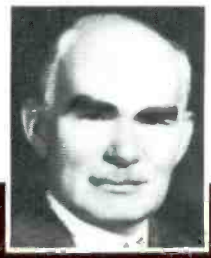
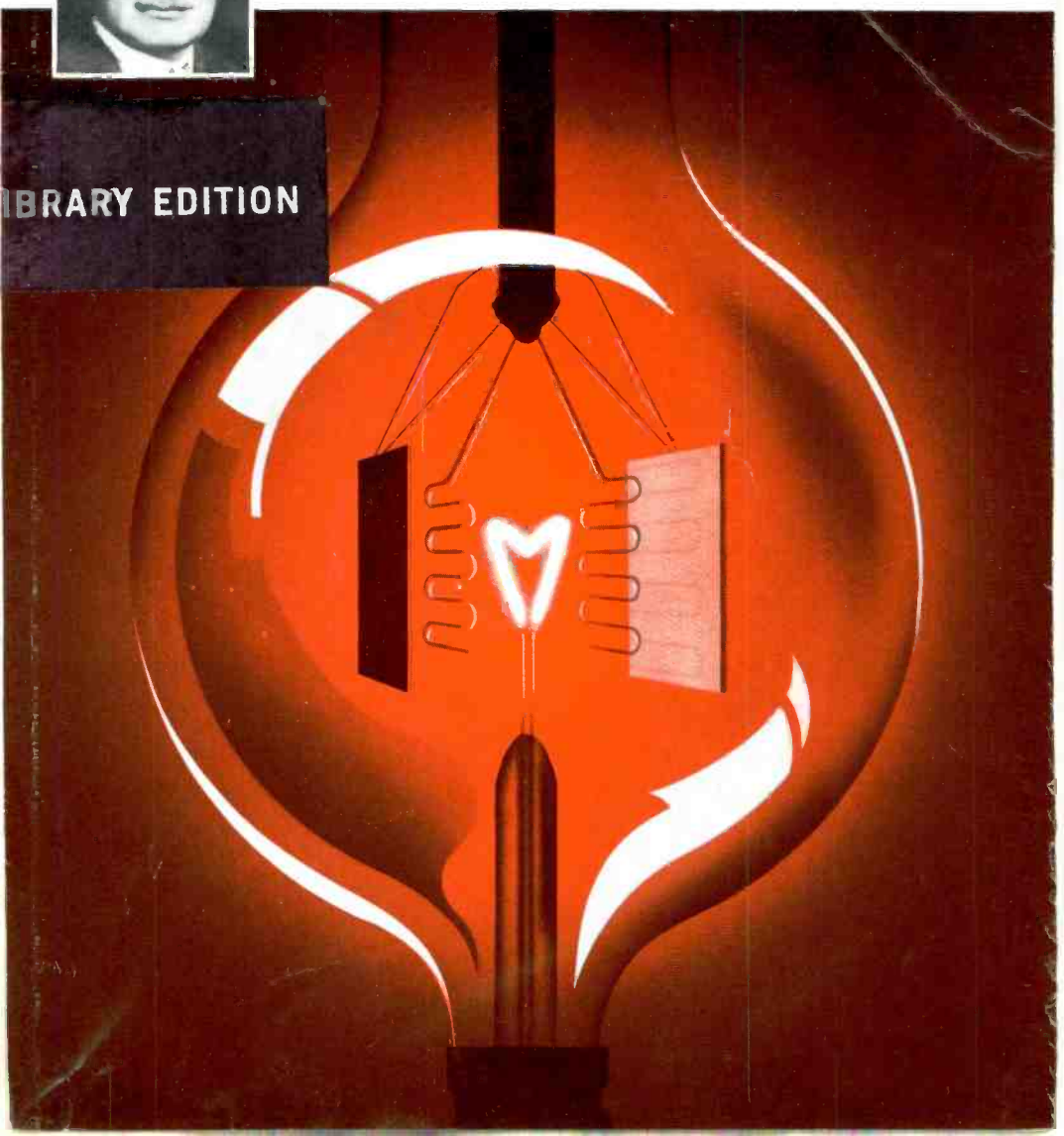
BY DONALD WOLLHEIM

Advancing the electronic age

Lee de Forest





LEE DE FOREST

By Donald Wollheim

Seldom has a single invention unlocked so many doors as did Lee de Forest's audion, the forerunner of the modern vacuum tube. The audion made possible radio broadcasting, effective long distance telephoning, modern high-fidelity sound reproduction systems, television, radar, and high-speed computers. So essential is the audion that de Forest, long known as the "Father of Radio," might also well be called "Godfather of the Electronic Age."

The road to triumph as an inventor was a rocky one for Lee de Forest. He had to struggle constantly to find the means to live while he studied, experimented, and invented. Twice he lost fortunes won by his inventions because of the financial chicanery of business associates. Only after a federal grand jury had found him and his patent lawyer, Captain Samuel E. Derby, not guilty of using the mails to defraud in promoting the audion did fortune turn a steadily smiling face on the indomitable inventor. But whether fortune frowned or smiled, from boyhood until his death at 87, Lee de Forest was always actively inventing

Advancing the Electronic Age *is the story not only of Lee de Forest, but of all the men*

CONTINUED ON BACK FLAP

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Advancing the electronic age

LEE DE FOREST

by Donald Wollheim

Illustrated by Robert Boehmer

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Advancing the electronic age
LEE DE FOREST

Chapter 1

The World of Power and Light

Nineteen-year-old Lee de Forest gazed at the dazzling white buildings of the World's Columbian Exposition with immense satisfaction. His feelings were like those of Columbus, whose feat of 400 years earlier the Fair now celebrated. It was a summer morning in August of 1893, and Lee had been thinking about the Fair, wanting to come since early spring. He felt that he just had to see the great displays of machines and inventions. Since he had been ten years old, Lee had known what he wanted to be: an inventor.

Though the spring had been full of plans for his graduation from Mt. Hermon Boys' School and for taking the entrance examinations to the Sheffield

Scientific School at Yale University, he found time to apply for a job as guide at the Fair. But he had been turned down. Lee did not give up. With graduation over and the entrance examinations passed, he sold books from door to door. When he saved enough for the $18 roundtrip fare to Chicago and a little more, he set out. He sat up all the way, sleeping as well as he could on the crowded excursion train.

Now he was at the Fair to stay until his money ran out.

Lee knew exactly what he wanted to see. He headed straight for the Manufactures Building, the largest at the Fair, and began to study the machines. The next day he moved on to the United States Building, where he pored over gun models and the exhibits of gun manufacture. Then he moved on to the Transportation Building, where a whole train was on display.

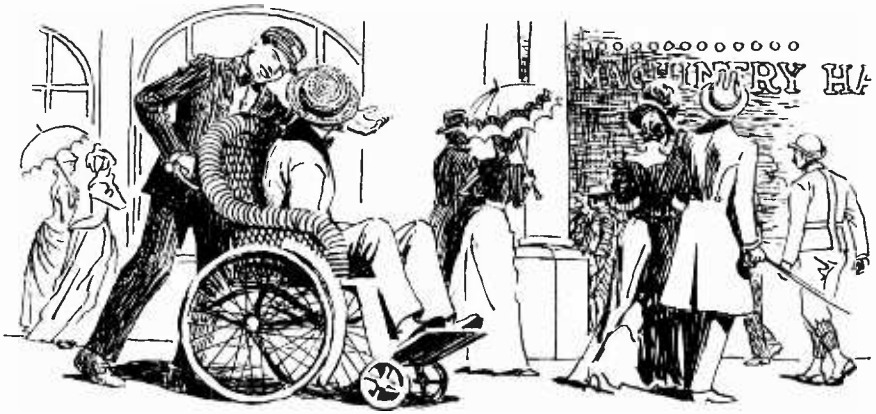
As he painstakingly examined it, his mind went back ten years or so.

Steam locomotives had fascinated him even then. One day, passing a locomotive idle on a siding, he had clambered up into the cab, then crawled underneath it, studying its intricate construction. He had seen drawings of a locomotive in an encyclopedia and had practically memorized them. But here was

the real thing. He stayed under the engine until he had a picture of the working parts fixed in his head. Then he went home, and from scrap lumber and junk in the cellar, Lee painstakingly contrived a wooden model. Barrelheads became drive wheels, strips became drive shafts, a tin can became a whistle. A cracked dinner bell was connected by an old piece of clothesline; packing cases made a tender, which Lee and his friends filled with stovewood. The locomotive had everything but power to move it. When the model was finished, it was complete with engine cab, throttle, reversing lever, boiler, steam chest, and cylinder. It even had a cowcatcher. So exact was Lee's work that the parts moved. The model locomotive was the talk of the town. Citizens of the sleepy Alabama town of Talladega who had never spoken to the de Forests because they had dedicated themselves to educating Negroes brought their children to see the wonderful wooden locomotive.

As Lee pushed through the crowds at the Fair to his favorite exhibits, he often noticed the traffic divide to make way for chairs pushed by uniformed young men. "That's the way to see the Fair," Lee thought, envying the chairboys' passengers. Then he learned there was a shortage of chairboys. Lee ap-

plied and was hired. He had to pay $8 for an ill-fitting uniform, but it was worth it. Now with the money he earned he could stay at the Fair until he had to leave for school. Pushing a chair was surely the most primitive form of transportation. Yet as Lee trudged along, stretching his muscles, his mind



When he could Lee took people to Machinery Hall.

was full of dreams of fast trains, of communications between cities at the speed of light, of wonders beyond measure.

Now, too, Lee had to see all the Fair, not just his favored exhibits, for his passengers often had definite ideas what they wanted to see. Everything relating to the history of the United States seemed

to be there. There was a replica of Columbus' flag ship, the *Santa Maria*, that had been brought to the Fair from Spain. In a reconstruction of La Rabida Convent, where Columbus had waited for King Ferdinand and Queen Isabella to make up their minds whether they wanted to finance his voyage of exploration, Lee saw the actual contract the Spanish monarchs made with the discoverer of the New World. Florida had built a replica of the fort at St. Augustine, the oldest in the United States. In the reconstruction of the Boston house of John Hancock, Lee saw John Alden's Bible and Miles Standish's pipe. He remembered his mother telling him that John Alden was an ancestor of his. In the French reconstruction of the Apollo Hall of Versailles lay the sword of the Marquis de Lafayette. In Pennsylvania's replica of Independence Hall hung the Liberty Bell. Lee looked carefully over the early locomotives, the *De Witt Clinton* from New York and Chicago's own *Pioneer*, noticing how even the first crude locomotives held the seeds of future power he himself had modeled.

Nor was there only yesterday represented at the Fair. There was today and tomorrow. There was a moving sidewalk on the pier at the east entrance. Edison's kinetoscope, forerunner of the motion-pic-

ture projector, was on view. Alvan Clark's telescope with a 40-inch lens, then the largest in the world, was there. Lee jumped with the others as an artificial lightning display cracked and flashed. Whenever Lee's passengers expressed no preference as to where they wanted to go, he took them to Machinery Hall to see his favorite mechanical exhibits. He learned a good deal about all of the Fair so that he could tell his passengers about it. But he talked longest and best about the mechanical marvels.

For many people at the Fair it was their first view of electric lights. In the Palace of Electricity, they gaped at the Pillar of Light rising above them, its colored incandescent bulbs flashing out varying patterns. The Fair had 17,000 horsepower of electricity for its lighting, three times the power used for lighting the city of Chicago at that time.

Lee heard a demonstration of the long distance telephone, but the connection was poor and uncertain. He remembered that only a couple of years before he had tried to talk to his sister four miles away, but he had given up because he could not understand her words. Most of all, when dusk came on, and the arc lights and searchlights made all brilliantly white and clear, Lee and his passengers were awed at the marvel of night turned into day.

There was the less serious side of the Fair,

and Lee saw that too. On the Midway Plaisance, adjoining the Fair grounds proper, there were the Irish Village and Blarney and Donegal Castles. Lee did not tell his passengers, as he himself had learned, that the Blarney Stone on exhibit had originally been a Chicago paving stone. There on the Midway, the constant flowing stream of derby-hatted men and strawhatted women in shirtwaists and long flowing skirts were jostled by Bedouins in desert robes, by fez-topped Egyptians, and by sari-clad Indian ladies. There, too, Little Egypt did her "shocking" dance, a favorite show of some of Lee's passengers.

Above all rose the world's first Ferris wheel. Cars holding more than 60 people were spun up to a height of 264 feet. The whole circle took 20 minutes. At the top, when Lee rode the wheel, he saw that the people below were dwarfed. Even the Manufactures Building, more than 1,600 feet long and nearly 800 feet wide, so big that a ten-story building could have been built inside it, looked small. Lee thought, as he looked down, "Some day I'll make something big and show it at a Fair like this."

As much fun as the Fair was, it was also an education to Lee, as valuable as money in the bank. He enjoyed the beauty of the flashing fountains. He stood behind his passengers as they fell silent

before the brilliant majesty of the fireworks at night. He learned from them and from his fellow chairboys. But always he came back to Machinery Hall with its 44 engines of nearly 20,000 horsepower. These and the electrical exhibits entranced him. In the Krupp building he saw the huge guns, 42 feet long, weighing 122 tons. He saw the huge Bethlehem steam hammer. After his first love affair with the locomotive as a boy, steam hammers had intrigued him. To the Science Congress at the Fair came Thomas Edison, inventor of the electric lamp; Nikola Tesla, who had first made alternating current feasible; and Hermann Von Helmholtz, whose brilliant student, Heinrich Hertz, had demonstrated the existence of electromagnetic waves. Lee wondered if he could ever, as they had, serve mankind so well. He resolved to try.

One of his fellow chairboys who had been at the Fair on the opening day told him how President Cleveland had officially opened the exposition. Finishing his speech, President Cleveland had pushed an electric key. All the electrical fountains shot their sprays aloft, flags unfurled, and guns boomed. It was an electric moment.

And for Lee de Forest, in more ways than one, it was an electric Fair. Someday he would be back at another Fair like this, he told himself. He would

put the name de Forest before the world.

Regretfully when the day came for him to go to Yale, he took leave of the wonderful, eye-opening Fair.

Chapter 2

The World in the Beginning

When Lee de Forest was 15 years old, he wrote his father a letter:

> DEAR SIR: Will you favor me with your ears for a few moments? I wish to state my desires and purposes. I intend to be a machinist and inventor, because I have great talents in that direction. In this I think you will agree with me. If this be so, why not allow me to so study as to best prepare myself for that profession? In doing this it would be much better to prepare myself for and take the Sheffield Scientific course than the Yale University; besides I could prepare for it in one more year and the cost

would be much less, which would be a great item with you, who have us all to educate. The time and money it would take to let me take both could not be spared, and a great deal of what I would learn in the University would be of no advantage to one of my profession. While what I would learn in the scientific course would be of greatest use. I think that you will agree with me about this on reflection, and earnestly hope you will act accordingly and educate me for my profession. I write this with no ill will in the least, but thinking it is time to decide and choose my studies accordingly.

Your obedient son,
LEE DE FOREST

On the back of the letter, he wrote to his mother:

Lives of great men all remind us
We can make our lives sublime,
And departing leave behind us
Footprints on the sands of time.

Dear Mama: The only footprints I will leave will be my inventions. I had better take the scientific course. Don't you think so?

Lee de Forest got his way. His father, the Reverend Henry Swift De Forest, D.D., and his mother, Anna Margaret Robbins De Forest, had to admit he was right.

When he was four years old in Waterloo, Iowa, Lee had been fascinated far beyond his years by an early Edison phonograph. He never forgot it. Years later he was to revolutionize not only the phonograph but every means of bringing music to men's ears.

Born in Council Bluffs, Iowa, on August 26, 1873, Lee, his older sister Mary, and his mother moved with their Congregationalist minister father first to Waterloo and then to Muscatine. On both his father and mother's side, Lee was descended from French Huguenots and English Puritans who had come to the New World before 1650. In 1879, the family, now including baby Charles, forsook the wandering life of preachers' families. Dr. De Forest accepted the presidency of Talladega College in Alabama. It was a curious school, and life at Talladega was a curious one for Lee and his family. Founded by the Baptists before the Civil War, as a college for white male students, Talladega College came into the control of the American Missionary Association after the war. In 1867 it had been opened to students regardless of their sex, sect,

race, or color. The townspeople of Talladega, Alabama, embittered by the Civil War and the misrule of Northern carpetbaggers, simply refused to recognize the existence of the Negro students and their white teachers. So Lee and his brother and sister grew up in a little island group of Negro students and the few other white faculty children.

The College was very rundown when the De Forests moved there. They lived for the first two years in two rooms in the girls' dormitory and ate in the common dining room. The only other college building held the classrooms. So well did the Reverend De Forest raise money, however, that soon there was enough to build a boys' dormitory and finally a house for the De Forests. To save money, the College made its own bricks, and the sight of the bricks baking at white heat in the huge fires was like a miracle to Lee.

Lee and Mary and Charles began their education in the grammar school classes their father had founded. A new school carpentry shop sparked Lee's first mechanical interest. Then, when a new blast furnace was constructed in the neighborhood, Lee was fascinated with the riveting and construction, and especially with the railroad the engineers built to carry the ore to the new furnace. After it was finished, Lee could follow the process of making pig

iron all the way from the mine to the furnace.

He determined to build his own blast furnace. An old ashcan provided the base. Two holes punched on each side near the bottom admitted the compressed air supply and furnished a taphole for the molten metal. Lee built a wooden platform beside the "furnace" to raise fuel to the top and added a wooden chimney. An antique bellows furnished the air. The blast furnace worked. To be sure the wooden chimney often caught fire as the charcoal fire roared with its charge of limestone and scraps of lead. When the fireclay plug was broken from the taphole, a mere trickle of lead flowed into Lee's sand mold, but in his imagination it was a mighty flood.

When Lee was not making things, he pored over the drawings in the *Patent Office Gazette* in the College library. Soon he had his own collection of drawings, and was hard at work on that favorite project of all beginning inventors, a perpetual motion machine. His drawing finally was completed. He had planned a complicated machine, indeed, involving permanent magnets, a walking beam, and a magnetic shield. At the bottom of the drawing Lee printed:

"I am actually amazed that I, a mere youth of 13 years, by my inventive genius and concentrated

thought and study, have succeeded where illustrious philosophers in times past have failed. I have at last furnished to humanity a machine which, without cost, can supply forever any and all demands of the human race for power."

Lee lacked the knowledge of physics that would someday show him why mechanical perpetual motion was impossible, but that day, in his own mind, he became an inventor.

Lee de Forest learned to use his hands and his mind. Tools and drawing pencil became familiar to him. At one thing he had no success. He could visualize, draw, and make things mechanical, but he had no luck at all with electrical devices. There was no electrical lighting or power plant in Talladega. Not until at 18 when he went away to a summer camp did he succeed in making electrical devices work. No wonder that his greatest interest at the Fair was in things mechanical.

