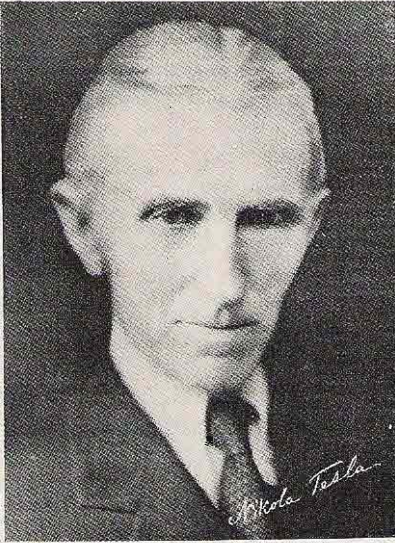




WHO WAS TESLA?

Ask any electrical engineering student today to tell you something about Tesla, and you are likely to get a blank stare. Or the counter-question: "Who *was* Tesla?" It seems preposterous that our educators should have ignored entirely the founder of our ac age, but such is the fact. Something should be done about our technical education system.

Born July 9, 1856 in the village of Smiljan in what is now Yugoslavia, Tesla rose from relative obscurity to a top position in the scientific world. He became a millionaire at 32 through his important inventions, only to fade later into obscurity, and died penniless.

His father was a clergyman. His mother, though she never learned to read and write, was known in the community as an inventor of domestic labor-saving devices, and it is to her that Tesla attributed much of his inventive genius. The young Tesla, opposing his father's urging to study for the ministry, insisted on a career in engineering. His mother encouraged him. He attended the polytechnic school at Graz, specializing in

physics and mathematics, and continued his education at the University of Prague. There he took a course in foreign languages, so that he could read the foreign technical literature. He became proficient in English, French and Italian, in addition to the German with which he was already familiar, and of course, his native Serbian.

Finishing at Prague in 1880, he took a post-graduate course in Budapest, where he debated the merits of alternating current with his professors. He then went to work for a Paris telephone company, where he acquired considerable experience with dc dynamos and motors. While there he invented regulating and control devices to protect the rotating machines he served.

Electrical Industry Was Limited

In those early days, direct current was universally acknowledged to be the only practical medium for generating, transmitting and applying electricity for heat, light or power. But dc resistance losses were so great that a power plant was needed for every square mile served. Early incandescent

lamps, glowing none too bright on 110 volts even close to the power plant, became pitifully dim on the power that dribbled from the lines less than a mile away. And everyone believed that motors could run only on dc. An alternating current motor was considered an impossibility.

This was the picture when, in 1884, young Tesla stepped off a ship in New York, his head full of ideas, and four cents in his pocket. His experience had convinced him that the commutator in direct current motors and dynamos was an unnecessary complication, causing endless troubles. He realized that the "dc generator" actually produced ac, which was rectified by the commutator into a series of waves, all flowing in the same direction through the external circuit.

Then, to get this dc to produce rotary motion in a motor, the process had to be reversed. The armature of each electric motor was equipped with a rotating switch (commutator) that changed the polarity of its magnetic poles just at the right instant as it revolved, to supply ac to the motor.

The Inspiration

To Tesla, this was sheer nonsense. It seemed logical to eliminate the commutator at both generator and motor, and use ac through the whole system. But no one had ever built a motor that could operate on alternating current, and Tesla struggled mentally with the problem. And one day in February, 1882, while strolling with a classmate named Szigetti in a Budapest park, he suddenly blurted out: "I've got it! Now watch me reverse it!" At that moment he had visualized the rotating magnetic field, which would revolutionize the whole electrical industry. He saw the magnetic pull racing around the stationary field (stator) of his motor while the armature (rotor), attracted by the moving field, chased around after it faster and faster until it was revolving at the same rate. He would need no switching to the rotating element — no commutator!

