Quickly, Tesla built not only the two-phase AC generator and the induction motor he had built in Europe but also the other machines he had designed in his mind while in Budapest. While concentrating on single-phase, two-phase, and three-phase systems, he also experimented with four- and six-phase devices. Tesla also developed the mathematical theory needed to explain the operation of his AC systems so that others could and would both understand and accept his work.

After having proven that his AC systems were practical, Tesla applied for a number of fundamental patents. These were granted to him in 1888. Word of Tesla's accomplishments and genius spread quickly. On May 16, 1888, Tesla was invited to present a lecture entitled "A New System of Alternate Current Motors and Transformers" at an AIEE meeting in New York. He now was a recognized and accepted member of the electrical engineering "establishment."

George Westinghouse was a farsighted individual who already had made a fortune in Pittsburgh manufacturing his air brake for trains as well as a variety of electrical devices he had invented. He recognized the major advantages which AC power systems held over DC and he saw huge commercial potential in the work Tesla had done.

The DC electrical systems favored by Edison could not be used to distribute power farther than about one-half mile from the generator due to the excessive voltage drops that resulted from the resistance of the power lines and the large currents that flowed through the lines. AC voltages, however, are stepped-up at the generator using transformers, thereby reducing both the current and the transmission losses. The result is a substantially increased distribution range. Transformers then convert the AC voltages to safe levels at the point where the power is utilized.

An Alliance with Westinghouse. Shortly after Tesla gave his AIEE lecture, he was contacted by Westinghouse who wished to see the AC equipment in person. The two men had many interests in common and immediately formed a good relationship. Westinghouse quickly offered Tesla one million dollars for his AC patents. He also invited Tesla to come to Pittsburgh for a year at a "high" salary as a consultant. Tesla quickly agreed. Half of the one million dollars went to A. K. Brown and his partner who had financed Tesla's work but Tesla still was now rich beyond his wildest dreams.

Problems developed when Westinghouse's engineers tried to use Tesla's designs to produce small, single-phase motors. In addition, the priorities and urgencies associated with manufacturing AC power systems for sale were different from Tesla's research priorities. Furthermore, Tesla was adamant that his AC machines worked most efficiently at a frequency of 60 Hz (then "cycles per second") while Westinghouse's engineers had been used to working with frequencies of 133 Hz.

Dissatisfied with working for others, Tesla returned to his New York laboratory. He was now independently wealthy and wanted to return to his research. He rejected a very lucrative offer by Westinghouse to remain in Pittsburgh on a permanent basis. Soon after leaving Pittsburgh, Tesla was granted U.S. citizenship.

High-Frequency AC. Aware that

the electromagnetic spectrum extends all the way up to visible light and beyond, Tesla now investigated the behavior of his circuits at higher frequencies. Part of his work would result in transformers, which we, today, call "Tesla coils." Another part of this work would result in tuned circuits.

While developing his mathematical AC circuit theory, Tesla became aware of the roles played by inductance and capacitance in producing electrical resonance. He found that he could produce extremely high voltages with frequencies measured in tens or hundreds of kHz by adding the appropriate amount of capacitance to the primary of an air core transformer. (While iron cores make 60-Hz transformers perform well, they severely degrade transformer performance at high frequencies.) A spark gap discharge connected to the transformer's primary winding resulted in an oscillator which produced high-frequency, high-voltage discharges.

As he predicted by theory and confirmed by experiment, Tesla quickly established that high-frequency AC current flows along the surface of the human body rather than through it. Thus, no electrical shock is felt. As early as 1890, he recognized the therapeutic value high-frequency electric fields could produce in the human body. The effect became known as "diathermy."

Tesla gave his first public lecture and demonstration concerning his high-frequency work to the AIEE in May of 1891. In addition to producing long electrical sparks from his fingertips, Tesla created electrical sheets of flame and caused sealed tubes of gas (Geissler tubes) to glow even though there was no direct electrical connection to the tubes. This spectacular demonstration, coupled with his AIEE lecture on polyphase AC power systems three years earlier, established Tesla as a premier scientist and engineer.