A monthly allowance of ten cents did not seem enough to support Lee's inquiries into the mechanical world. Luckily from magazine premiums he acquired an electroplating outfit. Over the months he made five dollars with it, money which he promptly put into other tools and supplies. One of his favorite premiums was a tiny steam engine, with an alcohol burner under the boiler. When money

for fuel ran out, Lee demonstrated his ingenuity by removing the base with a can opener and placing the bottom of the boiler on a lid of the kitchen stove. Then furious stoking of the stove would make the engine run.

Lee did not only study, plan, and make things. He also played baseball, swam, and built a crude tennis court with his friends. He built a gymnasium in the cellar and took part in children's plays in the barn loft. And he fought with his younger brother, Charles. Lee thought Charles was far too observant of his older brother's occasional lapses from the straight and narrow path and too eager to report these to their parents. The fact that he and Charles shared the same bed led to Lee's first really practical invention, a "bedstick." This long piece of walnut with thick padding on both ends to keep it from scratching the bedstead or tearing the sheets was laid exactly in the middle of the bed. Woe betide the brother caught moving the bedstick!

Dr. De Forest taught Lee many things, including wonders of the woods, afoot and on horseback. At Yale, Lee's father had studied astronomy, and on hot Alabama summer nights he opened the mysteries of the heavens to young Lee. Together father and son traveled one summer to Colorado, where

they climbed Pike's Peak together.

All of his studies except Latin and Greek were enjoyable to Lee. He realized, however, that he had to master languages to enter college. His father helped him with these, trying to make them enjoyable. Lee read voraciously—the Bible, the adventurous *Leatherstocking* and *Sea Tales* of James Fenimore Cooper, the Lambs' *Tales from Shakespeare*, and romantic novels and poems of Sir Walter Scott—everything he could get his hands on. He heard his first classical music on the Colorado trip and was thrilled. But most of all he dreamed and planned and devised new inventions.

Money was always scarce in the De Forest family, but Lee was lucky to get financial help for his university education. A distant cousin of Dr. De Forest, David Curtis de Forest, had established a scholarship at Yale that provided funds to pay expenses at Yale College and in the professional and graduate schools for anyone in the de Forest family. Only Lee's father had taken advantage of this fund so far. He wanted, as fathers often do, his two sons to follow in his footsteps, to be ministers or teachers. At least, he wanted Lee to take the regular Yale College course with its broader cultural and educational advantages than the Sheffield Scientific School, which was a part of

Yale University. But he could not stand in the way of Lee's strong desire.

Finally the De Forests had enough money to send Lee away to a school to prepare him for his studies at Yale. They chose the Mt. Hermon Boys' School in Massachusetts, near the Northfield Seminary where his sister Mary was already a student. Lee wrote to Thomas Alva Edison asking his advice on the best training for becoming an inventor. He was disappointed to get no reply. Edison was too busy inventing. He applied for a summer job at the Yost Typewriter Company, but was turned down. So off he went to summer camp before he entered Mt. Hermon to prepare for the Sheffield Scientific School.

Chapter 3

The Die is Cast

When Lee arrived at New Haven from the Fair in Chicago to begin his studies at the Sheffield Scientific School, he came into another new world. For the first time in his life he was all alone, free to pursue his studies and his work undisturbed. Money was scarce, but he was used to that. The De Forest Scholarship assured the expense of his schooling; all he had to do was find the money for his board and room. He quickly found a "Five Cent Restaurant," where meals were fifteen cents—even less, for he could buy $3 worth of meals for a weekly meal ticket at $2.75.

His head was even fuller of inventions than usual. First, what he had seen at the Fair still

excited him; and second, the sale of inventions might bring him the money he needed to stay in college. Lee worked on an improved typewriter space-bar movement, a new compass joint, and a puzzle game he called "Midway Plaisance." When he was not pursuing his first year studies, he planned and designed. There was no money for him to return home to Talladega for Christmas; so he busied himself with planning an underground trolley system. Through the *Scientific American*, the Metropolitan Transit Company was offering a $50,000 prize for such a scheme. He began working for two graduate students in experimental psychology, compiling their results for them at ten cents an hour, the same wage he had made for digging potatoes and piling rocks overtime at Mt. Hermon. In May his trolley system proposal was returned; the company had withdrawn the prize offer. None of his other schemes came to anything either, but he did not give up.

As the school year ended he devised a system for saving steam in a boiler system, and he wished fretfully for money so that he could make a model to test his ideas. He consulted Professor Hastings, famous throughout New Haven for his biting sarcasm, and heard his idea blasted to bits. He was to learn to dislike Professor Hastings intensely before he left New Haven. During the summer he began

studying telegraphy. He had begun to move toward his life's work.

To help pay his way he found work at Professor Seymour's. In return for a room, Lee mowed and watered the professor's lawn. Rising each morning at four for his yard work, Lee then put in eight hours in the psychological laboratory working for graduate students.

In his second year at Sheffield, the course was mechanical engineering, but he also read about Tesla, who had been at the Fair. Again he was being drawn to electrical studies, as if by a magnet. During the fall, he fell ill and was delighted to wind up in the infirmary where he could eat all he wanted for nothing. He labored during the spring on a prize essay titled "Aerial Navigation," but he failed to win. He noted in his diary in the spring of 1895:

Tried to invent a telephone relay.

Again he failed.

Eleven years later he was to succeed and to inaugurate the Electronic Age. Lee de Forest produced in 1906 the simple ancestor of the complicated vacuum tubes in use today. He called it the audion. Modern radio, television, high fidelity sound sys-

tems, long distance telephones, sound motion pictures, radar, and computers have reached their present state of development because of that one invention. So important was the audion that although Guglielmo Marconi invented a system of wireless communication in 1894, de Forest has long been called "Father of Radio."

Before the invention of the audion was possible came the work of many thinkers and doers. After its invention came the struggles of de Forest and other men to bring the human voice, bearing men's thoughts and song, around the earth.

In 1873, the year de Forest was born, one thinker, James Clerk Maxwell, had published a theory so simple, yet so revolutionary that fellow scientists were reluctant to accept it. Working from earlier experiments in electricity and magnetism conducted by Michael Faraday, Maxwell devised mathematical statements of Faraday's conclusions to show that electricity moved in waves, as it had long been recognized light did. Specifically Maxwell's equations meant that any electrical disturbance—from the spark of Benjamin Franklin's key at the end of a kite string to the spark coming off a stroked cat—set off electromagnetic waves which were comparable to the waves set off when a pebble was thrown into a pond. But with this

difference: the electromagnetic waves go on and on through space as far as the initial power impelling them will take them; the pond waves stop when they reach the edge of the pond. Maxwell concluded that electromagnetic waves moved with the speed of light, and he thought they behaved as light waves do.

Maxwell was right, but he had a profound indifference to proving his theories. In 1888, when de Forest was 15 years old, a young German professor of physics, Heinrich Hertz, whose teacher de Forest had seen at the Chicago Fair, had demonstrated the validity of Maxwell's theories. He placed two metal bars with brass balls on one end of each so that there was a short gap between the balls. When an electrical current was sent through each bar in turn, sparks bridged the gap between the balls. Then Hertz set up a receiver to detect the waves from these sparks. Across the room, he set up a coil of wire with a gap between the two ends. When sparks were set off in his sending apparatus, sparks also flew in the gap of his receiver. Before his untimely death in 1894, Hertz went on to show that his Hertzian waves could be reflected as light waves were. He also made the first crude measurement of these waves. Hertz died convinced that his Hertzian waves had no practical use. As it later

developed, Lee de Forest and others proved that he could not have been more wrong.

The ancestor of de Forest's audion appeared in 1883, when he was ten years old. Thomas Alva Edison had invented the incandescent electric lamp in 1879. Like the radio tube that was to follow, this lamp was a glass bulb with air removed to form a vacuum. In this vacuum, an electrical current made a filament glow brightly. But Edison noticed that though his filament glowed in a vacuum, after a while a black deposit formed on the inside of the tube. How could this happen? To find out, Edison introduced into the tube a strip of metal that did not touch the filament. From the metal strip Edison made a connection to a galvanometer, an instrument used to measure electrical current. When the light was lit by feeding current to the filament, the galvanometer indicated that electricity had jumped from the filament to the metal strip. The experiment did not solve Edison's problem, and he could think of no practical use for it; and so he merely patented it as the "Edison effect" and forgot about it.

John Fleming, another doer, did not. In 1904 he used the Edison effect to produce the diode tube. This tube got its name from its two working parts inside the tube: a filament like that in a light bulb

and a metal plate. It "rectified" Hertzian waves, that is it made dot-dash signals carried by them clearer.

In 1906, de Forest introduced a third working part in his audion, or triode. A fine wire grid placed between the filament and the plate and carrying a tiny current not only rectified the signals from radio waves but made them stronger. Thus the transmission of the human voice by radio waves became feasible.

Chapter 4

The Nerviest Man in His Class

In Lee de Forest's second year at the Sheffield Scientific School all this lay as unrealized by him and by the world as his perpetual motion machine, his steam saver. Lee was, however, moving purposefully toward his boyhood dream of becoming an inventor.

Early in the winter of 1896 Lee's father died suddenly after a fall. Now Lee as the oldest son was the breadwinner. Regretfully he gave up eating at Yale Commons and went back to the "Five Cent Restaurant." The next summer Lee rented a large house for student roomers, and his mother moved to New Haven to run it. Charles would transfer from Mt. Hermon to finish his preparation

for Yale, and Mary, who had finished her music course at Oberlin, would give piano lessons. At least, saddened as the household was, it was the end of fifteen cent meals for Lee.

In the spring Lee heard a lecture on Roentgen's cathode rays, and it excited him so much he determined to go to graduate school. If he was to be an inventor, and he *was* going to be, he would need to know all the Sheffield Scientific School could teach him. As Lee graduated, the class yearbook named him the "Nerviest" and the "Homeliest" man in his class. He hoped he was the first—he would need it; and he hoped he was not the second.

Lee could not find work that summer. He turned again to inventing and submitted a gear design for a chainless bicycle to the Pope Company. It was rejected. Desperately but determinedly he spent the summer reading about electricity.

In the fall, during his first postgraduate year, Lee began studying with Yale's great mathematical physicist, Josiah Willard Gibbs. Lee had always been good at mathematics and he enjoyed it, but mathematics had previously been to him only a way to solve school problems. Now, under Gibbs, he began to learn the language of mathematical theory. For the first time, he could begin really to understand what James Clerk Maxwell was saying about

electromagnetic waves. His first laboratory work was maddeningly difficult, measuring the temperature coefficient of a standard battery and making electric generator current-voltage curves. Slowly but surely he licked his problems.

Again Lee began reading the electrical studies of Tesla, who had been at the Chicago Fair. The spring before he had sought in vain to get work with him. Now he determined on his life work, "the intimate connection between light energy and electricity," as he noted in his diary. He saw that his work with Gibbs would enable him "to deal intelligently with light and wave phenomena, along which lines I see lies the great future of electronic advance." Indeed it did. But at that time, Lee's vision was even more dim than today's dreams of going to other planets. To talk across the world without wires seemed then as far away as landing on the moon.

During the summer after his first postgraduate year, Lee finally met Tesla, but his dream of working with Tesla did not materialize. It was another summer of reading Maxwell and Hertz, broken only by some work serving as an observer of meteors for the Yale Observatory and four days work for the gas company that paid him $8. Lee's old Latin and Greek professor from Talladega visited the de

Forests and convinced Lee's mother that her son should go on with his postgraduate studies.

In the fall a demonstration lecture on Hertzian waves by Professor Harry Bumstead determined Lee's thesis subject. He began measuring the wave lengths and frequencies of Hertzian waves in the basement of Winchester Hall. One night a lantern lamp he was using blew a fuse and cast the whole building into darkness. Upstairs a student lecture was in progress and it had to be dismissed. Professor Hastings, Lee's old nemesis, was furious. Several weeks before the professor had exploded when he discovered that Lee had driven some nails into a laboratory table to fasten some wires. Professor Hastings banished Lee from Sheffield Scientific School. Professor Bumstead came to his rescue, however, and got him work space in the Sloane Physics Laboratory of Yale, working with Professor Wright. For his thesis he chose to do original research, testing the reflection of Hertzian waves from the ends of parallel wires.

For seven long months, he worked in the cold, dark basement of Sloane Laboratory, four hours a day, six days a week, throughout the winter and spring of his last year of study. It was no fun. It was drudgery, it was tedious, it seemed an unending grind. But Lee loved it.

The work had to be done in the dark, for it meant watching the faint glow of his detector as he slid the little wire collars back and forth along the tightly stretched parallel wires in order to determine the exact locations of the peaks and valleys of each frequency.

It was monotonous in the extreme. After the first few minutes, everything was a constant repetition—the careful jotting down of figures in the near darkness, the faint flickering of the spark gap, the smell of ozone combining with the dampness and the winter chill, and the pale flickering of his responder.

So this was the price he had to pay for a career in science. It was good training and Lee did not give up; he was learning things. He was immersed in the real work of discovery, however obscure it might seem at the time.

That long chore was followed by more hours of hard grinding as he prepared his notes, worked out his mathematics, and presented his paper summing up his months of patient backbending experiment.

At last in June, 1899, Lee de Forest finished his schooling. He received his Doctorate of Philosophy. He was ready to go out into the world and show what he could do.

But now a strange thing happened. The nerviest kid in the class almost lost his nerve. With his bags packed, ready to leave for Chicago to find a job, he became strangely ill at ease. Before him was the prospect of a plunge into a life he was not really well acquainted with, one of people and business. Behind him was the laboratory world and the world of study in which he was at home. He faltered, set down his bags, and began walking back to the basement of Sloane Physics Laboratory.

Vaguely he knew that his next field of work would be in wireless telegraphy, that first practical application of the Hertzian waves. Vaguely he realized that his destiny lay there, but what impulse was this that was moving him counter to it?

He returned to the building, walked down the stairs to the dark empty basement where he had worked so long. He stood there pondering, for the first and almost the last time in his life in a stage of indecision. He looked over the batteries, the jars, the wires.

A professor came in then to see who was in the hall. He was surprised to find Lee there, and the young graduate was ill at ease. They talked.

What exactly they said no one knows. But they talked of the difference between studying and doing. Lee had mastered all that they could tell

him of a field which was still in its infancy.

"Go," in effect said the professor to him, "you've no use here now. Go out and do what you wanted to do. Put your brains to use. Find the real laboratories of the world and produce something that will make the world sit up and take notice. You've wet your feet here in the ocean of the Hertzian waves, now get out and swim."

Lee and the professor shook hands once again; then Lee strode out and went on to Chicago. He had left his childhood behind. It was time to call out a challenge to an opponent worthy of his steel.

He chose Marconi.

Chapter 5

Hall Bedroom Inventor

When Lee de Forest left New Haven to go out into the world, he knew what Marconi had done with Hertzian waves. Hertz's apparatus had involved all that was needed to make telegraphy without wires possible, a sender and a receiver. Had he wanted to, he could have sent Morse code across the length of his laboratory table

But what good would that have done? Anyone could have spoken more loudly, more clearly. Hertz's apparatus was strictly a laboratory apparatus. The miracle of invention results from the simple ability to know what purpose an experimental tool can be put to. Marconi turned Hertz's experimental laboratory device into a practical means of communica-

tion. At the receiving end he used the invention of a French physicist Eduard Branly to improve detection of the Hertzian waves. The Branley coherer was a glass tube filled with powdered metal filings that resisted the passage of electricity. A steady current run through the tube increased the waves so that they would actuate a receiving key. Metal filings are very obstinate. They dislike to keep changing, and in a few seconds of use, the coherer would "freeze" and would block transmission. This required a little device to shake up the filings by tapping the device with a little hammer. It was all very awkward.

Marconi also changed Hertz's receiver. By opening it up and enlarging it, he invented the radio antenna. One end was thrust as high as 40 feet into the sky; the other end was buried in the ground.

The transmitter was basically identical with Hertz's own, simply a device for generating a powerful electric spark, which could be operated with a telegraph key so as to stop and start this spark in code pattern.

Marconi was a wealthy young man, and he had an estate in Italy where he could play around with the device. In 1895 he had it working well. He was sending messages without wires across distances that finally reached a mile and a half.

The Italian government was entirely uninterested in Marconi's new wireless telegraph system; so he went to England where he patented his system and founded the Marconi Wireless Telegraph Company with the support of the British government.

Marconi became famous. He soon was able to improve his equipment and power until he could reach first four miles, then eight, then greater and greater distances. It traveled better over water than over land, and the greater the power of the transmitter, the farther the message could be received.

Lee de Forest knew all about Marconi's wireless. He had used the Branly coherer himself in his long series of experiments at Yale, and he knew its faults. The fact that it was always necessary to keep shaking the coherer down, to keep tapping it back into operation was a serious limitation to its use. Wireless telegraphers had to send at a much slower rate than the railroad telegraphers whose message traveled along a wire. If the message was sent too fast, the decoherer could not keep up with it. So wireless telegraphy was hampered by the inefficiency of its receiving device. Marconi experimented a lot with the Branly coherer, trying different metals and different techniques, but its faults remained. It worked, and that would have to do.

It wouldn't do for Lee. He knew that as long as the coherer was in use, just so long would wireless telegraphy be limited. The task was to find a better system, a superior means of registering the Hertzian waves.

First he had to find a job.

He found it in the Western Electric Company in Chicago. It was about as mean a job as possible. A workhorse task in their dynamo room, manual labor, greasing, mopping, finding parts. Hard work at long hours and all for eight dollars a week. He found a small room on a noisy street for eight dollars a month, and so he lived.

His room was his laboratory. He kept track of scientific events, spending what free time he had in the library, spending his nights experimenting with what little energy he had left over.

Fortunately, in a little while the company recognized his talent and transferred him to the telephone department where he would be wiring switchboards instead of doing such strenuous labor. It was dull work too, but it allowed him to associate with men who had scientific backgrounds themselves. Now he had access to new apparatus, to plans, to work in electricity. He made friends with his superiors in the telephone department, and fin-

ally was able to get their consent to use Western Electric's laboratory in his spare time for his wireless experiments.

He was determined to beat Marconi by finding a better coherer. As the year 1899 drew close to its end, he found something that promised to do the trick.

A German experimenter had described in a magazine Lee had read an experiment with a bit of tin foil that suggested the possibility of a better receiver.

Lee carefully read the article, and then attempted to duplicate the process. The article directed him to place a thin piece of tinfoil upon glass and cut it in two with a razor. He then connected a battery to the terminals and placed a drop of water or alcohol across the gap. With a spark generator operating in the vicinity, it was possible to detect by means of a telephone receiver in the circuit a weak rippling sound in response to the Hertzian waves.

This looked like the start of what Lee de Forest had been seeking. The device presented problems. For one thing, the drop of water or alcohol was itself decomposed by the current. It was highly erratic, and would work for only a few seconds.

Lee's problem resolved itself into a search for

better electrodes than tin foil on glass and better decohering fluids than water or alcohol. This kind of problem meant experiment, endless experiment, with every kind of material possible.

It would take time.

