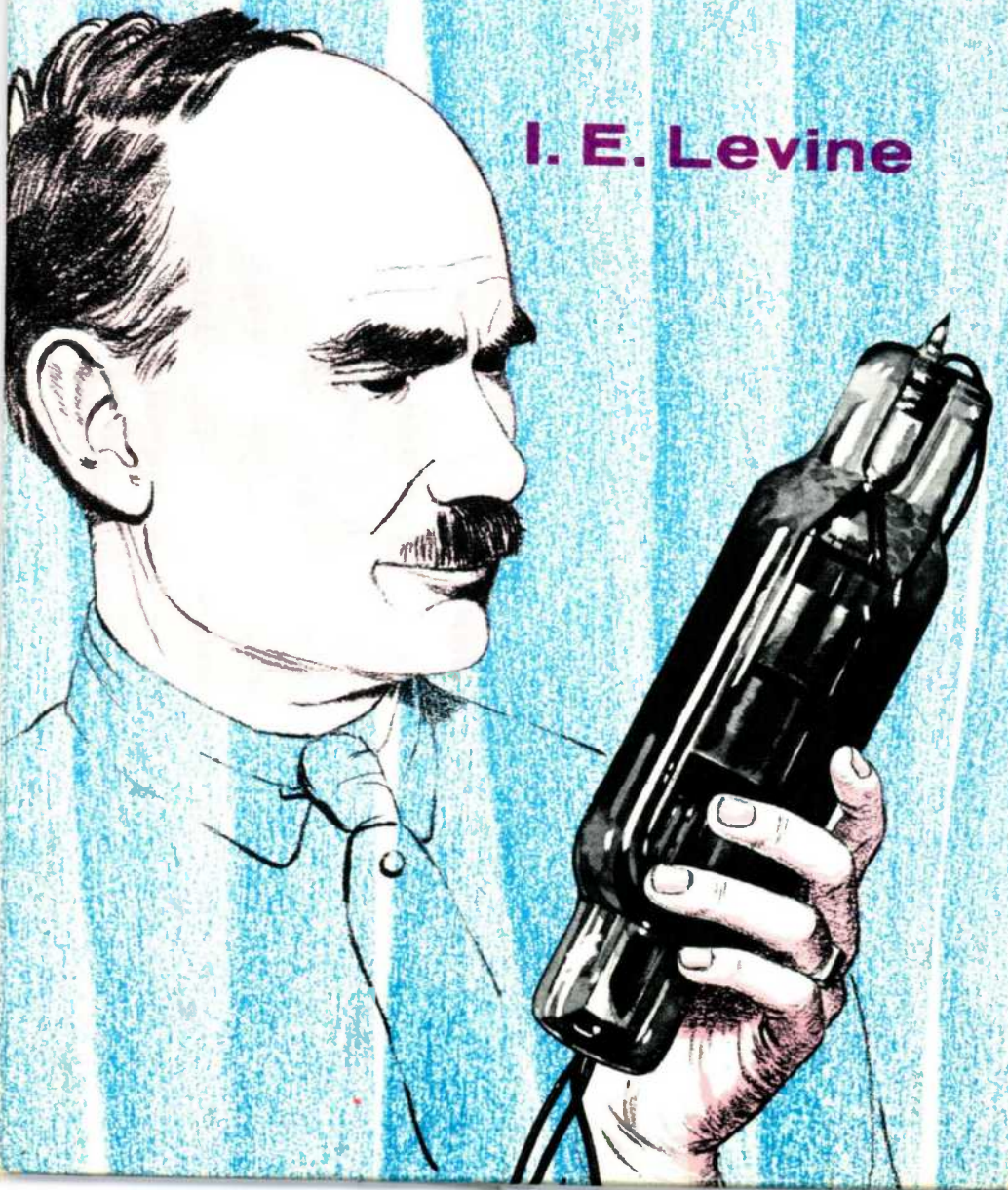
ELECTRONICS PIONEER
Lee DeForest

I. E. Levine



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Lee De Forest

by I. E. Levine

author of MIRACLE MAN OF PRINTING: Ottmar Mergenthaler, *etc.*

In 1913 the U. S. Government indicted a scientist on charges that could have sent him to prison for a decade. An angry prosecutor branded the defendant a charlatan, and accused him of defrauding the public by selling stock to manufacture a worthless device. Fortunately for the future of electronics — and for the dignity of justice — the defendant was found innocent. He was the brilliant inventor, Lee De Forest, and the so-called worthless device was a triode vacuum tube called an Audion, the most valuable discovery in the history of electronics.

From his father, a minister and college president, young De Forest acquired a strength of character and purpose that helped him work his way through Yale and left him undismayed by early failures. His first successful invention was a wireless receiver far superior to Marconi's. Soon he devised a revolutionary transmitter, and at thirty was manufacturing his own equipment. Then his success was wiped out by an unscrupulous financier. De Forest started all over again, perfected his priceless Audion tube and paved the way for radio broadcasting in America.

Time and again it was only De Forest's faith that helped him surmount the obstacles and indignities thrust upon him by others. Greedy men and powerful corporations took his money, infringed on his patents and secured rights to his inventions for only a fraction of their true worth. Yet nothing crushed his spirit or blurred his scientific vision. He gave the world radio and long distance telephone. He perfected talking motion pictures long before the movie industry saw the value of sound. Radar, television, guided missiles and modern computing machines were all made possible by his work.

This biography of Lee De Forest is full of memorable scenes that illuminate the mind and heart of this gifted man. His story is as exciting as his ideas and achievements.

Jacket by The Etheredges

ABOUT THE AUTHOR

Photo by L. D. Weiner

I. E. Levine is a native New Yorker who lives in Kew Gardens Hills, Long Island, with his wife Joy and their children David and Carol. After graduation from high school he entered the City College of New York with the idea of becoming a physicist, but in his junior year he was infected by the writing bug and changed his course of study to English and the social sciences.

During World War II he interrupted his education to enlist in the U. S. Army Air Corps where he received a commission and wings as a navigator. Assigned to the Eighth Air Force in England, he flew thirty-two bombing missions over Germany and Occupied Europe aboard a B-24 Liberator. After the war he returned to City College to complete his education and began to work in the college's public relations department. In 1954 he was appointed Director of Public Relations, a position he still holds. In addition to his public relations work he has written many articles for national magazines and is the co-author of two books for adults and numerous biographies for young people.

"I enjoy writing biographies for young people," Mr. Levine says. "Each time I undertake a new subject it's like embarking on a new adventure. I consider it a challenge to try to convey my own feeling of adventure and excitement to the reader. Since we expect young people to meet the challenge of tomorrow, I think it is important for them to have a sense of the drama of history, as reflected in the lives of the important figures who helped mold the past."

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by I. E. LEVINE

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BORN: August 26, 1873
DIED: June 30, 1961

In 1913 the U.S. Government indicted a scientist on charges that could have sent him to prison for a decade. An angry prosecutor branded the defendant a charlatan and accused him of defrauding the public by selling stock to manufacture a worthless device. Fortunately for the future of electronics—and for the dignity of justice—the defendant was found innocent. He was the brilliant inventor, Lee De Forest, and the so-called worthless device was a triode vacuum tube called an Audion, the most valuable discovery in the history of electronics, for it paved the way for radio, television, guided missiles, rockets and modern computing machines.

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MIRACLE MAN OF PRINTING
Ottmar Mergenthaler

ELECTRONICS PIONEER
Lee De Forest

To my mother and Mollie, with love

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Lee De Forest

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The Early Years

On an October afternoon in 1890, a seventeen-year-old boy sat quietly on a porch in Talladega, Alabama. Fall had arrived; yet the stifling air seemed like an oppressive blanket. In the South, he mused, the summer's heat is like an unwelcome guest that refuses to leave on time.

From the shaded veranda of the Reverend Henry Swift De Forest's modest home on the campus of Talladega College, the boy Lee leaned back in an ancient rocking chair and stared idly down the road. A lone Negro student, with a load of books under his arm, raised small, swirling clouds of red dust as he plodded up the unpaved street toward stately Swayne Hall.

To Lee De Forest it was reminiscent of the sweltering day in early fall eleven years earlier when the De Forest family had first come to Talladega from Muscatine, Iowa. He was only six then, but he could remember as if it were yesterday the excitement in Muscatine when his father announced that he had accepted the presidency of this small southern college for Negroes. And just as sharply etched in his mind was the memory of their arrival in Talladega.

Mr. and Mrs. De Forest and their three children had climbed down from the sooty day coach of the East Tennessee, Virginia and Georgia Railroad to find themselves on the dusty platform of a dingy rust-colored frame depot.

Waiting at the station for the luggage was a two-seated buckboard and a plank wagon driven by two of the older Negro students. While the bags were being loaded on the wagon, passers-by stared curiously, if not resentfully, at the white family from up north who had come down to Alabama to help educate the children of former slaves.

Six-year-old Lee was disappointed at the unimposing appearance of the town as the tiny caravan made its way up the unpaved red clay streets toward the hill on which stood the two brick structures that composed the whole of Talladega College in those days. There were broken windows in both buildings, and the yards were littered with debris. Pitifully thin hogs and cattle had a free run of the "campus"; apathy and discouragement were visible everywhere.

Yet with the customary zeal and devotion to duty, Lee's father had taken the institution in hand and brought order out of chaos. Within two years after the family's arrival a new boys' dormitory had been erected by Negro workers—many of them students—under the personal supervision of President De Forest. They had molded bricks in the middle of the campus, with the help of a primitive horse-turned mixing machine. Later, other structures were put up, including a home for the head of the college and his family.

As Lee De Forest thought back over the events of those past eleven years, he could not help marveling at what his father had accomplished. He envied the elder De Forest's ability to subordinate himself to the important cause he had agreed to serve, and he wished he could be more like his father in this respect.

In truth, Lee was unhappy, for he felt bowed down under a heavy burden of self-pity. At seventeen he considered himself a failure. He would have given anything to be like his parents, blinded by absolute faith in what destiny decreed for them. Of late, he had noticed a similar tendency to submit passively to fate's fortunes in his older sister Mary and

his younger brother Charlie. Sometimes it seemed to him that of the entire De Forest family, he alone had been cursed with the brand of the eternally dissatisfied.

The fit of despair in which Lee found himself had been touched off earlier that morning at the breakfast table. Once again as he had done so often in recent months, he had broached the subject of enrolling at the Sheffield Scientific School of Yale University; but as usual the plea proved fruitless, and the discussion ended with the familiar declaration by his father that such an ill-advised proposal was not to be considered.

Still, Lee's gloom stemmed not so much from disappointment—he was by now almost reconciled to his father's implacable opposition—as from the guilty realization that he held a philosophy of life fundamentally different from his father's.

Mr. De Forest was a minister of the Congregational Church. He was a man of God, strong of character and purpose, unyielding in his religious faith, unquestioning in his beliefs. Lee, on the other hand, saw himself as the representative of a new age, ridden with doubts and questions about life and the world, questions which he felt his father would consider blasphemous.

To his seventeen-year-old son, the tall, bearded Mr. De Forest appeared to be the symbol of another time, another generation. At fifty-seven he represented in Lee's mind a simpler, almost primitive past when people accepted the traditional virtues without question and everyone was satisfied with his lot.

"But this is 1890!" the boy told himself bitterly. They were living in a scientific age that no longer allowed for the luxury of uncompromising acceptance of the beliefs of the past. Why could his father not understand this?

The De Forests were descended from a New England family of French Huguenots who had been among the earliest

settlers of the New World. Many of their ancestors had fought in the Revolution.

His father, Henry, was born in 1833 in Mansfield, Connecticut, where for several generations the De Forests had maintained a homestead. There were six children in this sturdy farm family. Like most of the De Forest men, the boys were tall, big-boned and hard-working. Of the four sons, only Henry had the desire to leave the farm and continue his education. His ambition was to go to Yale University, an extravagant goal for a country lad with little formal schooling. However, he was encouraged by the knowledge that an ancestor, David Curtis De Forest, an adventurer who had made a fortune at sea, had given a sizable gift to Yale to establish a permanent scholarship for members of the De Forest family.

In order to prepare himself academically, Henry did odd jobs in addition to his regular farm chores and budgeted himself rigidly so he could attend a preparatory school. After completing a year of precollege training, he matriculated at Yale, under the scholarship set up by David Curtis De Forest.

Henry Swift De Forest was graduated with honors from Yale in 1857. Even before he received his degree, he had made up his mind to devote his life to the ministry.

In order to pursue advanced studies, he secured a position as a mathematics tutor at Beloit College, Wisconsin. By scrimping and saving he accumulated enough money to return to New Haven, where he entered the Yale Divinity School.

Shortly before he graduated the Civil War broke out. Drafted for the Union Army, he joined the Eleventh Connecticut Volunteers as a chaplain. For four long years he served on the bloodiest battlefields of that tragic war, ministering to the wounded and dying.

After the South's surrender Henry traveled for a time as a representative of the Congregational Churches of the North

and West. He visited Grinnell College, Iowa, where he met Anna Margaret Robbins, an extremely pretty young lady, who was serving as chapel organist. The youthful minister immediately fell in love with her. She was the daughter of the Reverend Alden B. Robbins of Muscatine, Iowa, founder of the first Congregational Church in the territory. A descendant of the famous John Alden who had come over on the *Mayflower*, Mr. Robbins was a member of an old and respected New England family. In the eighteen-thirties, after graduating from Andover Theological Seminary in Massachusetts, he joined a group of heroic Congregational ministers who were headed west. They were to become known as the "Iowa Band."

Sacrificing the comforts of civilization, they traveled to the unsettled territory of Iowa where they gained fame as pioneer missionaries. They helped establish towns and churches and preached the Gospel on horseback, risking hunger, disease and attacks by hostile Indians.

A year after their first meeting, Henry and Anna were married. They went east where the young minister took additional courses at Andover Theological Seminary and obtained his doctor of divinity degree. It was while they were in Massachusetts that their first child, Mary Robbins, was born.

Returning to Iowa, Henry became the pastor of the First Congregational Church of Council Bluffs. There, in the tiny parsonage, Anna De Forest gave birth to their second child, a boy, on August 26, 1873. They named him Lee, after Henry's father.

When little Lee was three, the family moved to Waterloo, Iowa. Two years later they went to Muscatine, where they lived across the street from Anna's father, the Reverend Alden Robbins. But since it is the duty of a minister of the Gospel to go where he is needed, they were not to remain in Muscatine for long. Shortly after the birth of their third child, Charles, Anna was informed by her husband that he

had accepted the presidency of tiny Talladega College in Alabama, a school of which she had never even heard.

Talladega had been established ten years earlier by the American Missionary Association as a college for emancipated Negro slaves, who were known as "freedmen," and their children.

Reverend Henry De Forest explained to his wife that he considered it an opportunity, indeed a sacred duty, to serve the cause of an oppressed and neglected people. "They have no resources and they have no friends," he said. "They are desperately in need of mental, spiritual and physical help. We must hold out our hands and guide them along the way."

For Anna De Forest it meant sacrificing the conveniences of a comfortable northern town for the isolation of a backward southern village. In Alabama, she knew, they would be ostracized by the white people who were consumed by hatred and the bitter memories of a war that had ravaged their land and reduced them to poverty.

In spite of these sober realizations, Anna did not hesitate a moment. As the daughter of a minister she had known that in marrying Henry De Forest she might be exposed to hardship and privation someday, and she had long been spiritually prepared. As a result, she supported her husband's decision with loyalty and devotion.

The early years at Talladega were hard for the grownups. Mr. De Forest had to struggle against a lack of qualified teachers and a critical shortage of funds. But as time went on he managed, through heroic personal effort, to interest many wealthy donors in the college. In a few short years Talladega began to gain a reputation as one of the leading institutions of education for the southern Negro.

For Anna De Forest, life was even harder than for her husband. During their first two years at the college they had been forced to live on the second floor of the girls' dormitory. But even after the construction of a modest little home she faced many problems. The salary of the president was

ridiculously small, so that the family was constantly on the brink of poverty. Moreover, with her husband away on fund-raising trips much of the time, she and the three children sorely missed the comforting presence of relatives and close friends. The white townspeople shunned them as if they were pariahs, while at the college itself Henry and Anna De Forest were forced to avoid intimate friendships with the faculty for fear they would appear to be playing favorites.

The most fortunate members of the family were the three De Forest children. Although the wall of prejudice and hatred erected by the people of Talladega kept them from making friends among the white children, there were many Negro youngsters, including the sons and daughters of the faculty members. A grammar school was organized on the campus for these boys and girls, called the Cassedy School. It offered classes in arithmetic, English grammar, penmanship, geography and history. The pupils included the children of President De Forest who studied, played and ate side by side with the Negro youngsters.

For an active, curious lad like Lee, there were a hundred ways to spend the days. On hot summer afternoons there was Talladega Creek for swimming. The fields and streams for miles around afforded great opportunities for exploration. And down by the railroad yard, where the childen were forbidden to go, one could sneak off after school and climb aboard the cab of a silent locomotive, a deliciously dangerous adventure.

When Lee was nine, life took on new interest and excitement. A group of engineers from up north came down to Alabama to erect a huge blast furnace for the smelting of iron ore. The furnace was built about a mile east of the De Forest home. To the sleepy backward village of Talladega, it was an important event. For months the blast furnace was the main topic of conversation in town and on the campus. At every opportunity, Lee led his little brother Charlie and a group of Negro children to the construction

site where they watched with fascination as the overalled mechanics riveted the heavy steel plates for the tanks and installed the huge air compressors.

Although some of the youngsters soon grew bored, Lee never did. When the Shelby Iron Works finally went into operation, he was awed by the sight of a molten river of fiery yellow liquid roaring down the main sluices of the furnace and into a multitude of molds where it slowly cooled under his very eyes and was transformed into pig iron.

Visiting the furnace and its foundry and machine shop was the most exciting thing that had ever happened to him. For the first time in his life he had seen huge machines in action, and it whetted his appetite to learn more about them. Before long he was seized with a desire to build his own blast furnace.

With the help of little Charlie and a group of classmates, he rolled a huge ash can into the back yard of the De Forest home and punched two holes near the base, one for the compressed air supply—provided by an old-fashioned hand bellows—and the other for the outward flow of the molten iron. Instead of iron ore, chunks of lead and limestone were fed into the can through the top, together with fuel in the form of red-hot charcoal.