Subsequently he worked the whole alternating current electrical system out in his mind — including alternators, step-up and step-down transformers for economical transmission and delivery of electric power,

and ac motors to supply mechanical power. Impressed by the wealth of available water power going to waste around the world, he visualized the harnessing of this great supply with hydro-electric plants capable of distributing the power to where it was needed. He startled fellow-students in Budapest by announcing: "Some day I will harness Niagara Falls."

Discouraged by Edison

The opportunity and fortune Tesla sought in the promised land did not come easy. When he met Edison, then actively engaged in developing a market for his incandescent lamp through his pioneer Pearl Street plant in New York, Tesla launched with youthful enthusiasm into a description of his alternating current system. "You are wasting your time on that theory," the great man told him, dismissing the idea promptly and finally.

For a year, the tall, gaunt Yugoslav struggled to keep from starving in this strange land. At one point he dug ditches to make a living. But the foreman of the Western Union ditch-digging project on which he was working listened to the visionary descriptions of new electrical systems that Tesla related during lunch hours, and introduced him to a company executive named A. K. Brown. Fascinated by Tesla's vivid plans, Brown and an associate decided to take a flyer. They put up a limited amount of money, with which Tesla set up an experimental laboratory at 33-35 South Fifth Avenue (now West Broadway). There Tesla set up a complete demonstration of his system, including generator, transformers, transmission line, motors and lights. He worked tirelessly, and without drawings; the plans for every detail were indelibly etched in his mind. He even included two-phase and three-phase systems.

Professor W. A. Anthony of Cornell University examined the new ac system, and promptly announced that Tesla's synchronous motor was equal in efficiency to the best dc motors.

Alternating Current Arrives

Tesla then attempted to patent his system under a single comprehensive patent cover-

ing all its components. The Patent Office would not approve the all-in-one application, insisting on separate applications for each important idea. Tesla's applications, filed in November and December of 1887, resulted in the granting of seven U.S. patents in the next six months. In April, 1888, he filed for four more patents, covering his polyphase system. These too were promptly granted, as were 18 more U.S. patents later in the year. These were followed by numerous European patents. Such an avalanche of patents, so promptly issued, was without precedent, but so completely novel were the ideas — so completely absent was any element of interference or "anticipation" — that the patents were issued without a single challenge.

Meanwhile Tesla staged a spectacular lecture and demonstration of his ac system — single phase and polyphase — at a meeting of the AIEE (now the IEEE) in New York. The engineers of the world were made aware that the limitations on electric power transmission by wire had been removed, opening the door to tremendous expansion.

But who would adopt this obviously better system? Certainly not the established Edison-General Electric organization — it would have made their whole investment obsolete. Apparently Tesla was stuck — with no market, no customer for what he had to offer.

It was at this moment that George Westinghouse walked into Tesla's laboratory and introduced himself. Tesla was then 32 years old, Westinghouse 42. Both were capable inventors, accomplished engineers and electrical enthusiasts. Westinghouse listened to Tesla's explanations, watched his demonstration, and quickly made up his mind.

"I will give you one million dollars cash for your alternating current patents, plus royalties," offered Westinghouse.

"Make that royalty one dollar per horsepower, and it's a deal," replied Tesla, without apparent excitement.

As simply as that, the two men arranged the historic deal and shook hands on it.

Tesla had arrived! But he was not a man to forget those who had placed their faith in