Fortunately for him, his bosses at Western Electric took an interest. They released him from his routine labors on switchboards and let him devote his entire workday to experimenting in the laboratories. They did not seem to be worried about what they would get out of it. For $8 a week it was a good risk. Who knew what this deep-eyed young fellow with the Ph. D. might come up with?

Lee de Forest called his new wireless receiving device a responder, but soon shortened it to sponder. His researches were progressing, but were still far from perfect. He had secured a friend and helper in Ed Smythe, another engineer with the company.

Life on eight dollars a week was far from an ideal existence, and at times Lee felt as if he were getting nowhere. He began to look around for a job that would give him more of a challenge and more financial reward.

At last he found what seemed like a more promising job. It was in Milwaukee, and it carried the grand title of chief engineer. The name of the company was equally exciting, the American Wireless

Telegraph Company, and the pay was the generous figure of $15 a week.

Lee de Forest took the job. It turned out to be a blind alley, but it proved one thing. The responder worked.

Chapter 6

The Flickering Flame

So Lee de Forest packed his few belongings to leave for his new job, and with them he carefully installed his sponder in a little wooden carrying box to take it with him. Of all his possessions, this was now his most valued, for it was his first invention and to him it held a possible hope for an American challenge to Marconi.

The head of the Milwaukee organization was a Professor Johnson, who was working on a wireless receiving device of his own. De Forest's job was to sit in a small shack outside the city limits while Johnson from his plant in Milwaukee transmitted messages to him. Using Johnson's device, Lee read those messages and suggested improvements in the Johnson receiver.

It did not take the clever young engineer long to realize that Johnson's contraption was just another variety of coherer, and one which held even less promise than the ones already in use. It seemed to Lee that Johnson was working entirely in the wrong direction, and as the weeks went on, the failure of the apparatus convinced Lee that he had indeed made a bad mistake in changing jobs. True, he was eating better and his lodgings were far more comfortable than his tiny hall bedroom in Chicago, but he chafed at the waste of time involved.

In order to continue in his own direction, he made use of his spare time and his lunch hour to test out and work on his own sponder. At the little shack, he took the sponder from its box, set it up, and used it to detect the signals from the Johnson factory. They came in fine. He received clearly the messages that he could hardly get in his regular work hours.

Eventually Professor Johnson realized that his work was not panning out. He had heard reports from other employees of de Forest's own little mystery device. So the showdown came. Johnson came out to the shack and confronted de Forest. He issued an ultimatum. "Either share your invention with me, or you are through."

But the willful young man from Yale was not

one to knuckle under to any such command. He parted company with the new job with its grand title, and returned to Chicago late in 1900, his sponder tucked under his arm, again jobless and nearly penniless.

His sponder worked—that he knew. He also knew that it worked better than the existing inventions in the field.

He returned to his hall bedroom in the Chicago boarding house, but he could not return to his old job with Western Electric. Instead he was able to find two part-time jobs, one translating articles from French technical journals for the magazine *Western Electrician*, the other teaching science to young boys at the Armour Institute three hours a week. The teaching job gave him access to the school's electrical laboratory.

He continued to exist in this manner for the next few months, and on into 1901. He found his friend of the telephone company, Edwin H. Smythe, still interested in him and still prepared to work with him in developing the sponder. They lived near each other, and they often worked together nights, sending and receiving, and suggesting changes and experiments with the de Forest receiver.

In all this work, the foremost thought in de-Forest's mind was to develop the audion, a tube that

would eventually make radio possible. He also wanted to improve wireless telegraphy, the sending and receiving of Morse code messages without wires. Telegraphy so managed would do many things to improve communications. It would enable ships at sea to keep contact with land. It would enable isolated areas to communicate with more populous ones without the expensive and complex setting up of telegraph wires and cables and the necessary repair crews. But telegraphy would not transmit music and voice. Something more than a mere receiver of spark-gap impulses was required for that.

De Forest undoubtedly was dreaming of the day when music could be sent to all homes and areas over the Hertzian waves. For he was and always had been a lover of music. The early Edison phonograph he had heard when he was four years old had left a permanent impression. His work on his experiments, often lasting late into the night, would have worn him down had he not made a practice of attending concerts as often as his finances would permit. He loved music. Sitting in the balcony in a quarter seat listening to a fine orchestra was his idea of perfect relaxation. Away from the thoughts and worries of the world, his brain relaxed under the flow of fine music and the fantasy evoked by it.

To bring this music into the home, to set up a

wireless device that would enable anyone to simply turn a knob, adjust a switch, and flood the kitchen, the dining room and the parlor with song and harmony—that was a worthwhile objective.

The first glimmer of the radio tube came like a fantasy on the night of September 10, 1900. It took the form of a flickering gas light.

To anyone else this would have meant nothing. In those days electric lights were few and far between, and de Forest's little bedroom was lighted, as were almost all homes in America, by a gas jet, set in the wall, and throwing its bright but often flickering glare on the little room.

To the observant eyes of Lee de Forest, anything that was unusual was something to be observed and investigated. There was a universe to be discovered and learned about; and all things, however trivial, were clues to it.

Lee was operating the transmitting key of his induction coil, continuing his endless efforts to analyze and improve his apparatus. As he depressed his telegraph key, and sparks snapped, the light in the gas mantle some 12 feet away dimmed. The gas light dimmed and flared in perfect unison as he depressed and released the key.

Lee stared in wonder. What was happening?

When the key sparked, the gas jet dimmed.

Were the flaming gases in the jet somehow picking up and receiving the Hertzian wave shocks just as if they were receivers of their own? He watched the flickering, then, in excitement, called in Smythe. They both studied the effect.

They worked intensely on the problem for the next couple of weeks. It seemed as if somehow they had discovered a new and different means of detect-

ing wireless vibrations. Inside the hot core of flaming gases, somehow the electronic impulses were registering, were affecting the temperature and flow of the gases. The two men adjusted the gas jet, moved the transmitter, and continued testing it until they found the best reception. Eventually they could cause the gas jet to respond to their signals almost instantaneously and clearly. Surely something was being discovered here!

Not until November did de Forest and his friend discover their mistake. If the gas jet was responding to Hertzian waves, then it would work as well from a distance, from another room. They moved the transmitter to another room—and the jet failed completely.

Why was it unresponsive? Simply because it was the sound waves in the air that had carried the snap of the spark and upset the flow of the gas current. A simple fact—and one that proved only that the most devoted of inventors can often mistake the simple for the complex.

But this mistake paid Lee de Forest well. It established in his mind the idea that the sensitivity of a gas flame might well indicate sensitivity to other impulses than sound. He wrote in his notebook at the time:

"Might I not expect an electromagnetic action

lurking somewhere in the sensitive flame, since that responds so to acoustic vibration?" He was convinced that this logic was sound, and went on to write, "If only I had the time to investigate, I know I would discover an entirely novel method of Hertzian wave detecting, something that might indeed challenge the progress of science in this direction, that might make possible the transmission of code and voice and music across thousands of miles . . . If only I had time! But the race is on for a wireless detector. The fight is getting too close to leave now and go off on any new line of investigation. But I will think about it in my spare time. I will take notes upon whatever ideas occur to me. I will await the time when I can turn again to this fascinating field for investigation, and I know that there awaits a discovery, although I cannot prove it."

In these thoughts he was correct. Later on, and not too much later on at that, he was to find what he sought for in the sensitivity of the gas flame. His first radio detector was in that field, though it was another five years before he had the time and energy to prove it. But Lee de Forest was a dogged and stubborn young man. He never forgot a good idea, even when it arrived in the wreckage of a misleading excursion.

Meanwhile there was the wireless responder to perfect and test. To that end he devoted his efforts through the summer of 1901. The work proceeded. The sponder worked more and more effectively and de Forest was anxious to increase the scope of his testing. He was transmitting in the laboratory of the Armour Institute, and already he had to move his spark gap out to the long hall and place his receiver at the farthest limit available. The time was coming for a really long-range test with the sponder.

Another challenge was now looming on the horizon. The field of wireless telegraphy was making headlines, and even Lee de Forest's work had not passed unnoticed. The news broke of Marconi's intentions to come to America and demonstrate his work in some spectacular fashion. De Forest squirmed in frustration as he read of this. He had a better device than the old coherer the Italian was using. There must be a way to establish it in the public eye, to meet the European on the field of battle.

But who was he, this young American, to fling such a challenge? Of money and backing, he had none; but of nerve and self-confidence, he had an endless treasure. Nothing better demonstrates his mind than this excerpt from his diary:

"Oh, the loneliness, the difficulties of these days. I have no place to work. No facilities. And I have to earn my food. Smythe's aid is and has been small enough for a task of this magnitude, an invention of this scope and difficulty. I am dwelling in a new realm. All in the dark. No precedents. No theory to guide. No apparatus. No co-workers. All things to be tried and tested.

"Thus I begin to lay the slow and tedious foundations of a lengthy and most difficult research. Even in my laboratory I am often intruded upon. At least one full day a week I must turn from my work and pay for the use of the laboratory. Never can the experiments go in full swing for lack of instruments properly built.

"Time is short. Marconi is headed towards America with his wireless detector, and I alone can pilot this weather-beaten craft. If it cannot meet him next spring, it as well sink now. And if it sink, I sink deeply with it."

The time had come to try a long-distance test and catch the public eye.

Chapter 7

A Challenge to Marconi

By May of 1901, Lee de Forest was convinced that his responder had had mechanical defects sufficiently ironed out and was now practical enough to be put to use. He began to draft the patent application which would establish his claim to it, and which would also mark his beginning as a true inventor.

The time had come to bring it out of the laboratory and test it in the public eye. July saw the thing accomplished. In July, Lee de Forest and Ed Smythe jointly filed their patent claim for his wireless receiving device under the title of "Apparatus for Communicating Signals Through Space." And at the same time they gave the responder its first big test.

Smythe would operate the transmitter on an upper floor of the Armour Institute. Half a mile away stood the Lakota Hotel, high enough for its roof to be in an unimpeded view of the Institute. Lee de Forest went around to the hotel and persuaded the manager to allow him to use its roof.

To pick up the signals, a good sized antenna would be necessary. Lee promptly invented what was later to be known as the bird-cage antenna, the remote ancestor of the big basket-like hoops that now grace radar towers and probe the depths of interplanetary space for the messages of the stars.

They took a barrel, pulled it apart and used its metal hoops for the "stays." They strung long reels of lamp wire between the hoops and six strands through the five hoops, until they had a long construction, which they hoisted up to the top of the Hotel Lakota's flagpole, and grounded it by attaching it to the hotel's steam pipes.

The time had come. Lee used a telephone type receiver to hear the sounds that his responder would pick up. It was afternoon, nearing three o'clock, and it was raining. Holding an umbrella borrowed from the hotel's manager, Lee stood on the roof, gazing across at the distant structure of the Institute and wondering if it would all work or whether it was all a dream.

"Whirr-whirr-whirr" sounded from afar.

The time came. He stood alone, receiver to his ear, holding an umbrella, listening. And then, *whirr-whirr-whirr.* Signals sounded in his ear. On and on, Smythe's transmitter sent its electronic messages; and clearly and strongly de Forest's invention brought them to him across the city blocks.

The responder worked. De Forest, though he had anticipated it, though he saw no reason for failure, nevertheless was moved to the core. At last his work had been rewarded by success, unquestionable success.

There was nothing to do now but to try it again on a greater scale. How about an over-the-water test?

Who owned a yacht they could borrow? There was a Professor Freeman at the Institute who had a friend with such a yacht. With the Professor's influence, they got permission to use the yacht, and proceeded to install the transmitter aboard it.

Then, with Smythe aboard the yacht and de Forest on the water crib four miles from shore with the responder, they tested their wireless again. The ship, almost out of sight on Lake Michigan, sent its message. And, gazing out across the waters, Lee received it.

The day marked two firsts in Lee de Forest's life. One, it was the first time that a wireless mes-

sage had been sent and received in code in America. Two, it was the first time he had been accorded newspaper publicity. For the trial had been noticed by the Chicago press, and newspaper reporters met the boat on its return to its Chicago dock.

The story of the experiment made the front pages of the newspapers the next morning. Public recognition for the first time felt good!

He was finally ready to enter the field against Marconi.

The newspapers carried a story about the forthcoming international yacht races to be held off Sandy Hook in New York Bay late in the summer. Sir Thomas Lipton would race his fine craft, the *Shamrock II*, on behalf of Great Britain against the *Columbia* representing Old Glory. Suppose, thought Lee, that we could go out there on the waters, sail along watching them, and report the story of their race directly to the newspapers by wireless?

In that way, we could get the news to the papers firsthand, fast, and accurately, and papers that got it from us would get the news of the race ahead of their competitors.

This would give the de Forest system of wireless telegraphy great publicity, it would establish it in the public eye as a rival to the Marconi system, and it would help it gain backers and the financial

support it now needed to expand out of the experimental stage.

Lee went to Smythe and Professor Freeman with his idea. They discussed it at length, and finally the other two agreed to help him get to New York City and place his idea before the newspaper associations. There was one condition de Forest had to agree to. Professor Freeman was the inventor of a new system of transmission, and he wanted it used in place of the simple old spark-gap induction coil transmitter. De Forest accepted this condition with misgivings, for he considered the Freeman apparatus overly complex and insufficiently tested.

So the young inventor packed his responder in its traveling case, threw a toothbrush and shirt in his bag, and set off for New York City. On arriving there he promptly went up to the offices of the Associated Press, the largest newsgathering organization of the American press. There he received a shock.

Marconi had thought of reporting the yacht race too, and had already signed a contract with Associated Press many months before. He was coming to America to hit the papers with a big splash.

Lee was flabbergasted, but only for an instant. Associated Press may have been the biggest service, but it did have some competition. He sought out

the offices of the Publishers' Press Association. There he was listened to. They liked the idea; they accepted it. Lee de Forest was put under contract and walked out of their offices ready to start. They would supply a tug to follow the yachts and carry the wireless apparatus.

It was up to Lee to get the apparatus together and fulfill his part of the contract.

That was a horse of another color. Unfortunately it is not possible to do anything in this workaday world without money. As Lee knew so thoroughly, one must eat and sleep; and so must the people you hire to work with you. Where was he going to get the money to carry on the necessary work?

Lee had once met a New York businessman named Henry Siedler. He set out for this man's offices for help. Siedler was in, and he listened carefully. Lee explained the two systems of wireless telegraphy—his own and the Marconi system; and he explained why his responder was superior to the coherer that Marconi persisted in using. His own system worked faster; it received code faster; it did not clog or freeze up. It also did not require a decoherer working with it. To top it off, de Forest had a contract from the Press Association.

Siedler thought it over, and agreed to give $1,-

000 toward their work. It would be placed in the treasury of a new company that they would agree to organize and incorporate under the title of the American De Forest Wireless Telegraph Company.

De Forest was in business. It was characteristic of him that he wasted no time. He wired for a mechanic to come from Chicago. He rented a small machine shop in Jersey City, and he set out to build the Freeman transmitter and install it on the tug in time for the big race.

Time was pressing. There was not a moment to be lost. The Freeman transmitter was big and complex, and it meant working night and day to beat the deadline. Lee gulped down a bite for a meal and continued to work on it.

Still trying to beat the deadline of the fast approaching races, overworked, nervous, and strained, he received a knockout blow. Lee collapsed, fainted dead away at his task, with the transmitter still incomplete and the race only a few days away.

He awoke in the hospital. He insisted on returning to the machine shop after three days in spite of his health, but the problem looked hopeless. Then, respite! The race was postponed six weeks! The cause was saved at last.

When the morning of the big race dawned, they

were ready to go. The tug was equipped with the complex Freeman transmitter, and Lee and a telegrapher were aboard ready to send. On shore Freeman and Smythe sat together in the shack alongside the Morse telegrapher, the man who would read the signals.

Off they went into the clear blue waters under a sunny sky. The two contestants, trim, fast beneath billowing white sails, cut through the water. Following them were the tugboat, and Marconi's equipment on James Gordon Bennett's yacht.

In the sending room of the tug, which became one of the first radio rooms of any ship in history, de Forest started the transmitter. There was a flash of spark and a puff of smoke. The Freeman transmitter had collapsed before it had even sent one dot!

De Forest met the disaster with quick action. He had brought along coils and Leyden jars—just in case. Hastily he rigged up the old reliable form of transmitter, opened it up, and signaled to the telegrapher to begin sending.

Dot, dash, dot, dot. . . . Over the invisible waves the story began to go out from the de Forest tug. This yacht was gaining, now that. The race was going this way, that way, and all was excitement and news.

Nearby, the yacht bearing Marconi equipment was steaming along, sending its own message, dit-dotting the Hertzian waves with a similar story transmitted to the Associated Press cabin somewhere on the shore.

Then the race was over, and the *Columbia* the winner. The two wireless vessels came into port, each confident they had won. The two telegraph crews clambered ashore, tired, happy, and glowering at each other. But they were met by unexpected news.

Nobody had been able to read their signals. The telegraphers at both shacks reported only a jumble of noise, static, and confusion. No clear signals, no clear Morse code stories had been received from either one. They had between them discovered a new fact of wireless and radio transmission.

They had jammed each other.

The principle of tuning which enables radio stations to send out messages on different wave lengths and thereby not interfere with each other's receiving was known in theory to both Marconi and his determined American rival. But never before in history had there been occasion for *two* stations to be transmitting in the same locality at the same time! Neither had bothered to resort to "tuning"; both had broadcast on wide bands. Both had inter-

fered with each other and nobody could read any signal from either of them!

Chapter 8

The Dark Before the Dawn

They had challenged Marconi. They had come East, worked themselves into near-collapse, met their competitor on the appropriate waters of contention, and fought it out all the long hours of the race. And they had . . .

Lost?

No. The newspapers had saved the day. When the tired and disappointed young inventor and his friends awoke the next day, they looked at the morning newspapers with amazement. There was the story of the race under the headline: "Received by wireless telegraphy from tug following the yachts." How was this?

It wasn't the truth, of course, but the papers

were determined to get their money's worth out of the experiment anyway. So, despite the actual failure of the effort, Lee de Forest gained one important part of what he had set out for—national publicity. The country now knew of his existence. They knew there was a de Forest wireless system. They had been told that wireless had a practical use and was a coming thing.

That was something. But the news meant that Lee had a decision to make. If the papers had revealed the fact that the experiment had failed, he would have had to return to Chicago. But now the press had given him a start. For better or for worse, he would remain in New York and try to make something of the newly formed company. It was now just a name and had not even been incorporated. Its funds were reduced to zero.

So Lee de Forest stayed in New York and Smythe and Freeman returned to Chicago. The next few months were bad ones for de Forest. Siedler would not put any more money into his account. The problem now was to use the newspaper stories and the goal of wireless to get other businessmen to buy an interest in his system.

This meant that experimenting, working with science, which was de Forest's burning desire, had to be set aside in favor of trudging from one office

to another trying to talk men into buying stock in the company. There followed three months of almost continuous disappointment, of hopes smashed, of living virtually from hand to mouth, of rising each morning with hope and retiring each night, half-hungry, and in despair.