One of the youngsters was assigned to operate the bellows, which he proceeded to do with the nozzle close to the air hole, while the rest of the "ironworkers," most of them suffering from singed hair and eyebrows, waited breathlessly for the river of molten lead to come pouring out of the taphole. A few drops of metal did appear; but then disaster struck. The nozzle of the bellows burned off! With the "blowing engine" out of commission, the short-lived plant was forced to close down.

However, for Lee De Forest the construction of his blast furnace was an important turning point. For the first time in his life he was exposed to the joys of invention.

Another time, he built a miniature locomotive out of an

elaborate assortment of packing cases, sugar barrels and paint kegs. Although there was no means of locomotion, the device was fully equipped with cowcatcher, throttle, driving rods, whistle and bell. Even the white children in town heard about it and casually wandered by the De Forest home in small groups in order to catch a glimpse of Lee's creation.

Everything and anything mechanical excited him. Trains, farm equipment, steam engines—all were studied with meticulous attention to the principles of operation and the details of construction. Once he had a chance to observe the operation of a small, hand-operated device to cut grass, called a mowing machine, and he marveled that no one had ever thought to invent one before.

As soon as he was old enough to be entrusted with good tools, his father allowed him to use the college carpentry shop, where he constructed numerous devices for the house —brackets, book shelves, small cabinets and cupboards. He designed and built a "gate opener"—an extended lever arm attached to a pulley—which enabled the driver of a wagon to open or close a gate without descending from his vehicle.

As a birthday gift his father gave him a subscription to the *Youth's Companion*, the most popular boys' magazine of the day. In its pages Lee came across a wealth of scientific and pseudoscientific gadgets which he had to have. Since his allowance was only ten cents a month, he earned additional money by performing chores for his parents and for some of the faculty members, laboriously saving up until he had enough for the device desired at the moment.

In this way he acquired such equipment as a silver-plating outfit and a tiny Weeden upright steam engine which used alcohol as a fuel. He played with these toys constantly and never seemed to tire of them. Lee was only twelve, but he had already made up his mind to become an inventor.

2

The Letter

In spite of his absorbing interest in machines, Lee De Forest was a good student. He received excellent grades in all his subjects, even those he found boring. From his parents he had inherited a love of reading. Before he was fourteen he had gone through the adventure novels of James Fenimore Cooper, the works of Sir Walter Scott and the poetry of Tennyson and Longfellow. And the Bible from cover to cover. There was even a time at the age of ten when he had grandiose ambitions of becoming a famous writer.

But from the moment he decided to make inventing his life's work he never wavered from this determination. It was reinforced when he began to study elementary physics at the Cassedy School. Furthermore, Henry De Forest, who had studied some astronomy at Yale, unwittingly encouraged him by explaining the immutable laws that governed the movement of the sun, planets and stars.

Lee was fascinated by the idea that the heavenly bodies were in a state of perpetual motion, never pausing in their endless paths through the heavens. If this were true of the stars, why could scientists not build machines which, once set in motion, would never stop?

Accordingly, he set to work drawing up plans for a perpetual motion machine. It took him weeks to design the elaborate device, which was composed of a multitude of

strange wheels, gears and weights. By the time the drawings were finished they were so complicated that he had no hope at all of obtaining the materials necessary to build a working model. Nevertheless, he was convinced the machine would work, and for months he delighted in taking the plans out of the box in which they were hidden to secretly gloat over them away from the prying eyes of his sister Mary and brother Charlie, who undoubtedly would have ridiculed him. It was not until he learned about the principles of friction and gravity in his physics course that he realized why the perpetual motion machine could never have worked!

Henry De Forest was a firm parent who did not believe in mollycoddling his children. When they misbehaved they were punished. Yet he loved them deeply and spent as much time with them as he could spare from his arduous college tasks. He enjoyed taking them on camping and fishing trips. Once, in the summer of 1888, Lee accompanied his father on an exciting trip west. First they traveled north to Iowa, where they stopped off to visit old friends at Des Moines and Council Bluffs.

They continued on to Colorado, and when they stood in the shadow of Pike's Peak, Henry De Forest asked his son, "Are you game to climb the mountain?" Lee, though small and slender, nodded unhesitatingly.

On foot, and then on horseback, they proceeded up the fourteen-thousand-foot peak, pausing to admire the mighty mountains and towering crags in the distance. Somehow, braving the dangers of the climb with his father and sharing the grandeur of this mighty work of nature made Lee feel closer to him than ever before.

As a result, on the last leg of the trip, he confided his dream of becoming an inventor. Much to his surprise Henry De Forest did not leap with joy at the idea. On the contrary he said solemnly, "I do not favor it, Lee. Nevertheless, this is not a matter to be settled on the spur of the moment. Let's discuss it another time."

His father's tepid reaction served to temper some of the joy of the memorable trip west. However, when they arrived home in Talladega, his disappointment was temporarily allayed by the excitement of seeing his mother, sister, brother and friends again. For the remainder of the summer he was the center of attention as he recounted over and over his adventures in the "untamed West."

During the next two years Lee tried many times to convince his father that he would never be happy except as an inventor or scientist. But Henry De Forest steadfastly refused to give his approval. "You are still too young to choose your life's work," he declared. "You must give yourself time."

In truth, Mr. De Forest, like most fathers, was convinced that what he was doing was best for his son. As an educator with experience in working with youth, he knew that young people often were impulsive and changeable. He felt a lad of fifteen was incapable of making a mature decision regarding his future.

Furthermore, it had long been his dream to have both of his sons follow him into the ministry or at least into teaching. Lee's fine record as a student convinced him that the boy had the makings of an excellent scholar. He could not understand why his son should want to dedicate his life to machines. Despite his interest in amateur astronomy, he knew little about physics, chemistry or engineering and thus was incapable of understanding their appeal for Lee. In resisting his son's pleas to be allowed to choose his own profession, Henry De Forest apparently had forgotten his own spirited determination as a youth when he had departed from *his* father's way of life to make his own future.

Lee had always resisted the suggestion that he become a preacher. His heart and mind told him that he had neither the interest nor the necessary spiritual gifts. He had seen the demands made of his father over the years and was convinced that he lacked the sense of dedication and moral fiber for such a calling.

Still Henry De Forest did not give up. He nurtured the hope that in time his son might come around to his way of thinking.

Accordingly, as Lee grew older, Henry De Forest directed his studies to prepare him to meet the entrance requirements for Yale University. At the Cassedy School Lee now took heavy doses of Latin and Greek flavored with a liberal sprinkling of rhetoric and moral philosophy.

One day in 1888, while thumbing through the Yale catalogue in the Talladega College library, he noticed the curriculum requirements of the Sheffield Scientific School, which was a separate branch of Yale. The Sheffield School was rapidly gaining a reputation as one of the few institutions where a young man could obtain adequate training in science without going abroad to one of the European universities. Some of America's leading scientists, including the world-renowned physicist, Josiah Willard Gibbs, were on the faculty of the Sheffield School.

To Lee, the Yale catalogue was a source of sudden inspiration. What if he were to ask permission of his father to enroll at the Sheffield School? After all, it *was* affiliated with Yale University, even if it was not the college that the elder De Forest had attended and where he wanted his son to matriculate. The scholarship set up by David De Forest could be applied to any branch of Yale.

There was something else, too. The entrance requirements for the Sheffield School included Latin. That would appeal to his father! And his study of Greek, though not required by Sheffield, would prove useful—for weren't the letters of the Greek alphabet used as symbols in higher mathematics?

Through this curious logic Lee convinced himself that he would have no difficulty demonstrating to his father that an education at the Sheffield Scientific School was not so different after all from the baccalaureate studies at Yale University.

He was profoundly mistaken. Mr. De Forest, who taught the advanced philosophy course at Talladega and was

thoroughly familiar with the techniques of sophistry, would have none of it. "I will not foresake my duty as a parent by permitting you to make a choice which you may very well regret later on," he replied severely.

Despite this rejection, Lee persisted. He argued with his father regularly and earnestly, hoping to persuade him to change his mind. But Reverend Henry De Forest was adamant. Lee tried to convince his mother, but she replied simply, "I will not go against your father's wishes in this matter."

Gradually Lee began to lose heart. He told himself that he would never win his father over to his way of thinking, and with each passing day his feeling of hopelessness grew, and with it self-pity. He even toyed with the idea of agreeing to study for the ministry, then failing his courses in order to prove his father wrong. However, upon sober reflection, he realized that such a course of action would be dishonest and self-defeating, and he felt ashamed. No, he must be true to himself.

It was little wonder, then, that a sense of futility gripped seventeen-year-old Lee De Forest on that sweltering October day in 1890 as he sat on the porch of the De Forest house and stared unhappily across the Talladega campus.

Desperately searching for an answer to his dilemma he decided on a final, dramatic gesture. He arose from the rocking chair, entered the house and made his way to his father's study. From the kitchen, where his mother was preparing supper, came the savory odor of cooking; but at this moment he had no interest in food.

In the study he removed the dust cover from his father's recently acquired Fitch typewriter and inserted a sheet of paper in the platen, noting the superiority of this machine to the ancient typewriter that belonged to Mr. Silsby, the college treasurer.

Slowly, with painstaking care, Lee began to peck away at the keys. He addressed the following letter to his father:

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 that it is time to decide and choose my studies accordingly.

Your obedient son,
Lee De Forest

He was about to remove the paper from the typewriter when a thought struck him, and he decided to add a postscript:

This machine beats Mr. Silsby's all to flinders.

Lee reversed the paper in the machine and carefully typed a note to his mother on the back. It began with the lines of a poem by Henry Wadsworth Longfellow that he had once read:

"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?

He folded the letter meticulously, inserted it into an envelope and laid it on his father's desk where it was sure to be seen.

When Henry De Forest returned home that evening, he went first to his study to check the day's mail. A short time later he came out and took his accustomed seat at the head of the table without a word. All during supper, Lee maintained a discreet silence, although little Charlie chattered away so noisily that he had to be shushed by their older sister Mary.

Afterward, Lee studied Caesar's *Commentaries* for a while and went to bed. But he could not sleep. For half the night, feelings of anxiety kept him wide awake and alert to every sound, including the chirping of a tireless cricket in the yard. He could hear his mother and father in the parlor, conversing earnestly in low tones, but try as he might, he could not make out their words.

The next day was Sunday, and there was no school. After services in the college chapel, presided over by Mr. De Forest, Lee returned home with his mother and father. Sister Mary, who was on summer vacation from Northfield Seminary in Massachusetts and was due to go back to school the next day, had stopped off at the girls' dormitory to say good-by to a few friends. Charlie had run off to examine a litter of puppies that had just been born to Mr. Silsby's dog.

When Lee and his parents reached the house, his father said solemnly, "Your mother and I would like to talk with you, Lee." The youth remained standing while Mr. De Forest wearily eased his six-foot frame into an overstuffed easy chair.

"We've read your letter," his father said at last. "It is a persuasive document. In spite of it, I confess I cannot understand why you have fixed on inventing as a life's profession."

Lee's heart sank. He had learned from bitter experience that a lengthy prologue almost invariably was a prelude to an unfavorable decision.

Mr. De Forest continued, ". . . I am certain that I have been right in opposing your plan. Your mother, as you know, agrees with me that if we had not voiced our disapproval, we would have been derelict in our parental duties. Is that correct, Anna?"

Mrs. De Forest nodded silently, and her husband, after pausing to let the import of his words sink in, addressed Lee again: "However, after giving the matter sober thought, I am convinced that nothing I can say or do will dissuade you. Since that is the case, we are now prepared to support you in your endeavor. I hope that future events will prove that I was wrong in my opposition."

Lee was dumbfounded with surprise and joy. Was he hearing correctly?

"Do you mean that you will allow me to take the Sheffield Scientific course?" he asked, trying to suppress his excitement.

"Yes," his father replied, the faint trace of a smile appearing on his stern, bearded face. "If you insist on becoming an inventor, we must help you to become the best inventor you are capable of being."

3

Student Days at Mt. Hermon

Henry De Forest was not a man to tackle a job halfheartedly Once decided on a course of action, he went ahead with stubborn determination. Now that he had agreed to Lee's matriculation in the scientific course, he resolved that his son should be well prepared for college work.

Although the Cassedy School had given him a solid grounding in basic courses, Mr. De Forest felt that Lee needed the advanced work only a college preparatory school could provide. He particularly needed mathematics and science, fields in which the Cassedy School's offerings were severely limited by a shortage of qualified teachers.

While there were many good prep schools, the tuition fees ran high. It was decided finally to send Lee to the Mt. Hermon School, a low-tuition academy in Massachusetts. The Mt. Hermon School had been founded by Dwight L. Moody, a preacher-educator who had also established Northfield Seminary where Mary was a student. In fact, Mt. Hermon was only three miles from Northfield.

But even a nominal tuition presented problems. To Henry De Forest, it meant going into debt. Yet he went to work unhesitatingly to scrape together the first year's tuition by borrowing against his salary.

At eighteen, Lee was a small, slender youth with delicate features and innocent blue eyes who looked no more than fifteen or sixteen. Mr. De Forest was convinced that he needed "building up" physically to prepare him for the grueling years of study ahead. Accordingly, during the summer of 1891, just before enrollment at Mt. Hermon, he made arrangements to have the boy attend a summer camp on a lake near Worcester, Massachusetts. There, Lee rowed and swam and practiced cross-country running until his body grew hard and muscular.

On September 1, Mr. De Forest came up from Talladega. He was amazed at how much his son had matured in one brief summer. Together, he and Lee took the train for Mt. Hermon, and after officially enrolling in the school and depositing his luggage in the dormitory to which he had been assigned, Lee accompanied his father to dinner at an inn in nearby Northfield.

During the meal, Lee was suddenly overcome by a wave of homesickness at the thought of his father's departure that evening. Of course, his sister Mary would be nearby once the new term began at Northfield Seminary, but that was still two weeks away; for now Mary was still in Alabama, and he was here in Massachusetts. It was strange, he thought, that he had not felt the least bit homesick in July, when he had left Talladega to go to camp. Perhaps it was the excitement of going off on his own for the first time that had helped then. Now, however, the sight of his father after an absence of two months had released a tide of emotion that he found difficult to control.

Later that evening he walked with his father to the train station to say good-by. As the snorting locomotive puffed its way slowly into the tiny depot, Mr. De Forest proffered his hand and said quietly, "Take good care of yourself, son. Work hard. And write to us as often as you have time."

Instead of shaking hands, Lee gave in to a long-discarded habit of his childhood and reached up and embraced his

father. Henry De Forest's eyes were moist as he turned away quickly and mounted the steps to the coach.

A few minutes later the train pulled out. Lee caught a last glimpse of his father waving from behind a sooty window. Then he started the lonely walk back to the school to spend a sleepless night in what was to be his home for the next two years.

The educational principle on which the Mt. Hermon School was established had its roots in a theory expounded by its stern rock-ribbed New England founder, Dwight Moody: a worthy life must be compounded of work, religion and study. To this end, each student was required to spend two and a half hours a day at manual labor on the school farm, where the pupils milked cows, dug potatoes and cleared the fields of huge rocks. It was the proceeds from the farm that helped support the school and kept tuition fees low.

In addition to daily Bible study classes, every boy was required to attend Sunday church services, the highlight of which was an hour-long sermon by Preacher Moody himself.

Finally, there was the academic portion of the curriculum. Although scholastic attainment was rated by the school administration as of less importance than the ability to carry out farm chores, the course offerings were surprisingly comprehensive. Lee took classes in Latin, literature, geography, algebra and physics. Understandably, he devoted most of his attention to mathematics and science. In physics, he was a star student. One of the science professors, Charles E. Dickerson, took a particular interest in this boy with the southern accent who sat enthralled during his lectures. Soon he gave Lee advanced assignments, which were accepted with the alacrity of a starving man offered a morsel of food. In later years, Lee was to credit Professor Dickerson with providing "an inspiration and incentive in science study which I especially needed at that formative stage of my life."

Despite the heavy burden of work and study, Lee found

time to engage in sports, including ice-skating, virtually unknown in Alabama, and competitive walking, in which he won the school championship. He also applied for overtime work on the farm to earn expense money and thus relieve his parents of at least a part of their financial burden. The wages were ten cents an hour!

At times the demanding combination of farm work and studying proved too much, and he would find himself deep in an abyss of depression. On such occasions he visited Northfield Seminary to see his sister Mary and her schoolmates, many of whom he found exceedingly pretty. Invariably, he would walk the three miles and back to save bus fare.

He and his parents exchanged letters every week, which also helped lift his spirits and relieve his homesickness, particularly the words of constant encouragement from his father. Once, in a letter which Lee pasted in his scrapbook, Henry De Forest wrote: "Self-reliance is developed in helping oneself. . . . No weak-kneed, fainthearted namby-pamby among my male successors; only two, but each a lion. Heroism at school augurs success in after years."

Almost before Lee was aware of it, the school year had drawn to a close. How to utilize his summer vacation was a grave question. He could return to Talladega and spend a restful two months with his family; on the other hand, train fare was expensive, and he was desperately short of funds. In the end, he decided to search for a job.

Unfortunately, temporary employment was almost impossible to find. He and a schoolmate finally signed up as book agents for *King's Handbook of the United States*, working on a commission basis. After a ten-day "training course" they were assigned to territories.

After the first few days, Lee was convinced that door-to-door selling was the worst punishment a sensitive human being could endure. Potential customers were often surly, sometimes slamming their door in his face. Others were

overly friendly and only too willing to pass the time of day with someone who would listen to their troubles; but too often these people had no intention of making a purchase.

Finally, he made his first two sales, and was delighted. He sallied forth with renewed enthusiasm only to run into a dry spell that stretched over a period of two weeks. Then, just as he was ready to give up, his luck changed. Suddenly, he was making sale after sale with almost no effort. By the time he was ready to return to school in September, he had earned nearly forty dollars!

The new school year was little different from the previous one. There was the same heavy diet of work and study. In addition, he began to practice seriously on the cornet, an instrument he had taken up some time before, and joined the school band.

Toward the end of the fall, a fine new science building was opened at Mt. Hermon. Lee managed to land a part-time job cleaning up the new qualitative chemistry laboratory. As a would-be scientist and inventor, he felt it was more suitable employment than digging potatoes on the school farm. However, one day the water supply to the laboratory was cut off. Finding nothing more to do, he opened a textbook and began to study. Mack, the school functionary in charge of student jobs, walked in unexpectedly and denounced him for reading during working hours. Lee tried to explain but Mack refused to listen and immediately reassigned him to farm work.