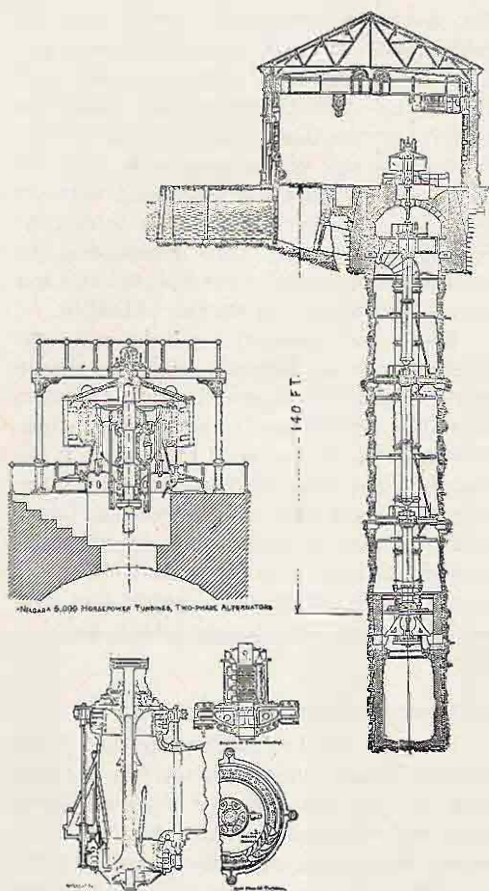
his ideas, and promptly signed over his million-dollar fee to Brown and his associate, who had financed his laboratory. Although the backers of Westinghouse later forced him to get a release from Tesla on the dollar-per-horsepower part of the agreement, such was the friendship that had developed between the two men that an amicable settlement was quickly reached. Tesla relinquished the royalties that would have supported him and his research efforts for the rest of his life.

The phenomenal success of the Westinghouse ac systems across the nation made it clear to General Electric engineers that they would have to get a license from Westinghouse if they were to keep up in the rapidly expanding electrical industry. The license negotiated at a handsome fee — was a feather in Tesla's cap; he distinctly recalled Edison's statement that there was no future in alternating current and that experimenting with it would be a waste of time.

A Dream Realized

In 1890, the International Niagara Commission began trying to determine the best way of using the power of Niagara Falls to generate electricity. The scientist Lord Kelvin was appointed chairman of the Commission — and he immediately announced that a dc system would obviously be best! It was not easy to challenge this world-famous authority, but he eventually came to realize that if power were to be transmitted even the 26 miles to Buffalo, ac would be necessary. So it was finally decided to use Tesla's system and generate ac with massive water turbines. Bids were invited by the newly formed Cataract Construction Co. in 1892. Westinghouse won the contract for the ten 5,000-HP hydro-electric generators, and General Electric the contract for the transmission system. The whole system — the line, step-up and step-down transformers all followed Tesla's two-phase design. He designed the big alternators with external revolving fields and internal stationary armatures, to minimize the weight of the moving members.

This historic project created a sensation, for nothing of this magnitude had been



One of the 5,000 h.p. Niagara Falls units, with detail at left. Upper drawing shows the hollow drive shaft that goes through the stationary armature to rotate the field, which hangs outside and around the armature.

attempted at the time. The ten big 2,250-volt alternators, revolving at 250 rpm and delivering 1,775 amperes each, produced an output of 50,000 HP or 37,000 kW, 25 Hz, two-phase. The rotors were 10 feet in diameter and 14 feet long (14 feet high in these vertical generators) and weighed 34 tons each. The stationary members weighed 50 tons each. The voltage was stepped up to 22,000 for transmission.

Remote Radio Control

Tesla's pioneering in the realm of radio ("wireless" as it was then called) went further than Morse code communication. In 1898 he staged a spectacular demonstration of remote control without wires at the

original Madison Square Garden, New York City. The first annual Electrical Exhibition was then in progress, and in the center of the vast area where Barnum & Bailey's circus usually performed, he had a large tank constructed and filled with water. Afloat on this small lake he had a 3-foot-long iron-hulled boat, with its mast supporting an antenna. Inside the hull was a radio receiver and an assortment of electric motors, driven by storage battery, to perform various "ship" functions.

From the opposite end of the auditorium, Tesla put the vessel through a variety of maneuvers, including sailing forward, steering left and right, stopping, reversing, and lighting the lights in its rigging in response to audience requests. The impressive demonstration of course "stole the show" and made the front page of the daily newspapers. But how many dreamed that one day, using these radio-remote-servo-control principles, we would land some of our citizens on the moon?