What was the problem he faced? In order for a man to be convinced that he should risk his money in a new enterprise, he must be shown why there is a need for that enterprise, how it can perform a service that will prove profitable, and that backing it will eventually return money invested several times over.

What could wireless do to justify such a financial risk?

Wireless can be defined simply as a system of sending *coded communications* over the Hertzian waves without direct wire connections. How does this differ from radio? Radio is a system of sending *sound* over the Hertzian waves without direct wire connections.

There doesn't seem to be much difference between the two. But the difference, though slight, represents a wall between one world and another. Wireless and radio operate in the same fashion. A transmitter is opened and something is sent across the invisible all-pervading Hertzian waves by means

of electronic disturbances. Somewhere else, a receiver which is sensitive to these man-made disturbances, reacts to them, and translates them back into the same kind of audible sound that had been made in the transmitting station.

In 1901 the only thing that could be sent from a transmitter was the noise of a spark-gap, a sharp click or snap, similar to the click used in telegraphy. Although sound, a voice, music, could be transmitted, the sound could be broken up into electronic vibrations and sent, there existed no means of hearing this on a receiver. Neither Branly's coherer nor de Forest's responder were capable of "hearing" anything clearly except the dot and dash of spark-gap code.

The telephone was able to send voice and did every day. But the electronic vibrations had to be carried by direct wire connection. Then they could be reassembled in the earphone at the other end, and the listener could understand what the sender was saying.

It could not be done by wireless. Not in 1901.

So what could de Forest sell to the men who had money to invest?

He could sell the fact that wireless telegraphy was the coming thing for the sea. Ships could not be attached to shore by long wires. Once at sea, they

were helpless, unless they could communicate with each other and with the land by wireless telegraphy. There was no other way. This meant that, even as a means of sea-communication alone, wireless was bound to become a big business. Wireless telegraphy would be invaluable to navies. In battle, ships could communicate with each other even when out of sight or at night. This could easily mean the difference between victory and defeat in war.

Wireless telegraphy would also be a valuable means of message transmission between areas not yet covered by wire telegraph systems. For instance, the many islands where no cables reached.

De Forest realized that it was possible, quite possible, to build wireless transmitters big enough to send messages back and forth from Europe to America. These transmitters might prove fully as practical someday as the oceanic cables. Money was needed to finance experiments, however.

Then there was the hope of radio. It was simply referred to as the idea of wireless telephony then. (The word *radio* did not come into general use until much later.) But in order to invent a device for sending the full voice over the wireless—or more specifically a device for receiving it, money and time were again of prime importance.

Lee de Forest tried to explain that such an invention would bring financial return. Daily he set forth to argue the merits of his system in the business offices of Manhattan. Daily he returned home after argument, discussion, and refusal.

He raised a little money, a few hundred dollars given him here and there by men who had been classmates only a few years before at Yale or Mt. Hermon. This was barely enough to keep him from starving, to keep him going. He set up a small limited trial wireless station on the Jersey shore opposite New York. Finally there was a de Forest system in existence, something real and waiting for expansion.

Even in those dark days, de Forest was making scientific discoveries. In the course of setting up this small transmitter, he found he had to use alternating current for its operation. Until then the source of power had always been direct current.

De Forest adjusted the system to alternating current, found that it worked, and realized that the use of alternating current was worth investigating further when time and money permitted. This was a step forward in the face of obstacles.

The experience of arguing endlessly with men who knew little of science but a lot about finance was trying to the young inventor. He wished he

could tell them what was right and not have to hear their uninformed ideas and listen with assumed patience. He wrote in his diary:

"Never was one so tied and handicapped in the promotion of one of the most logical business ideas that have ever appeared before the microscopic mentalities of the men to whom I am forced to appeal. And all of them, if they only knew it could make for themselves a place in the history of communication as well as great wealth. I am left to do it all, to be diplomat, inventor, executive, errand boy. I draw five dollars a week if I am lucky. Three months of this have shown me the measureless disparity between the inventor's and the investor's point of view."

But persistence often triumphs. In November and December, de Forest began to find men who listened with understanding. As he began to get larger amounts advanced to him, his hope for the future brightened. Near the very end of the year, it blazed strong. He met a wealthy speculator named Abraham White who took an enthusiastic interest in his ideas. White accepted the inventor's claim and backed the company. So it was that the American De Forest Wireless Telegraph Company was finally incorporated, stock was issued, and funds were made available. White took over the handling of the

finances and began selling stock to the public.

De Forest was receiving a regular salary again, and he was free to go ahead, full steam, to perfect his ideas.

He felt he had no time to waste. Marconi, his self-chosen rival, was still making headlines. On December 12, 1901, Marconi had achieved a new success. He had proven that wireless could bridge the Atlantic. Building a high transmitter at Poldhu, England, and a giant antenna and receiving station at St. John's, Newfoundland, he had managed to bridge the tremendous static and distance of the Atlantic Ocean to receive an audible *dot-dot-dot* of the Morse code letter S.

Not practical, of course, but it got publicity. And at that stage of the game, this was important.

De Forest knew it was high time he was off and running.

Chapter 9

The Sparks Are Flying

It was a simple step to establish a good basis for operations in New York City, once alternating current was successfully utilized, as it had been at the transmitting station in Jersey City. De Forest set up a receiver in a small room on top of the Metropolitan Life Insurance Building in downtown New York, at that time the tallest structure in the city. That location should surely be able to attain perfect reception from the transmitter across the river.

Alas, it did not. For some reason it simply could not receive the messages being sent. Finally, Lee shifted the location, set up a new laboratory and

station further downtown at the tip of Manhattan Island, in a little glass-walled penthouse atop the roof of an office building on State Street. From there the reception was perfect. Lee was not the kind of man to leave a mystery unsolved. Why, for instance, did the one location work and not the other?

He went back and made a minor discovery. At the first station he had unknowingly erected his antenna atop a copper-domed part of the roof. The copper had acted to absorb all the power of the antenna. Hence—no reception!

With funds coming in now to enable real development, the De Forest company began to expand. The Jersey City station was set up atop the Castleton Hotel in Staten Island, seven and a half miles away from the tip of Manhattan across the water. With these two points of communication, wireless telegraphy began to hit a new pitch of speed.

Several telegraphers who had joined the company began to work part time under de Forest. Most of them found it still necessary to find other work, for de Forest's funds and the work available were still not enough to pay for full-time use. But they were all young and eager experimenters, fascinated by the new science. They saw eye to eye with the scientific experimenters of the day who were challenging the unknown waves of space.

Throughout history it has been men such as these who have accounted for much of the advance of society. The people who see in a thing the ideal rather than the financial plum. The history of wireless and radio is filled with the names of men who, holding down other jobs, spent their spare hours at their wires and tubes and sets, signaling, experimenting, publishing in little journals the results of their tedious unpaid efforts, and moving the horizon of knowledge ahead inch by inch.

Such were the men who worked with de Forest now. Some gave up better paying jobs to work with him in cramped quarters on inadequate equipment. Others came to his laboratories after hours, putting in time and effort after their regular jobs had taken toll of their bodies and minds.

Lee de Forest never lacked volunteers for his new stations. He lacked the space and funds necessary to take care of all those who would have helped. Besides, the American De Forest Company was not intended to be a scientific laboratory; it was intended ultimately to be a profitable business. And there was a limit to the amount of voluntary help it could use.

Stations went up at Coney Island and Rockaway, at Montauk Point out on the tip of Long Island, and at Atlantic City. At the same time plans were

being made for a Key West to Havana transmission, thereby linking the island of Cuba with the mainland of North America.

By the summer of 1902, operations were well under way. The War Department took an interest in the new systems of wireless telegraphy. The Army and the Navy were going to conduct their summer maneuvers in New England and off its coast. De Forest was invited to go there and demonstrate the ability of his wireless system to assist in the defense of the country. Could it do the trick? Could wireless be used to carry messages in wartime? To keep the warships informed of the actions of their land forces, and at the same time to keep enemy ships misled? It was a great chance. If de Forest could prove the capacity of his methods, then surely large orders would come in from the armed forces and new expansion would be possible.

But the chance did not come to de Forest alone. The American De Forest Wireless Telegraph Company did not exist without competition. The Marconi Company, the wealthiest of them all, was financed by the British and tested by their navy. It was ready to compete for the American Army contracts. Besides, there was another American company in the field, a wireless telegraph organization

headed by Reginald Fessenden, and known as the National Electric Signaling Company. The field tests were to be given to all three of these rivals.

De Forest set up his stations at Fort Mansfield and aboard a Navy tug. He had confidence, even though the job was handicapped by cannon explosions and unusual circumstances. He wrote in his diary during the trial:

"I am sitting in our little station here, telephone to my ear, awaiting a message from our tug boat lost somewhere on the broad waters of the Sound. Wherever it is I will soon hear its mysterious call speeding over waters and islands—invisible, bodiless—yet awakening responses in this tiny tube which rests on the case before me and listens always. It is a marvelous thing, this etheric language, and when not too much engrossed in the mechanics and business of it all, my mind is lost in admiration of its infinite mystery."

De Forest was confident of the success of his method of receiving. He had found a better system of automatic decoherer than the sponder which had given him his first push. It was a simpler device consisting of two aluminum wires, with rough upper surfaces, and a needle laid across it. This did the job effectively, and de Forest was able to challenge the rivals.

How successful he was is best given in a report published at the time. This reads in part:

"The stations of both the Marconi and Fessenden systems were practically inoperative from the start, and the entire burden of the three fell to the de Forest system, which system, though handicapped by insufficient equipment, as well as by the adverse conditions prevalent in wartime, performed its work in so eminently successful a manner that General Greely personally congratulated the inventor in complimentary terms, stating that 'the de Forest system was the only one, of the three represented, fruitful of results, and therefore the only one of any benefit during the operations.' "

De Forest soon began to reap the benefits of this success. He received contracts from the Army and the Navy for sets of equipment and for stations to be set up. The next years were booming ones for the installation of wireless in the Navy. Navy Wireless Station Number One went up at Block Island; Lee and his men built it and taught the first sailor-wireless operators how to run it. New stations sprang up at Annapolis, at Toronto and Hamilton in Canada, at sites in midwestern cities, and along the lake near Cleveland.

Lee liked the publicity, and he reveled in the opportunities opened to him. Funds were never

too ample, but they were enough, and he himself lived rather frugally. He liked the publicity attached to his name; he was amused at being referred to as the Wireless Wizard by the newspapers.

But he never lost track of the objective of bringing the full voice through the air. Wireless was good; it did things, but it was not the whole good. The Hertzian waves could be forced to do more—and when he had the time and the chance, they would be made to bend to his will.

Time was limited in the booming days, and Lee had to spend more and more of his working hours supervising the activities of the various stations, overseeing the work going on at the former Jersey City post which had now become a small factory for making wireless parts.

Lee de Forest did not stint himself the hardships. The station was set up near Cleveland in the middle of a bitter winter far from comforts. The ice and snow were strong foes, and he and his men worked together to get the lakeside station set up. They went from cold weather to warm, for the Navy authorized the Cuba station to be immediately set up at Guantanomo Bay.

Conditions in Cuba were fierce. Not only was the heat and humidity unbearable, but Lee had to work in uncut jungle, amid the onslaught of insects and

the worst sanitary conditions. His health seemed almost on the verge of wreckage, and there were days in the murderous climate when he was so much in despair that he was ready to give up the task. But he persisted, got the station built and functioning, and went home at last, a hero to his men, and a steadfast "good soldier" in the eyes of the Navy.

In 1903 came the opportunity to repeat the famous effort which first brought him to prominence. Sir Thomas Lipton was again coming to America to sail his fast yacht, *Shamrock III*, for the America Cup.

De Forest gave this some careful thought. The time before which had brought him fame had really been a disaster. Marconi again would represent a press association, as might Fessenden also. Would the same thing happen? Would they jam each other again? Perhaps this time the true story of the former fiasco would leak out, to the detriment of wireless.

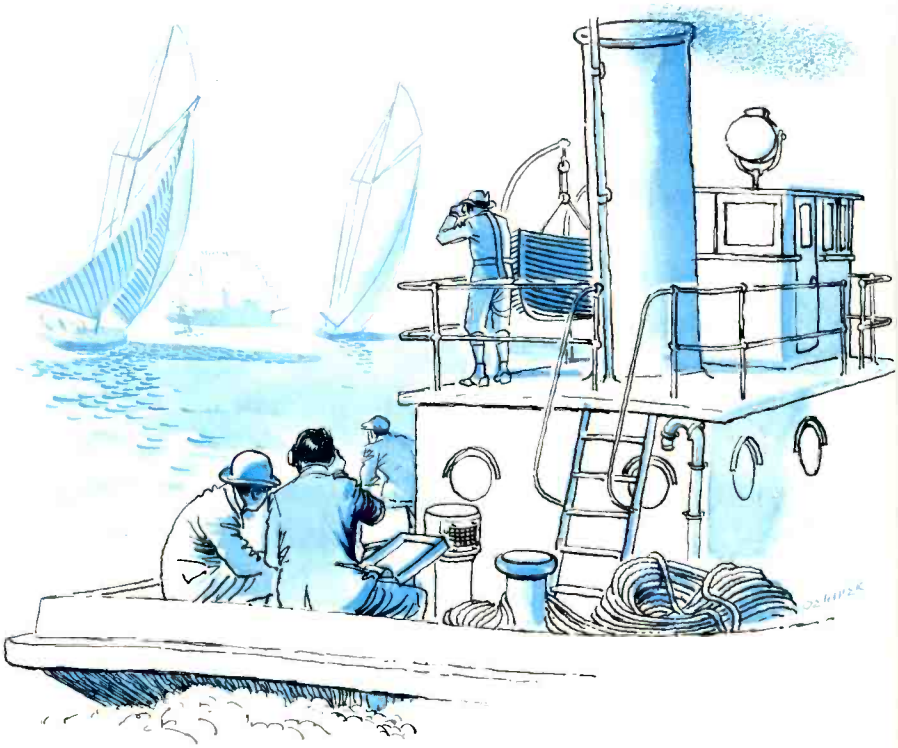
But he braved the challenge a second time, anyway. He would be there, representing the Publishers' Press Association. The day arrived. Could they keep from getting their messages jammed? In the trial runs, it looked bad. Tuning was still something known more in theory than in fact. De Forest had added as much power to his transmitter as he could

in hopes of simply drowning out the rival messages, but it did not seem to help. They drowned each other out, and the keenest ears could barely sort out from the jungle of screams, squeaks, groans, and hammering dots and dashes anything that made sense.

Further interference came from a rival tug, offically barred from the races and representing neither Marconi nor de Forest. It suddenly appeared and began transmitting steadily in Morse everything from poetry to curse words. The intent was obvious —to ruin both rivals. A new station sprang up unexpectedly along the Atlantic highlands where the racing yachts would pass. The Fessenden system set it up in order to demonstrate its ability.

Fortunately the Hertzian wave fight had started in the trial runs preceding the race, and this gave Lee time to work out a method of solving the problem. In the uproar, he saw a new way out.

He had experimented with high frequency sparks at the old Armour Laboratory in Chicago two years ago. Although there were difficulties in generating such a spark on the spur of the moment, this spark would have a distinctly higher pitched and shriller squeal than the thundering notes of the spark gaps everyone was using. Lee hastily rigged up the system from long rods and tubes of acid.



The operator flashed news of the race to shore.

The race was on. The speedy, trim yachts set their sails to the wind. Behind them were various boats carrying the reporters, members of the Marconi and de Forest companies, and the "pirate" crew.

The day was clear and the sun bright, but if Hertzian waves were visible, there would have been

as black a storm as was ever seen. Sounds of thunder and slam and uproar echoed from the receiving rooms on shore, as each operator tried desperately to decipher his own sender's signals from the howls and hammerings of his rivals.

Lee's scheme won out this time. His men at the Coney Island station were able to pick up his tug's messages correctly. The steady *squeak-squeak-squeak* of the high frequency spark overrode all the noise. And de Forest's wireless reportage was successful.

The false reports of two years ago were vindicated.

Chapter 10

Another Fair

It seemed but a short time back to the days when Lee de Forest, as a youth, had pushed a chair at the Chicago Fair. Possibly he remembered how he had dreamed then of someday building something that would dominate another such fair. That day came in 1904. The place was the city of St. Louis, coming into its own with the rising nation, and crowing over itself in a gigantic world exposition celebrating the Louisiana Purchase. Dominating that fair, indeed sprawling all over it, was the name Lee de Forest and exhibits of his wireless enterprises.

At first it was one single tower that housed the de Forest wireless exhibit and station. This alone stood out, for it was the tallest tower in the whole

exposition. At the hundred foot level was a glass-walled wireless station, visible to all eyes, and audible as well. The operators purposely left the spark unmuffled.

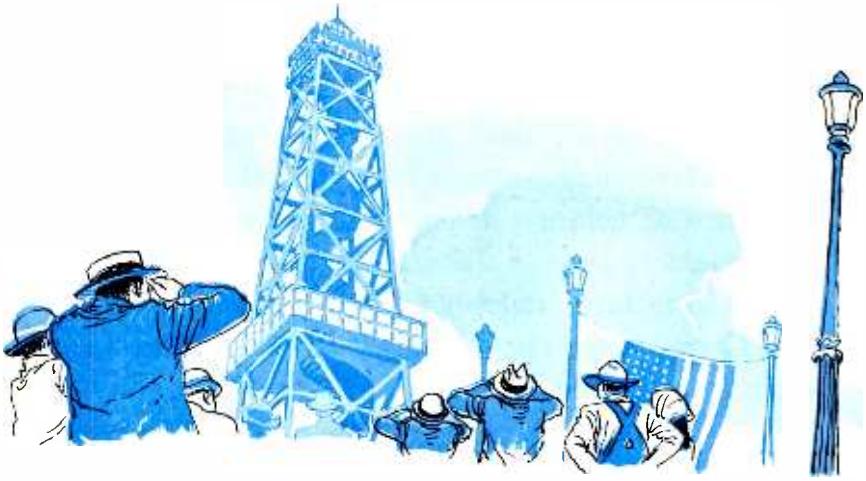
It was, like all de Forest stations, a laboratory and a commercial operation. The snap and bang of its spark-gap transmitters could be heard far and wide. A contract was signed with the St. Louis *Post Dispatch*, and a receiving station was set up downtown in the paper's plant. De Forest's men telegraphed reports about the Fair to the paper's plant regularly.

There was a second pioneering stunt—the first proof that airships could also use the mysterious waves to keep contact with the ground. A brave balloonist was found, his giant gas bag was inflated, and into its basket stepped the balloonist and one of de Forest's more daring telegraphers, along with a portable receiver.

The line was cut, and away the great balloon soared into the sky, with the eyes of thousands of excited Fair-goers glued upon it. In de Forest's mind there was some doubt and some hope. Could wireless waves reach up into the sky, or were they limited to close proximity to the surface of the earth? De Forest had made experiments the year before that showed that these waves channeled

themselves along the ground, following lines and natural gulleys.