Lee accepted the demotion philosophically. He took comfort in the fact that he would have to dig potatoes for only a few short weeks—since graduation was just around the corner.

Commencement! For Lee it was a thrilling moment. Although he narrowly missed out on several senior prizes, he *was* elected to deliver the school's annual scientific oration. The title he chose was "Scientific Discovery," a topic close to his heart.

The graduation exercises were solemn and impressive, but the baccalaureate sermon, delivered as usual by Dr. Dwight Moody, seemed interminable. Lee was disappointed that his parents had not been able to come, but he realized that his father, too, had commencement duties to perform. Besides, the trip would have been expensive, and with Yale in the offing he knew they had to save every penny. However, Mary was in the audience, and after the ceremonies she and several of her girl friends took him to a confectionary in Northfield and insisted on treating him to cakes and sweet soda.

Although his prep school days were over, Lee stayed on at Mt. Hermon an extra week to prepare for the entrance examinations of the Sheffield Scientific School. He reviewed his Latin, algebra and geometry for ten hours a day with almost no letup.

Finally, on a warm June day, he entrained for New Haven, Connecticut, wearing a broad-brimmed straw hat which he had been told was the fad at Yale that year. Upon arriving, he and two hundred other nervous subfreshmen were marched to the university's Winchester Hall for the entrance examinations.

Lee passed.

It was 1893, and the World's Columbian Exposition was being held in Chicago. Like thousands of other young people, Lee was desperately anxious to see this spectacle which had been heralded in the press as "the greatest fair ever held." Several weeks earlier, while still at Mt. Hermon, he had written to exposition headquarters, applying for a job as a guide, but he had received a reply stating that no more guides were needed.

Disappointed but far from ready to give up, Lee took on the hated task of book canvassing again with the idea of earning sixty dollars in a hurry to finance a visit to the fair. This time he was assigned to sell a pointless volume entitled

What Can a Woman Do? His territory was Syracuse, New York.

He discovered that either the people in Syracuse were not interested in reading books or else their tastes were too sophisticated to be taken in by *What Can a Woman Do?* Sales were so slow that days went by with only a book or two sold. Finally, he managed to collect eighteen dollars in commissions, and rather than lose his chance to see the exposition he impulsively purchased an inexpensive round-trip ticket to Chicago on a crowded excursion train, where he slept upright the whole night.

He arrived in Chicago the next afternoon. Lee was like a child let loose in a toy store. He stared in a state of enchantment at the magnificent exhibits and outdoor water displays.

Most of his time was spent at the machinery exhibits, where he studied models of new inventions and manufacturing equipment. He marveled at the new locomotive and railroad car designs that were shown and devoted hours to examining in minute detail the latest typewriters and other mechanical devices.

To stretch his funds, he ate only two cheap meals a day and slept at a boardinghouse known as "Bingo Farm" for fifty cents a night. Even so, his money was virtually exhausted within three days.

Then good fortune struck. As a last resort, but without real hope, he applied to the exposition office for a job as a "pusher" to transport fair visitors around in a wheeled chair. He got the position!

Immediately Lee went out and purchased a uniform with the last of his funds and went to work. The summer heat was punishing, and chair-pushing was a grueling business, yet he didn't mind in the least. He had achieved his ambition of being able to remain at the fair for the rest of the summer.

He got to know every inch of the exposition intimately. Whenever a customer asked what to visit, Lee invariably

steered him to Machinery Hall, where he proceeded to explain how many of the mechanical devices worked. Then after work, he returned to the exhibits on his own time.

In addition to the machines, Lee was fascinated by the electrical displays. Undeniably, those reflecting the latest progress in the use of electricity for power, communications and light were the real hit of the fair. He saw the most up-to-date advances in generator design and telegraph and telephone equipment.

It was clear, he told himself, that electrical development was the wave of the future. At night it was symbolized by the myriad of electric lights that illuminated the giant buildings, landscaped gardens and exotic lagoons. In truth, the Columbian Exposition was a City of Light. A system of 250,000 lamps had been installed by the electrical pioneer George Westinghouse, and it created a scene of such magnificence and beauty that each night there were awed murmurs from the crowds of visitors.

For a whole month Lee lived in the dreamlike world of the exposition. Finally, on September 16, he packed away his uniform, took a last fond look at the fair grounds and boarded a train for New Haven and his new life as a Yale undergraduate.

4

Life at Yale

Lee's first task was finding a place to live. He soon located a boardinghouse on Temple Street, owned by Mrs. Goldsmith, a motherly landlady. She assigned him to a cozy little room where he would have the privacy needed for serious study. On her advice he purchased a meal ticket at a local restaurant which catered to the student trade by offering fifteen-cent meals.

From the first, Lee made it clear that he was at Yale to study rather than to enjoy the social life which many of his classmates seemed to feel was the primary reason for attending college. Once they were convinced of his intensity of purpose, they respected him for it. There was rarely an evening that he was not hard at work at his studies.

So conscientiously did he apply himself that by the middle of the first term he achieved a reputation as one of the best students in the freshman class. During those early months he left his books only on Saturday afternoons to watch the varsity football team in action.

Lee's refusal to involve himself in social activities was due not only to his desire for academic success but to lack of money. In order to stretch his dwindling funds, he knew he would have to avoid any unnecessary expenditures. Therefore, he even made it a policy to stay away from the sweetshop where so many of the undergraduates congregated.

To overcome the growing sense of loneliness that gripped him, particularly on week ends, he turned once more to inventing. He became an indiscriminate inventor, flitting from one curious device to the other. Any idea that occurred to him at the moment was carefully noted in his diary. Then, when he had the time, he worked out the details of the invention on sheets of white drawing paper.

One week end he developed an improved type-bar movement for a typewriter. Another time he invented what he felt was a superior point for a draftsman's compass. Finally, he designed a new game which he sent off to a well-known puzzle company, volunteering to accept less than the standard royalty in order to encourage the firm to begin manufacturing it. Lee's generous offer was politely declined.

During the Christmas holidays, he read in a science magazine about a $50,000 prize for the best design submitted for an underground trolley system. He spent the next few days in the public library reading the *Street Railway Review* in an attempt to understand the operation of underground trolley systems already in use. When he felt he had mastered the principles, he sat down at his desk and laboriously outlined a new design and prepared sketches. Then, with a silent prayer, he enclosed the outline and drawings in an envelope and mailed them to the Metropolitan Railway Company, which had offered the prize.

Two anxious weeks of waiting followed. At last the drawings were returned with a printed form stating that the company had withdrawn its generous prize offer. Lee felt a sharp pang of disappointment. He had been counting heavily on the prize money to ease the financial burden of his schooling.

In fact, all of his inventions at that time were undertaken not only to provide relief from intense loneliness but with a profit motive in mind. He had begun to feel increasingly guilty at the idea of draining his father's meager resources, and hoped in this way to supplement his income.

In spite of his disappointment, the disastrous trolley pro-

ject did not discourage him for long. Cursed with the traditional compulsion of the inventor always to pursue some new will-o'-the-wisp, he began to look about for something else. Recalling the exhibits on electrical communications at the Columbian Exposition, he started reading up on telegraphy. He studied every book and pamphlet he could find on the library shelves, in the hope that he would thereby discover a new avenue for exploration.

But he had to interrupt this work to get ready for final examinations. His preparation was thorough; when the grades were posted he found himself in the top quarter of his class.

With the school year over, he faced a financial crisis, for his assets were close to rock bottom. Unless he got a job at once, he could not even continue to eat. In desperation he applied for employment at the restaurant where he bought his meal tickets. The manager put him to work waiting on tables and paid him off in meals.

While this form of barter enabled him to eat, it did not provide for his room rent, books or other necessities. Finally he was directed to Professor Seymour of Yale's Greek Department, who offered him a small room in his home in exchange for services as a gardener. At about the same time, Lee learned that two graduate students in psychology were looking for a summer assistant to check experimental reaction charts. The salary was ten cents an hour. He applied for the job, got it, and gave up waiting on tables.

During the sweltering months of July and August, he was up at four in the morning cutting weeds and grass for Professor Seymour. Then he put in another eight hours in the psychological laboratory. The schedule was so strenuous that on week ends he found himself completely exhausted, wanting to do nothing but sleep.

It was little wonder, then, that Lee welcomed the beginning of fall classes with a profound sense of relief. Since the Sheffield Scientific course offered only a three-year cur-

riculum, he was now considered a member of the Yale junior class, although it was only his second year at the university. As a junior, he was entitled to certain privileges, such as the right to smoke. So he invested twenty-five cents in a pipe and smoking tobacco and smoked steadily one evening until his mouth seemed to be on fire and he felt sick to his stomach. He did not touch the pipe again.

Lee's second-year curriculum at Sheffield included courses in mechanical engineering, solid analytics and drafting, as well as calculus, French, German and English. However, his interest in telegraphy, which had been awakened the previous spring, now began to reassert itself. Soon he found himself enmeshed in electrical theory during his spare time. He began to read about the experiments of Nikola Tesla, the brilliant young electrical genius from Serbia, whose experiments with high-frequency alternating currents had aroused widespread attention.

On the basis of this reading as well as his earlier study of telegraphy, Lee decided to invent a telephone relay that would permit the transmission of long-distance voice messages. After spending a week on the problem, he realized that his knowledge was too limited and gave up, but not without a vow that someday he would return to the project and find a solution.

Next, he tried out for the Yale Scientific Prize by writing a five-thousand-word essay on "Aerial Navigation." Again he waited anxiously for the results only to receive the disappointing news that he was not among the winners.

Summer arrived once more. Reviewing the past year, Lee could not help feeling depressed. For him it had been a year of failure in which everything he had attempted had come to naught. To make matters worse, the only job he could find was as a waiter in a summer-resort hotel at Block Island, Rhode Island. The months of July and August seemed to drag by. When Labor Day came and the hotel closed for the season, Lee had thirty dollars saved, hardly a munificent sum

with which to finance his senior year. However, he was cheered somewhat by a letter from his mother informing him that she and his father were traveling north on a fund-raising trip and would be near New Haven.

A week before the start of classes, his parents picked him up at Mrs. Goldsmith's and took him to a small residential hotel in the Hoosatonic Valley, about an hour's train ride from the university. Seeing his parents again after such a lapse of time was a bitter-sweet experience. Lee's happiness at being with them was tempered by homesickness and the knowledge that they could only stay for a few days.

Yet they tried to make the most of the brief visit. His mother gave him the latest news from home, telling him how excited his brother Charles was at the prospect of entering Mt. Hermon that fall and how his sister Mary, who was back in Talladega, had begun to give piano lessons.

In the afternoons, Henry De Forest accompanied his son on strolls along the quiet banks of the Hoosatonic River. They discussed Lee's progress at school and his future plans. Lee shamefacedly admitted that in spite of his good grades he had tried for a number of prizes but had not succeeded in winning a single one. He also told his father about his series of unsuccessful inventions. Mr. De Forest put his arm around the youth's shoulders and urged him not to be discouraged. "You cannot rush life," he said. "You must have patience until your turn has come."

Lee was surprised to discover how much easier it was to talk to his father than in the past. Had his father changed? Or had *he* changed?

There was little doubt, however, that his father had aged considerably in the past two years. His hair and beard were silvery gray and his huge bony frame was a little more stooped than Lee had remembered.

When at last his parents had to leave, they accompanied him back to New Haven and said good-by at the train depot. Anna De Forest hugged and kissed him and warned him not

to work too hard. Henry De Forest grasped his son's hand and squeezed it, promising to return to New Haven on his next fund-raising trip, which was scheduled for the spring.

With the beginning of his senior year, Lee found himself in a dilemma. Until now he had casually assumed that his career would lie in some branch of mechanical engineering, a field which offered considerable opportunity for someone with an inventive turn of mind. But of late he was beginning to feel a growing attraction to the new field of experimental electricity.

Moreover, he found himself increasingly bored with the courses in mechanical engineering. He was at work on a thesis dealing with steam turbines, and though his professor assured him the paper was coming along well, he himself looked upon it as a necessary chore, little more. His class in stresses and strains seemed even duller, adding to his dissatisfaction and sense of uncertainty.

Shortly after New Year's Day of 1896, he was rudely jarred out of preoccupation with college problems by a telegram from Talladega. It was from his sister Mary. The message read: "Father hurt by falling, medical attention secured, will keep you informed."

After an agonizing twenty-four hours, he received another telegram. His father had died. Lee wept unashamedly.

Later, he learned what had happened. While at home, Henry De Forest had suddenly become dizzy and fallen. For a day he had remained in a coma, finally slipping peacefully away without regaining consciousness.

Since the burial was to take place in the old De Forest family plot in South Edmeston, New York, it was decided that Lee and Charlie, who was at school in Mt. Hermon, should not come south. Instead, they were to meet their mother and sister in New York City and accompany them to Edmeston with the body.

Henry De Forest, sixty-three, was laid to rest at a simple burial ceremony attended by members of the family and a

few close friends. There were messages of condolence from philanthropists, educators and leading figures in the Congregational Church who mourned the passing of a man who had steadfastly devoted his life to the tenets of Christianity.

On the train ride back to New York City, Mrs. De Forest quietly discussed her plans for the future with her three children. It was agreed that she and Mary would take a house in New Haven that summer so the family could be together.

Lee spoke of his own dilemma and mentioned his interest in a career in electrical research, explaining that to enter this new field would mean staying on at Yale to do postgraduate work.

"But now that father is gone, that's out the window," he observed.

Mrs. De Forest dabbed at her eyes with a handkerchief and replied, "No, Lee, it's more important now than ever before to follow the star you've chosen. Your father would have wanted it that way."

Lee protested that there was no money, but his mother explained that there was a small sum available from modest investments his father had made in earlier years which still remained untouched. Mary assured her brother that she would also help with her earnings as a music teacher. Lee promised that he would let them know as soon as he came to a final decision.

Back in school, he went through several dreary weeks. The memory of his father's death, still fresh in his mind, made it difficult to concentrate on studying, and he plodded through his classes dispiritedly.

By spring he began to pick up the threads of his college career once more. Furthermore, interest in electricity among the Sheffield students had suddenly mushroomed. The reason: an announcement from Germany that a physics professor named Wilhelm Roentgen had discovered an entirely new form of radiation which enabled him to photograph

objects hidden behind opaque, solid shields. With this new penetrating ray, which Roentgen called an "x-ray," he had even managed to take a picture of the bones of his hand!

The announcement of this discovery created a sensation in the scientific world. Physicians were agog at what the x-ray could mean to diagnostic work in medicine. To physicists, the existence of the rays opened a new dimension of scientific investigation that might hold the key to a world or worlds still unknown.

At Yale, would-be scientists like Lee spoke of nothing but Roentgen's discovery. Finally one of their physics professors, Arthur Wright, consented to give a lecture on the x-ray.

On the afternoon of the lecture, the hall was mobbed. Every science student at Yale showed up. The audience listened, entranced, as Wright proceeded to explain the importance of the German physicist's work.

To the youthful science students attending Professor Arthur Wright's lecture, the question of what causes the x-ray phenomenon carried all the mystery of an adventure thriller. Not even Roentgen himself had been able to supply a definitive answer.

Lee was mesmerized like the rest. The mystery of the x-ray whetted his curiosity and his desire to learn more about the unexplored world of electrical phenomena. Suddenly, he was no longer uncertain about what he must do. The day after the lecture he wrote to his mother that he had decided to stay on at the university for postgraduate study in electricity.

The Yale commencement ceremonies that June were solemn and impressive. Mrs. De Forest and Mary sat in the audience as Lee, in cap and gown, marched up to receive his bachelor's diploma. Yet for the family the moment was tinged with sadness, too, for it had been Henry De Forest's dream to be present when his alma mater conferred the degree on his son.

Lee's mother and sister had settled their affairs in Talladega and were now living in a rented house in New Haven.

Originally, they had planned to spend only the summer in the East, but they soon decided to stay permanently and rent out rooms to Yale students.

For Lee the closeness of his family meant a great deal. It brought a sense of reassurance, an end to the feelings of loneliness and separation that had plagued him. And the fact that his brother Charlie, who had remained at Mt. Hermon to do summer work, was only a few short hours away and could travel to New Haven on week ends added to his much-needed sense of personal security.

At the same time, Lee could not help feeling a heavy burden of responsibility, since he was now the head of the De Forest household. Consequently, the day after commencement exercises he went looking for a summer job. After pounding the pavements of New Haven and the outlying areas for a week, he came to the bitter conclusion that there simply was no work to be found. Not even the university could provide him with a student-assistant's job which, while paying absurdly small wages, would have at least kept him occupied.

The failure to find employment was a severe jolt to his pride. He felt he had failed miserably in his first real test where his family was concerned. Moreover, the prospect of a long vacation without work filled him with dread, and once more he turned to inventing in order to keep busy. Above all he wanted desperately to invent something that would prove commercially successful and thus compensate for the lack of gainful employment.

Once, while passing a cycle shop, he had gotten an idea for a hydraulic gear that would eliminate the need for bicycle chains. The invention involved the use of a coiled collapsible rubber tube and a roller arrangement which would force a stream of fluid through a similar device inside the hub of the bicycle's rear wheel. In this way, speed could be multiplied many times with little added effort on the part of the rider.

Lee hurriedly prepared a detailed description and drawings of his invention and sent them to the Victor Bicycle Company. The idea was promptly rejected as impractical. He next tried the Columbia Bicycle Company, which also turned it down. Finally, he wrote to a firm in Hartford—the Pope Company. Receiving another discouraging reply, he disgustedly put the drawings aside and took refuge in books on electrical theory and practice, particularly those dealing with the work of his hero Nikola Tesla.

Lee was grateful when September came again. He plunged into his graduate studies with an intensity that was almost frightening. The discouragement and failure of the summer had merely added to his desperate need to succeed at something, at anything, and academic work was the most likely avenue for immediate accomplishment.

Under the supervision of his graduate professors he determined the temperature coefficient of a storage battery, learned to use a galvanometer and capillary electrometer and spent days in the electrical laboratory of Yale's Winchester Hall preparing intricate current-voltage curves.

In addition to the formal studies in his classes, Lee continued his intensive outside reading about high voltage, high-frequency electric current phenomena and the intimate connection between light energy and electricity.