Mathematical Wizardry

Tesla's mathematical genius stood him in good stead in the design of the items of ac equipment that Westinghouse and GE undertook to manufacture. (In his early student days, he solved complex problems in his head, without pencil and paper). His teachers suspected him of cheating, and put him to conclusive tests. Young Tesla, it developed, had memorized whole logarithmic tables!) The now established frequency of 60 cycles per second (Hz) stems from Tesla's mental calculations, which convinced him that it was the most practical frequency for commercial use. At higher frequencies, ac motors would become inefficient; at lower frequencies they would require too much iron. Lights would also flicker at low frequencies.

Though the original Niagara Falls plant was designed for 25 Hz to accommodate the limitations of the early Westinghouse turbine generators, subsequent expansion included conversion to 60 Hz. Today this Niagara power is transmitted all the way to New York City, 360 miles away, and at times is fed over the Northeast power grid for much greater distances. (When Tesla arrived in

New York, the limit for efficient power transmission was less than a mile!)

High Frequency Pioneering

During his investigations into the unknown realms of high voltage and high frequency, Tesla adopted a most sensible practice. When handling high-voltage apparatus, he always kept one hand in his pocket. He insisted that all his laboratory assistants take this precaution, and to this day it is always employed by sensible experimenters around potentially dangerous equipment.

Tesla's explorations in higher frequencies and in the field of incredibly high voltages paved the way for modern electronics, although the word had not yet even been coined. With his unique high-frequency transformers (Tesla coils) he showed that he could actually pass millions of volts harmlessly through his body to glow-tube lamps held in his bare hands. They would light up to full brilliancy from the high-frequency, high-voltage currents. In those early days he was actually demonstrating neon-tube and fluorescent tube lighting!

Tesla's experiments up and down the frequency scale sometimes led him into unexplored regions. Studying slow mechanical or physical vibrations, he caused a virtual earthquake in the vicinity of his new laboratory on Houston St. His mechanical oscillator, approaching the natural period of the building itself, threatened to tumble the old structure. Furnishings in the police station over a block away began to dance around mysteriously as Tesla confirmed his mathematical theories of resonance, vibration and "natural periods."

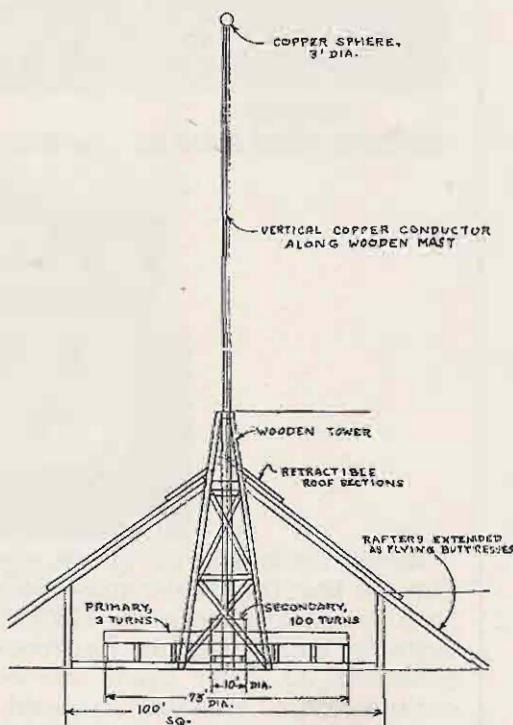
World's Most Powerful Transmitter

Investigations of high-voltage and high-frequency electrical transmission led Tesla to construct and operate the world's most powerful radio transmitter, on a mountain near Colorado Springs. Around the base of a 200-foot mast, he built a 75-foot diameter air-core transformer. The primary was only a few turns of wire. The secondary within it was 100 turns, 10 feet in diameter. Using power from a generating station several miles away, Tesla created the first man-made lightning. Deafening bolts 100 feet long

leapt from the 3-foot copper ball at the top of this mast. The thunder was heard as far away as the horizon. He was using voltages of the order of 100 million — a feat not to be equalled for half-a-century.