The transmitter in the de Forest tower snapped and crackled. Was its message being received? The bag had long since vanished in the sky, driven



Fairgoers gaped as sparks cracked in the tower.

by the winds of the upper atmosphere. Hours later the balloon came down somewhere in Illinois. The phone rang at St. Louis. Yes, the messages were received. Not always clearly, but reception continued all the way up and all the way down. Waves did travel through the air and would some day be

used to help guide the flying machines that were then only in prophetic science-fiction stories.

Lee de Forest began to try out the tower in St. Louis' Fair for distance. It was not adequate, and they proceeded to build still a second tower, a cross of wooden timbers more than 200 feet high on a hill near one of the exhibits. Public demonstrations were not made from it; the glass laboratory did well for that. Instead de Forest equipped it with tremendous power batteries, utilized hitherto unheard of volumes of current, and worked with it for weeks to achieve distance results.

Using large currents proved difficult and costly. There were many failures and burn-outs, great noises and strong smells of ozone, before finally the giant new station was working. But it reached out and "talked" with Springfield, Illinois, 105 miles away, and shortly after established steady communication with their Chicago station, 300 miles away.

The public was skeptical. How, they said, do we know you're telling the truth? It may be all "fixed." Prove it to us. A committee was set up to investigate. From Chicago, one part of the committee phoned in a secret word they had chosen on the spur of the moment. The other part of the committee, in St. Louis, kept it secret from de Forest

and asked him to get the code word by wireless from Chicago. Snap and crackle went the receivers, and by and by, de Forest handed them a slip of paper bearing the mystery word, which he could have learned only over the space waves. There was a phone check with Chicago.

It worked. The public was convinced. At the close of the Fair, Lee de Forest's wireless was awarded the Grand Prize and the Gold Medal.

Lee de Forest regarded that exposition as the high point of his early career in wireless telegraphy, and perhaps it was. He had many such triumphs that year and the next. Things seemed to be going well with him.

Such was the surface aspect of the American De Forest Wireless Telegraph Company's operations —success, triumph, and headline-making achievements. But underneath the private world of wireless inventors was a bitter turmoil of claim and counter-claim.

Marconi's company, for instance, was suing de Forest on a number of grounds, claiming that their patents for devices were infringed by de Forest's own inventions. The suits eventually were won by de Forest, but it meant a continual aggravation, a lot of bad feelings, lawyers' expenses, and a great amount of time spent in argument and explanation.

An even bitterer fight was being waged by Fessenden and his backers. For de Forest had, they said, infringed on their wireless detector by building and using a device similar to it.

This all came about the time that de Forest paid a visit to the home and workshop of his rival, Professor Fessenden, in Virginia. There he observed a new form of anti-coherer detector that was decidedly superior to the sponder and its successor. The basis of this Fessenden device was a fine platinum wire, partly immersed in a solution of acid in which a carbon electrode also rested. A tiny voltage passed across these two wires to produce a rectifier that proved quite efficient, one that could turn alternating current into direct current by simply passing only half of the received current. This tube was far easier to manipulate, far less messy to deal with, and far more efficient than the sponder.

De Forest returned to his home laboratory in New York and proceeded to investigate the matter. He soon determined that the concept of this rectifier had been originated by the famous Professor Michael Pupin in 1899, and therefore Fessenden's patent was not original.

With this in mind, he and one of his assistants Clifford Babcock, set to work to improve on this type of rectifier for the de Forest stations. After a

few weeks of experimenting they came up with what they called the "spade electrode" detector, based upon the same principle as Fessenden's and working very efficiently in the same way. The spade detector was an instant success, and orders for it kept the de Forest factory in Jersey City humming.

Fessenden promptly sued. But the way of the courts is long and slow, and it was three years before the matter came to a decision. The court decided against de Forest, and he was ordered to cease using these detectors. By that time, however, de Forest had one or two things better to replace it with.

One was the audion.

Before the audion, however, there were two busy years of wireless pioneering for Lee de Forest. A message was successfully transmitted to a man in an automobile. A great deal of work was done with the U. S. Navy, establishing stations along the American coast, testing them out, learning about the difficulties of static, and overcoming problems of climate and location.

Static was a problem all the time. The Hertzian waves transmit not only the deliberate sound of electrical sparks but everything in nature that is electrical, every vibration and jolt, the sounds of the stars, the noise of the sunspots, and the jar and

clamor of lightning. There is always static and the fight for a clear detector was always the fight to cut down this natural noise in favor of clarifying the man-made noise.

More power merely made the static louder. Listening to a wireless broadcast was a contest for the ears of the best men. In the earphones were a constant crackling and wheezing and often a dismal howling like banshees on the wind or dogs howling at the moon. To sort out the deliberate dots and dashes through this ear-splitting storm was a feat under the best of circumstances. In some areas, as de Forest found in building the Navy stations, natural static was worse than others. In some spots it was so bad as to make wireless seemingly impossible. But he kept at it, studying and learning the mysteries, and he usually made his conquests good.

Inspired by his fight with static, Lee de Forest finally determined to make the supreme effort of wireless—he would try to send a message across the Atlantic Ocean itself!

He sailed for England in the spring of 1906. From there he went to the west coast of Ireland, a stormy, windy area facing the Atlantic Ocean, but as close as he could get to America thousands of miles away. The receiver was attached to a high-

flying kite, a form of antenna developed for the Navy the year before.

In the dead of night, he sent his assistant out to try to get the huge kite up into the gale-driven air and keep it aloft long enough to pick up the messages being sent regularly from the New York station. Night after night, the kite was blown about, split, tossed, knocked to the ground. Night after night, Lee de Forest sat in the little stone hut they had put his receiver in and kept his ears keen for the sounds of man-made signals from across the sea.

All he heard was static, the tremendous uproar of noise that is carried across the vastness of the Atlantic Ocean. Try as he might he could not hear anything else above the horrible tumult.

Finally, at five minutes after four on the morning of April 11th, when he was just about ready to give up, the natural static seemed momentarily to quiet down. He heard something that sounded like the rapid sending of his star operator in New York. He couldn't quite read it, but the characteristic sign-off signal came along, and that was unmistakable.

It was a moment of triumph. If a real message had been received that could have been read, it would have been a moment of international glory. But such glory as that had to wait a little while longer.

Chapter 11

The First Audions

Meanwhile, what about radio? Did these exciting events in wireless telegraphy contribute anything to discovering the art of transmitting the voice and the sound of music across space without wires?

In a way they did. This progress was necessary to lay the groundwork for radio. Yet, for Lee de Forest, the time spent on wireless meant time taken away from the study of wireless telephony. He did not forget his dream of wireless music, but he was very busy. He did not have much time for pure speculation, or for laboratory work not in some way directly connected with the advancement of his wireless business. He managed nonetheless to find a little time some days.

He had kept at the back of his mind the curious

event that had taken place in his Chicago bedroom back in September of 1900 when he had mistaken the action of a gas burner for a reaction to his wireless transmission. Although the gas flickerings turned out to be just air current waves, he realized that the electromagnetic responses of hot gases should be investigated. The gas burner on his wall did not pick up his disturbances. But under other circumstances could it not be made to?

It was not until 1903 that he found a little time to play around with this purely investigative idea. He rigged up a Bunsen burner in his laboratory, inserted two platinum wire electrodes in the flame, and attached those to a battery and a telephone receiver. Rigging up an antenna and a ground, he then proceeded to see if he could bring in wireless signals with this curious gas-flame detector.

It worked. Not marvelously, but it did bring in the signals. This proved at least that his first suspicion had been sound: a gas flame could be used as the basis of Hertzian wave detection.

The Bunsen burner detector was totally impractical for any commercial use. Ships could not very well be equipped with such clumsy live flame mechanisms. The next step would be to try to refine the principle, to make it a bit more practical, and to see what could be done with it.

A gas flame, bright and burning, was a rather awesome thing, but what did it amount to chemically? It was simply hot gases. Hot gas did not have to come from an open flame. So he next tried a different sort of hot gas container—a carbon-arc incandescent bulb. Although an electric light bulb is thought of as being a vacuum, of course it is not. The finest methods of drawing the air out of the glass tube available in those days still left a faint trace of gas within the tube. Gas is gas, and if that gas be then brought to high heat, it should do the same task as the open flame of a burner.

The carbon-arc lamp worked as a detector, but with a terrific amount of noise in addition. Not practical, but the idea was worth working on.

Clifford Babcock, de Forest's enthusiastic laboratory assistant at the time, attempted to make a different kind of bulb, one which would heat the gas in a more practical fashion. But his efforts were futile, for neither Babcock nor de Forest was very good at glass blowing.

The pressure of work on other enterprises caused de Forest to set this experiment aside until some time in 1904.

It is one of the more fascinating aspects of history that when the time is ripe for a thing, it is often invented and reinvented by several men working

separately. For when human knowledge reaches a level at which certain problems are posed, many men, given the necessity, can work out the answers.

So it was that the British scientist, John Ambrose Fleming, within nearly the same period came up with almost the same invention that de Forest was to come up with. This was a diode or two filament vacuum tube. Fleming was seeking a rectifier for wireless reception, and the diode tube did the job.

De Forest did not know of Fleming's work. He was working in secret himself, knowing that every discovery that could be put to commercial wireless use was important in the race between himself and his rivals. Thus the tube he worked on in 1904 was very nearly the same as that which Fleming invented. But there was a significant difference.

De Forest wanted a method of using hot gas as a detector. It had to be in a tube. One filament would be needed to heat the thin gas within the tube. The other filament, or plate, would have to be the charged wire that would serve as the source of detection for the action of the gases under the influence of wireless waves. To heat the first filament he used one dry battery, which he called the A battery. To charge the second filament, he needed a second battery, and this he called the B battery.

The idea was original, and no sooner had de Forest hit upon the thought of two power sources in the one tube than he realized that here was a basic new device. What it would lead to he could not be sure, but it suddenly opened the door on many possible variations of tube. He filed a patent on the idea of the tube with a B battery.

The use of the B battery made a fundamental difference between his tube and Fleming's. For Fleming's tube merely corrected and modified the one source of current. What de Forest's did, with its additional source of power, was to control and direct that current. It could add to the strength of a weak signal. De Forest's two-filament tube held the potential for really improved wireless detection and reception.

But the first examples of it were still in a clumsy and impractical stage, and the continued press of other work put off further experiments until 1905. Meanwhile it had at least acquired a name for itself among the few who knew of it. Babcock suggested the name audion, and so they called it.

By 1905, de Forest realized that the law suit against his firm started by Fessenden over their use of the spade detectors soon would be coming to a head. While de Forest did not consider Fessenden's

patent claim as holding, there was still the possiblity that a court might rule against de Forest and order his stations to cease using and manufacturing them.

There was thus a growing necessity to find a better detector than the spade tube. Could the audion, this laboratory stunt, be made more practical? Could it be made ready to replace the Fessenden tube if necessary?

After trying again without success to make their own glass tubes, Babcock and de Forest decided to put the matter in the hands of a professional lamp manufacturer, McCandless by name. In short order he provided them with several good specimens of the audion tube, properly constructed little glass lamps, with a partial vacuum within, containing a carbon filament and a thin platinum plate.

Like a pair of conspirators, de Forest and Babcock set up their audion tubes inside little wooden boxes so that they could not be seen. With six brass connecting posts on the outside, the boxes could be wired to the respective circuits and the A and B batteries. In this form, so that no one would know the secret of what was in the box, they demonstrated the first audions.

It always surprised their wireless operators. De Forest and Babcock would come in like a pair of grinning magicians, connect the mystery box up to

the wires of the wireless receiver, and wait for a message to come in from some other station. When it was coming in, they would switch from the old detector to the mystery box. Immediately the reception would change startingly. Loud and clear and sharp the signals would come in, and the operator would be amazed and delighted.

The audion was ready. They had McCandless make up a batch of them, installed them in the sealed boxes, and sold them to the Navy for use in the government stations. They worked, but the Naval operators began to increase the power to raise the distant signals more, and the result was a continous burning out of the tubes in mystery boxes. Soon the operators were calling for new audions to replace the old and McCandless could not keep up with the blowouts.

The Navy did not like this kind of continuous trouble, and the order finally went out: give up the audions; use the old detectors

A setback, indeed, but one which turned out ultimately to be all to de Forest's good. He had to stop mass manufacture of the audion and go back to his other projects. He nevertheless applied for patents on the various stages of the audion.

In the summer of 1906, he returned to his laboratory to work on the audion. This time he decided

to increase the efficiency of the tube by cutting down a certain loss of power that was escaping to the ground by means of the telephone and battery circuit. Cut down this loss and the amount of energy passing within the tube would be increased. He wrapped a piece of tin foil around the outside of the tube and connected it to the antenna. This helped, and de Forest then considered that if he could put this tin foil, in the form of a third electrode, inside the tube it would be still more effective.

McCandless made him a special audion with this third filament inside the tube between the two electric plates. This new tube worked and showed a definite improvement over the old form.

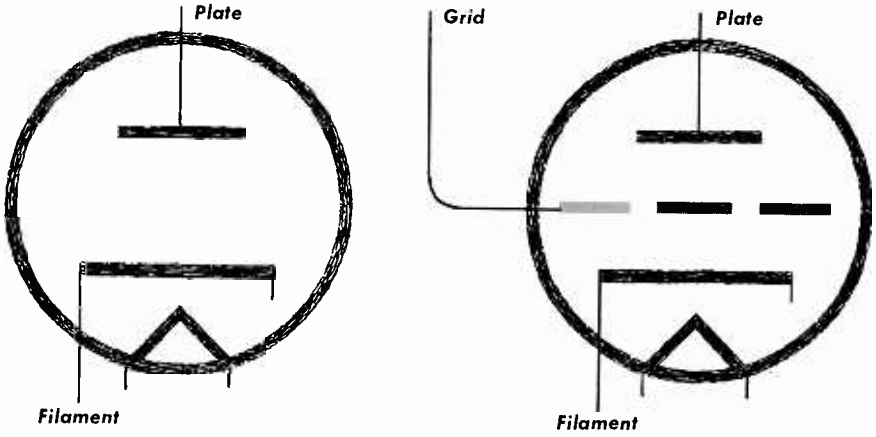
De Forest looked it over, and decided that there was still room for more improvement. Why should this third filament be a solid plate? It should be even more efficient in the form of a perforated platinum plate. And that worked still better. But it would be still simpler, thought de Foreset, to simply use a wire bent zigzag in the shape of a grid.

So McCandless produced still another audion tube with the grid wire inserted as directed, located not midway between the two filaments but as close to the A battery filament as possible in order to better act as a control.

When he had this new tube in his laboratory,

Lee de Forest had finally come into possession of the first triode vacuum tube, the original device that was to prove the key to all his dreams. He began to test it, carefully, cautiously, keeping his secret until he was ready in October of 1906 to file a patent claim for it.

But while the inventor was busy working on this



What a difference a grid made!

most important step of his career, dark clouds had been gathering about the de Forest enterprises. He tried to disregard them, hoped they would clear, but a few short weeks after he had filed his patent for the new and better audion, the storm broke. Short, sudden, and sharp, disaster struck.

Chapter 12

Short-Circuited

What happened? The De Forest Wireless Company collapsed.

Lee de Forest was the chief engineer and the driving force behind the wireless telegraph company that bore his name. When stations were built he was there supervising, building, working out the problems. When new designs were made, he worked them out in his laboratory. He put on all important demonstrations, such as the work that won him awards at the St. Louis Fair. But Lee de Forest was not the whole of the company.

The money to finance these new stations, to fulfill the terms of contracts with the Navy and other purchasers, had to come from the sale of stock. The business of convincing people to invest their money

was the business of other officers of the corporation. These officers were the financiers who had originally helped de Forest to incorporate and go into business. Abraham White was the foremost of those backers, followed by C. C. Wilson, and others. White was the actual president of the company, while de Forest himself held the vice-president's title and about 20 percent of the stock.

White, Wilson, and the others were not inventors and scientists. They were men whose business was making money by selling stock. When de Forest made headlines, the publicity was an excellent way to attract new investors. A huge new drive to sell de Forest stock to the public began in 1906. Exaggerated claims were made about the wealth to be earned by de Forest's forthcoming inventions.

The Fessenden suit was coming up, and the officers realized that it might result in a court order denying the de Forest Company the right to use their spade detectors. Lee de Forest left for England on business early in 1906, but before he sailed he held a conference with his officers, ordering them to make ready the diode audion. For if the order to cease using the spade detectors came, they had to be ready to make the substitution in all their stations.

De Forest returned from England in the sum-

mer of 1906 to find that the court had indeed ruled in favor of Fessenden. But White and the other officers had ruled against the use of the audion. Instead they had substituted a carborundum detector invented by someone else.

De Forest became uneasy at that point. Somehow, his former backers had turned against him. He was kept busy, as always, in his laboratory and with the details of the actual business. He was too busy to confront his fellow officers as he would have liked. Then, in November, he saw that the grandiose ads and notices of the company had reached a new peak of exaggeration. They were now claiming to have bought control of the American Marconi Company. When de Forest saw this in the papers, he knew it had to be a lie. Marconi promptly denied it as a total falsehood. De Forest went to a meeting of the officers. There he found out the full truth of what had been happening.

They had oversold the company to the public. They had sold more shares of stock than existed. The treasury of the American De Forest Wireless Telegraph Company was bankrupt. But the foxy directors had known what was coming and had saved their own fortunes. They had created a new corporation called the United Wireless Telegraph Company and had "sold" to it for next to nothing

the patents and properties of the old company, leaving nothing in the old organization but bad debts and worthless stocks.

Lee de Forest was shocked and furious at this revelation of bad faith and financial skullduggery. He was an inventor, and his name was at stake. He resigned from the company and turned back his shares to the empty treasury of the old organization. White and Wilson gave de Forest what he asked for —$1,000 ($500 of which was promptly taken by a lawyer as his fee) and the audion patents, which they had been assured by a patent attorney had "no value"!

So it was that Lee de Forest walked out of the board meeting on November 28, 1906, just about back where he was in 1901, almost penniless, and having to face starting all over again. It was a gloomy and shocking prospect. For several years he had been riding high in public esteem, acclaimed as the Wizard of Wireless, forging ahead in his dreams of conquering space for man's use, and dreaming of the day when he could comfortably establish himself as a great inventor no longer beset by money worries.

He had never taken a big salary out of the company even during its most profitable period. He had been content to live in a modest apartment, and

had put off even the hope of marriage and children until he could feel himself firmly established. Now this. Thirty-three years old and back on the streets at loose ends.

But his mind, dwelling on such gloomy thoughts, pulled back. This is not so, he thought. You have a name that millions already have heard of and respect. You still have a laboratory of your own. You have the audion patents and great prospects to come of them. You are not the unknown young man who came to New York just a few years back to challenge Marconi.

The main laboratories of the De Forest Company were still down at the Battery in New York, but a few months before, Lee had set himself up a small private workshop in the Parker Building on 19th Street and Fourth Avenue. He used the shop primarily for work on the audions, for he wanted to keep those experiments away from the eyes of the many engineers and enthusiasts who were always crowding into the main laboratories.