It was the intriguing puzzle surrounding the composition of light waves that fascinated Lee the most—the same mystery Professor Wright had discussed in his lecture on Roentgen's x-ray the previous spring. What was light? How was it related to electricity? Lee could not help feeling that the future of electrical progress lay in the answers to these questions.

To understand intelligently the findings of the electromagnetic wave pioneers like Roentgen required applied mathematical knowledge of a kind which Lee had not received during his undergraduate years. So he added mathematics to his outside reading. In particular he read the works

of Professor Josiah Willard Gibbs, who was on the Yale faculty, and with whom Lee soon struck up a warm friendship. Talks with Gibbs, the leading American physicist of the day, encouraged him to pursue his graduate studies and his interest in electromagnetic waves.

At the end of the spring, Lee spoke to his mother and Mary about the possibility of continuing on at Yale for his doctorate. "You mustn't stop now," his mother said, "not when you're so close to the end." Mary agreed, pointing out that with the fees from her piano lessons and the income from rooms rented to students, the family's financial situation had actually improved.

Lee needed no further urging. He promptly filed an application indicating his intention to remain at Yale and asked for a renewal of the De Forest scholarship.

Despairing of another jobless summer, he now hit on a grandiose plan. Why not go down to New York and ask Nikola Tesla for summer employment? After all, having read most of Tesla's published works, he felt as if he knew him. Certainly it was worth a try.

On the last Monday in June he took the train for New York. Trying his best to assume an outward air of self-confidence to hide his inner trepidation, he made his way down Houston Street and found the ancient building where the Tesla Laboratory was located. He walked up a dimly lit staircase and strode into a large workroom cluttered with batteries, generators and electrical gauges and instruments of every description. Two men were quietly at work in one corner, and it was several minutes before one of them finally noticed him and came over.

"I am Nikola Tesla," he said in a pleasant, slightly accented voice. "Can I help you?" He was a slender, dark-haired man with intense, sharply chiseled features. To Lee, who had expected to see someone much older—he had read that Tesla was forty—the inventor's youthful appearance was a complete surprise.

Lee explained that he was a graduate student at Yale who had long admired Tesla's work. "Frankly, sir, I am looking for a summer job," he declared bluntly.

Nikola Tesla was cordial and talkative. He asked many questions about the electrical courses at Yale and wanted to know if Lee had met Willard Gibbs. Lee nodded.

They discussed in detail the importance of experimental work in electromagnetic waves. Tesla, like Gibbs, urged Lee to pursue his interest in this field. But on the question of a summer job, he was frank but discouraging. "I think you have great promise, Mr. De Forest," he said. "I would like very much to have you work for me, but I simply cannot afford to take on additional help at the present time. Perhaps someday, yes. But now, no."

When Lee left Tesla's laboratory he was walking on air. True, no job had materialized, but he had met the great man and received encouragement; that was triumph enough.

Several days later, Lee bicycled to Meriden, Connecticut, in search of a job—without success. He obtained several nights' work making observations and taking notes of meteors for the astronomers in charge of the Yale Observatory. Then he got a week's employment with the New Haven Gas Company, reading meters. But financially it was another unsuccessful summer, and only the recollection of his meeting with Nikola Tesla uplifted his spirits during those steaming August days of enforced idleness.

With the beginning of classes in October of 1897, Lee was assigned to the advanced electrical laboratory in North Sheffield Hall. Now he had a chance to repeat some of the experiments in electromagnetic wave phenomena that he had read about earlier. Using a device called a "Lecher parallel wire resonator" he began to undertake original investigations in the measurement of high-frequency waves.

It was fascinating work, this business of determining the lengths and frequencies of waves nobody could see but which were known to exist and which, if harnessed properly,

might be made to do amazing things, as Roentgen had already proved with his x-ray. However, there was one disconcerting aspect to his academic work at this time: his relationship with his supervising professor, a physicist named Hastings. For some reason or other professor and graduate student did not hit it off from the start.

A cold, distant man, Hastings seemed to have taken an instant dislike to Lee, who sometimes could appear annoyingly overconfident. And Lee, sensing Hastings' hostility, masked his own anxiety by an even greater show of brashness.

Once, while the professor was delivering a lecture, Lee was assigned to operate a battery-powered slide lantern. Halfway through the lecture the lantern lamp blew a fuse. The lecture hall was plunged into darkness, and Hastings finally dismissed the class by candlelight. Then he turned on Lee in a cold rage and accused him of deliberately sabotaging the lecture.

Another time, the professor discovered some nails driven into the surface of an oak laboratory table. They had been in the table before Lee had come to the lab. Nevertheless, Hastings accused him of vandalism. "A man who hasn't any better sense than to drive nails into a table will never amount to anything!" he shouted.

By the end of the fall term Lee made up his mind that life with Professor Hastings was next to impossible. He discussed the problem with a young assistant professor, Henry A. Bumstead, who managed to get the unhappy graduate student transferred to the supervision of Professor Arthur Wright. But before Lee could get settled in Wright's laboratory, war in Cuba jarred him out of the routine of academic life.

For years the people of Cuba, encouraged by the United States, had been carrying on a revolt against Spain, which had oppressed them for almost four centuries. On February 15, 1898, the American battleship *Maine*, while on a friendly

visit to Cuba, was mysteriously blown up in Havana harbor. Two hundred and sixty members of the crew lost their lives.

Many Americans, inflamed by bold headlines in the more sensational newspapers, were convinced that the battleship's destruction was a Spanish plot. Accordingly, they demanded action by President William McKinley. "Remember the Maine!" became a popular slogan across the nation.

Two months later Congress passed resolutions recognizing the independence of the Cuban people and empowering the President to use armed force. On April 25, the United States formally declared war on Spain.

The Yale student body was full of military fervor, and an impromptu parade started on the campus as soon as it was announced that the Senate had recognized Cuban independence. Then the parade spread and continued around town until New Haven found itself in the grip of mass hysteria.

The war spirit seized Lee. Like a majority of the students, indeed like most Americans, he was convinced that the war against Spain was morally right. A Yale Light Artillery Battery, to be composed of student volunteers, was already forming, and he decided to join. He felt the war might prove a brief but interesting diversion from the routine of college life, a vacation, really; and besides, the rigorous duties at military camp would help harden his flaccid muscles and get rid of his student's pallor.

Before Mrs. De Forest and Mary could talk him out of it, Lee rushed off to Niantic, Connecticut, where the Yale Battery was being formed. Since he played the cornet, he aspired to be a bugler and could already envision himself astride a huge horse, garbed in a fancy uniform with two red stripes running down the pant legs.

Unfortunately, he arrived too late to get into the Yale Battery—which turned out to be merely a platoon in the Connecticut Volunteer Militia Battery. Furthermore, he discovered he would have to hang around the camp in his civilian clothes for "a day or two" until his turn came to enlist. The

wait stretched out to a week. It rained every night, and the weather was cold and damp during the day. Finally, Lee and several dozen other would-be soldiers, most of them sniffling from head colds, were thrown out of the camp itself by the commanding officer and forced to sleep at a commercial hotel. To save money they subsisted on crackers and apples.

At last, the volunteers were mustered into the Army and issued uniforms and equipment. The first weary weeks were devoted almost exclusively to drill, guard duty and clean-up details. Lee, after pleading with every officer on the post for an assignment as a bugler, was finally given the job.

However, by now it was already July, and it began to look as if the war would peter out before the Niantic contingent even left Connecticut.

Early in August, the troops received orders to embark for Puerto Rico, still in Spanish hands. But while they were packing their gear the American government announced triumphantly that the five-month war in Cuba was over! Spain, having suffered a disastrous defeat, both on land and sea, pledged to evacuate Cuba and to cede Puerto Rico to the United States. Adding a final confusing note to the incredible little war in the Caribbean was the fact that American army units near Havana, unaware of the peace, marched into the city and captured it the day after the truce was reached!

For Lee and the other citizen soldiers at Niantic, the brief stay in the Army proved to be a miraculous antidote to the martial fever that had seized them earlier. Now their one ambition was to receive their discharges, particularly the Yale students who were hoping to get back to civilian life in time to enroll for the fall term.

By an amazing short-cutting of red tape, the Army managed to discharge the entire Niantic contingent by September 15, and Lee and the others, enriched by sixty dollars in army pay, happily made their way back to New Haven.

To compensate for the time lost in military service, Lee now locked himself in his room and studied for eight to ten

hours a day until he felt he was ready to take Professor Gibbs' advanced lectures on the electromagnetic theory of light. It was a course he had looked forward to since the start of graduate work.

Too, he was faced with the perplexing problem of deciding on a subject for his doctoral thesis. Making a choice was no easy task, for he knew that it was not merely a matter of satisfying academic requirements, but of selecting a specialization that might well determine his area of work after graduation as well.

During the early part of the term Lee felt strongly inclined toward x-ray research. He even discussed the matter with Professor Wright, his supervisor, whose talk the previous year had spurred his interest in Roentgen's discovery. Wright agreed that it was a promising field for further investigation, but at the same time wisely cautioned against a hasty decision. "Give yourself a little more time, Mr. De Forest," he said. "Examine the possibilities thoroughly before you make up your mind."

The professor proved to be right. One day in November, Lee walked into Dr. Henry Bumstead's lecture room and sat spellbound for a full hour as the physicist discussed the amazing phenomenon of "Hertzian waves." In every way they were as fascinating and puzzling as Roentgen's x-ray. Heinrich Hertz, a brilliant young German physicist, had discovered them in 1887. He had found that these invisible electromagnetic waves would cause a flow of electrical energy in a distant wire.

In a sense, Hertz's waves were analogous to Roentgen's x-ray, for just as the x-ray exerted a chemical influence by causing a treated sheet of paper to fluoresce or photographic film to be exposed, the Hertzian waves created an electrical effect on a metal surface.

Using this principle, Hertz had managed to build a simple device that enabled him to send and receive spark signals in the laboratory without wires! And though it was only a few

years since the German physicist's discovery, some engineers were already talking about using Hertzian waves to transmit messages through space.

Lee immediately discarded his earlier plan to do his thesis on the x-ray. Within a week after Professor Bumstead's lecture, he completed a preliminary outline for a new thesis topic. Entitling it "Reflection of Hertzian Waves from the Ends of Parallel Wires," he submitted it to Professor Wright. It was approved enthusiastically. At that point, Lee could not help feeling a strange sense of elation, not only because the topic had been accepted but because he knew instinctively that he had stumbled on his life's real purpose at last.

5

The Magic Waves

The subject Lee had carved out for his doctoral thesis was a narrow one. Actually, it was but one small corner of the vast and unexplored field of Hertzian waves. Still, he had little choice, for doctoral candidates were expected to investigate a specialized topic intensively rather than a general area superficially. Indeed, some academic cynic had wryly observed that doctoral studies were simply a process of learning more and more about less and less!

The purpose of Lee's research was to devise a laboratory method for the measurement of Hertzian waves. Working under Professors Wright and Bumstead, he set up experimental apparatus in the basement of Yale's Sloane Laboratory. The equipment was relatively simple, consisting of a "Blondlot generator," which produced the electrical sparks that, in turn, radiated high-frequency Hertzian waves. The waves were then picked up by a nearby "glow" tube which was a flask from which most of the air had been evacuated.

As the Blondlot generator sparked, the tube was filled with a purplish glow which varied in brightness according to the intensity of the spark and the waves. By peering into the little box containing his glow tube and using the reliable Lecher parallel wire resonator, Lee was able to determine the lengths and frequencies of the Hertzian waves.

After the first few observations, the work became little

more than repetitious drudgery. Lee was required to sit constantly in front of the glow tube box taking Lecher readings and recording them meticulously in his notebook. Nevertheless it was the sort of "donkey work" that a postgraduate student was required to perform in order to earn the precious doctoral degree. So he stuck to it without complaint, hour after hour, day after day, six days a week. If nothing else, it taught him a profound respect for the patience of the laboratory worker who spends his life delving into the deep hidden mines of the unknown in the hope of coming up with a single nugget of truth.

Meanwhile, he did not neglect his reading. If the subject of his thesis was to demonstrate accurate laboratory measurements of wave lengths and frequencies, his actual interest in the vast Hertzian wave realm went far beyond these narrow limits.

Starting with the very beginning of scientific interest in electromagnetic wave phenomena, he proceeded systematically to review the entire history of exploration in the field. He reread the works of Michael Faraday, Joseph Henry and James Clerk Maxwell. Then he went on to the experiments of Heinrich Hertz and the more recent efforts of a youthful Italian named Guglielmo Marconi, who was one of those who claimed that Hertzian waves could be used to devise a practical system of wireless signaling.

Although Hertz had made his monumental discovery in 1887, the roots of his work were entwined in the findings of earlier scientists who had first investigated the curious relationship between electricity and magnetism.

In 1820, Hans Christian Oersted, a Dane, found that a current flowing through a wire would move a compass needle, thus showing that electricity exerted a magnetic effect. At the same time, a French physicist, André Marie Ampère, found that he could measure the magnetic effect of an electric current. Ampère learned that two wires carrying electric current attracted and repelled each other just as

magnets do. From this knowledge he was able to work out scientific laws governing electricity.

Scientists now began to use the magnetic property of electricity to build electromagnets. They wound wire around an iron core, and when electric current was passed through the wire, magnetism was induced in the iron. One mathematics professor at Albany, New York, Joseph Henry, built an electromagnet that could actually lift a ton!

But Henry wasn't satisfied. He asked himself: if electricity produced magnetism, why couldn't magnetism produce electricity? In England, the world-famous physicist Michael Faraday was asking himself the same question at about the same time.

Previous investigators had looked into this problem but had failed to solve it. They had been misled by the fact that a *steady* electric current induced a *steady* magnetic field. Therefore, they had constructed experimental apparatus designed to produce steady magnetism, hoping that such a field would induce electricity in a wire.

In 1831 Henry and Faraday, working independently, came up with identical answers to the puzzle. They found that the solution lay not in using a steady magnetic field, but in setting up a *changing* field. Taking a closed coil or loop of wire, they suspended it near a magnet, then began to move the magnet. Immediately, an electric current was induced that lasted as long as the magnet was kept moving.

The next major effort to clarify the relationship between electricity and magnetism was undertaken by a Scottish scientist, James Clerk Maxwell. Maxwell, who was born in 1831, achieved a reputation as one of the world's most brilliant mathematicians and physicists by the time he was in his early thirties.

Using the experimental discoveries of Michael Faraday and Joseph Henry, Maxwell was able to arrive at the exact mathematical equations governing the laws of electricity and magnetism. But he didn't stop there. On the basis of his

equations he assumed that these two fields acted together to produce a new kind of energy called *radiant energy*. Then he made a remarkable announcement. According to his calculations, *there must exist invisible electromagnetic waves that move through space with the speed of light.*

Maxwell's prediction was to provide the framework for the discovery of the x-ray and Hertzian waves.

In 1885 the young German physicist Heinrich Hertz undertook to prove Maxwell's theory. His logic was simple: if there were indeed unseen electromagnetic waves as Maxwell had claimed, then he should be able to harness them and put them to work. He constructed a simple apparatus in which two metal electrodes whose ends were separated by a small gap were connected to a spark coil circuit capable of building up a high-voltage current. When the circuit was switched on, the high voltage caused the current to jump the gap between the electrodes, producing sparks.

Hertz now took a small piece of wire and looped it so that it formed an almost complete circle; but instead of closing the ends of the wire, he left a tiny gap. He suspended the ring a little distance from the high-voltage circuit and turned on the current. A remarkable thing happened: *the sparks in the high-voltage circuit were reproduced in the gap of the small wire ring, although there was no connection between the two pieces of apparatus and the ring was not wired to any source of power.*

His explanation of this phenomenon left no room for doubt: the sparks in the high-voltage circuit radiated the invisible electromagnetic waves which Maxwell had predicted. These waves were then "received" by the wire ring and a current was induced which re-created the original sparks. Thus, Hertz had proved Maxwell's theory. The scientific world hailed his remarkable discovery and referred to the waves as *Hertzian waves* in his honor.

But Hertz's monumental accomplishment held out more than theoretical interest. Some engineers and inventors were

quick to see its promise in practical terms. If Hertzian waves could be made to reproduce sparks, why couldn't a system be devised to turn the sparks on and off according to a code, thus making it possible to send messages by a system of "wireless telegraphy."

In the years immediately following the announcement of Hertz's findings, a number of interesting discoveries were made. A Frenchman named Édouard Branly and a Russian, Alexander Popov, had been experimenting with electricity in the atmosphere. Although working separately, they both found that a distant bolt of lightning could affect loosely packed metal filings. Such metal particles normally offered high resistance to the flow of direct current, but a flash of lightning momentarily lowered the resistance.

Branly made up a circuit consisting of a battery, a vial of metal filings and a telephone receiver. Whenever atmospheric electricity was present, he found that he could detect it by a clicking in the telephone receiver. What happened was that under normal circumstances the high resistance of the loosely packed filings in the vial kept the battery current from flowing easily through the circuit. But when lightning flashed or other atmospheric electricity was present, the particles stuck together, so that electrical resistance was lowered, thus permitting the momentary passage of an increased surge of direct current from the battery. In turn, this flow of electricity caused a click in the telephone receiver.

An English electrical engineer, Oliver Lodge, suspected that such a vial of metal particles had other uses. He named it a *coherer* because atmospheric electricity made the metal particles cohere, or come together. Lodge discovered that a coherer responded in the same way to sparks produced by a high-voltage circuit as it did to atmospheric electricity. Soon, he began using it as a laboratory detector for Hertzian waves.

Guglielmo Marconi, an Italian electrical engineer, now decided to apply Lodge's coherer to the art of signaling by means of Hertzian waves. He improved Lodge's design and

introduced an additional device—the "aerial wire." By attaching one end of the coherer to a wire extending high into the air and "grounding" the other end of the coherer to the earth, he found that Hertzian waves could be received over a vastly increased distance. In 1896, he succeeded in transmitting Morse code over a span of nearly two miles!

Marconi was independently wealthy. Moreover, he had connections in England with many influential people. After repeating his earlier experiments and increasing the distance of wave reception to eight miles, he convinced his British friends to back him in the formation of the British Marconi Wireless Telegraph Company.

Marconi hired the most talented electrical engineers and inventors he could find, including Oliver Lodge and Ambrose Fleming, an Englishman. As people everywhere were preparing to usher in a new century, it began to look as if they would soon have a revolutionary new means of communication that would outstrip even the telegraph and telephone in its ability to shrink distances and bring together the farthest-flung corners of the world.