Tesla burned out the power plant generator with his first experiment but repairing it, continued his experiments until he was able to transmit power without wires for a distance of 26 miles. At that distance he was able to light a bank of 200 incandescent lamps — a total of 10 kilowatts. Fritz Lowenstein, later to become famous for his own radio patents, witnessed this spectacular accomplishment, as Tesla's assistant on the project.

In 1899, Tesla had somehow spent the last of the money he got from Westinghouse for his ac patents. Colonel John Jacob Astor came to his financial rescue, and put up the necessary \$30,000 for the Colorado Springs experiments. Now this money was also gone, and Tesla returned to New York.



The 100-million-volt transmitter, power from which lighted 200 50-watt lamps at a distance of 26 miles.

Enter J.P. Morgan

In New York, Tesla was prevailed upon by his friend Robert Underwood Johnson, editor of *Century* magazine, to write a feature story describing his accomplishments at Colorado Springs. But the story Tesla turned out proved to be an involved discourse on the subject of philosophy and "the mechanical process of humanity." Although of the highest literary quality, the treatise said little about the powerful transmitter at Colorado Springs. Johnson had to return the manuscript three times before getting some coverage of the subject he had requested.

In the end, the article was published under the title, "The Problem of Increasing Human Energy." It created a sensation when it appeared in print. One of the readers who was deeply impressed was John Pierpont Morgan, who had financed the General Electric Co. in its pioneer dc days, and more recently its part of the Niagara Falls project. Morgan was fascinated by the genius of Nikola Tesla, by his spectacular accomplishments and his winning personality. Tesla soon became a regular guest at the Morgan home. Impeccably dressed, always the polished gentleman with European manners and cultured speech in several languages, Tesla became a favorite of New York and Newport society. Many prominent matrons regarded him as a "good catch" for their daughters, but Tesla insisted that there was no room in his life for women and romance — that they would interfere with his research efforts.

Historians differ on what motivated Morgan to finance Tesla's next big project. Some believe that he was genuinely interested in the wireless transmission of power. Others argue that — in the light of subsequent developments — it seems obvious that Morgan's interest was in getting control of Tesla and his achievements to protect the Morgan investments in the electrical industry.

Finding that Tesla was broke again, Morgan agreed to underwrite Tesla's project of transmitting electric power without wires. In 1904, Tesla acknowledged in *Electrical World and Engineer*: "For a large part of the

work I have done so far I am indebted to the noble generosity of Mr. J. Pierpont Morgan."

From this alliance sprouted the fantastic "world-wide-wireless" tower on Long Island.

World Wide Wireless

The strange structure that slowly rose near Wardencllyffe, in the hilly portion of Long Island, mystified all observers. Resembling nothing so much as a huge mushroom, except that it was not solid, it had a lattice-work skeleton, broad at the base and tapering toward its 200-foot top. There it was capped by a 100-foot diameter hemisphere. The structure was made of stout wooden members joined by copper gussets bolted to the wood with sturdy bronze bolts. The hemispherical top was draped over its upper surface with copper mesh. There was no ferrous metal in the entire structure.