Tesla Demonstrates Wireless. At the Spring 1893 meeting of the National Electric Light Association in St. Louis, Tesla gave his first public demonstration of the wireless transmission of electrical energy and, thereby, the feasibility of wireless communication. On one side of the stage, Tesla had a tuned circuit consisting of a bank of Leyden jar capacitors and a coil. The tuned circuit was connected to a spark gap and a 5-kVA power-distribution transformer. A vertical wire (antenna) extended from the coil to the ceiling. This arrangement formed his "transmitter."

On the other side of the stage Tesla had his "receiver," which consisted of another, identical tuned circuit with a vertical wire extending to the ceiling. A gas-filled Geissler tube was connected to this tuned circuit in place of the spark gap used with the transmitter.

No wires connected the transmitter and receiver. When Tesla applied power to the transmitter, the Geissler tube in the receiver glowed brightly. This demonstration occurred two years before Marconi went to London with his wireless telegraphy equipment. Soon, Tesla was routinely causing gas-filled tubes to light in a manner that predicted the development much later by others of neon signs and fluorescent lamps.

At this same time, a grand example of the value of Tesla's polyphase AC system was being undertaken. The concept of harnessing the energy of Niagara Falls and using it to generate electricity had been discussed for some time. Now the technology existed to achieve this goal. If the power of Niagara were to be used to generate DC, the area over which this potentially huge amount of electricity could be distributed would be very small. Even Buffalo, only 22 miles away, could not be served if DC were generated.

Both the Westinghouse Electric Company and the General Electric Company (successor to the Edison General Electric Company) submitted proposals in 1893 to install a Tesla polyphase system. GE, now a firm believer in AC since Edison no longer controlled the restructured company, had obtained a license to use Westinghouse's Tesla patents.

Westinghouse won the contract for the generating plant at Niagara while GE was chosen to build the transmission line to, as well as the distribution system within, Buffalo. The plant was delivering power in 1895, and the transmission line was completed the following year. Tesla's stature as a technological hero was reinforced once again.

From 1891 until 1893, Tesla lived the life of a celebrity. He was in constant demand at scientific and high society gatherings both in the U.S. and abroad. Lectures and spectacular demonstrations were given in both London and Paris. Now Europe, too, fully appreciated the magnitude of Tesla's accomplishments. Tesla then abandoned the active celebrity life, because it kept him from the research he loved. However, he had become attracted to the trappings of affluence and would endeavor to maintain that image for the rest of his life, even when he clearly could not afford to do so.

The previous successes Tesla had achieved in making sealed tubes of gas glow when in the vicinity of his high-frequency, high-voltage transformers demonstrated that wireless transmission of electrical energy over short distances was possible. Now Tesla wanted to develop that concept further—much further. He envisioned transmitting energy without wires, not only for communicating, but also for powering lights and motors around the world.