This workshop was his and remained his. He went down there and stood in thought looking around. It was a single large room, with two windows from which he could see the tall towers of the Metropolitan Life Building. There were a couple of tables; a workbench; a few battered chairs; a new,

large high-frequency generator (on which he still owed money); batteries; a phonograph; not much else.

As he stood there, looking around and brooding, he was struck by a new thought. For years he had been so busy rushing around on company projects that he had had no time for his pet dream—bringing music and voice into the homes of the land. He had often dreamed of being able to just sit and work on his experiments, to follow through to the goal of wireless telephony or *radio* communication.

Until then he had had no time. He had had to work on the audion in spare moments, set it aside for months at a time. Now he had all the time in the world. He had no more worries about the operations of the wireless telegraph stations. He had the time, the place, and the will.

All right, then, he thought to himself, they say the audion has no value. I will show them what value it has. I will show the world that the spoken word over the air is worth a hundred times more than the dot and dash of a spark gap. I will produce the radio telephone, and I will bring music over the world without wires.

And I will do it with my new patent that was so mockingly returned to me; my three-filament tube will do something that the two-filament audions and

Fleming's valves and Dunwoodie's detectors and Fessenden's shenanigans can never do—it will amplify.

And I will start this very afternoon of the day the world was pulled down over my head. I will begin by completing my work on this high-power carbon-arc transmitter, which alone would be powerful enough to project the voice.

You want to fight, you financial frauds and stock manipulators? All right, I'll give you a fight!

He sat down and took up the pliers . . .

Chapter 13

Miracle on New Year's Eve

What was the significance of that new generator and the new experimental transmitter that de Forest was finishing in his little laboratory that otherwise dismal November day? De Forest was not a man to work simply to give vent to his fury. He had no time for such foolish angers. He would "get even," if that was the phrase, by proving his own ability to outdo his competitors. There was no time to be lost.

The transmission of such a signal as the human voice or a musical melody over the Hertzian waves required more than just the making and breaking of a single spark gap. It required a continuous controlled disturbance—a steady stream of vibrations such as would be made by a continuous open arc,

allowing a flow of electrical energy from one pole to another. This arc, creating a steady hum in the mysterious vibrations of the universe, could be used as a carrier wave. The specific patterns of the human voice could be imposed upon it in the same manner that the human voice was imposed upon the electrical current running through the wire in a telephone system.

So, the condition necessary to transmit the voice was a steady electric stream. The generator could produce a steady continuous spark of sufficiently high frequency, which could be controlled—or modulated—by means of a microphone. (In this case, the microphone consisted of a simple telephone mouthpiece.)

When such a proper transmitter was developed, the voice could be carried over the wireless. The device for receiving this transmission would be the new audion, able to sort out the modulated carrier wave from the rest of the static and noises, clarify it, and, if the audion happened to be the new grid invention, magnify it to greater audibility.

De Forest was not alone in his search for long. He still held the esteem of the engineers and technicians of the old laboratory downtown. He also had the support of a loyal band of wireless amateurs—men and women in other lines of work who found

building wireless sets a pleasurable hobby.

His first helper in this new stage of discovery was a Mrs. Hogan, who came to his little laboratory with her teen-age son, John. John wanted to work for Lee de Forest as his assistant, for he hoped some day soon to attend college and follow a scientific curriculum. He wanted to learn something of the methods of scientific work before he started. John Hogan had a remarkably low and powerful voice for his age; he was willing to assist de Forest in any way possible, and de Forest took him on.

The year was drawing to a close, and Lee de Forest was driven by the desire to achieve something before it ended. The year's end had always symbolically meant a great deal to him. This had been such a strange year, with its ups and downs, and he needed one last triumph to make up for the lack of money which would surely bar any New Year's Eve celebration. And that was the day he got his reward, December 31, 1906.

He set up his new carbon-arc transmitter at one end of the workroom in the Parker Building, stationed young Hogan at the other end with the audion receiver, and spoke into the microphone. De Forest's exact words are unknown. No carefully thought out phrase such as Morse's first telegraph message,

Amazed, John Hogan heard de Forest's words.

"What hath God wrought?" More likely something like "John, are getting this?" Whatever he said, John got it. It came in just as it was transmitted. Radio was born and with it the Electronic Age.

A few hours later, sitting in his apartment about to go to bed, while the rest of the city celebrated the New Year, Lee de Forest wrote in his diary:

> A New Year, a new Era, a new Hope has dawned upon my life. The world in the years past has dealt hardly with me, and I have seen hopes fail, friends betray. Courage only and faith in a final happiness have remained unchanged, the unaltered star toward which the world ever points its pole.

Romantically enough, the last days of the old year had also brought him another loyal supporter, the girl who later became his wife. He had made the acquaintance of a young lady who lived in the apartment next door. She was Nora Stanton Blatch, a recent college graduate, and strangely enough for our day as for then, a woman graduate civil engineer. She agreed to work alongside him in his development of the new wireless telephone, and became one of his most valued assistants.

Now that radio had its start, the first step was to organize a corporation to develop the de Forest

patents and projects. With financial assistance from John Hogan's father and a few other friends, the De Forest Radio Telephone Company was created. With that, de Forest faced the problem of how to go about catching the public eye, and how to find new financial backing to expand and improve inventions.

He wanted to begin the systematic broadcasting of music. Some wireless operators were bound to pick it up, demonstrators could use de Forest sets to set up public demonstrations, and he would gain newspaper publicity and gather in support.

There existed at that time a company called the Telharmonium Company, which sent musical programs over the telephone wires to restaurants and public halls. De Forest went to this company with the suggestion that they join him in publicity by allowing him to broadcast their programs as well.

He ran an antenna wire up the flagpole in their building near Times Square, and asked the owners of the company to be at the Times Building when he would have a receiving set ready for them to hear. At the appointed time, music was transmitted from the Telharmonium offices and perfectly received four blocks away.

They listened, they agreed that reception was good, and recognized the fact that the sound was

not carried by wires. On the other hand, they could not see how they would benefit from it. They could supply their customers with receiving sets, suggested de Forest. In that way, do without the telephone company wires and its charges. This was the beginning of a new form of music that would eventually reach every home, he said.

But the owners were sorry. They couldn't take the chance. Not discouraged by the failure to realize business from his demonstration, de Forest continued to broadcast music regularly, hoping to attract public attention. It was not necessary to have the amplifying type of audion to receive such broadcasts if they were powerful enough. A surprising number of wireless operators were able to hear music coming in along with their routine signals and the clash of natural static.

At the Brooklyn Navy Yard the wireless operator shook his head in bewilderment as he heard the strains of the *William Tell* overture coming through his headphones. He called his superior, who thought he was joking, and the chief, too, listened in amazement.

Nevertheless, de Forest still faced the problem of earning his daily bread. A man needed money to pay his rent, to buy food, to enjoy the simple comforts of life, and such money was hard to come by

in the early days of 1907. Newspaper headlines, as he had learned in the past, may feed one's pride; they do not fill one's stomach.

It was "hard times come again." This passage from his diary, on March 7, 1907, speaks for his feelings at that time:

"Not since 1901 have I known such a winter as this, never ending, ever overclouded with storm and gloom. No sooner am I free of one dread, or rid of one enemy, or clear of the blight of one error and mistake, than another horrid shape usurps its place . . . ever-reappearing poverty, debt constantly upon me—the supreme difficulty to get started anew and aright—patent complications and constant drain and continual strain of expense—to create again something from nothing, or with nothing—to organize a new company, to make a demonstration, meet rent, secure loans, file patents, emerge from one difficulty into another—one foot always sinking into the mire while I struggle to release the other! Oh, when will it all end? When can I be myself and work as I would, and can, and ought? When will this world allow me to earn my way in the fullness of my life, its possibilities, its deserts?"

Chapter 14

The Radio Telephone

Gloom and despair could never hold down the spirit of Lee de Forest for long. Still young for a scientist of renown, still in many ways "the nerviest in the class," he was also aware of how far better basically his position was than it had been six years before. He had friends, he had fame, he had found romance that had hitherto been lacking—and he had the audion.

Whenever he felt despair, he went to his laboratory and worked on his set. There were many experiments to be made, new adjustments of radio sender and radio receiver, tests to be made of new audions. This was the kind of excitement for which de Forest lived.

There were also others who found a similar thrill in this kind of work. Some of them were very helpful to the inventor as he sought to test the carrying power of his broadcasts. For he was faced with the problem of communication. What good is it to send a message if there is nobody to receive it? What good is a radio station if nobody has any radio sets?

But there were receivers—sets built at home by men to whom radio and wireless were hobbies not businesses. They had built these receiving sets themselves, buying the parts where they were available—the wireless companies could and did sell parts when they had an excess—and making the rest themselves.

One of these radio amateurs had an office high up in the Metropolitan Life Insurance Building within view of de Forest's workshop in the Parker Building several blocks away. Occasionally people walking in the street below might look up to see what seemed to be a crazy man leaning out of a window of the taller building, waving a white towel back and forth.

But the towel waving had meaning. Either de Forest or John Hogan would be peering out of the window to watch. For the waving was a signal from one of their enthusiastic friends that he was receiv-

ing de Forest's experimental broadcasts on the homemade set in his office.

Such listeners were valuable. After an experimental broadcast, de Forest's phone would ring; it would be one of his friends calling to tell him how the broadcast had come in. Was it garbled or was it clear? Was it strong or was it weak? If it was a musical record, did the low notes come over? Was there static?

It all went down in the records. It all contributed to the perfection of the radio.

There still remained, however, the problem of raising funds for the new Radio Telephone Company. De Forest was indeed getting newspaper headlines, but it was a particularly bad year in which to raise money. For 1907 was a depression year, business was panicky, and people were holding onto their money until prospects looked better. It was a difficult uphill fight all the way to get investors to buy stock in the new radio enterprise.

The first ray of light came from the Lackawanna Railroad which operated a ferry across the Hudson River from Manhattan to Hoboken in New Jersey. The officials of that railroad decided to let de Forest install a radio-telephone system between their two stations and on the ferry that ran between them.

Sets were installed in the two terminals, and then de Forest and two assistants went aboard the ferry and set up their system. In short order they completed their task, and the first ship's radio telephone was in operation.

The newspapers again picked up this story. It was an achievement for which the young inventor deserved to be proud. It was time to renew the effort to raise funds so that his public experiments could expand and the idea of radio telephony could lead eventually to radio broadcasting. Already de Forest had told one magazine that he was thinking of putting an opera performance on the air.

How did this first radio work? Lee de Forest wrote a simple outline of his system for use in promoting the sale of his stock. In his own words, let him describe what he had to sell:

". . . waves are used in the transmission of wireless telephony, just as in wireless telegraphy. The present form of wireless telegraphy is that of vibrations arising from a noisy flashing spark, and these act upon a detector which makes the sounds of dots and dashes of the Morse alphabet in the telephone receiver.

"In the same way, but with an arc instead of a spark gap, I generate a continuous succession of electric waves which are utilized in transit to carry

the sound of the human voice. When you speak into the microphone transmitter on the wireless telephone your voice changes the resistance of the circuit and a larger or smaller part of the high-frequency current goes into the aerial wires which are elevated some fifty feet above the building.

"We use much stronger currents than in the wire telephone. At present, we employ the ordinary Edison current of 220 volts, the same power that is used for electric lighting. The atmospheric disturbances will not affect the wireless telephone nearly as much as they do the telegraph, for one is able to distinguish the human voice through a great amount of disturbances.

"The feature about my radio telephone is that it does not need a trained operator. Any person of average intelligence can operate it. To call up a station you first throw on the power by closing a switch. The next move is to set a little disc to the number of the station you want, and adjust a thumbscrew until a pilot lamp burns. Next you set a tuning rod until the needle on the quadrant corresponds with the number on the disc, and your connection is established. It takes longer to describe this than it does to do it.

"All the time one is talking it is necessary to press a small button, releasing it at the end of every

sentence. To listen to a message you place a headpiece on your head and receive it as you would with the ordinary telephone."

Simple enough. Basically each owner of a radio telephone would be broadcasting on his own established wave length. Unfortunately, it was also true that the use of a radio telephone in a business office in place of a regular wire telephone would make every conversation public property—for anyone who cared to tune in on that particular wave length could listen in! It could be useful where wires could not be strung, but as a telephone substitute, it had its drawbacks.

There were many places where the radio would fit in commercially and many places where its use would be welcomed by the public. De Forest, who knew this very well, tried his best to convince the more imaginative money men of this.

The year before there had been a reunion of his Yale graduating class at New Haven. The dean, in greeting the alumni hailed that class of '96 as "The Wireless Class." Reflecting upon this, de Forest had an inspiration. Surely these fellow graduates were the ideal men to invest in the future of radio? College men, men who knew him personally, men of imagination. Supposing he went to them and

offered them an exclusive arrangement for the control and development of radio? Surely they would have the foresight to realize how profitable it must some day be. Surely they would not be as obstinate and short-sighted as the average businessman.

Armed with this thought, de Forest left his laboratory and began the task of paying visits to these fellow classmates. He went to their offices in the business metropolis of New York, sat by their desks, and explained his unique proposition.

In a few weeks he realized that he had overestimated their daring. Yes, they knew him and had shared his youthful dreams with him. But—now they were in the business world. Dreams were not enough; his classmates wanted only cold cash transactions. Radio was a great idea and someday everybody would be happy for it—but right now, in 1907, these Yale men had better uses for their money. De Forest raised a few hundred dollars. But not the tens of thousands needed to make radio telephony a success.

Later in life, de Forest commented that if those men had trusted him, that graduating class might well have become the wealthiest class in the world's history!

Alas! The stone canyons of Wall Street were not the ivied halls of Yale.

De Forest went back to his laboratory, leaving the task of selling the public stock in his company to his partners. Two other men who had been associated with the old wireless telegraph company had left that organization at the same time and for much the same reasons as de Forest. These two, James Dunlap Smith and J. J. Thompkins, had joined with de Forest and a patent attorney named S. E. Darby, and others in launching the Radio Telephone Company. Smith and Thompkins, both crack stock salesmen, kept at the task of raising money through the sale of stock.

The work was hard, but as the year went on, and de Forest's radio produced new triumphs, they began slowly to gather support.

Chapter 15

Carrying the Fight to Marconi

History seemed to repeat itself when de Forest's new company received a request to equip a yacht with ship-to-shore radio communication, in time for use in an approaching yacht race.

The forty-foot motor yacht *Thelma* was to race on Lake Erie. Lee de Forest and one of his best operators dashed up to the yacht's anchorage just before the race, and worked like beavers to install the generator and the equipment. The races went on for five days and the reception was excellent.

The feat again called up a snowstorm of newspaper reports and magazine comments. These in turn brought a second good break, again similar to the luck de Forest had had with his first company. The

United States Navy, keeping alert for new developments, asked about the new invention.

Could de Forest install wireless telephones aboard the two battleships *Connecticut* and *Virginia* in time for them to be tested in September on maneuvers off Cape Cod? Yes, the inventor answered; yes, he could.

De Forest and his assistants set themselves to work constructing new sets. Then they were carried to the Brooklyn Navy Yard, where the two big ships were docked, installed, and tested. De Forest seized that occasion to score a new first. He invited a young contralto to his laboratory and had her sing "I Love You Truly" over the waves. This test broadcast of live singing was heard by two seamen-telegraphers at the Brooklyn Navy Yard.

The two battleships, now carrying radio telephones, put to sea. Admiral Evans, known as "Fighting Bob," had come aboard to observe the final tests. After listening to the crisp but clearly audible orders and observations passing between the ships at sea and their shore base, he promptly notified de Forest that he wanted every ship of his fleet immediately equipped with the same kind of communication.

"Fighting Bob" was in a hurry, for he was preparing a round-the-world cruise to show off

United States naval power, and his fleet consisted of 24 vessels, including 16 battleships. It was a tough order to fill, for de Forest had no factory, only his workroom in the Parker Building, and few hands to help him.

They all pitched in with a will, working day and night, wiring, splicing, testing. Then they carried the sets to the Navy Yard, installed them, and finally tried to teach the sailors how to use them. It was an exhausting and trying task, but de Forest and his men all realized that the future of their work might well depend on their success at this.

Teaching men how to handle and use a radio telephone was not easy especially since there was so very little time. These sailors would not only have to learn to send and receive messages, but also to make minor repairs when necessary, and to keep the sets in working condition under the stress of sailing the high seas.

De Forest and his assistants slept in snatches on the floor of the laboratory. They ate when they could get sandwiches sent up. But they finished the job, putting the last set on the last ship at the very moment it was pulling up anchor to join the others sailing around the world.

A weary de Forest came back from Hampton Roads, but the task was done well. For the most

part the ships reported excellent communication, and the fleet went around the world carrying the news of de Forest's inventions far and wide.

The news perked up Wall Street's interest somewhat. There was no great flood of money, but a few thousands of dollars came in. The year 1907 drew to a close and 1908 began with high hopes. The directors of the Radio Telephone Company felt that de Forest now should go to Europe and demonstrate his work there. Wireless and electrical research was being carried on in Europe, and de Forest could benefit the company by looking into it.

Before he left for Europe, de Forest went to Chicago to set up a radio telephone exhibit at the Electrical Exposition that was held there. He managed to arouse great interest, for the public was allowed to watch men talking to each other over telephones without wires. He personally explained the mysteries of radio to everyone who asked.

Then came a crashing blow. There had been a fire in the Parker Building. His laboratory had burned, and with it his notes, his equipment, his experimental audions, everything! At some other time this news could have thrown him into the blackest gloom, but things were still moving upwards for him, and the trend could not be stopped. A new laboratory was found a few blocks further

downtown. De Forest got ready for Europe.

The occasion was perfect for double duty—a honeymoon as well as a business trip. So Lee de Forest and Nora Stanton Blatch were married. His new wife had just completed an intensive course in mathematics and physics in order to help her husband in his work. She assisted him on the trip.

The French Army was interested in how far radio could carry. Would de Forest care to use the Eiffel Tower to find out? Would he? He jumped at the chance. They set up their station on the lower platform of the tower. They connected it with the great antenna that ran up to the top of the tower, which was one of the tallest structures in the world. One night they played phonographic music into their transmitter.

The next day they waited for reports. Who had heard it? A station a hundred miles away had picked it up. Then later, another report came from 150 miles away. At last news from a station near Marseilles, nearly 500 miles away. The music had been heard there.

That did it. The French were interested. But the Italians jumped the gun. The Italian Army ordered four sets. The de Forests were to go there to install them.

While waiting for the sets to come across the

Atlantic, de Forest and his wife went to Germany and talked with scientists there. He met George Seibt who was doing experiments with a new method of wireless transmission, known as the "quenched spark" system. It was more effective than the systems in use in America for wireless telegraphy and immediately de Forest thought of bringing Seibt and his knowledge across the Atlantic. With Seibt's system the Radio Telephone Company could get back into the field of wireless telegraphy again and show what it could do.

Seibt said he would think about de Forest's offer, and the de Forests went on to Italy and several strenuous weeks of installing and testing. Marconi and Marconi's admirers in his native land objected strenuously to this upstart invading the Italian market. But all went well, and the Italian government order was filled satisfactorily.