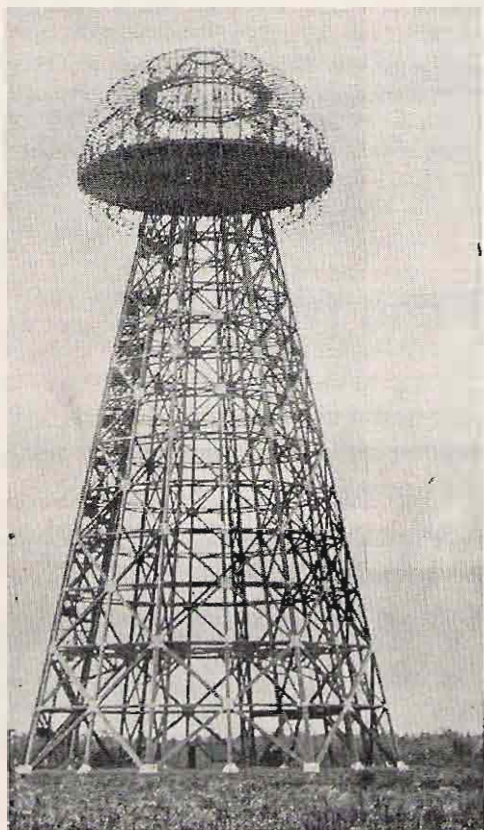
The famous architect Stanford White became so interested in the project that he did the design work without charge, assigning one of his best designers, W.D. Crow, to the task.

Tesla commuted daily to the construction from his quarters in the old Waldorf-Astoria Hotel on 34th St., riding the streetcars to the East 34th St. ferry, then the paddle-wheel steam ferry to Long Island City and the Long Island Railroad to Shoreham. The railroad's dining service prepared special meals for him so that his supervision of the project would not be interrupted.

When the 100-foot square brick power plant was completed near the base of the big tower, Tesla began moving his Houston St. laboratory into the structure. Meanwhile, annoying delays were encountered in the manufacture of the radio-frequency generators and their driving motors. Several glass-blowers were busy fashioning special tubes, the design of which still remains a mystery.

The Prophet Tells of The Future

Meanwhile, Tesla issued a descriptive brochure that revealed his far-reaching insight into the future of the great industry that at that time (1904) was limited to dot-and-dash telegraphy. That document has persuaded many that the man was actually clairvoyant. He announced that the World



Not all the facts on the mysterious Long Island tower were ever known. Some believe that it was intended to transmit at low frequencies, "shaking the earth" to send signals to distances then believed impossible. Tesla foresaw a complete modern type of service, but never stated how large an area he intended to cover. But, he called it the *World Wide Wireless System*!

Wide Wireless system was being prepared to provide a variety of facilities, including:

Telegraph Communication, Telephone Communication, News Broadcasting, Stock Market Quotations, Aids to Navigation, Entertainment and Music Broadcasting, Accurate Time Service, Facsimile, Telephoto and Teleprinter services.

Tesla was describing the Radio City of the future, which he actually lived to see come into existence!

Morgan's Support Ends

In *Electrical World and Engineer* of March, 1904, Tesla revealed that the Canadian Niagara Power Co. had offered him

inducements to locate his wireless power transmission project at their plant, and that he proposed to employ those facilities to distribute 10,000 horsepower at a potential of 10 million volts.

The Niagara project never materialized, but may have had some influence on the fate of the spectacular Long Island project. For reasons that have never come to light, J.P. Morgan had a change of heart, and Tesla's financial fountain suddenly went dry. At first Tesla refused to believe that Morgan would not arrange for the nearly finished job's completion, but Morgan's withdrawal was abrupt and final. Historians of the industry wonder why. Did Morgan lose patience? Did engineers of high repute convince him that Tesla's visions, so openly revealed in the brochure, were nonsense, and that he was wasting his money on a hopeless dream? Did he suspect that Tesla was diverting time and money to the Niagara project? The facts will probably never be known.