These then were the exciting prospects that greeted Lee De Forest as he worked frenziedly to finish up his doctoral thesis on Hertzian wave measurements in the late spring of 1899.

At last, after seven months in the damp basement of Sloane Laboratory, his observations were completed and his paper submitted. Now he had to cram for his final examinations, preparation for which took him nearly two weeks and involved more than ninety hours of studying. Finally, after three trying days of exams, he found himself past the last difficult hurdle. Less than a week later, he received notification from the graduate dean of the university that he had completed all the doctoral requirements.

By way of celebrating, Lee attended a banquet in New Haven, sponsored by his fellow alumni in the class of '96, in observance of the third anniversary of graduation. Three

members of the class—Charles Warren, Holmes Jackson and Lee—had remained at Yale to earn the doctorate, so they were toasted as the guests of honor.

The reunion was a hilariously gay occasion. They sang songs, paraded around the banquet hall and set off fireworks. Finally the party broke up, and Lee stumbled off to bed at four thirty in the morning, tired but deliriously happy.

The next day was commencement. A dripping rain blanketed the campus. But not even the bad weather could dampen Lee's spirits that day. As he sat with the other doctoral candidates at the exercises, he turned and grinned at his mother, sister and brother Charlie, who was due to enter Yale in the fall. When his name was called, he walked up to the platform, received his doctoral diploma and shook hands with President Woolsey, the head of the university.

With his formal education now completed, it was difficult for Lee not to feel a sense of urgency about life in general. Because of circumstances beyond his control, he had started his college career late. At twenty-six—an age when most men were married and launched on their life's work—he was just starting out. Therefore it was not surprising that he felt a compulsion to make up for lost time. He tried to tell himself that this hunger to get ahead stemmed from a desire to repay his mother and sister for their devotion and sacrifices; but in moments of truth he came to realize that the yearning grew out of his own personal need.

Now, Lee's immediate task was finding a job. But where? There were not many employment opportunities for a doctor of philosophy in science outside of teaching. And he was convinced more strongly than ever that he had neither the interest nor the emotional make-up to adjust to academic life. Mary and his mother urged him to give it a try, but he resisted stubbornly, arguing that he could always turn to teaching as "a last resort."

He discussed the problem with Professor Bumstead, who suggested that he apply for a position at one of the large

electrical firms. "I would go to Chicago, Lee," Bumstead advised. "There are a number of big companies there, and with your academic record you might find something suitable. Naturally, I will be glad to give you a letter of recommendation."

Lee respected Bumstead and agreed to take up his suggestion. He felt too that even if he failed to find employment there, the trip to Chicago would provide a welcome break after the long, grueling weeks of writing his thesis and preparing for final examinations.

Mrs. De Forest and Mary endorsed the idea. Furthermore, Mary pointed out that it would be nice if he stopped off at Council Bluffs, Iowa, his birthplace, to visit their old friends before going on to Chicago. Lee consented, for he still recalled with nostalgia the visit he and his father made to Council Bluffs that summer long ago when he was fifteen.

Mrs. De Forest wrote to Deacon Wallace, an old friend and neighbor, and in reply received a cordial invitation for Lee to spend a few weeks with the Wallace family.

Early in July, Lee kissed his mother and sister good-by, got on a train and headed west. He arrived in Council Bluffs three days later, after stopping briefly in Chicago to visit his Aunt Hattie, a large, cheerful woman who had been widowed for many years, and Cousin Nellie, a prematurely gray-haired young schoolteacher.

In Council Bluffs he was met at the station by two attractive girls, Nettie Wallace and her younger sister Jessica. Nettie he recognized at once, but Jessica, whom he vaguely remembered as a spindly twelve-year-old, had blossomed into a lovely young woman. Her freshly scrubbed appearance and beautiful red hair reminded him of his own sister Mary.

Nettie, who was engaged to be married, laughingly informed him that he was to be her sister's beau during his stay in Council Bluffs.

During the next two weeks Lee and Jessica were together constantly. They went on long walks and carriage rides and

picnicked alone on the bank of the mighty Missouri River. Sometimes, to get relief from the July heat, they took a small boat out on a nearby lake. While Lee rowed, Jess dangled her arm in the cool water whose surface gleamed golden from the later afternoon sun. When they found a secluded creek or bayou, Lee put the oars aside and plucked away zealously, if amateurishly, on a mandolin while Jess, who had a really fine soprano voice, sang along.

They talked of many things. Lee grinningly confessed that his classmates at Yale had voted him the homeliest member of the class, as well as the nerviest, but Jess solicitously replied that they were probably just envious. "I see great things in store for you," she declared, patting him on the cheek with her cool hand.

He told her of his plans to get a job in Chicago and to continue his research on Hertzian waves; but when he tried to explain some of the technical aspects of electromagnetism, she laughed and said, "I just guess I've got a woman's head on my shoulders. I can't understand anything at all about scientific matters."

For Lee the two weeks in Council Bluffs seemed to fly by. He would have proposed marriage to Jess in a moment, but was restrained by the sober knowledge that without a definite prospect of a job he had no right to ask her.

On the last Monday in July, he sadly took leave of Jess and the rest of the Wallace family and boarded a coach for Chicago. Even while he was on the train he found himself writing a long letter, concluding with an original lilting poem entitled "To Jessie."

In Chicago, he went to his Aunt Hattie's on the west side of town and made arrangements to rent a room in her home. Over Aunt Hattie's and Cousin Nellie's protests, he insisted that he pay his own way. Finally they agreed to accept eight dollars a month for room and breakfast.

The very next morning, he took out the list of electrical companies that Professor Bumstead had suggested and began

to make the rounds. The employment managers at the first two firms were impressed with his educational background but explained regretfully that they had no openings at the present time.

The third place to which he applied was the Western Electric Company on Clinton Street, which manufactured equipment for the Bell Telephone companies. A gray-haired supervisor interviewed him and examined the letter of reference he had brought from Bumstead. Finally he said: "We have an opening in our dynamo department, De Forest. The job is yours if you want it. The starting salary is only eight dollars a week, but there is excellent opportunity for advancement. How about it?"

Lee gulped nervously and said yes, hoping that the supervisor would not hear the excited thumping of his heart.

When he left the company his brain was spinning as he tried to think of the most dramatic way to break the good news to Jessie as well as to his mother and sister when he wrote them that night. While eight dollars a week was hardly a munificent wage, he could not help feeling that the job represented the first rung on his own personal ladder to the clouds.

6

Telegraphy Without Wires

Though assigned as an engineer in the dynamo department, Lee found he was also expected to function as a mechanic. He worked from 7:00 in the morning to 5:15 at night, trying to find parts, repairing broken-down equipment and mopping up grease.

Occasionally he was called in by a senior engineer to help design a new part or analyze a defective circuit. Aside from these brief and welcome departures from routine, however, the job's duties were so elementary that he was convinced any second-year science student at Yale could have performed them.

Meanwhile, his courtship of Jessie Wallace was running into a snag. Her first letters to him had been warm and tender, and he had taken it for granted that they were bound together in a sort of unofficial engagement. However, as the weeks passed her tone cooled, though he could not understand why this should be.

Worried and torn with doubts, he borrowed ten dollars from a fellow engineer and boarded a train for Council Bluffs one Friday evening in September. He sat up all night listening to the clickety-clack of the train's wheels as it raced through the darkness.

He arrived in Council Bluffs the next afternoon and rushed immediately to the Wallace house where Nettie, who opened

the door, gave a little gasp of surprise at seeing him. The Wallaces greeted him warmly, and Jessie kissed him affectionately on the cheek.

After dinner, he and Jess sat alone on the porch. She confessed that since he had left she had been able to appraise their romance more objectively, and doubts had arisen in her own mind as to whether she really was in love with him.

Heartsick, Lee tried to persuade her that all couples in love experienced moments of uncertainty, but she refused to be convinced. Finally he pleaded with her to be patient and give herself more time before arriving at a definite decision. She nodded and assured him quietly that she would not make up her mind in haste.

The next afternoon she saw him off at the station. They kissed good-by, and as the train rolled out of Council Bluffs he had a foreboding that he would not see Jessie Wallace again.

On his return to Chicago he decided to apply for a transfer to Western Electric's experimental laboratory, where the work was more advanced and interesting. The head of the laboratory, William Warren Dean, was impressed with Lee's academic background, but he explained that there were no vacancies. However, he did succeed in obtaining Lee's transfer from the dynamo department to the seventh-floor telephone cable section, where life was cleaner and less routine. "When a position opens up in my laboratory, I'll keep you in mind," Dean promised.

In the meantime, the letters from Jessie were growing progressively colder and more discouraging. As a diversion from his unhappy courtship, Lee turned to music. Several evenings a week, after finishing work and eating dinner at Aunt Hattie's or in an inexpensive restaurant, he went to the Castle Square Opera, where he became so absorbed in the musical drama on stage that he managed briefly to forget the pain of his unrequited love.

At this time, too, he felt a reawakening need to continue

his work in Hertzian theory. He wrote to Professor Bumstead describing the job at Western Electric. In reply his former teacher urged him to keep up his interest in electromagnetic waves. "Work on your own, if you must," Bumstead wrote. "Set up a laboratory at home—in a closet if need be."

Lee took Bumstead's advice to heart. He got permission from Aunt Hattie to put up electrical apparatus in the basement of her house and began construction of a spark circuit similar to the one used in his doctoral research.

His plan was to continue the work he had begun at Sheffield on Hertzian wave measurements. Thus, he hoped to accumulate additional findings that could serve as the basis for a paper for one of the scientific journals.

But in the midst of setting up his experimental equipment, he was sidetracked by published accounts of the latest work of Marconi. The Italian engineer had predicted that the time would soon come when Hertzian waves would be sent thousands of miles across the ocean. He hinted that he himself was planning such an experiment. From what Lee could gather, the trouble lay with the sensitivity and efficiency of the coherer system of receiving waves. While the vial of metal particles which Branly and Lodge had used was satisfactory for detecting primitive Hertzian signals in a laboratory or over a distance of several miles—provided conditions were perfect—its utility for practical signaling was sharply limited.

For one thing, the coherer was not very sensitive, and only strong signals could be detected. Secondly, any sort of atmospheric electricity created such interference that the device became almost worthless. Finally, the coherer was not "self-restoring." This meant that when a Hertzian wave caused the metal filings to cohere, thus enabling a surge of electric current from a battery to pass through the particles, the filings *continued to cling together.* The vial then had to be tapped with a hammer to loosen the particles before an-

other signal could be detected. It was painfully slow and clumsy.

The problem of finding a better way began to fascinate Lee. Surely, he told himself, there must be a more efficient method of receiving those magic signals.

He constructed a coherer and wired it into a battery circuit equipped with a telephone receiver. Soon, his spark circuit was busily radiating Hertzian wave signals across Aunt Hattie's basement to be picked up by the coherer which transformed them into clicking sounds in the earpiece.

Lee now satisfied himself that the disadvantages of the coherer were only too true. It was frustratingly impractical. The constant need to "restore" the coherer by tapping the metal filings loose made reception slow and complicated. Moreover, there was the equally serious problem of obtaining a sharp and distinctive signal. Even when he was transmitting across a distance of forty feet, atmospheric interference often created a crackling that made it impossible to distinguish between his own spark signal and the outside waves.

What was needed, he decided, was a more sensitive device that would detect a signal, then "restore" itself automatically to receive another and then another.

Lee began a systemized search of the scientific publications to see if anyone had come up with an improved method of detecting Hertzian waves. Each evening after supper at a local "ten-cent" restaurant, he visited the free libraries and combed through French and German physics journals as well as those published in English, in the hope of unearthing a clue.

One night he was thumbing through a dog-eared copy of a physics journal when he came across a brief article that seized his attention. It was a description of an obscure phenomenon discovered by a German named Aschkinass.

Aschkinass had laid a thin piece of tin foil on a glass plate and cut it in two with a razor. Next, he had wired the two

pieces of foil to a battery-telephone circuit and placed a drop of alcohol over the narrow gap produced by the razor cut. Upon switching on a spark generator nearby, a curious thing happened. Each time a spark was activated, Aschkinass heard a weak ripping sound in the telephone receiver!

The explanation advanced by the German physicist was interesting. The Hertzian waves transmitted by the spark circuit caused a momentary lowering of electrical resistance in the alcohol. As a result, current from the battery flowed across the gap between the two pieces of tin foil, producing a sound in the telephone receiver.

Lee felt a sense of mounting excitement at the realization that Aschkinass' electrolytic device was acting as a "detector" of Hertzian waves in the same way as the coherer developed by Branly and Lodge. With one difference: while the metal filings in the coherer had to be tapped loose after each signal, the alcohol drop was *self-restoring.* After each Hertzian signal was received it was instantaneously ready for the next one.

Eagerly, he began to leaf through a huge stack of physics journals to see if anyone had duplicated Aschkinass' work. While he had no doubt that Aschkinass was reporting results accurately, his training under Wright and Bumstead had made him too wise in the ways of research to pin all his hopes on a single experiment.

Sure enough, in a later issue of the same journal he came across an account by another German researcher named Neugschwender who had duplicated Aschkinass' experiments with greater thoroughness and under more rigorous laboratory conditions. The results confirmed the earlier findings!

Lee was convinced that he had come across something important and decided to follow up the work of the two German scientists. The next evening he began to construct a simple electrolytic detector.

However, his work was interrupted by word from William Warren Dean that he had been promoted to the experimental

laboratory at Western Electric. Just a few weeks before, he would have jumped with joy at the announcement; now he took it in stride, for he was so preoccupied with his own research that the promotion to Dean's laboratory no longer seemed as important somehow.

Indeed, he even felt a small twinge of resentment, for he knew that during the next few weeks he would have to devote all his efforts to meeting the demands of a new job, instead of giving his attention to the experiments in Aunt Hattie's basement.

Nevertheless, the promotion did have its advantages. It meant that he was in line for a raise in salary. Furthermore his associates in the experimental laboratory were a friendly, good-natured crew who quickly accepted him into their ranks. In addition to Bill Dean, the laboratory head, the experimental lab workers included Ed Smythe, an engineer with twinkling eyes and a fine sense of humor, and Ray Manson, a pleasant young man who considered Dean his idol.

The first few weeks Lee dedicated himself wholeheartedly to his assigned tasks. He was so spent at the end of the day that progress on his new detector slowed almost to a halt. However, as he became more familiar with the laboratory routine he resumed work on his own experiments at night.

On December 30, 1899, two days before the New Year, Lee was notified that his wages were to be increased from eight to ten dollars a week. He wanted desperately to write to Jessie, who had not answered his last two letters, but pride kept him from doing so. However, he did write to his mother and sister in New Haven that for him "the new century is starting out well."

His relations with Jessie Wallace had hit a low point, and he was now convinced that nothing he could say or do would ever persuade her to marry him. So finally one evening in January he sat down and wrote a long farewell letter to his beloved. His tone was reproachful and maudlin by turns,

but his determination to break off with her was real enough —so much so that he ran down and mailed the letter at once for fear that he would change his mind.

Jessie did not answer his letter.

Experiments on the new Hertzian wave detector—Lee referred to it as a "responder"—began to occupy more and more of his time. Even at work, when he was supposed to be engaged in tests of new telephone devices, his brain was usually buzzing with some scheme for improving his wireless apparatus. He even brought the spark-gap equipment and responder from Aunt Hattie's to the laboratory so he could work on it every moment he could spare.

One of the problems that soon became evident was the tendency of the responder to stop receiving signals after a few minutes of operation. Lee concluded that it was because the drop of alcohol across the gap became decomposed by the passage of electric current through it, for when a fresh drop of alcohol was substituted, the device bounced back to life. He began to substitute all sorts of liquids—water, oil, dilute ammonia and even Woodbury's Facial Cream! Eventually he found that by using tin electrodes instead of tin foil and inserting between them a thin paste of lycopodium powder or lead peroxide, the responder would remain sensitive for hours, sometimes even for days at a time.

In the beginning, Bill Dean did not object to his young subordinate's extracurricular research efforts in the laboratory. An inventor himself, he was as curious as the others about the fascinating scientific toy Lee had developed. But as the responder became increasingly distracting, Dean grew impatient. One day, after his entire staff had wasted half an hour taking turns listening to Lee transmit wireless signals across the laboratory, he threw his hands in the air and shouted despairingly, "Look here, De Forest, you'll never make a telephone engineer. As far as I'm concerned you can go your own way. Do as you please!"

Lee blandly took his supervisor at his word. Thereafter he

spent most of his working hours on the responder, justifying the use of company time by telling himself that wireless signaling might someday be of deep significance to the telephone industry of which Western Electric was a part.

Of all the men in the laboratory, it was Ed Smythe who showed the keenest interest in Lee's work. Having grasped the practical importance of the responder, he asked intelligent questions and made helpful suggestions for improving it. One day Smythe came in with interesting news. He had heard of a man named Johnson, a wealthy heat-equipment manufacturer in Milwaukee, who had taken up wireless signaling as a hobby. Johnson was so intrigued with its possibilities that he had recently organized the American Wireless Telegraph Company. What's more, Johnson was looking for an engineer to assist him. "Lee, if you don't write to Johnson at once to offer your services, you're a fool," Smythe declared.

Lee sent off a letter that evening, describing his academic background and experience. Johnson telegraphed that he would be in Chicago on business the following week and wanted to meet him.

On the day of their appointment, the Milwaukee manufacturer came up to the Western Electric building and interviewed Lee in an unused office near the experimental laboratory. Johnson turned out to be a tall, thin man with gold-rimmed spectacles and an unexpectedly high-pitched voice. He asked an endless stream of questions before announcing that he was satisfied that Lee was the man for him. "I take it you are interested in working for me," he said. "If so, what wages do you require?"

Lee swallowed hard and volunteered nervously that fifteen dollars a week seemed fair.

"Done," Johnson said in his squeaky tone. "Fifteen dollars it is. You'll come to work for me two weeks from now." Then, without waiting for a reply, he marched out of the office and down the stairs.

On April 1, 1900, Lee went to Milwaukee. Johnson and an

assistant, Fournier, had devised a Marconi-type system of wireless reception using the coherer. However, Johnson was convinced he had solved the problem of "decohering" the iron filings automatically. His plan was to loosen the metal particles by little puffs of air blown through the coherer chamber from a pump driven by a small motor. It was based on a principle used in the automatic heating equipment manufactured by Johnson's company.