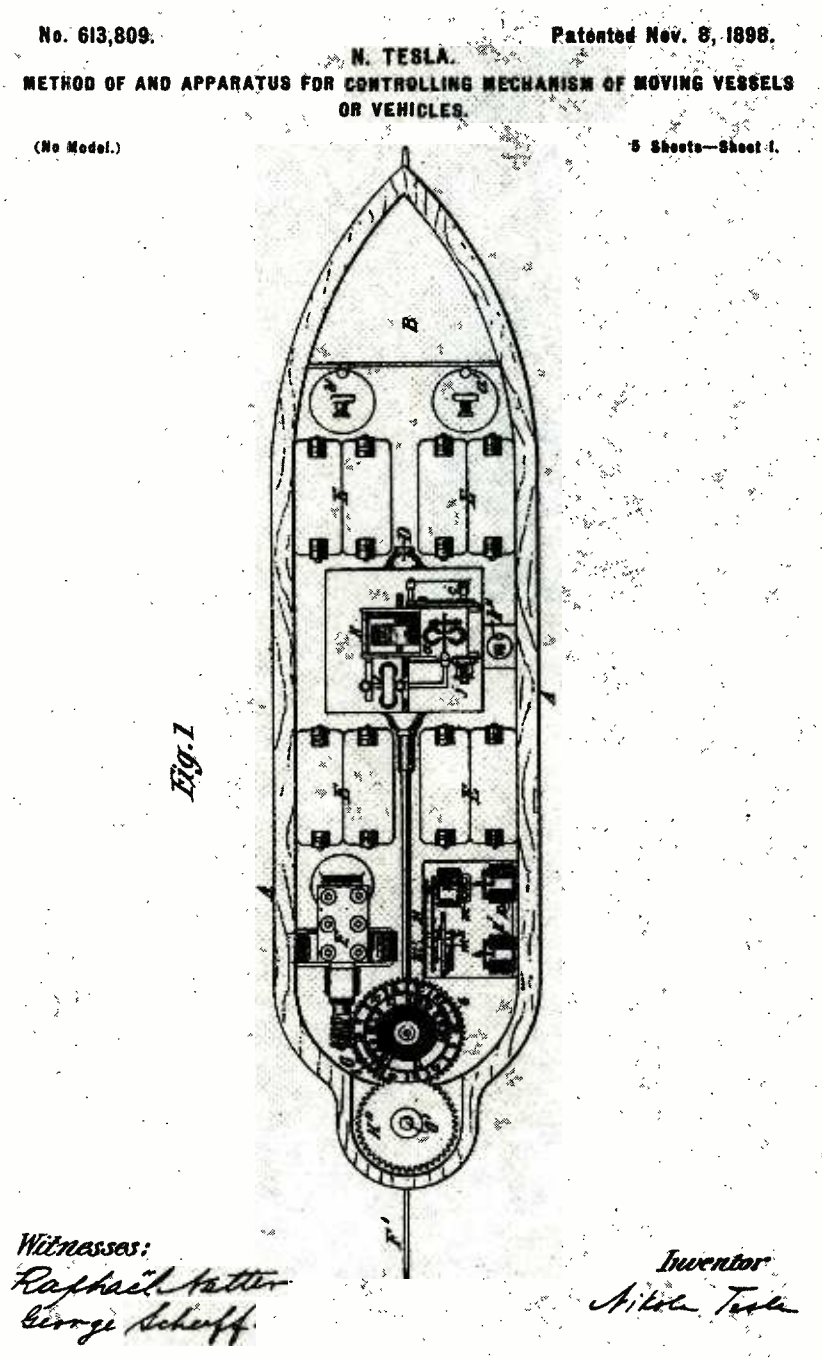
During the winter of 1894-95, Tesla built a transmitter at his laboratory together with a portable receiving station to test his latest plan. Successful wireless transmission was achieved over short distances. Then tragedy struck. Just as he was preparing to make the first public demonstration of his wireless transmission system, fire completely destroyed Tesla's laboratory together with all his equipment and records. Tesla was devastated. Virtually all his money had been invested in his work. Nothing had been insured.

With funds personally provided by the man who had organized the Niagara power plant project, Tesla painstakingly reconstructed his laboratory. He resumed the wireless transmission tests with his transmitter and portable receiver in the spring of 1897. The receiver was operated on a boat traveling up the Hudson

River, successfully demonstrating the feasibility of wireless transmission at distances of 25 miles. Tesla's two fundamental wireless patents (645,576 and 649,621) were issued in September of 1897. In 1943, the U.S. Supreme Court would rule that this work of Tesla's, together with related, independent achievements by Oliver Lodge and John Stone, anticipated Marconi's work. As a result, Marconi's important 1904 wireless patent was declared invalid.

First RC Boat. A year later, in September of 1898, Tesla startled visitors to the Electrical Exhibition at New York's Madison Square Garden by demonstrating the world's first radio-controlled boat using what he called his "mind-powered" or "Teleautomatic" system. Tesla remotely controlled a 3-foot long iron-clad boat through a variety of maneuvers in front of large audiences every night for a week. To demonstrate its simplicity of operation, Tesla permitted volunteers from the audience to operate the controls. Patent number 613,809 was awarded to Tesla for this invention. His goal was to sell a similar remotely operated submarine to the U.S. Navy for use in the Spanish-American War. Tesla hated war and felt his invention could save lives. The Navy was not interested.