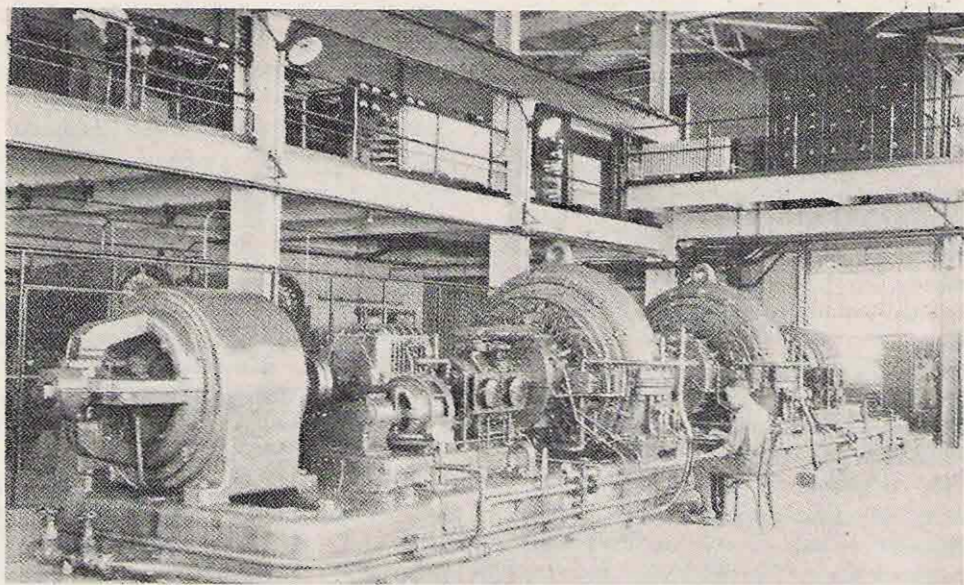
Brainless Desecration

During World War I much senseless desecration was perpetuated in the name of national defense. For some strange reason (or lack of reason) it was decided that Tesla's spectacular tower at Wardenclyffe, Long Island jeopardized the safety of the United States, and must be destroyed. After vain attempts to topple the lofty structure by attaching cable to it and trying to drag it off balance, it was finally capsized by dynamiting its foundations. Even then, the tower did not collapse nor disintegrate. It simply lay intact on its side, and was finally dismantled piece by piece.

But why did this structure have to be dispensed with? Many taller objects closer to New York City — including the Ramapo Mountains — were allowed to remain intact!

The Radio-Frequency Alternator

As early as 1890 Tesla built high-frequency ac generators. One, which had 184 poles, produced a 10 kHz output. He later produced frequencies as high as 20 kHz. More than a decade was to pass before Reginald Fessenden developed his rf alternator, which had an output of 50 kW. This machine was scaled up to 200 kW by



*"The Author as a Young Man," E. J. Quinby
New Brunswick, N.J.*

watches over the great 200 KW alternators at WII,

General Electric, and put on the market as the Alexanderson alternator, named after the man who had supervised the job, and who had constructed some of Fessenden's earlier alternators.

When it appeared that British interests (already in control of most of the world's cables) were about to acquire the patents for this machine, the Radio Corporation of America was organized, at the urgent suggestion of the United States Navy. The new company was formed in 1919, around the Marconi Wireless Telegraph Co. of America, and the powerful but inefficient Marconi spark transmitters were replaced by the highly successful rf alternators. The first one was installed in New Brunswick, N.J. at station WII. It produced a 21.8 kHz signal at 200 kW, and handled commercial business previously the exclusive domain of the cables. This was the first continuously reliable trans-Atlantic radio service.*

*Dr. E. Stuart Davis, of the National Telegraph Office (Museum) in Union, N.J., happily reports that one of these giant alternators has been preserved in the Smithsonian Institute, where it stands as a monument to Tesla's pioneering. Fessenden's perserverance, Alexanderson's development and Sarnoff's leadership. This one originally served at Trans-Atlantic Transmitter Station WSO at Marion, Mass.

The writer, as the most junior of the junior engineers on the project, struggled like the rest to keep the first machine running until the next was ready to provide relief. So well did these alternators perform that a whole battery of them was ordered, to be installed at Radio Central, Rocky Point, L.I., almost within the former shadow of Tesla's tower.

Thus Nikola Tesla's World Wide Wireless dream was fulfilled some three decades after he initiated the project and right where he started it, using the type of transmitter he devised.

Radar and Turbines

Tesla continued active research in many fields. In 1917 he suggested that distant objects could be detected by sending short-wave impulses to them and picking up the reflected impulses on a fluorescent screen. (If that doesn't describe radar, what does?) He described cosmic rays 20 years before other scientists discovered their existence.