In theory the idea was not at all farfetched. However, Lee saw at once that from a practical standpoint the equipment was too complicated to work efficiently. He explained this to Johnson and Fournier, but his new employer snapped, "I did not hire you to criticize or offer unwanted suggestions, Mr. De Forest, but to carry out my orders." In view of Johnson's attitude Lee saw little point in pressing his objections.

His assignment turned out to be a fairly simple one. He was to be stationed on a lofty hill overlooking Lake Michigan where he would try to receive wireless signals with the Johnson coherer equipment. The signals were to be sent out by a large spark-gap transmitter located at the Johnson factory in Milwaukee. An assistant was assigned to work with Lee—a man with a thick German accent, Lyman, who turned out to be a plumber from the Johnson factory. He knew heating equipment but absolutely nothing about electricity.

For two weeks, Lee and Lyman camped in a tent on the hill, waiting patiently for the wireless signals to come through. They took turns by the hour, gluing their ears to the telephone receiver; not a sound issued forth.

Lee grew bored and disgusted, but Lyman urged him not to lose heart. "Mr. Johnson is a genius," he declared obsequiously. "He would not have made a fortune otherwise. The machine will work, you will see."

But the Johnson-Fournier detector did not work. One day, Lyman went to town for supplies. To allay his boredom, Lee took out his own electrolytic responder, hooked it up to a battery and rigged a primitive aerial wire. The plop-plop

sound of the signals from Johnson's spark transmitter in Milwaukee came through the telephone receiver at once. They were weak but surprisingly clear.

For half an hour, Lee played around with the responder and the aerial, to see if he could improve the strength of reception. He was so intent that he did not notice Lyman's return. Suddenly, he became aware that the plumber was watching over his shoulder, a sly grin on his face. He hastily switched off the responder and replaced it in its carton.

More weeks went by, but still the Johnson-Fournier apparatus continued its silence.

Finally, even Johnson had had enough and recalled them to Milwaukee. The receiver would have to undergo a complete revamping, he told them sourly.

The next morning, Lee received an order to report to Johnson's office at once. Instinctively he knew that Lyman had told all, so he braced himself for the expected onslaught. He was not wrong. The moment he set foot in the office, Johnson charged him with disloyalty and directed him to bring in his "gadget" immediately.

"Apparently while in my employ you've constructed a wireless receiver, and I understand you've gotten it to work," the manufacturer said. "Under the circumstances your invention is the property of my company."

Lee replied that such an argument was sheer nonsense. The apparatus had been developed in Chicago, he pointed out, and he had witnesses who could prove it. It had no connection with his present job.

This explanation took the wind out of Johnson's sails momentarily. It was obvious that Lyman had misinformed him by reporting that the responder had been built at the Lake Michigan receiving station.

However, Johnson was not ready to give up. He began to plead and cajole, promising Lee a fortune if he would turn over his invention. But Lee was adamant. He declared that the receiver required additional work and that in any case

he had no intention of letting it get into the hands of a company not under his personal control.

"Then you refuse to share your knowledge?" Johnson demanded.

"At the present time and under the present conditions, yes," Lee retorted firmly.

Johnson was furious. He shouted that Lee was ungrateful and selfish and warned that a failure to produce the invention would mean dismissal. With his squeaky, high-pitched voice, the manufacturer somehow reminded Lee of an angry, oversized rabbit, and he could not help grinning inwardly, in spite of the tenseness of the situation.

Finally, Johnson ran out of steam. He repeated his ultimatum: "Do you still refuse?" Lee nodded. "Then you're fired."

Lee walked out of the office, stopped at the paymaster's window to collect his wages and went directly to the rooming house to pack his things. That evening he boarded the night boat for Chicago.

Upon his return to the Windy City, he looked up Ed Smythe, who advised him to find a rooming house closer to the center of things, rather than return to his Aunt Hattie's on the West Side.

Lee located a small room on Washington Boulevard. Then, once more at the suggestion of Ed Smythe, he reapplied to Western Electric and got a job as assistant editor of the company's magazine, the *Western Electrician*. His salary was again ten dollars a week—a big step down from the fifteen dollars Johnson had been paying him, but at least the work was interesting, he told himself. His main task was translating scientific papers on electricity which recently had been presented at the International Exposition in Paris.

In the evenings, Lee, Ed Smythe and Ed's brother Will experimented with the responder, trying a hundred different schemes to improve reception. Soon it became clear that the field of wireless signaling was far too vast to be conquered

by night work alone. More time was needed for experimentation. But where was it to come from?

It was Will Smythe who came up with the answer. Why not go into the project in a businesslike way? Suppose he and Ed were to contribute five dollars a week toward support of the experiments. Would Lee be willing to work half-time at the *Western Electrician* and devote the rest of his time to the responder? It seemed like a perfect solution, and the three quickly agreed on the financial arrangements.

Lee persuaded the editor of the magazine to let him work on a half-time basis at half pay. However, to supplement his income he also secured a position teaching two nights a week at Lewis Institute, a local technical school.

Through his job at the *Western Electrician* he had met Professor Clarence Freeman from the staff of the Armour Institute of Technology. Freeman liked Lee and was keenly interested in wireless. He agreed to allow Lee to use a laboratory at the Armour Institute for experiments, in return for which Lee was to take care of the apparatus and assist some of the students in their laboratory work. It was a fair exchange.

In the early fall of 1900 the partnership of Lee De Forest and the Smythe brothers began actively. It was supported by little more than a shoestring, yet for Lee it meant at last the fulfillment of his lifelong ambition to become a professional inventor.

7

The Signal Grows Stronger

Even as work on the responder went forward, Lee's sights were fixed on more distant horizons. The electrolytic detector was superior to Marconi's coherer—no question of it. Still, he was convinced it was not the final answer. He knew he must continue to search for ever better ways of receiving Hertzian waves. Accordingly, as he proceeded with the responder experiments, he was constantly alert to other possible approaches.

One evening in September, while making adjustments in the spark-coil circuit, he noticed a curious phenomenon. The Welsbach gas burner which illuminated the room began to flicker. Each time he switched on the electrical circuit and crackling sparks appeared in the transmitter gap, the gaslight brightened perceptibly. When the current was turned off and the sparks ceased, the flame returned at once to its normal intensity. This strange reaction took place even though the Welsbach burner was located some twelve to fifteen feet from the electrical circuit.

Lee's curiosity was aroused. He repeated the experiment for Ed Smythe, who agreed it was worth further investigation. They conducted several simple experiments, including shielding the flame from the spark transmitter with a sheet of tin. Nevertheless, the burner flame remained as sensitive to the flow of current across the spark gap as before. Lee was

now bursting with the excitement of potential discovery. Had he found some new form of sensitivity to Hertzian waves that could lead to a different method of wireless reception?

He decided on an additional test. The transmitter was moved to the bedroom. Ed Smythe was to switch it on while Lee observed the Welsbach burner with the wooden door between the two rooms closed. "The transmitter is on," Ed shouted from the bedroom. Lee studied the gas flame intently. Nothing happened. The experiment was repeated, but the intensity of the light did not change. There was not even a ghost of a flicker.

The transmitter was brought back to the room with the burner and switched on again. The moment the sparks began to crackle, the Welsbach flame brightened as it had done initially.

Suddenly, the answer to the puzzle became clear, and Lee slammed his fist on the table in disgust at his own stupidity. It was not the Hertzian waves at all, but the movement of air due to the *sound* waves from the crackling sparks that had caused the flame to flicker.

He explained it to Ed. To demonstrate the principle he slammed a metal ruler on the table sharply several times. Sure enough, the Welsbach flame momentarily increased in intensity.

Yet in spite of his disappointment, Lee could not quite shake off his earlier notion. The electrolytic responder had proved that Hertzian waves were capable of lowering electrical resistance in a drop of liquid. Was it possible for the waves to affect a gas in the same way?

It was certainly an interesting theory to play around with, and he decided that one day he would delve into it more deeply. For the moment, however, there was neither the time nor the equipment to undertake such a diversionary investigation. Not unless he was prepared to sacrifice his work with the responder which, after all, had proved that it worked.

Up to now, Lee's transmission tests had been confined to a single room. In Wisconsin, while working for Johnson, he had proved to himself that the responder could receive signals transmitted many miles away. He felt he was now at the point where he could profitably turn his attention to the problems of transmission. But first he decided to have a heart-to-heart talk with Ed Smythe.

"If we're as successful in transmitting as receiving, we will have a good thing on our hands," he said. "This work is confining and time-consuming, so I want to quit my job at the *Western Electrician* and give full time to it. But it's got to be with your help, for I don't have a dime, as you well know. What do you say?"

Ed agreed that it was the only right way to go about it, but explained that he did not have another cent to spare. For several weeks he had been paying his brother's as well as his own share of Lee's five-dollar-a-week subsidy because business at the shop where Will worked was doing badly and the employees had been forced to take a cut.

"You see how things are," Ed said apologetically. "I would do it, but I just don't have the money."

Lee patted Ed on the back and told him he understood his position. Then he added, "But I'm going to quit my job at the magazine anyhow. I'm a fool, perhaps, but I've *got* to take this chance. With your five dollars a week and the five dollars I earn by teaching at Lewis Institute, I think I can squeeze by, for a while at least."

The next day he submitted his resignation to the editor of *Western Electrician.*

Lee began his transmission experiments methodically. He obtained a larger spark coil and battery and borrowed a sensitive "Wehnelt interrupter" from the Armour Institute to serve in place of the slow "hammer interrupter" he had been using to make and break the spark circuit. While the latter was satisfactory for experimental work in the laboratory, Lee felt that a more sensitive interrupter would be better for

"long-distance" transmission because the signals were more sharply defined.

After testing the new transmitter in the laboratory, he moved it to the institute corridor and continued the trials. After each successful test, the transmission equipment was moved still farther away from the responder, until at last he reached the end of the corridor. Finding that the signals were still coming in clearly, he decided he was ready for outdoor experiments.

An antenna was needed, so he got to work rigging an aerial out of whatever material he could find. He removed five hoops from discarded wooden barrels and connected them at fifteen-feet intervals using strands of lamp cord. Then he and Ed Smythe hoisted the bizarre contraption to the top of the Armour Institute flagpole and brought the spark-gap transmitter to the top floor of the building. Lee connected a lead wire from the flagpole antenna to one spark terminal and wired the other terminal to a steam pipe for a "ground."

Smythe was stationed at the institute with instructions to begin transmitting in half an hour. Lee made his way to the Lakota Hotel, half a mile away, where he had been given permission to put up an aerial. He climbed the stairs to the roof, rigged a long wire as an aerial and connected it to the responder. When his preparations were completed he sat back and held the telephone receiver to his ear. Suddenly, the instrument seemed to come to life. Dit-dit-dit-dit, it went. Then a short pause, and again, dit-dit-dit-dit. It was the four dots of the letter *H*, the prearranged signal.

Lee felt giddy at his triumph. The transmitter worked! True, the signal was weak, but it had come over clearly enough to be "read"—and that was what mattered.

Hurriedly packing his equipment, Lee ran all the way back to the Armour Institute to break the good news to Smythe. Ed did a little jig and delightedly slapped his partner on the back.

The next day Lee secured permission to string his receiv-

ing antenna to the lofty tower of the Chicago Auditorium, four miles from the Armour Institute. With Ed once more at the key on the top floor of the institute and Lee in the auditorium tower, the experiment was repeated. Again the signal came whirring through the receiver distinctly.

That evening, Lee and Ed discussed their next step. They agreed that what was needed was a dramatic way to publicize the practical advantages of their wireless system. But how?

"On shipboard," Lee declared thoughtfully. "We've got to show that it can be used to communicate over water. On land, the telegraph and telephone are available, but ships need a wireless system. An effective demonstration will attract attention. Look at Marconi's success at the yacht races."

What Lee had reference to was the fact that the year before, Marconi's company had arranged to transmit news of the International Yacht Races from ship to shore by wireless transmitter. The plan had not worked too well because of the inadequacy of Marconi's equipment. However, it had achieved almost as much advance publicity as the races themselves.

Lee and Smythe discussed their idea with Professor Freeman. Freeman, who had been following their successful tests with avid interest, came forth with a first-class idea. A friend of his maintained a yacht on Lake Michigan. Undoubtedly this friend could be persuaded to use his boat for over-water tests.

The professor was as good as his word. Within two days he had made the necessary arrangements. The owner, flattered to have his yacht used for scientific experiments, had even offered the use of the ship's generator as a power source.

The transmitter was installed, and early the next morning Lee, Smythe and Freeman went down to the dock with the responder. Lee was startled to find newspaper reporters present. Ed Smythe grinned and confessed that he had tipped off the wire services and Chicago papers.

"Very well," Lee replied uncertainly. "But I hope we don't fall flat on our faces."

The plan was to station Ed aboard the yacht to operate the spark transmitter while Lee and Freeman remained on land to receive messages.

As the yacht moved out of its berth, Lee and Freeman set up the antenna wire, placed the responder and battery on an old packing case and grounded the equipment to a sewer pipe.

Then, surrounded by newsmen, they watched as the boat steamed off toward the horizon. Soon it was a speck, and finally it disappeared altogether.

Seated at the packing case, Lee anxiously held the telephone receiver to his ear while Professor Freeman at his right was ready with pencil and paper. Soon he heard a faint ticking sound and called out for Freeman to adjust the antenna wire. The professor dropped his pencil, hurried over to the aerial and slowly swung the wire around until Lee shouted that the signals were much stronger and clearer. By now the dots and dashes were coming in with the regularity of a musical beat; the familiar four *dits* of the *H* signal were unmistakable. Lee grinned and offered the telephone receiver to the amazed reporters who took brief turns listening in.

Now the rhythm of the signals changed. Apparently, Smythe had decided to send a message. As the responder clicked away, Lee repeated the sequence of dots and dashes to Freeman, who wrote them down on his sheet of paper. For a professional telegrapher the transmission would have been child's play, but neither Smythe nor Lee had ever worked as telegraphers, and the process of sending and receiving was still unfamiliar and painfully slow. Finally the signals ceased. With the reporters staring over his shoulder, the professor converted the Morse code into letters. The message read, "Smythe to De Forest. Equipment fine. If you can read this we have succeeded."

The reporters questioned Lee eagerly. How did the gadget work? Did he think signals could be sent over longer distances? What were his future plans?

Lee patiently answered all the questions. He gave them a brief explanation of Hertzian wave phenomena and described as simply as he could how the electrical spark of the transmitter on shipboard radiated invisible electromagnetic waves. He went on to tell how these waves induced a weak current in the antenna wire and how the current in turn was translated by the responder into sound in the telephone receiver. Ultimately, Lee predicted, as improvements in transmission and receiving equipment were made, the distances spanned by wireless would be stretched beyond imagination. "Someday the human voice will be carried through space by these waves," he asserted. As far as his own plans were concerned, he would continue his efforts to develop the De Forest system for practical use.

The next day, several Chicago newspapers carried the story on page one. It was Lee's first taste of publicity, and he liked it!

Lee, Smythe and Freeman now held another policy meeting. They decided that in view of the success of the yacht tests and the public attention it had received, the time was right for them to enter the commercial field. Lee suggested that a start should be made in the East, where the communications industry was centered, and Smythe and the professor agreed. Freeman offered to put up some of his own funds if Lee could manage to obtain the additional financing needed. "Experimental work is one thing," the professor pointed out. "Once you get into commercial work, big money is involved."

Lee had already given the matter considerable thought. He replied that he planned to ask Max Stires, a Yale classmate in Jersey City, who was in the business of obtaining financial backing for new ventures, to help. "I'll ask Max to interest some New York newspaper in fitting us out for

reporting the next International Yacht Races by wireless, as Marconi did with the Associated Press," he told them.

Lee wrote a long letter to his fellow alumnus explaining the plan. To his delight, Stires, who even as a Yale student had been enthusiastic about daring new schemes, pledged full cooperation. From then on a steady stream of letters and telegraph messages were exchanged between Chicago and Jersey City.

Stires soon learned that the Associated Press and the *New York Herald* had renewed the contract with Marconi to report the yacht races. Undaunted, he approached the Publishers' Press Association, a competing organization, and convinced them that Lee De Forest's new American system had many advantages over the English system used by Marconi.

Encouraged, Lee rushed east to meet a prospective backer whom Stires knew, a wealthy businessman named Henry Siedler. Siedler needed little persuasion. He immediately agreed to finance the construction of a new and more powerful transmitter.

Lee had devised a plan for a new alternating current transmitter which could be wired up to a ship's generator, but Freeman, now a partner, argued that it would not be powerful enough. Instead, he offered to design a different type consisting of numerous condensers and a motor which could be used with a special 500-volt direct-current generator. Lee protested that such equipment was too bulky and complex and likely to break down easily, but Freeman pooh-poohed his objection. In the end, Lee reluctantly went along.

Since less than two months remained until the races, Lee, Smythe and Freeman worked feverishly in Jersey City to finish the transmitter in time.

The work progressed rapidly despite the difficulty of finding parts. Because of the new design, standard electrical parts could not be used, and much of the apparatus had to be specially constructed by hand. As the transmitter neared completion, Lee managed to convince himself that his earlier

erning the workability of Freeman's de-
:d. Nevertheless, he made up his mind to
ıall spark transmitter they had used in
ıutionary measure.

The ıces dawned clear and cool. The sleek sail-
boats silhc_. gainst a cloudless blue sky presented a pic-
ture postcard vie '. Aboard the small tugboat chartered by the Publishers' Press Association, Lee and Ed Smythe checked their equipment carefully. The boat was standing off Sandy Hook, a narrow spit of land in northern New Jersey. On Lee's instructions, the telegrapher employed by the press association began to tap-tap a test message to the Sandy Hook operator who was to receive the news reports. Nothing happened.

Lee felt his heart sink. There was not even the hint of a spark in the transmitter gap! Frantically, he and Smythe rechecked the complicated apparatus, hoping against hope that it was nothing more than a loose connection.

They found the wires all in place and the connections in good order. To tear down the transmitter now was out of the question, since the first race was about to begin. There was only one thing to do: set up the small transmitter he had brought along for emergency use.