Tesla had long been the beneficiary of good press coverage concerning his numerous previous inventions. Now he attempted to enlist assistance of the press to create public support with the hope of pressuring the Navy into using his invention. Tesla's written announcement concerning his "mind-powered" submarine together with his responses at a press conference were too fantastic, even for the press of that day which normally thrived on sensationalism. As a result, Tesla found himself criticized in print by some of the members of the press for, what seemed to them as, his exaggerated claims and blatant attempts at headline-seeking. Nonetheless, the journalists still found Tesla's activities to be of great interest to the public. However, as Tesla continued to announce what seemed to be ever more fantastic plans,



In 1898 Tesla demonstrated the world's first radio-controlled boat, and received another patent for a device that would survive him in some form for decades.

the enthusiasm of the press became tempered with skepticism.

Tesla was anxious to proceed with his planned project to beat Marconi in establishing a worldwide wireless communication system, as well as one for the global distribution of electrical power. The problem, again, was money until a wealthy friend loaned him $10,000. Now Tesla built a high-frequency oscillator, which generated 4 million volts, but the sparks produced were too large and violent for his New York City laboratory. More space was needed.

Off to Colorado. Leonard E. Curtis, a former Westinghouse lawyer who now was associated with the Colorado Springs Electric Company, invited Tesla to move his laboratory to Colorado. Curtis promised Tesla the use of land east of Colorado Springs

Shown here is the breathtaking discharge from Tesla's "magnifying transmitter" in Colorado Springs. (Courtesy of the Smithsonian Institution.)

as well as all the electricity he needed, both free of charge. John Jacob Astor, owner of the Waldorf-Astoria Hotel where Tesla now lived and had dined for years, provided the $30,000 needed to make the move and set up a laboratory.

Tesla arrived in Colorado Springs in May of 1899. Within three months, he built a laboratory complete with a tower and mast topped by a 3-foot copper sphere reaching 200 feet into the sky. A giant high-frequency oscillator, which Tesla called his "magnifying transmitter," also was readied. This magnifying transmitter incorporated a resonant transformer designed to electrically excite the earth and was optimized for maximum wireless transmission of energy. Tesla had carloads of laboratory equipment together with several assistants sent to him from New York.

Using a receiver connected to the earth to monitor the effects of the large number of lightning discharges that occurred in the region daily during the summer, Tesla reached a dramatic conclusion. He now was sure that the earth was filled with fluid electrical charges. Tesla believed that when this electricity is disturbed by repeated electrical discharges occurring at the proper time interval, resonant low frequency electrical waves of tremendous magnitude are produced.

Tesla had produced similar resonance effects in his electrical circuits. He reasoned that he could cause resonant waves in the earth with his high-voltage discharges. Tesla also believed that these waves would provide large amounts of electrical energy that could be tapped throughout the world.

Tesla's nighttime initial test of his new magnifying transmitter went well. Lightning bolts 135 feet in length surged from the top of the mast, and the resulting thunder crashes were heard 15 miles away. Then came silence and darkness.

At first, Tesla thought that his assistant had turned off the power. Finding that not to be the case, he telephoned the power company to demand that his power be restored. The curt reply from the power company was that his experiment had destroyed their generator. All of Colorado Springs was in darkness. A standby generator soon restored power to the city, but Tesla was told that his power would be restored only if and when he repaired their damaged generator.

One evening when the monitoring receiver was connected to the earth to listen for distant thunderstorms, Tesla heard three pulses in quick succession. He knew that these sounds were not characteristic of thunderstorms and declared that they must be of extraterrestrial origin. Later he concluded that the signals had not come from just any planet but that they had come from Mars!

On January 7, 1900, Tesla left Colorado Springs for New York. He had spent $100,000 in eight months and now was out of money. He intended to return to Colorado to conduct additional experiments once his finances were in better order, but this plan was never realized.

During his time in Colorado, Tesla performed many interesting experiments and learned much from them. However, there is no evidence that he succeeded in transmitting any significant amount of power over long distances without wires.