At various times up to 1929, he devoted his attention to a "bucketless" high-speed turbine for steam or gas. Friction between the increasingly irascible Tesla and some of the engineers and assistants cooperating with him on tests at the Edison Waterside power

plant and in the Allis-Chalmers factory did not help his cause, but many respected engineers today agree that we have not heard the last of the Tesla turbines with the smooth rotor discs.

As the years passed, less and less was heard from him. Occasionally, some reporter or feature writer would look him up and manage to get an interview. His prophecies became increasingly strange and involved, inclined toward the abstract and delving into the occult. He never acquired the habit of writing notes, always claiming (and proving) that he was able to retain complete detailed data on his researches and experiments in his mind. He said that he intended to live to 150, and upon reaching age 100, would write his memoirs, which would include a detailed record of all the data he had compiled during his researches and experiments. At his death — during World War II — the contents of his safe were impounded by military authorities, and nothing has been heard as to the contents of the records — if any — it might have contained.

One of the peculiar inconsistencies of Tesla's character was revealed when two high honors were offered him, and he rejected the one but accepted the other. In 1912 it was announced that Nikola Tesla and Thomas A. Edison had been chosen to share the Nobel Prize, including the \$40,000 honorarium. Tesla could well have used the \$20,000 at the time. Nevertheless, he flatly refused to share an honor with Edison. However, when in 1917 the AIEE's Edison Medal — founded by anonymous friends of Edison — was awarded to Tesla, he was persuaded to accept it, after first refusing.

The Esteemed Eccentric

Tesla's natural demeanor was that of the aristocrat. With the passage of time and the depletion of his resources, he sank into a condition of genteel poverty. Continuing to live in the best hotels, his credit would become exhausted and he would be forced to seek other quarters. Finally, moving into the newly opened New Yorker, he found his problems solved. Some of the organizations for which he had made millions arranged with the hotel management to take care of the aging genius.

Having once met Tesla through the mutual friendship of the intrepid Hugo Gernsback (possibly Tesla's last friend) this writer later recognized the distinguished pioneer strolling in the grand concourse of the Pennsylvania Terminal. Impeccably dressed, his head bowed low over his pristine collar and red-and-black silk necktie, his whole bearing was that of a high-born nobleman from the past.

"Good evening, Dr. Tesla," I ventured, disturbing his solitude in the midst of the turmoil. "Are you catching a train for somewhere?" His soft-spoken reply was memorable. "No," he explained, "I often come here to think."

Tesla insisted on carefully wiping each item of silverware, china and glass before starting a meal, using a fresh napkin for each. In view of this effort to achieve perfect sanitation, it seems inconsistent that the maids reported Tesla's room to be an "unholy mess." It wasn't Tesla's untidiness they complained about — it was the pigeons! When he was not feeding them out in the park, he fed them in his room, where he left the window open so they could come and go.

The gold-plated telephone beside his bed, over which he enjoyed a universal frank to talk to anyone anywhere in the world without charge, was the roost of his favorite pigeon, a white one with grey-tipped wings. "When she dies, I will die," predicted Tesla.

And so it was that one day in January 1943, his favorite dove paid him her last visit. "She was dying," lamented the lonely, unhappy Tesla. "I got her message, through the brilliant beam of light from her eyes."

One of the maids, observing that the "Don't Disturb" sign had been hanging on Tesla's doorknob for an unusually long time, used her pass key to investigate. Tesla had passed to his reward, leaving his gaunt 87-year-old frame peacefully in bed. She fed the mourning pigeons, gently ushered them out, and closed the window.

...Quinby

Author's Note: I am indebted to the late Hugo Gernsback, friend and confidant of Nikola Tesla; to *Prodigal Genius*, the biography of Tesla by John J. O'Neill; to the *Proceedings of the AIEE*, and various publications for help and information.