De Forest was about to return home when the British Admiralty expressed interest in seeing a demonstration. This could mean big business. First de Forest had to return to New York to look into his business there. His wife remained in Europe until he was able to come back.

Back in New York business was humming. A bigger and better laboratory had been set up at 103 Park Avenue, and a steel tower had been built

for a broadcasting antenna. Businessmen, recovering from the bad days of 1907, were beginning to back the new company. Enough money was coming in to allow great things to be planned. A subsidiary company called the Great Lakes Wireless Radio Telephone Company was organized for the purpose of erecting and maintaining stations for wireless telegraphy and radio communication in such cities in that area as Chicago, Toledo, Milwaukee, and Cleveland.

Another change de Forest put in at that time was to shift from using the old Leyden jars as condensers for the transmitters to a new and improved type of condenser invented in Europe. These Moskicki condensers, as they were called after their inventor, were made in Switzerland. De Forest asked his wife to go there and learn how they were made and used.

De Forest went back to Europe, and he and his wife put on a good demonstration for the British Navy. He sent from one ship; she received on another. The work went well, and the newspapers covered the story completely. But the British withheld their business.

Returning home, de Forest realized that he had never really stopped challenging Marconi. From the day that he had left Chicago with his "sponder" to

that moment in England, he had been clashing with the Italian. Marconi had received his greatest financial support in England. In this clash, though de Forest's radio worked, Marconi's friends had defended support of Marconi, and won.

Chapter 16

There's Music in the Air

The company was still expanding and there was plenty of work to be done. Nora de Forest took over the task of supervising the building and installation of the plant to manufacture the new condensers.

A factory was set up in Newark, New Jersey, to manufacture parts for the various de Forest enterprises, and soon orders began to pour in from other companies as well. Their stations along the Great Lakes had to be supervised and maintained. New operators had to be trained, and new inventions tested. Lee de Forest had his hands full in the months to come.

Dr. Seibt, the German inventor, came to America early in 1909 and joined their organization. To-

gether with de Forest he perfected his quenched spark transmitter and helped install it in the various Radio Telephone Company operations. It soon demonstrated that its powerful carrier wave was superior to the spark gaps of the United Wireless and American Marconi's spreading band of stations. But in over-all procedure the Radio Telephone Company was still far from the level of the two older organizations who were dominating the field of wireless telegraphy.

A new variety of business began to flood the affairs of de Forest's company. The little band of amateurs who first joined de Forest had added members in the previous years and assumed unbelievable proportions. Radio was seizing the minds of Americans and the number of requests for information and for parts was assuming a scale that could not be handled in anyone's spare time. A new business therefore grew up around the work of assisting these radio "hams," as the amateurs came to be called. De Forest had the foresight to allow them to inspect his plants, and to set up a showroom where amateurs could see and buy wireless and radio parts for their home built sets.

At that time, too, he made the acquaintance of a young publisher named Hugo Gernsback who had just begun the publication of a magazine for ama-

teur radio engineers called *Modern Electrics*. Gernsback advertised the availability of these electronic parts, gave de Forest support in his magazine articles, and did valuable work in making available the latest findings in radio communications.

One of de Forest's ambitions was to achieve the successful transmission of the human voice across the Atlantic Ocean. The one time he had tried, he had with a tiny spark of success received a wireless message across the seas. Now he thought again of demonstrating the possibilities of the radio telephone.

He gazed at the tower of the Metropolitan Life Building, where he had already installed a transmitter, realizing that it was at that time the tallest building in America. If he erected a high antenna from this tower, and if the French hooked up an antenna in the Eiffel Tower, it should be possible to broadcast directly from one point to the other.

The idea excited him. He wrote to France; their scientists were interested. The Metropolitan antenna was undertaken immediately. When it was finally up, it towered perilously. Then came a furious winter storm. The antenna crashed into the street, nearly killing someone below. The owners of the building were horrified. They would not permit it to be put up again. What if the next time it fell someone was

actually killed? They were, after all, an insurance company and could not be expected to take such a risk. So that was the end of that effort.

Since the antenna on the top of 103 Park Avenue was functioning, de Forest decided to begin regular broadcasting from there. There were amateurs who could listen. It would make for regular publicity. It was time for a broadcasting station.

An aria from the opera *Carmen* was the first program, sung by a well-known soprano. It was a successful broadcast. Thereafter the de Forest laboratory broadcast musical performances regularly with phonograph records and live voice. The first political speech to be broadcast was delivered by Lee de Forest's mother-in-law, a famous suffragette, who made a stirring speech on behalf of giving women the vote.

During the dark days in Chicago an occasional concert had provided Lee de Forest with his only relaxation. He loved great music all his life, and there was no music he held in greater esteem than that of grand opera. He had a dream which he must fulfill—to bring great music to every home that could afford a simple radio receiver. He wanted to broadcast the opera itself.

De Forest sought out the director of the Metropolitan Opera and discussed it with him. To de

Caruso's mighty voice soared out on radio.

Forest's delight, the director was interested and plans were eventually perfected for a broadcast from the stage of the Metropolitan Opera House.

On the night of January 13, 1910, the great event took place. A small transmitter was installed in the attic of the theater with an antenna rigged on the roof. A special microphone was tucked away in the

footlights and another located on a table on stage. Ricardo Martin sang the lead role in *Cavalleria Rusticana*, and the world-famous Caruso in *Pagliacci*. It was another successful broadcast.

How many people heard the broadcast? Perhaps fifty in all. A group of newspapermen were gathered in the company's Newark plant and they reported it with enthusiasm. As for the rest—wireless operators and amateurs here and there about the city and on ships in the harbor picked up the momentous event.

It must not be supposed that de Forest's ambitions did not have opposition. The old story of jamming and wireless interference that had first occurred during the international yacht races became a continuous routine in the early days of competition between companies. A technical journal *Telephony* which reported the opera broadcast carried the following message:

"All these stations got encouraging results although there was some interruption owing to deliberate and studied interference from the operator of the Manhattan Beach station of the United Wireless Company. All other stations refrained from unnecessary demonstrations of their power, and the Marconi Company was especially courteous in placing special equipment aboard the *Avon*, an-

chored off 13th Street in North River."

United Wireless was the name given to the old American De Forest Company after de Forest severed relations with it. This sort of deliberate interference between stations of competing companies went on a good deal in those years.

Very often the operator would open the transmitter, put a brick on the key, and simply walk away. The sound, as a result, would be a steady uproar of static to the annoyance of any neighboring transmitter that was attempting to operate. There was only one way to get the brick off the key. Send a man over to the other station, have him bribe the operator, or have him take along a baseball bat and "persuade" him with a threat of violence. The police could not help, because there was in those days no federal control over the airwaves, and there was nothing illegal about keeping a transmitter open.

During 1909, however well his experiments were going, things were not happening so favorably in Lee de Forest's marriage. He realized that in asking his wife to work as an engineer and assist him that he was taking her away from the duties of a wife in a normal marriage. She drew apart from him, being occupied with her own tasks for the company, and they came to regard each other more as two engi-

neers than as husband and wife. De Forest tried to improve the situation. He put up all his savings, and borrowed money besides, to establish a home for his family. The site he chose to build on was in upper Manhattan overlooking the river.

His wife bore him a baby daughter in June of 1909, but the gulf between them continued to widen. It seemed best for the mother and child to remain with her parents out of town rather than live in New York, for de Forest was too often called on to make long trips out of town for his company. The marriage ended in divorce a year or so later.

By that time it was simply one of a series of blows that had befallen Lee de Forest. The pattern of his life seemed destined to repeat itself—a pattern of achievement and of disaster, of favor's smile and misfortune's frown. Favor had smiled on his second company's endeavors exactly as it had on his first company's initial efforts. Now came the frown. It was very nearly the same frown that had appeared before.

Chapter 17

Genius for Hire

The first blow fell at a directors' meeting of the Radio Telephone Company late in the spring of 1909. Up to then, business had looked good. The company was expanding and the public was beginning to have confidence in it. As the exclusive owners of the audion and of several other basic patents in the radio field, the future appeared excellent.

J. D. Smith, president of the company, entered the meeting and announced that he was resigning from the firm. You see, gentlemen, he said in effect, I have robbed you blind. You thought that the stock that we have sold has put money in the company treasury, but it has not. The stock I sold was

my personal stock and the money has gone into my pocket. There is nothing left in the treasury.

He produced a new set of figures, a true set, he explained. The other directors, shocked speechless at this revelation of dishonesty, could only look. The company was not only virtually lacking in funds; it

Smith tipped his hat and left.

owed some $40,000. Smith then nodded coldly to the others, took his hat, and walked out.

The other directors, Lee de Forest, Darby, and E. E. Burlingame caught their breaths. What should they do?

Darby and de Forest were at first of the opinion that they should reveal the disaster to the public.

They wanted to go to the federal district attorney and ask him to bring criminal action. But they also knew that that course would surely mean the ruin of their work. The public would not again trust them. The stockholders, those who had put money in de Forest's hands, would lose everything.

No, Burlingame advised. We have been hard hit, but we have assets; we have a company that is still in business; we still have a chance. If we work hard, if we continue as we have, we can make up the debt, put the money back in the treasury, and save the day. The way to do this, he said, was to organize a new company, the North American Wireless Corporation, which would take over the Radio Telephone Company and its patents and stations, then take a public loan by means of selling bonds.

Instead of retreating, advance! The new company, with such a loan, could then enter into full competition with Marconi and United Wireless and really make progress.

De Forest had his doubts, but the vision was tempting. It was too hard to give up all that he had worked for just because of the despicable dishonesty of one man. He allowed himself to be persuaded. Yes, they'd try Burlingame's suggestion.

He later realized that this had been the wrong choice. Crime should not be covered up. Years before

he should have fought White and Wilson in the courts for the American De Forest Company. And at this second disaster he should have entered criminal charges against Smith. Had he followed his true instincts, the situation would have been bad for him financially, but he would have eventually saved his companies, saved his inventions, and emerged the greater for it. But no one could blame him for the path he finally chose to take. He was a genius of science—he could not voluntarily surrender all his hopes to further the course of justice.

The North American Wireless Corporation was launched, and the swindle covered up. But Burlingame's plans did not prove successful during 1909. Money was tightening up to restrict the many operations of the company. De Forest had to stop construction of his new home. Salaries of company officials were cut to the minimum. Plans for new stations and new projects were set aside or cut down in size, because the money was not there to carry them out.

Throughout 1910, the company struggled to keep afloat. Competition for the wireless telegraph business became intense, and the stations of the de Forest companies had to fight against the opposition of the strong chains set up by their competitors. United Wireless again gave them the worst time.

The American Marconi Company, a British financed organization, maintained its lead, based upon its solid standing and conservative, careful dealings. The two American companies, both based upon de Forest's inventions, and both in many ways more advanced than their British competitor, struggled violently for the rest of the business.

In 1910, Lee de Forest transferred most of his field of operations to the West Coast. The U. S. Army Signal Corps had awarded him a large contract to install equipment aboard two transports in the Pacific. After successfully completing that job, de Forest stayed to set up radio telegraph stations for San Francisco and Los Angeles and to establish a regular business.

He traveled between the two cities until the stations were finally set up and running. The stations got some business, but not enough to make them profitable.

During all this time de Forest never ceased trying to improve the transmission and the carrier wave. He experimented in improvised laboratories or the borrowed workshops of friends; his fertile mind would not permit him to quit.

The company was doing no better in New York than on the West Coast. Finally, early in 1911, it became obvious to Lee de Forest that the Radio

Telephone Company was dying. Its plant in Newark had shut down. Its laboratory in New York was barely functioning.

He was supervising the station in San Francisco when it became necessary to return East once more. He asked for funds to pay his fare, but this disastrous message was all he received, "There are no more funds."

A man must eat. A man must pay his rent. De Forest had faced financial difficulties before in his life. The thing to do was to find a job until such time as the Radio Telephone Company could get back on its feet.

He went to a friend of his, an engineer he had met during the past year, C. F. Elwell. Elwell was the chief engineer of a California company known as the Federal Telegraph Company. This organization was doing a profitable business in telegraphy, and they could use a good inventive engineer. They were glad to hire Lee de Forest.

For the next three years Lee de Forest worked for the Federal Telegraph Company. He was given a good salary—something which he never had from his own companies—and a good laboratory in Palo Alto, California. He found himself doing the kind of work he had always dreamed of. For the first time in his life he was without financial worries, without

the problem of supervising business projects not connected with research, free of worries about gathering funds, and of efforts to get the eye of the press.

He very rapidly realized that he had long needed this sort of tranquillity. The Federal Telegraph Company was an intelligently run and progressive organization. It was the first to establish a profitable wireless business between two distant cities. Its chief engineer was a friend and admirer of de Forest, its president was a loyal supporter of his staff, and his fellow engineers were an unusually able and talented group.

De Forest was not limited to the laboratory. His duties often would take him "trouble-shooting" around the various stations of the company. On one such expedition he made a new discovery concerning the mysterious Hertzian waves. He discovered what has become known as selective fading.

He observed that a signal sent out at a specific strength in one area might be received at another point faintly, while at a third point, equally distant, the signal came in strongly. Sometimes, while listening, the signal would fade out or die out completely, only to come back strongly a while later.

This curious phenomenon was especially strong along the Pacific Coast and created a good deal of

trouble for the Federal Telegraph Company. Lee de Forest studied the matter carefully, analyzed the conditions, and discovered that here he was dealing with a natural phenomenon.

There was, he explained, something in the atmosphere that could deflect much of the energy of a wireless signal. Exactly what this was could not be determined at that time, but it would have to be taken account of eventually. Probably, he pointed out, it was due to weather, or other natural changes. Generally, this is considered to be the correct explanation of fading to this day.

So 1911 passed and faded into 1912. De Forest visited New York once more to see his new daughter and to arrange his divorce. He returned to his work in Palo Alto, hoping that he would be free now to devote his time to research. Then, on an afternoon in March, two men came to his laboratory. They asked to see him. When Lee de Forest came up to them, and asked what they wanted, they took out a warrant.

"Dr. de Forest," one man said, "you are under arrest."

Chapter 18

Two Great Discoveries

Lee de Forest was stunned. What was the charge? Whom did these men represent? It seemed as if his world was suffering a severe earthquake.

The two men were United States marshals. They had a warrant from the federal court in San Francisco, and the charge was "using the mails to defraud." The mischief that had been done by the directors of the Radio Telephone Company had come to this. Action by stockholders charging it with fraud in the sale of stock had been taken to the criminal courts. As one of the directors of the corporation, de Forest was being placed under arrest, as were the other directors of the corporation in New York and New Jersey.

The court set de Forest's bail at $10,000. Where could he get that amount of money quickly enough to keep himself out of jail that night? De Forest telephoned the president of Federal Telegraph, Beach Thompson, in San Francisco and explained what had happened. Thompson rallied at once to his defense. Despite the fact that the hour was late and the banks closed, two directors of Federal Telegraph whom de Forest had never even met went out and raised the money. By nine o'clock, the bail was posted and de Forest was saved the shame of going behind bars.

The trial came, but not at once. The mills of justice grind slowly. The trial of de Forest and his directors might be held up a year, maybe two. Meanwhile, he was free to continue life as before.

In spite of the worry hanging over him from the ordeal that was to come—and the danger of a criminal confliction and a possible prison sentence—Lee de Forest made the next year at Palo Alto one of achievement and contentment. He was free to work in the laboratory on research as much as he saw fit. He had two good men working with him.

Charles V. Logwood was one of them. He was a clever, self-taught mechanic with a natural knack for wireless and its problems. Unschooled in both engineering and higher mathematics, he had an

uncanny sort of practical ability in working with electrical equipment. The other assistant was Herbert Van Etten, a graduate engineer, who had left a position with another company to join de Forest in his exciting researches. With their able assistance, Lee de Forest made two of the most important discoveries in the history of radio. These two discoveries were important enough to open the field to all the advances that have been made since.

The first discovery was that the triode audion could be used for amplification in series. The second discovery was that the triode audion could be used as an oscillator.

De Forest's three element vacuum tube had the ability to sort out extremely weak signals received and strengthen them by supplying current from the B battery until the signals came through the headphones distinctly and clearly. It did this by picking up the incoming vibrations and reproducing this pattern in an electronic flow in the identical pattern.

But the amplification—and that word merely means the enlargement, or the magnification—from one audion tube was still not sufficient for signals to be heard except by means of a receiver similar to that of a telephone receiver. The device consisted of a disc clamped tightly to the ear, barring outside noise. Could incoming sound ever be amplified

enough to be heard without the need of earphones? Could it be made as loud in the receiver as it was when first spoken into a transmitter?

No, not with only one audion. But, reasoned de Forest, suppose he found a way to amplify that original amplification? Could not a second audion amplify the results of the first? And a third add to the volume of the second? The idea seemed reasonable. It even seemed simple. Just attach a second audion in sequence after the first, and run the output from the first through the second. That should do it. It sounded easy, but in practice it was not.

A way had to be found to wire the two audions in order to obtain this effect. The three men also had to discover how to feed the output of one tube into the intake of the second. They spent weeks working it out. At last they achieved their aim and got their boost in sound. But the result was not exactly satisfactory. For with each increase in the sound of the voice, they also got an increase in static, background noise, and a loss in clarity.

De Forest decided the trouble lay in the audions he was using. They were still being made in New York by McCandless, the lamp manufacturer, and they contained some gas. McCandless did not have the means to exhaust all the air from inside the tubes, but de Forest knew that the presence of gas

inside the tubes added nothing. It was an electronic flow that passed between the filaments, not gas molecules.

So he sent a batch of audions to an X-ray firm in San Francisco, which had the means to really exhaust the tubes and make them more the vacuum tubes that they should be. When the re-exhausted tubes came back, and de Forest tried them in the cascade amplification circuit, he got wonderful results. They worked so well that he could now get reception over a loud speaker. He could make sound loud enough to be heard blocks away if need be—and it was clear and sharp enough to override the background static.

Without this one discovery—using several tubes in sequence—modern radio would never have been clear enough for public use.

The second great discovery was made during the experiments on the use of audions for amplification. This discovery made effective radio broadcasting possible. While de Forest was working out the method of feeding the output of one audion into the lead-in of a second, it occurred to him to wonder just what would happen if he tried to make one audion do double work? What if he took the amplified output of a single audion and fed it right back into the same audion again? Could he then make the

one tube re-amplify its original work?

They tried it. It did not amplify itself. What it did was something quite different. It whistled. When they fed back to an audion its own output, they got a single steady musical tone, a whistling sound that could be made high or low depending on the amount of current.

What was happening? The tube was oscillating. This means that the current within it was rapidly switching back and forth. The plate within the tube was being charged and was discharging. This process was repeated over and over again many times a second. The result of this constant vibration, this rapid series of on-again-off-again, was manifest as a whistling sound.