When he reached New York, Tesla was ridiculed by reporters for his claim of having heard extraterrestrial signals. Shortly afterward, he wrote a seemingly fantastic, metaphysical magazine article entitled "The Problem of Increasing Human Energy," which did little to help his believability in the minds of most people. His own extravagant claims and predictions again were eroding his credibility. Not every prediction in this article was preposterous, however. One prediction described the "radar" systems that were not developed by others until almost 40 years later.

During this same time, Tesla filed for and was granted several patents involving the use of cryogenic techniques for the underground transmission of high voltages. These anticipated similar developments that would later take place in the 1970s, both in the U.S. and abroad.

The Wardenclyffe Project. Tesla needed badly to obtain new financing for what would be his most ambitious project: a giant tower and laboratory with which he planned to establish worldwide wireless communication. There he also expected to refine his plans for wire-

No doubt Tesla's most ambitious project, the tower at Wardenclyffe was designed to establish worldwide communication—no small feat for the dawn of the 20th century. Unfortunately, Tesla lost the tower to creditors in 1915.

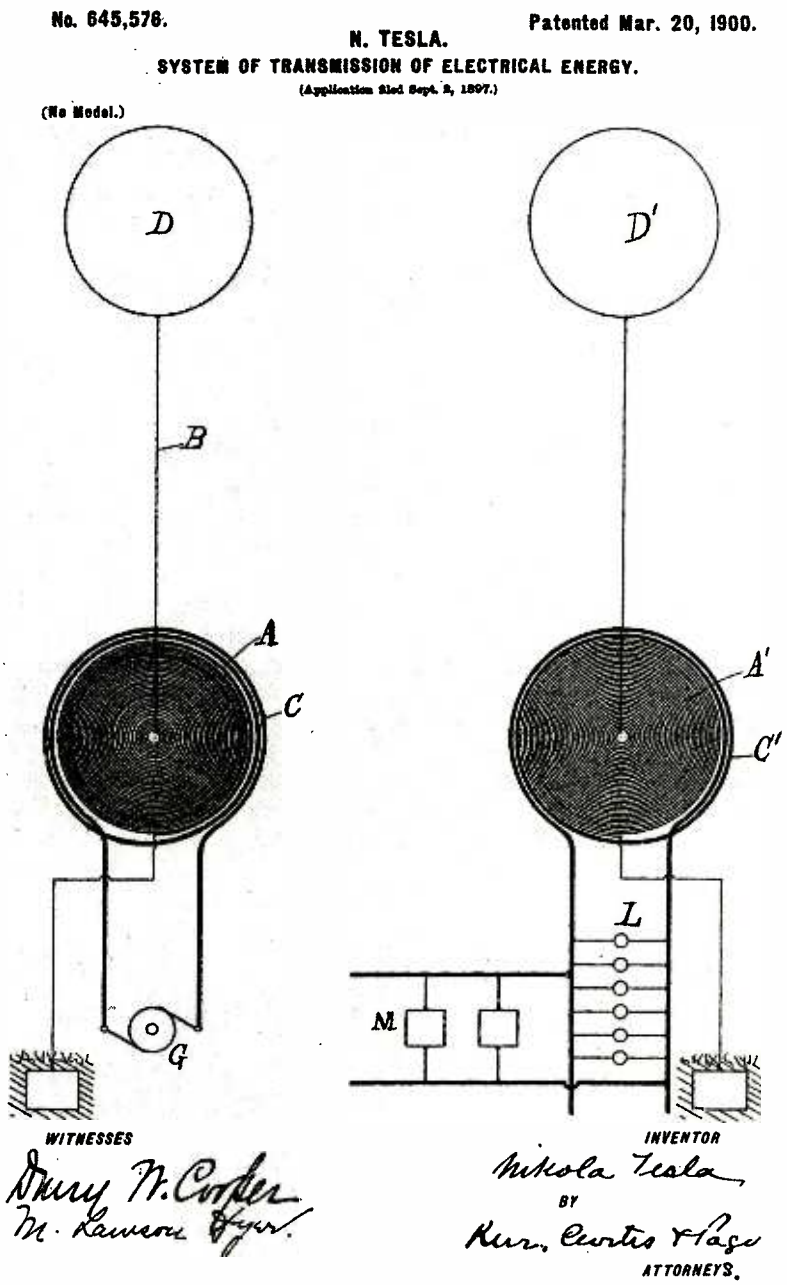
less electrical power distribution. Neither Westinghouse nor Astor was willing to loan Tesla the money he needed. J. Pierpont Morgan, however, did provide $150,000 to build the tower and other needed facilities at Wardenclyffe, Long Island in exchange for control of some patents Tesla still had.