Lee and Ed hurriedly disconnected the Freeman apparatus and wired the old equipment to the antenna. Then they had their operator send a message to Professor Freeman, who had remained on shore with the Sandy Hook operator, explaining what had happened.

"Tell him not to be surprised if reception is weaker than expected," Lee instructed.

The spark jumped and crackled as the operator's fist on the telegraph key clicked out the message. Lee grinned triumphantly at Smythe. The tug was now about a quarter of a mile offshore, still within sight of land. In the bow, a reporter from the Publishers' Press Association watched the races through powerful binoculars. On the starboard deck

a sailor was stationed, ready to act as an emergency signalman if flag communication with shore was required.

After each race the reporter penciled a brief dispatch which was quickly sent out over the transmitter. Shortly after the end of the second race, the sailor assigned as starboard observer shouted that something was wrong. "There's a flag signal coming in from shore, Mr. De Forest," he called out excitedly.

Lee borrowed a pair of field glasses and searched the Sandy Hook coastline. Sure enough, a signalman with red and white flags was wigwagging frantically.

"What is he saying?" Lee asked anxiously.

The sailor related the message. It was from Freeman. There was atmospheric interference, the message said, and the Sandy Hook operator seemed to be receiving two sets of wireless waves so that the dispatches were hopelessly garbled!

Lee wracked his brain for an explanation. The sky was marvelously clear, and there was not a remote sign of a storm or electrical disturbance in the air. What was wrong?

Suddenly, the answer came to him, clear as the morning air itself. The second set of signals was from the Marconi transmitter nearby. Marconi's men, working on behalf of the Associated Press and the *New York Herald*, had installed their equipment on the palatial yacht of James Gordon Bennett, owner of the *Herald*. The Bennett boat was only a short distance away, transmitting signals that interfered with their own.

Lee explained the problem to Smythe. It was a totally unforeseen and catastrophic development. "Can't we do anything?" Ed inquired in a small, strangled voice that reflected quiet desperation.

Lee shook his head sadly. "Not a thing," he replied. "Not a blessed thing." Then he forced an unhappy grin and added, "Marconi's people must be experiencing the same thing.

Perhaps we should invite them out for a drink afterward and commiserate with each other."

With wireless transmission hopelessly out of the question, the news dispatches were sent to shore by the traditional semaphore system of flag signals.

After the races were over, the boats docked. Marconi's engineers rushed up and angrily accused Lee of ruining their transmission. Lee quietly explained that he had had the same trouble. "It's really no one's fault," he said. "After all, this is a new business and we're all pioneers in it."

The next day the headlines in the New York newspapers boasted of the "Wireless Reports of the Yacht Races" carried in their columns. Literally, this was true. But what the papers neglected to point out was that the "wireless" used was the old-fashioned wigwag method that had been in use for over a century.

For Lee, the weeks following the Sandy Hook fiasco were a time of bleak despair. Freeman left for Chicago in disgust. Ed Smythe returned, too, for fear of losing his job at Western Electric. Siedler, the backer who had lost a thousand dollars on the Freeman transmitter, refused to have anything more to do with wireless. Only Stires retained his faith—but he had no funds of his own to invest.

At twenty-eight, Lee looked and felt like a dismal failure. The soles of his shoes were worn thin and his overcoat was frayed. There was barely enough money to pay his board bill. Only Smythe's check for five dollars, mailed weekly from Chicago, stood between him and absolute poverty.

Physically, too, he seemed to have aged. Ordinarily, his round, pink-cheeked face made him seem much younger than his years, but the tension and overwork of the past months had brought lines of strain to his features, and he had taken on a sunken, pale look. His shock of black hair and dark, bushy eyebrows accentuated the pallor, as did the heavy mustache he had grown to make himself appear older and more mature. Although Lee was of medium height, the

sense of weariness and defeat combined to give him a sagging, almost shrunken look.

One week end he took the train up to New Haven to visit his mother and sister. They were shocked at his appearance and urged him to stay for a week or two to rest up. But he insisted that he must return to New York to resume his work. Of course, it was pride and the inability to admit his failure that made him refuse, for in actuality he had only two dollars in his pocket and not a prospect in sight.

To make matters worse, the newspapers were full of a new Marconi triumph. While the yacht races had proved disastrous for Marconi wireless as well as for Lee, Marconi still retained strong financial support. Consequently, he set out at once to achieve a dramatic recovery by announcing to the press that he planned to send a wireless signal across the Atlantic Ocean!

The Marconi engineers set up a powerful transmitter on the English coast and hooked it up to aerial wire connected to a kite. A receiver was installed in Newfoundland, off the eastern coast of Canada. The English operators were instructed to send out the three dots of the letter S on a round-the-clock basis. For weeks nothing happened, but Marconi kept his operators at their keys. Finally, on December 12, 1901, the Newfoundland station reported the reception of a weak S signal.

The news had the impact of a thunderbolt. It immediately revived public interest in wireless. Lloyd's of London, the world's foremost marine underwriters, commissioned Marconi to erect wireless stations all along the coast of England. The British Admiralty signed a contract with him to have thirty-two ships equipped with transmitters and receivers.

For Lee, almost penniless in New York City, the news of Marconi's success added to his own sense of frustration and failure. How could he hope to compete with a Marconi who had the advantages of personal wealth and powerful friends?

In truth, he now found himself at an important crossroads where he must make a decision. Should he continue his will-o'-the-wisp search for success in wireless? Or should he find a secure job and settle down to a normal existence?

Curiously, he found his thoughts at this critical moment turning to the memory of his father. Now, for perhaps the first time, he could understand his father's stubborn insistence on following the way of life he had set for himself, even if it meant constant discouragement and poverty. It was Henry De Forest's unswerving dedication to a cause, so perplexing to Lee as a boy, that he began to comprehend at last. It had meaning for him now for the simple reason that he was beginning to detect the stirrings of a similar fervor within himself. It was an awakening, a new understanding, that more than ever strengthened his sense of identity with the memory of his dead parent.

No, he would not give up. Come what may, he would pursue the goal, even if the odds were against his success. He knew now that the weaving of dreams was not the consequence of rational thought but of inner compulsion which could not be cast aside.

Shortly before Christmas, Lee set out to raise fresh backing for his wireless work. He was armed with a new sense of purpose and an idea, little else.

The idea was simple enough. He would build a transmitter powered by alternating current which would be capable of supplying a steady "high-frequency" spark. Such a device would replace the old spark coil sender—a European development—which used direct current and severely limited the speed and efficiency of transmission. If the alternating current design proved as effective in practice as it appeared in theory, he would have two important weapons with which to re-enter the wireless battle: a transmitter superior to the spark coil favored by Marconi and the electrolytic responder which surpassed the clumsy coherer used in Marconi's receivers.

Actually, the inspiration for an alternating current transmitter was not new. Lee had first gotten the idea months before, when he began his transmission experiments on the top floor of the Armour Institute. During spare moments he had even worked out the necessary drawings. Only the lack of equipment had stopped him from developing it further. A transformer and generator needed to build such a transmitter cost three hundred dollars, and during his Chicago days it might as well have been three thousand or three million dollars! Later, he had hoped to build the transmitter for the yacht races, using the thousand dollars advanced by Siedler. But Freeman's insistence that they use *his* design had thwarted the plan.

At this point, Lee was convinced that in order to obtain a fresh start, a fresh idea was needed with which to interest prospective backers. The alternating current transmitter design suited this admirably, he decided.

Armed with a list of twenty-five prospective investors drawn up by his friend Stires, Lee began to make the rounds of business offices on Wall Street, the heart of New York's financial district. Stires had frankly warned him that the chance of raising money from these hardheaded businessmen was remote, but at Lee's urging he had supplied the names anyway. Raising money proved to be discouraging work. To explain to men who did not know a transmitter from a receiver the principle of Hertzian wave signaling was difficult at best; to convince them to invest money in a shoestring scheme with no immediate guarantee of profit was almost impossible.

One after another of the men on Stires' list turned him down. Some did so politely; others were brusque and even rude. But three or four did show a lively curiosity, particularly those who had been following the newspaper accounts of Marconi's work. Not only did they lend a sympathetic ear but they agreed to advance small sums, ranging from as little as twenty-five to as much as a hundred

dollars. Such contributions, minuscule as they were, provided Lee with encouragement he sorely needed at this time, for it was like finding a tiny oasis of interest in a vast desert of indifference.

By the middle of January, 1902, Lee had managed to raise two hundred dollars in cash and another two hundred in pledges. With characteristic impulsiveness, he made up his mind not to wait any longer. A Jersey City machine shop recommended by Stires agreed to build his new alternating current transmitter inexpensively, and Lee went to work at once supervising its construction.

The project had barely gotten under way when he received an urgent telephone call from John Firth, one of his new backers. "A friend of mine named Abe White wants to meet you," Firth told him. "He's sold on wireless telegraphy and is eager to help."

The next morning Lee rushed to New York City. Abraham White turned out to be a small, impeccably dressed man with a dynamic personality and a colorful background. He was a Wall Street character, a stock gambler who had made several fortunes in bond speculation. White had read newspaper stories about Lee's work in wireless. Then, upon learning from John Firth that the young inventor was in desperate need of funds, he had decided to step into the picture.

"I believe in you, De Forest," Abe White said. "You'll hear tell that I'm a stock market gambler. That's true. But I'm also a visionary—it's the secret of my success. I've been optimistic and dared to plunge where others have feared to tread. In my opinion, your wireless holds great promise for the future. I want to be in a position to share that future with you. What do you say?"

8

Pursuing a Dream

Lee was overwhelmed at Abe White's offer. He could only mumble that he would be grateful for any support he could get. White now proceeded to outline a grandiose plan. A corporation would have to be formed and stock issued. All those who had given financial backing in the past—Smythe, Freeman, Stires, Firth and the others—would be asked to exchange their holdings for shares in the new company. "That way the ground will be cleared for solid financing of future operations," White explained crisply. Lee agreed that the plan made sense.

With an amazing display of energy, Abe White took over the job of fiscal reorganization. In a matter of weeks, he set up the American De Forest Wireless Telegraph Company as a Maine corporation. Three million dollars of common stock was issued for sale on the market.

Convinced that his affairs were in capable hands, Lee returned to Jersey City to complete construction of his new transmitter. White had assured him that he was not to worry about financial problems. "The initial sale of stock is encouraging," his new partner told him. "Money is coming in. Your job now is to build the best sender you know how. Don't spare expense."

Lee took White at his word and went ahead with furious determination. By early spring, the transmitter was com-

pleted. At White's urging, Lee filed patent applications covering every aspect of his work.

As a promoter, White shrewdly realized the value of bursting on the commercial scene with a dramatic display of fanfare. He had a metal-framed glass-walled house erected on the roof of the Chesebrough Building at 17 State Street, overlooking Battery Park in lower Manhattan. A second station was installed at the Castleton Hotel, on Staten Island, just across New York harbor. "These will be our 'experimental stations,'" White told Lee. "I intend to sell the idea that this is the home of wireless telegraphy in the United States."

Newspapers were encouraged to send reporters to cover the public demonstrations that were held almost daily. Code messages were exchanged across the harbor, a distance of seven miles. Within weeks, the publicity campaign began to have its effect. From all over the United States and abroad letters poured in from scientists, engineers and the lay public requesting more information about the De Forest system of wireless signaling.

The alternating current transmitter was successful beyond Lee's expectations. Simply constructed and reliable, it made its predecessor, the spark coil sender, seem as antiquated as a bow and arrow in an age of high-powered firearms.

By the summer of 1902, the future looked bright indeed. In addition to the stations spanning New York harbor, Lee had two installed at Coney Island and Rockaway. Plans were under way to erect more stations at Montauk Point, Long Island; Atlantic City, New Jersey; Key West, Florida; and Havana, Cuba. Moreover, a contract had been signed to outfit two steamboats with complete wireless equipment, and negotiations were under way with other private companies for additional shipboard installations.

However, the company's most important triumph occurred in the fall when Lee was asked to come down to Washington by officials of the War Department. Both the Army and Navy were interested in wireless signaling, particularly the

Navy, since wireless was the only possible means of communication for ships at sea.

The Navy already had carried out some tests using the clumsy European equipment developed by Marconi and others, but these had proved inefficient from the start, and at times the apparatus had broken down altogether. Now Lee was asked to set up two pilot installations at the old Navy Yard in Washington, D.C., and at Annapolis, Maryland, where the United States Naval Academy was located.

He dropped everything to meet the Navy's request. Equipment was sent from Jersey City, and Lee personally took charge of the installations. By Christmas week two-way communication was begun and maintained for more than a week without a single breakdown.

The Navy officials were delighted. In mid-January of 1903, the first of a series of government orders for equipment arrived in the offices of the American De Forest Wireless Telegraph Company, together with the welcome announcement that the De Forest system had been adopted for official Army and Navy use. By the end of the winter, orders were pouring in at such a rate that the machine shop in Jersey City could not keep up with the demand.

As the months passed, Lee's triumphs mounted. One day an editor of the *Providence Journal* walked into the offices of the De Forest company with a proposal. Could Lee erect a wireless station at Block Island? Block Island was a summer resort for many Providence residents and news of the activities of these people was slow in reaching the *Journal,* the editor explained. Therefore, wireless dispatches from the island would give his paper a "beat" on all the other New England publications.

Lee immediately saw the value of such a system. Utilizing wireless to transmit news would be a tremendous step forward. Until now, it's use had been almost wholly restricted to ships. But the newspaperman's idea would open a new frontier in both journalism and wireless.

True, the notion of using wireless signaling for news transmission had first been tried in connection with the International Yacht Races. But then showmanship rather than utility had been the dominating theme. Even if the experiment had succeeded, no one really believed that it was more practical to transmit news of yacht racing by wireless than by the old reliable hand wigwag system.

Yet the *Providence Journal* plan was something else again. Here it was proposed to use wireless to transmit news on a continuing daily basis, not because it would be dramatic but because it would be faster and more efficient. In the long run such practical applications of wireless would guarantee the future of the infant industry far more securely than any publicity demonstration.

Lee did not hesitate. He immediately accepted the newspaper's offer and dispatched a team of engineers to install stations at Block Island and at Point Judith, Rhode Island. Within a few weeks news was being flashed back and forth between the resort and the mainland.

In the meantime, marine wireless stations were also established by the De Forest company at regular intervals along the East Coast of the United States, the Caribbean and Canada. At the request of the U.S. Army Signal Corps, overland wireless stations were set up in Alaska, at Fort Safety, near Nome, and at Fort St. Michael—a distance of 107 miles.

In the fall, Lee was invited by the British General Post Office to come to Britain to give a demonstration of the American wireless system. He was informed that His Majesty's government was interested in setting up a regular service between Holyhead, Wales, and Howth, Ireland, near Dublin. A short time before, the English engineer Oliver Lodge had tried to install such a service using Marconi equipment, but he had failed badly.

To Lee, the invitation to conduct tests in Great Britain, Marconi's home grounds, was a challenge that could not be taken lightly. As a result, he wasted no time in booking

passage to Europe for himself and one of his best wireless operators, Mac Horton.

The small wireless station they set up at Holyhead stood high on a rocky eminence overlooking the Irish Sea. The coast of Wales stared up at them sullenly, as if defying them to succeed where the best engineering brains of Britain had failed.

Since the equipment was stored at Holyhead, installing the companion station at Howth, fifteen miles from Dublin, meant plodding back and forth by night boat from Wales to Ireland. However, in spite of this difficulty, they managed to complete both stations within two weeks.

A small army of dignified silk-hatted officials from the General Post Office in London came up by train to witness the test. Some remained at Holyhead; the rest continued on to Howth. Lee and Mac Horton were to man the Holyhead station while an English telegraph operator named Cornish was to be in charge at the Howth end.

Lee invited the dignitaries to write out messages. These were collected and handed to tall, leathery-faced Horton, who was seated calmly at his telegraph key with two telephone receivers clamped to his ears by a leather headband. Without changing expression, Horton, a veteran Western Union telegraph operator, began to click out the signals in Morse code at a crisp thirty-five words per minute. Finally, he took his fist off the key, sat back and announced that the messages had been sent.

A few seconds later, his telephone receiver began to rattle frantically as Cornish, the English operator, began to transmit. At a furious rate Horton wrote down the incoming messages, while the postal officials gaped in amazement.

For the next two hours, the exchange of wireless signals continued. At Lee's request, each of the visitors donned the telephone receivers and listened to the rapid click-clacking of Cornish's transmission across eighty miles of Irish Sea.

The day's triumph was complete.

The Post Office officials praised Lee's system and muttered complainingly at the failure of their own English engineers to devise a wireless service as simple, rapid and reliable as the De Forest system. "Steps should be taken to employ your equipment on this side of the ocean," one visitor told him appreciatively.

Lee was delighted at the enthusiastic reception and informed the officials that he was ready at any time to install commercial service in Great Britain. He was told that the matter would be taken up in the near future with the proper authorities. The next day the British newspapers were full of accounts of the successful trial. To Lee's surprise, the stories even contained generous praise from Marconi himself, in spite of the fact that Lee's victory merely underscored the failure of the Marconi Company's own earlier attempt to carry off such an experiment.

A few days later, Lee and Horton left for home on the British steamer *Majestic*. One of their fellow passengers was Captain Lionel James, famed war correspondent of the *London Times*, who was headed for the Orient. War between Japan and Russia seemed inevitable, and *The Times* had sent him to cover the impending hostilities.

Lee and Horton struck up a friendship with James. They explained what they had done in Britain. He was intrigued by the infinite possibilities of wireless and asked if Lee thought it could be used to send news dispatches from shipboard during a battle. "Conditions are quite rough during the shooting, you know," he pointed out.

"It most certainly can be done," Lee confidently assured him. "I'll stake the reputation of wireless on it."

By the time they docked, James had been sold. He immediately contacted the *London Times* bureau in New York City and negotiated on a free-lance basis with *The New York Times*. Both papers were soon convinced of the feasibility of the idea and agreed to sponsor wireless coverage of hostilities. Then, leaving orders with Lee to send two complete

De Forest wireless sets to a forwarding address in Yokohama, Japan, as soon as possible, he departed for Seattle, Washington, en route to the Orient.

In a matter of weeks the expected war broke out between Russia and Japan. Aboard a swift chartered tug equipped with the De Forest apparatus, James followed the course of the sea battles as an eyewitness. His shipboard dispatches, sent during the thick of the fighting to a receiving station on the China coast, were then relayed by regular telegraph service to his newspapers. Almost overnight they were hailed as a milestone in the history of war reporting.