Did this have any value? The greater the number of spark breaks per second, the better the transmission. All the work that had been done in creating better spark-gaps for transmitters had been done to create steadier, more flexible, and more constant spark-gap sequences. In an oscillating triode vacuum tube, de Forest now had produced the ideal generator of Hertzian waves in steady ultra-rapid vibration. An oscillating audion used for the transmission of radio and wireless was absolutely superior to all the previous methods.

It was and still is the perfect radio transmitting

mechanism. The principle de Forest discovered is what is known as the feed-back effect or regeneration.

As we saw in the case of the diode, when the time is ripe for discovery, several minds working along the same channels may hit on the same idea. It was true in the case of this discovery too. Only a half year later the feed-back and oscillation principle was to be discovered again by another of radio's pioneers, Edward H. Armstrong.

It was only the fact that Van Etten had kept a careful day-by-day record of the work being done that insured de Forest the credit for the discovery. For in Van Etten's notebooks for August 16, 1912, the account and diagrams of the feed-back system proved to the world that de Forest had been first.

Chapter 19

The Fruits of his Labor

Testing was completed and patents were applied for. De Forest realized that with his method of hooking up several audions to amplify incoming messages, he possessed an invention which should make an immediate profit. For unlike most inventions, which required the development of an entire industry before they could be put to general use, there was already an industry that needed and could use his cascade amplifier. That was the telephone business.

At that time the distance a telephone message could be sent was limited by the strength of the electrical impulse that traveled along the wire from speaker to listener. No matter how powerful the

electrical impulse might be at the start, there was a limit as to how long a wire it could traverse before becoming too weak to be heard. This limited the use of the telephone to areas close to each other.

For a long time the telephone company had been looking for a means of extending the distance their messages could reach. What was wanted was a system of amplification that could boost the strength of the electrical impulse whenever it needed it. Such an amplifier, which could be hooked in every few hundred miles, would enable the phone company to run its wires from coast to coast, allowing a person in New York to talk by phone with someone in San Francisco.

De Forest knew that his cascade amplifier could do the job. Add such an audion relay series to the telephone circuit, and it would accurately boost and relay the electrical messages just as received. The telephone people should be willing to pay a good price for this. There should be enough money not only to get de Forest's Radio Telephone Company out of its troubles but to leave de Forest himself a rich man.

He described his new discovery in a letter to a friend in New York, John Stone. Stone suggested at once that de Forest come to New York and demonstrate the amplifier. Beach Thompson, of the

Federal Telegraph Company, who had acknowledged the invention to be de Forest's property, was interested enough to accompany the inventor across the country.

Once Stone had seen the amplifier demonstrated, he eagerly invited the officials of the telephone organization to see it in operation. De Forest took his equipment to the offices of the Western Electric Company and the Bell Telephone Laboratories, two subsidiaries of the mighty American Telephone and Telegraph Company. The engineers there were skeptical at first. They had seen many systems for boosting calls, and none of them had been practical.

But as the audion amplifier went into action, their enthusiasm was aroused. Other engineers were called in. By the time the demonstrations were over, there was no doubt in de Forest's mind that he had "put it over." The telephone engineers were very interested and excited, plied him with questions, and finally asked him to leave his apparatus there for further study.

When de Forest went back to his lodgings in New York, he felt sure that it would be but a matter of days before he would receive an offer for his invention. The telephone company needed the invention. They alone could use it, and they could not get it elsewhere.

Slowly the weeks went by, and de Forest heard nothing from the company. After eight long weeks of idle waiting, Thompson informed de Forest that since he was still on the payroll of the California telegraph company he had better return to his job. So de Forest went back to Palo Alto and his laboratory there, considerably puzzled by the silence of the telephone company.

He spent several more months living comfortably in California, even contributing a couple of important discoveries to the field of wireless telegraphy. But, desirable as the work was, de Forest was troubled by the thought that the longer he stayed away from New York, the longer he was neglecting his own personal interests. His fortune was still to be made. There must be other ways of making money out of the audion amplifier before the telephone company was ready to buy.

So, early in May 1913, he returned to New York. A small group of financiers were considering the use of the amplifier for putting sound into motion pictures. These men were ready to pay him a small salary to study the problem. This was sufficient income to enable him to pay for his daily bread, and he took them up.

Back in New York, the house he had started building at the northern tip of Manhattan had been

completed, and he retained ownership. So he moved in, although he was almost without furniture. He at long last had a home of his own.

The work on sound moving pictures petered out, and things became more difficult for de Forest. There was still not a word from the telephone company, although he had heard from friends that they were still experimenting with his invention. The Radio Telephone Company, too, was in bad financial straits.

De Forest went over to the offices of the company of which he was still a director and part owner. Since the arrests, the business of that company had come to a standstill. There were debts that must be paid. There were taxes that must be paid. The company owned many de Forest patents that were basic to the growing radio industry. They were the only remaining things of value that the company had.

By August of 1913, the outlook for both de Forest and his company was black indeed. He was virtually penniless. The company had nothing in its treasury. In a few short weeks, the State of New Jersey would seize the company and put it up for public sale to satisfy the state's demand for payment of its back taxes. If this happened, de Forest would lose everything. The audion rights would be sold

Coolly, the young lawyer made his offer.

cheaply, and these rights would also include control of the cascade amplifier; for the patents on that depended on the original patents for the audion itself.

De Forest and the other directors of the Radio Telephone Company feared the coming court fight for their freedom. One day a well-dressed, fast-talking young lawyer made a timely appearance. He introduced himself, talked about their difficulties,

about which he was very well informed, and then said that he had been hired by a group of businessmen who were interested in buying the wire transmission rights to the audion cascade amplifier.

This news was very puzzling to de Forest. Who besides the telephone company could possibly make use of those rights? Politely, the lawyer assured him that his mysterious clients—he would never name them—were definitely not the American Telephone and Telegraph Company or anyone connected with them.

"No," he insisted, "on my word of honor as a gentleman, I do not represent the telephone company."

He was prepared to offer de Forest and the Radio Telephone Company the sum of $50,000 for the amplifier.

Now de Forest was in a quandary. He had been told by friends that the A. T. & T. would pay at least $500,000 for this invention. It was worth that and more. Should he sell now for a tenth that amount, or could he wait longer and get the telephone company's offer? He could not afford to wait. He would lose everything if he did. So, with his back to the wall, he accepted the offer.

The papers were drawn up, and the Radio Telephone Company sold the stranger their rights to

the audion amplifier for $50,000. It saved the company, paid their debts and taxes, and enabled de Forest to start plans for further developments.

But a few weeks later, the truth came out. De Forest had been deceived. The mysterious buyer of his invention quickly resold the patent to the American Telephone & Telegraph Company. The strange young lawyer had known of the telephone company's interest and probably saved them hundreds of thousands of dollars. He had taken away from Lee de Forest the rightful rewards of his genius.

The Wizard of Wireless was left to face the ordeal of a trial and possible imprisonment without funds of his own to help him.

Chapter 20

"Not Even a Good Lamp"

The money that had been paid for the telephone relay rights to de Forest's amplifier did not put a cent in his pocket. He used it for the benefit of his company, which was to undergo a complete reorganization, a change of name to Radio Telegraph and Telephone Company, the creation of new and better equipped laboratories, and a new program of scientific research. De Forest himself was virtually penniless.

The other directors of the company had already secured lawyers and had prepared arguments to keep themselves out of prison. De Forest had been too busy for this. The trial was set for November 12, 1913, and time was pressing. Would he have to go

into court with nobody to speak for him, with nothing planned for his defense?

He had never been without friends and admirers, and this time aid came from his old classmates at Yale. They believed him innocent and, unknown to him, they had created a de Forest Defense Fund, which raised a couple of thousand dollars from the old grads. With this money, de Forest was able to hire a youthful lawyer, who was ready and willing to do his all to defend him.

Almost from the start it appeared to be de Forest's great invention that was on trial, and not just the five directors of his company. The district attorney concentrated his attack on showing that the audion, the basis on which the company had been promoting the future of its radio and wireless enterprises, was just a fake, a fraud, a piece of junk.

In his opening statement, the prosecutor charged the five men with "use of the mails to defraud, by selling stock to the public, in a company incorporated for $2,000,000, whose only assets were de Forest patents directed chiefly to a queer little bulb like an incandescent lamp which he called an 'audion,' and which device had proven to be worthless—was not even a good lamp."

The district attorney paused here and sneeringly

held up one of the audions for all to see.

It didn't look like much, held up that way. It was seemingly just a glass bulb. How could this simple device be of any value? The prosecutor set it down again and continued his attack. He outlined what he called the fantastic nonsense that the inventor had claimed for his little bulb.

"De Forest has said in many newspapers, and over his signature, that it would be possible to transmit the human voice across the Atlantic before many years!"

Snickers were heard in the courtroom. De Forest sat, not believing his ears. Was this trial to be one built on ridicule and ignorance?

"Based on these absurd and deliberately misleading statements of de Forest, the misguided public, Your Honor, has been persuaded to purchase stock in this company, paying as high as ten and twenty dollars a share for the stock!"

The district attorney paused, then went on in a loud and demanding voice, "Your Honor, members of the jury, in the name of the people of the United States, I ask that these scoundrels, de Forest, Darby and their associates be given the very limit of the law, that they deserve nothing less than long terms at hard labor in Atlanta Penitentiary!"

De Forest's heart sank. Was it really to be so?

Did his work appear to the public to be criminal? Yes, such men as Smith deserved jail. They were scalawags, men who had tried to line their pockets by misleading statements; but the invention was real, the audion was not just an incandescent lamp. It was a key to the universe that was worth far more than the $2,000,000 the firm had been capitalized at.

De Forest based his defense upon this. A procession of the men who had worked with him, who had sweated out the rush orders for the Navy, who had traveled with him and worked with him in summer heat and in winter cold, appeared in court, went on the stand, testified to the integrity of the inventor and the worth of the audion.

Unexpectedly, even his old rival, the American Marconi Company, sent one of their men to court to testify to the audion's merits. But the company that could really have testified to the audion's value, that had just finished an exhausting series of tests on it, and had just paid out a substantial sum for it, the telephone company, sent no one.

The trial dragged on for six long weeks. During this time the full story of Smith's looting of the company treasury came out, the story of how Thompkins had covered up for him and how greatly they had worked to sell stock by promising virtually anything to get people to invest.

There had been indeed criminal operations going on behind de Forest's back, and he winced as each revelation came out. Yet he knew that even the most exaggerated claim could someday be made real. The audion could be the means to create marvels that would transform the world. With it man could span the continents, bring light into darkness, plumb the depths, guide men in times of peril on land, sea, and in the air. Someday the audion might extend the frontiers of human knowledge out to the farthest corners of the universe itself. But it would take a lot longer to realize those claims than was expected by the hopefuls who had been persuaded to buy a few shares of stock and become rich in a few short months.

It was typical of the strange sequence of dates that marked the milestones of de Forest's life that the last day of the trial fell on the last day of the year. At noon on December 31st, the case was concluded, and the jury filed out to begin their consideration of the case.

It was a tense afternoon. The result of the jurors' discussions might well mean prison and the end of de Forest's career as a scientist. He waited out the hours with dread in his heart and his mind a turmoil of conflicting visions. Were his next years to be ones of creation, challenge, and discovery or

would there be dreary hours of useless toil behind the stone walls of a prison?

Night came and the jury was still out. The hour of the New Year approached. Still no word from the jury room. Outside now the church bells rang, and there were whistles and cheers and laughter in

"Not guilty!" What a way to start the New Year!

the streets. It was 1914, the first day of the New Year, and still the courtroom was silent and waiting the word.

De Forest recalled that on another New Year's he and John Hogan had used the audion to speak to each other the length of a room. Now, just a few

years later, the audion was facing a quite different sort of trial.

At one o'clock in the morning, the jury returned and took their seats. The judge rapped for order. The jury had reached its verdict.

"Smith, Thompkins, Burlingame—guilty on all counts.

"De Forest, Darby—not guilty!"

In that verdict, de Forest saw the audion achieve its rightful recognition. It was no swindle. It was not just an incandescent lamp—and a poor one at that! There had been a swindle, but it had not been in the product nor by its inventor.

De Forest and his friend Darby, the patent attorney, celebrated that New Year's Day after all. The audion was in the world to stay. It had survived its birth pangs.

Chapter 21

The Electronic Age

The dawn of the first day of that New Year may be said to close one period in de Forest's life and in that of the radio. The days ahead were much brighter. Although de Forest's life did not always run smoothly after that, never again was he to know the depths of poverty and despair that he had known during the days of his three basic discoveries.

What radio had needed to become a practical, popular, and universally applicable instrument had been precisely those three inventions, all of which were summed up in the small glass tube called the audion. The audion supplied the receiver, the transmitter, and the amplifier that were the elements necessary to turn the universal ocean of Hertzian waves to mankind's service.

In the trial, it had been the audion that had been really weighed and considered by the jury and it was the audion that had emerged with a clean bill. It was no fraud. It could do the wonders that even the most exaggerated boosters had claimed for it.

All the audion needed was time and the work of many experimenters and engineers of the de Forest caliber. All it needed was the opportunity.

The coming of World War I in 1914 demanded that its development be speeded up. So by the end of that war and the beginning of the peace-time boom in the 1920's, radio was already out of the budding stage and entering the first full flower of its bloom. Today the work that began in a small laboratory in 1906 has become a giant, worldwide industry that has transformed every home and factory and country as the Electronic Age spread from that one workshop to cover all of civilization. The audion has grown into thousands of varieties, some huge, some tiny. It has produced television and radar, hi-fi phonography and radio telescopes, space-probing satellites, and ocean-probing eyes. It saves lives in hospitals, and it operates automatic machinery in factories.

Lee de Forest lived to see it all in full flower. He made his home in New York City in the house he

had built overlooking Spuyten Duyvil Creek. In the last decades of his life, he moved back to Los Angeles, where he continued to experiment and invent almost to the very end of his life, which came at the ripe age of 87, on June 30, 1961.

Perhaps one of the things that kept "Doc" de Forest young in spirit and strong in health was the vigorous combativeness of the young radio industry. Its history, and de Forest's history, in the years following 1913 show almost the same patterns as the years that had gone before, although without the blackest parts. There was a continuous progression of business efforts, of intense competition, of court battles between one inventor and another and between inventor and corporation. Lee de Forest for very many years put in a burdensome amount of time in the courts defending his rights to his discoveries.

For it is one of the facts about modern invention and particularly about radio that it was not the product of one single mind but the work of many minds, sometimes working together, more often working separately and in conflict. De Forest's claim to the audion is now conceded by the world, but it was not without struggle. Fleming insisted that it was just a variation of his own tube, and that was a point of argument in scientific journals and court-

rooms. Fessenden locked horns again and again with de Forest over their inventions, and Edward Armstrong put up a terrific fight to gain credit for himself for the feed-back principle. Marconi's companies clashed with de Forest on further occasions over the years.

All these men, Fessenden, Armstrong, Fleming and others, were themselves brilliant inventors and devoted scientists. They contributed much to the rising field of electronics, and their differences of opinion with de Forest is just a part of that constant clash of thought that makes for the advancement of science.

De Forest, after the trial, re-established his company on a firmer basis and continued his progress. He carried on business on future occasions with the telephone company and its subsidiaries and got what he asked for. After World War I he concentrated for a time on the development of talking pictures in which field he was also a true pioneer. He was one of the first to work on television. There was no year of his active life that did not see two or three patents in electronics registered in his name.

Today the very idea of that district attorney holding the audion to scorn is incredible. The great engineer Charles F. Kettering, himself an inventor,

had perhaps the last word on the subject when he wrote:

"Perhaps the most important event in the history of electronics [occurred] when a young experimenter named Lee de Forest inserted a third electrode in the form of a grid between the cathode and anode of a vacuum tube. The spectacular growth of electronics to an enormous industry employing over a million workers and benefiting untold millions of people in all parts of the world may be said to have begun with that event. . . Even today the full extent of its utility and value has only been scratched."

What became of the companies that de Forest founded? Was there a victor among them? The first de Forest company became the United Wireless Telegraph Company, and as such enjoyed a period of rapid growth and apparent widespread strength. But for all that success, it finally reaped the inevitable reward of its stock-manipulating founders—enforced bankruptcy. Wilson ended up in jail and White in a pauper's grave.

When the first de Forest company was bankrupt, its de Forest patents were bought by the American Marconi Company. American Marconi was also eventually to come into possession of the patents and properties held by de Forest's second company as that firm closed its doors, also. So, in the race for

radio, it was Marconi that won after all!

The de Forest patents and others bought or developed by the telephone companies, as well as those owned by General Electric, were finally merged with those of the American Marconi Company to form one large organization, the Radio Corporation of America. Later RCA was cut loose from its founder companies and set on its own as an independent firm.

It is true that eventually all of de Forest's contributions to radio flowed together into the one great stream of the rising electronics industry.

Perhaps the best way to conclude this story of the young inventor and the first days of radio would be to quote the editorial in the *New York Times* the day after he died:

"Lee de Forest was credited with more than 300 inventions; but his name will forever be associated with one magic word—audion. It was this single invention, a vacuum tube in which he introduced a third element, known as the grid, into a two-element tube invented four years earlier by Dr. J. A. Fleming of England, which brought into being the Electronic Age with all its marvels. Its immediate achievement was to make possible radio broadcasting and the long-distance telephone. Later it led to the talking motion picture and to television.

But these were only the early manifestations of an age that is just now beginning to unfold. The electronic tube and its more sophisticated modern descendant, the transistor, have made possible the giant computing machines that in many ways challenge the human brain. It has opened up the age of automation, more revolutionary in its social implications than the industrial revolution. And finally, it has made possible the age of satellites and interplanetary travel, which has opened for man the road to the stars.

It is, therefore, no wonder that the de Forest invention of the tiny tube that harnessed the electron to man's uses is regarded by many as one of the greatest single inventions of this or any other age."

Donald Wollheim

For more than 30 years Donald Wollheim has combined an enthusiasm for writing and an enthusiasm for science. A free-lance short story and article writer in the 1930's, he became an editor in 1940 and has remained one since. From editing pulp magazines, he turned in 1946 to book editing with Avon Books. In 1952, he helped launch Ace Books, a paperback publishing firm of which he is now editor-in-chief.

Wollheim edited the first American collection of science-fiction stories in 1943, the *Pocket Book of Science Fiction.* Since then he has compiled many editions of science-fiction, detective, ghost, and general fiction stories. He collects science-fiction tales as a hobby, and his library of several thousand such books is one of the largest private ones in the world. As a member of the American Rocket Society, he has been one of the earliest followers of space flight efforts. He is also a member of the Company of Military Collectors and Historians, and is an expert on equipment and history.

Among his dozen novels are the following science-fiction books for young readers: *The Secret of Saturn's Rings*, *The Secret of the Martian Moons*, *The Secret of the Ninth Planet*, and *One Against the Moon.* He is the author of a continuing series of space flight novels that has so far included *Mike Mars, Astronaut*, *Mike Mars Flies the X-15*, *Mike Mars at Cape Canaveral*, and *Mike Mars in Orbit.*

Born in New York City in 1914, he attended elementary and high school there, and is a graduate of New York University. He lives now in Forest Hills with his wife and one child.