Although Tesla wanted something taller, the finances available limited him to the construction of a tower 187 feet high with a hemispherical dome 68 feet in diameter. The Wardenclyffe project was still under construction in December of 1901 when Marconi succeeded in sending wireless telegraph signals across the Atlantic using much simpler equipment and facilities than what Tesla was proposing. Tesla contended that Marconi's equipment violated many of his (Tesla's) patents. Nonetheless, Tesla's plan was looking more and more extravagant.

Rapidly rising prices together with an overly ambitious design made it impossible for Tesla's Wardenclyffe project to be completed as planned. Creditors constantly hounded him and, despite Tesla's best efforts, additional financing could not be found. Negative rumors concerning the status of Tesla's remaining patents together with growing skepticism concerning his fantastic predictions made people wary. Tesla became despondent.

By 1906, virtually all construction at the Wardenclyffe site had stopped due to Tesla's inability to pay his bills. The high-voltage oscillator had been completed, but lack of funds made it difficult for Tesla to test it. When he did, however, people throughout Long Island and as far away as Connecticut could observe the bright flashes in the nighttime sky. However, no wireless transmission of messages or electrical power ever occurred from Wardenclyffe.

In 1915, Tesla finally lost Wardenclyffe to creditors. The tower was dynamited for its scrap value in 1917. Despite this huge setback, Tesla never gave up his ideas concerning wireless power transmission and broadcasting. Coincidentally, the years 1915 and 1917 also were the years of Tesla's alleged selection for the Nobel Prize and his receipt of the Edison Award, respectively.



The US Supreme Court in 1943 declared Marconi's important wireless patent of 1904 invalid due, in part, to this earlier patent of Tesla's.

Down, Not Out. While Tesla was dejected due to his inability to complete the Wardenclyffe project, his mind still produced many far-sighted ideas. He designed a VTOL (vertical takeoff and landing) aircraft during 1907-08. A turbine placed at the center of the aircraft had a propeller mounted above, as in a helicopter, for takeoffs and landings. Once airborne, the pilot operated a lever that moved the propeller to the front of the craft, as in a conventional airplane. Tesla did not build a prototype of this VTOL but was awarded patents on its design. In 1908, Tesla publicly described the limitations of propeller driven airplanes and predicted the development of jet aircraft.

Tesla filed for patents in 1909 on a powerful and lightweight "bladeless turbine," which appeared to have the potential to revolutionize the design of prime movers in terms

of horsepower produced per pound of weight. Tesla's turbine consisted of a series of horizontally stacked, closely spaced disks attached to a shaft and enclosed in a sealed chamber. A fluid (liquid or gas) under pressure entered the sealed chamber at the periphery of the disks. Viscosity caused the disks to rotate as the fluid moved in circular paths toward the shaft where it exited the turbine.

Successful small models of the turbine were built, but the inadequate materials then available together with Tesla's serious financial problems prevented his development of larger versions. Several firms paid for the rights to refine Tesla's turbine design, but their efforts were largely unsuccessful. The two patents Tesla was awarded on his turbine design in 1909 are still being studied today by engineers trying to develop this far-sighted design.

The Gernsback Connection. Shortly before the Wardenclyffe tower was demolished, a man named Hugo Gernsback renewed an old acquaintanceship with Tesla. Gernsback was editor of the magazine *The Electrical Experi-menter* that had evolved from his earlier publication, *Modern Electrics*. Both were similar in many respects to the two magazines, *Popular Electronics* and *Electronics Now*, currently published monthly by Gernsback Publications, Inc. During his lifetime, Gernsback would publish a variety of magazines devoted to electrical technology and related topics.

As a youngster in Luxembourg, Hugo Gernsback had first heard of Tesla and had become fascinated by his accomplishments. Fixed in Gernsback's mind was the photograph of Tesla he had seen which showed high frequency arcs of current passing through the electrical inventor's body. His admiration for Tesla would continue lifelong. Gernsback immigrated to the U.S. in 1903, at the age of 19, after having studied electronics in Europe. The two met briefly in 1908 but Gernsback had followed the press reports of Tesla's activities.

A legitimate scientist and electrical inventor in his own right, Hugo Gernsback was awarded 37 patents during his life. Most people, however, recognize him as the "Father of Modern Science Fiction." Gernsback authored a number of science fiction (or "scientifiction" as he initially called them) stories. He is better known, however, for publishing the science fiction works of many other popular authors in the various magazines he headed between 1910 and his death in 1967.

In 1916, Gernsback asked Tesla to edit a major article on the magnifying transmitter and the Wardenclyffe project. The article was published in the March 1916 issue of *The Electrical Experimenter*. Tesla needed the modest amount of money Gernsback paid him for this work. Gernsback, in turn, was pleased to publish this article about a device and project which, if Tesla had been successful, would have turned many science fiction predictions into reality.

In 1919, Tesla wrote a 6-part series entitled "My Inventions," which Gernsback also published in *The Electrical Experimenter*. Articles by or about Tesla still fascinated Gernsback's readers.

In 1983, the United States honored Tesla with a postage stamp.

Tesla continued to spawn new ideas in his mind. However, as time went on, more and more of these ideas seemed in the realm of science fiction and some appeared even to violate the known laws of nature. Several of his more fantasy-like ideas included a machine for capturing and utilizing the energy of cosmic rays, a technique for communicating with other planets, and a particle-beam weapon for destroying a fleet of 10,000 enemy aircraft at a distance of 250 miles.

Some of Tesla's ideas were more practical, and occasionally he was able to sell to others the rights to develop these concepts. Designs for an automobile speedometer and a locomotive headlight were particularly innovative and practical. These sales provided him with a small amount of money but, due to his many staggering debts, he lived in near-poverty for the rest of his life. Despite his chronic financial problems, Tesla always tried to project a personal image of sophistication and elegance.

Tesla was saved from complete destitution in 1934 when the Westinghouse Corporation agreed to pay his hotel rent together with a monthly stipend to serve as a "consultant." In exchange, Tesla agreed to drop his complaint that Westinghouse had violated his wireless patents. The government of Yugoslavia charitably awarded Tesla a pension of $600 per month in 1937. Anxious creditors eagerly awaited the monthly arrival of these funds.

Tesla became virtually a total recluse and an extreme eccentric in his last years. His main contacts were with the city's pigeons that he cared for and fed. Tesla died alone in a small hotel room on January 7, 1943 at the age of 86.

The New York City cathedral in which Tesla's funeral service was held was packed with over two thousand mourners. Tributes from political and scientific notables, including three Nobel Prize Laureates, poured in from around the world.

Still a great admirer of this world famous scientist and inventor, Hugo Gernsback was among the first to be notified of Tesla's death. Gernsback arranged to have a death mask made and covered with copper. The mask was kept it in Gernsback's office as a personal remembrance of this scientific savant.

Hugo Gernsback firmly believed that Nikola Tesla was the world's greatest inventor of all time—bar none. His admiration for Tesla is best summarized by the following tribute Gernsback wrote in the January 1919 issue of *The Electrical Experimenter*:

> "If you mean the man who really invented, in other words, *originated* and discovered—not merely *improved* what

(Continued on page 88)

ELECTRONICS LIBRARY

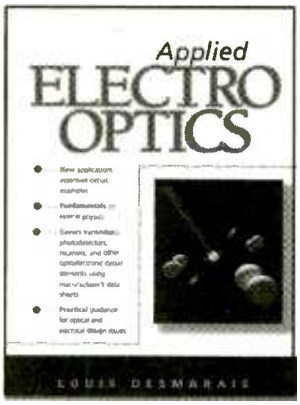
(continued from page 30)

APPLIED ELECTRO-OPTICS

by Louis Desmarais

An understanding of both the fundamentals of optics and electronics is essential to successfully build optoelectronic circuits. This "back-to-basics" guide provides engineers, designers, and technicians with a firm background in both optical physics and circuit design.

The book introduces the basic theory of optoelectronics, covering such topics as Maxwell's equations, reflection and refraction, and interference phenomenon. Each major element of an electro-optic system is discussed, including semiconductor light sources, optical transmitters, and optical receivers. After the theory is thoroughly covered, the book guides readers step by step through the practice of building circuits for a variety of applications, including CD players and infrared data transmission.



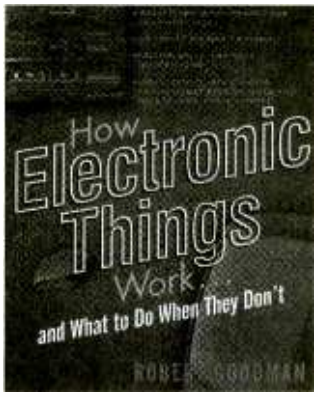
Applied Opto-Electronics costs $62.99 and is published by Prentice-Hall, One Lake Street, Upper Saddle River, NJ 07458; Tel. 800-811-0912; Web: www.phptr.com.

HOW ELECTRONIC THINGS WORK...AND WHAT TO DO WHEN THEY DON'T

by Robert Goodman

This is an everyperson's guide to electronics designed to help ordinary electronics users understand, live with, and maybe even learn to love the technology in our lives. Whatever your goal—saving on repair bills, maintaining your equipment, or making your own repairs, this book gives clear explanations of how things work.

The text is written in easy-to-understand language, and no technical experience is needed. There are clearly illustrated instructions on using test equipment to analyze and diagnose problems. Guidelines are provided on whether or not professional repair is needed. There are also tips on protecting expensive equipment from lightning and other electrical damage, as well as lubrication and maintenance suggestions.

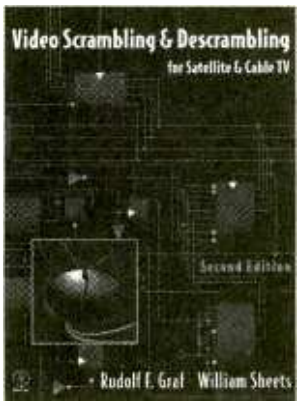


How Electronic Things Work...and What To Do When They Don't costs $62.99 and is published by McGraw-Hill, 1221 Avenue of the Americas, New York, NY 10020; Tel. 800-2MCGRAW; Web: www.books.mcgrawhill.com.

VIDEO SCRAMBLING & DESCRAMBLING FOR SATELLITE AND CABLE TV, 2nd EDITION

by Rudolf F. Graf and William Sheets

Video, audio, and computer hobbyists, technicians, and commercial TV personnel interested in satellite signals and programming will find this book an invaluable resource. This completely revised edition details the hows and whys of encoding and decoding video signals. Included is information on analog/digital conversion, phase-locked loops, digital techniques, and IC data sheets.



The book provides an understanding of encoding/decoding systems and the theory and techniques of encryption and decryption. An overview is given of the rules and regulations governing the availability and use of satellite signals, antennas, and programming materials. Schematics and details for several encoder and decoder circuits and experiments are included.

Video Scrambling & Descrambling For Satellite and Cable TV, 2nd Edition costs $29.95 and is published by Newnes, Butterworth Heinemann, 225 Wildwood Avenue, Woburn, MA 01801; Tel. 800-366-2665 or 781-904-2500; Fax: 800-446-6250 or 781-904-2620; Web: www.bh.com/newnes. ■

NIKOLA TESLA

(continued from page 48)

> had already been invented by others, then without a shade of doubt, Nikola Tesla is the world's greatest inventor, not only at present but in all history.... His basic as well as revolutionary discoveries, for sheer audacity, have no equals in the annals of the intellectual world."

Countless others around the globe share Gernsback's feelings concerning Nikola Tesla. ■