Of all the triumphs Lee experienced during that momentous year, 1903, none gave him greater satisfaction than the events that took place during the International Yacht Races in September. He was still smarting from the disaster of two years before, when he and Marconi had jammed each other's signals. Accordingly, he persuaded the Publishers' Press Association to give him another try at beating the rival Associated Press, which had once again commissioned Marconi to transmit race news from shipboard.

A tug was chartered and dispatched to Sandy Hook, where it was fitted out with the new alternating current transmitter.

During the early races, the jamming of signals was worse than ever, in spite of the superior new equipment employed by Lee. So intense was the sense of competition that the rival operators exchanged angry insults in code and accused each other of deliberately jamming the air waves.

Finally, Lee had an inspiration. He recalled the time during his Armour Institute days when he had borrowed the institute's Wehnelt interrupter and a "Ruhmkorff coil" for his early experiments. The result had been a high-frequency spark that was remarkable for its ability to "get through" in spite of electrical disturbances in the atmosphere. Would the same principle hold true if the interference was caused by other wireless signals? It was worth investigating.

Since the races still had several days to run, Lee's assistants

scoured the metropolitan area looking for equipment similar to the Wehnelt interrupter. But the search was fruitless: there wasn't one to be found in all of New York City. So Lee hurriedly concocted a substitute—a collection of long thin steel rods and a porcelain tube dipping down into an earthenware crock containing sulfuric acid and a lead plate.

This strange device was installed on the tug, and transmission was resumed. It was amazing how well the apparatus worked. The shrill, squealy signal was not loud, but it pierced Marconi's soft, low-frequency transmission like a knife stabbing through butter. The De Forest operators had no difficulty reading each other's signals.

In this way, news of the yacht races was transmitted to shore and relayed to the subscribing papers of the Publishers' Press Association, much to the chagrin of the Associated Press and Marconi's engineers. For Lee, the experience carried two valuable lessons. From the scientific standpoint, it had shown that a high-frequency signal, though faint, could get through where more powerful low-frequency waves were useless. Secondly, it taught him that achieving victory after an initial defeat was sweetly satisfying indeed.

The America to which Lee De Forest introduced commercial wireless telegraphy in 1903 would have been unrecognizable twenty-five years before. In science and industry an upheaval had taken place with profound consequences in human thought, outlook and behavior.

The horseless carriage, powered by gasoline, was opening a new epoch in land transportation. Two young brothers named Wright, in building a successful flying machine, had taken a giant step forward in the conquest of the air. New typesetting machines and printing presses had made the large-scale production of books, periodicals and newspapers a reality, thus setting in motion a basic revolution in education. And in communications, electricity had enabled man

to shrink distances by the simple clicking of a telegraph key or the cranking of a telephone.

There was no field of endeavor in which society was not on the march. In this new era of human aspiration and achievement, inventors like Lee De Forest were playing a key role. In a single year his system of wireless telegraphy had added a bold new dimension to the frontiers of science and technology.

Lee was proud of his participation in the expansion of man's horizons. By now, too, his name was becoming a familiar one to scientists and laymen alike, for hardly a week passed that articles about him did not appear in newspapers and magazines.

When he journeyed up to New Haven to visit his mother and Mary, they introduced him proudly to their neighbors and friends. His brother Charlie good-naturedly referred to him as "the famous De Forest." Dr. Bumstead and his other former teachers at Yale invited him to deliver guest lectures to their classes. Lee, who felt an overwhelming sense of gratitude to his alma mater and his professors, accepted these invitations cheerfully, although the preparation of notes and experiments had to be done at the expense of his own work.

In spite of his newly acquired success and fame, Lee continued to live simply, almost sparingly. He rented a flat in an apartment building on Riverside Drive, overlooking the beautiful Hudson River, and furnished it so modestly that when his mother visited him she invariably complained that it was too austere for a youthful bachelor.

In addition, Mrs. De Forest, like most mothers, worried regularly about her son's health. In spite of her own pride in his accomplishments, she was forever urging him not to work so hard. "You need time to relax," she told him. "A young man must have friends. You are alone too much, and you spend far too much time in that laboratory."

His sister Mary was even more blunt. She declared, "You

should meet some young ladies and go out more often. Don't you ever want to get married?"

Rather than argue, Lee agreed that they were probably right and promised to become more sociable. In truth he felt a deep need for companionship, but he could not bring himself to tell them of the pain he had suffered as a result of his ill-fated relationship with Jessie Wallace. How could he explain that the sense of humiliation and disappointment was still so strong within him that he dared not run the risk of a similar rebuff?

So, in spite of the well-intentioned pleadings of his mother and sister, Lee continued to devote his entire attention to his work, for in a very real way it served as an escape from the longings and personal conflicts that beset him. Moreover, like all pioneers, he was not content to rest on his past victory. Success had made him restless, ever eager to push on to new and unexplored terrain. With the American De Forest Wireless Telegraph Company in the efficient hands of Abe White, he now felt free to resume the early experimental work he had been forced to put aside three years before.

From the beginning, Lee had considered wireless telegraphy only a first, limited application of Hertz's monumental discovery. He was convinced that the true potential of those invisible waves would be realized only in the years to come. Back in 1901, following his first successful ship-to-shore tests on Lake Michigan, he had predicted to newspapers that in the future the human voice would be carried through space in the same way that the dots and dashes of the Morse code were already being transmitted. Toward the end of 1903 he decided that it was time to begin making that prediction come true.

The problem of using Hertzian waves to carry speech or music instead of code was not unlike that faced by Alexander Graham Bell when he sought to apply the principle of telegraphy to the transmission of the voice over wires. Bell was quick to recognize that whether the signal to be sent was

a simple dot-dash Morse sequence or the more complex vibrations of speech or music, the basic principle was the same. Code transmission consisted of a series of electrical impulses produced by a telegraph key acting to make or break a circuit. The telephone was fundamentally a telegraph circuit in which a transmitter sensitive to sound vibrations was substituted for the telegraph key.

Because of his work at Western Electric, Lee knew the principles of telephone transmission intimately. He saw that in many respects the problem of wireless telephony was similar. A transmitter which produced a good, continuous high-frequency spark could be made to radiate Hertzian waves reflecting the human voice. But instead of using a telegraph key to make and break the spark circuit and control wave radiation, he would simply substitute a telephone mouthpiece.

As in the standard telephone, sound waves striking the thin metal diaphragm would cause it to vibrate. Since the vibrations controlled the amount of electric current passing through carbon granules, a varying current could be produced which, in turn, would cause the spark in the transmitter to vary. The result would be a continuous flow of Hertzian waves, increasing or ebbing according to the strength of the spark. The waves would then be picked up by a wireless receiver and converted into sound again through a telephone earpiece.

On paper it was as simple as that. However, Lee knew that in wireless there was a vast gap between theory and practice. Unlike the standard wire telephone, which simply sent electrical impulses of varying strength over a wire directly to the earpiece, wireless signaling required that the Hertzian waves be picked up by a receiver in order to be converted into electric current. In the case of "dot-dash" code signals, the electrolytic responder did a satisfactory job. But receiving Hertzian waves that reflected the subtly vary-

ing sound patterns of the human voice was something else again. A far more sensitive receiver was needed.

The concept of transmitting speech by wireless was not new. Even before Lee had publicly predicted that such a feat was possible, scientists had been toying with the idea. Some had even conducted experiments along this line. One was Professor Reginald Fessenden, an American physicist. As early as 1900, Fessenden had used a spark transmitter and electrolytic detector to transmit music from one end of his laboratory to the other. While what came out of the receiver sounded more like the weak croaking of an expiring frog than a symphonic masterpiece, Fessenden had shown nevertheless than it was possible to radiate Hertzian waves reflecting various gradations of sound.

In his laboratory, a small upper loft at 27 Thames Street, Manhattan, Lee repeated Fessenden's experiment, using his own electrolytic responder, but the result was disastrous. The responder, with its tin electrodes separated by lead peroxide paste, simply was incapable of providing the sensitivity of reception needed for wireless telephony.

In spite of initial failure, Lee repeated his attempts with the responder. He readjusted the transmitter spark a dozen times and experimented with various bizarre-shaped aerials, but each unsuccessful trial merely pointed up the need for a radically new method of receiving Hertzian waves.

At last Lee was convinced. Putting the responder aside, he now devoted every minute he could spare to finding a substitute for the efficient little electrolytic receiver that had helped establish him in wireless telegraphy.

He began his search by going back to the experiment he and Ed Smythe had attempted in Chicago but had abandoned—the Welsbach burner tests. Even after three years, he could not shake off the illusion that somewhere in the sensitive gas flame of the burner existed an electromagnetic response to Professor Hertz's magic waves.

True, the flickering which he had at first believed to be

caused by the spark itself had turned out to be nothing more than the flame's reaction to the spark's sound waves; yet a nagging doubt persisted. In ruling out the significance of the flickering, had he really proved that the gas flame was incapable of responding to electromagnetic waves?

Intuition told him no. After all, the fundamental principle of both the coherer and the responder was that Hertzian waves exert an electromagnetic effect on solids or liquids like metal filings, lead peroxide or alcohol. They did this by lowering the resistance of such materials to the flow of current. "Why should it not be true of gases, too?" he asked himself.

He was aware that gases respond more sensitively to changes in pressure or temperature than other forms of matter. For example, any schoolboy knew that heating or cooling a gas caused it to expand or contract more readily than either liquids or solids. Was it possible that certain gases would also react more sensitively to electromagnetic waves?

It was a bold theory, he decided, but one worth testing.

Assisted by a bony, hawk-nosed technician, Clifford D. Babcock, whom he had just hired, Lee devised an unusual experiment. He took two platinum rods and held them close together in a Welsbach burner flame. One platinum electrode was wired to an aerial running out the window and to the top of the flagpole on the roof. The other electrode was tied to a water pipe in order to "ground" it. At the same time, the electrodes were connected to the terminals of a simple circuit containing an eighteen-volt battery and a telephone receiver. What he had done, in effect, was to rig up a form of responder using a gas flame in place of alcohol or lead peroxide paste between the electrodes.

Clamping on the telephone headset, Lee instructed Babcock to operate the spark transmitter in the next room. At first he detected no sound at all, but as he listened more intently he thought he heard a faint crackling noise. He called Babcock in and handed him the receiver. The assistant lis-

tened for several seconds and blinked. There was a sound, all right, but it was so indistinct as to be worthless.

Encouraged, Lee removed the Welsbach lamp and substituted a Bunsen burner, on the theory that a different type of gas might give improved results. Babcock ignited the Bunsen and played the intense blue flame on the ends of the platinum electrodes. Then he returned to the next room to work the transmitter, while his employer listened for sound.

Not in his wildest imagination was Lee prepared for what he heard. The signal came through the telephone headset with such force and clarity that he had to hold it several inches from his ear. He shouted excitedly, "Babcock, you've got to hear this!"

The assistant rushed in, almost tripping over a cable in his haste. As he listened to the signal his jaw dropped in astonishment. "Why this gadget has the responder beat seven days to Sunday," was all he could say.

They took turns listening in fascinated silence. First Babcock then Lee clicked out messages in code. It was amazing how distinctly each dot and dash came over. Even with the crackling of static the signal was strong and sharp enough to be "read" with ease.

Then, as he sat with the telephone receiver glued to his ear, Lee suddenly was aware of a new sound—a second weaker signal that seemed to be coming in from somewhere else. He ordered Babcock to switch off the transmitter in the next room.

Sure enough, they were picking up signals from a wireless station at a distant point. After a while Lee was able to make out that the signals were coming from a ship in New York Bay.

In the following weeks they subjected the gas flame detector to dozens of tests. Lee had Babcock enrich the Bunsen flame with various salts. They found that in this way they could increase the sensitivity even more.

Nevertheless, Lee continued to use the electrolytic re-

sponder as standard equipment in all American De Forest Wireless Telegraph Company stations. The reason was simple: the gas flame detector, while more sensitive and efficient, was still in an experimental stage. Besides, in its present form it was impractical. An open flame aboard a pitching, rolling ship would present a constant fire hazard.

But suppose the gas could be contained in a glass container—similar to an incandescent lamp? Lee wondered. And what if it could then be heated by means of electric current? It was an idea that seemed well worth following up.

He lost no time getting to work on the scheme. Babcock, who owned an old mercury air pump, volunteered to construct such a lamp. Though he tried hard, it turned out that glass-blowing was not one of his talents, and the initial results were pathetic. Even when he managed to produce a satisfactory bulb, it invariably shattered when he attempted to pump out the air.

For several months the futile attempts to construct a satisfactory gas lamp went forward. While Babcock concentrated on glass-blowing, Lee worked up plans to wire a telephone mouthpiece to a spark transmitter as the first step in developing a system of wireless telephony. However, in the midst of his preparations, he was forced to put his experiments aside to supervise the construction of a new group of stations in the growing De Forest wireless network.

He complained irritably to Abe White that he felt his time could be spent more profitably in research and that the routine job of directing wireless installations should be taken over by others. But White was his usual persuasive self. "I don't doubt the value of your work in the laboratory," he said with a winning smile. "But remember, Lee, our first task is to attend to the commercial needs of our company."

Toward the end of 1904, Babcock suggested to Lee that they give up their attempts to construct a lamp themselves. "I don't have the skill and our equipment is too crude," he

said frankly. "Why not turn it over to a commercial firm and have them do the job for us?" Lee finally agreed.

They got in touch with McCandless, a small independent glass manufacturer whose shop was just a short distance from the Thames Street laboratory. Using a rough sketch, Lee described exactly what he had in mind. He wanted a small incandescent lamp similar to an ordinary electric bulb. But instead of a single element it would contain two separate elements: a carbon filament and a small platinum plate. Furthermore, the air in the bulb must be pumped out and replaced with gas.

As Lee continued listing his requirements, McCandless interrupted. "No need to go farther, Mr. De Forest. I think I understand what you want."

When would the sample be ready? Within a week, the manufacturer replied confidently.

McCandless was as good as his word. In short order he came up with a glass lamp that seemed to suit their needs perfectly. It was small and spherical, about the size of an ordinary electric bulb, but it contained a carbon filament *and* a small platinum plate—each with wire terminals on the outside, just as Lee had specified.

Under Lee's careful supervision, Babcock now proceeded to construct a simple electrical circuit. The carbon filament, which had two outside terminals, was attached to a small battery. In his circuit diagrams, Lee labeled it an "A" battery. The battery's sole function was to light the filament in order to heat up the gas in the lamp. The platinum electrode was wired to an aerial so that wireless signals would be "led" from the antenna to the hot gas interior of the lamp. To complete the circuit, Lee had Babcock wire a high-voltage battery—he named it a "B" battery—and a telephone headset receiver to the carbon filament and the platinum electrode. The "B" battery was to serve as the source of current for the circuit.

"If all goes well, here is what will happen," Lee explained

to his assistant. "The signals from the aerial will change the electrical resistance of the heated gas in the lamp just as in the case of the open Bunsen flame. Electricity from the 'B' battery will flow from the carbon filament through the gas to the small platinum electrode. The amount of current will depend on the resistance of the gas as determined by the incoming wireless signals. The current will then proceed from the platinum plate electrode to the telephone receiver and activate it before returning to the 'B' battery to complete the circuit."

"It's so simple, it's hard to believe it will do what you say it will," Babcock declared.

"No reason why it should not work at least as well as the gas flame detector," Lee replied with self-assurance. "The basic principle is the same."

When the apparatus was ready, Lee donned the earphones while Babcock switched on the transmitter in the next room. Immediately a surge of sound issued from the headset. But for some curious reason it was neither as strong nor as clear as the signals from the open flame apparatus.

Lee was disappointed but not disheartened. At least the instrument worked. "Perhaps it's nothing more than a bad lamp," he suggested optimistically. "Or maybe the amount of gas in the lamp is at fault."

He instructed his assistant to order half a dozen more bulbs and to have McCandless fill them with varying amounts of gas. One bulb was to serve as a "control" for the experiment—McCandless was merely to exhaust the air but add no gas at all.

When the lamps were ready, Lee and Babcock tried each of them. There was no improvement over the results of the first test. But Lee made a curious discovery: the evacuated bulb with no gas worked as well as any of the others.

"What do you suppose is the reason?" Babcock inquired.

"I don't know," Lee replied, rubbing his chin thoughtfully, "but I intend to find out."

9

Birth of the Audion

In the following days Lee visited science libraries and pored through back copies of physics journals hoping to find the answer. He also reviewed his old college textbooks and class notes. Curiously enough, the first clue came from one of his own notebooks, saved from a Yale graduate course.

It contained an account of a lecture by Professor Willard Gibbs on the electron theory of matter, formulated in 1896 by an English physicist, Joseph J. Thomson. Thomson believed that all matter was composed of *atoms*, tiny spheres in which even tinier particles called *electrons* were embedded like raisins in a pudding. The atom itself was positively charged with electricity; the electrons were negatively charged. According to the Thomson theory, each element was characterized by a different number of electrons. Hydrogen had one; helium had two; lithium had three and so on.

Like most of the professors and students at Yale, Lee had accepted Thomson's idea, in spite of doubts expressed by laymen and even a few scientists who refused to go along with the fantastic notion that solid matter was composed of billions and billions of tiny "raisin puddings."

Reviewing the theory now in the intuitive belief that it might hold the solution to the riddle confronting him, Lee came upon a recent technical journal containing an account

by an Englishman, John Ambrose Fleming, of experiments related to the electron theory.

Fleming had once served as an assistant to Thomas Alva Edison. Back in 1883, while Edison was experimenting with carbon filaments for electric lamps, he noticed that the inside of the bulbs gradually became blackened. Edison guessed that the carbon on the glass was coming from the filament. Next, he inserted a small metal plate in the bulb and connected it to the positive pole of the battery supplying current to heat the carbon filament. The result was surprising. Edison found that the plate was drawing a small current *even though it was physically separated from the filament.* However, when the plate was wired to the battery's negative terminal, no current flowed.

Thirteen years later, in 1896, the introduction of the electron theory provided Fleming with a scientific explanation for the strange phenomenon known as the "Edison effect." He theorized that the carbon filament, when heated to incandescence, "boiled off" electrons. Since the tiny electrons were negatively charged with electricity, they were attracted across the vacuum in the tube to the positively charged plate. When the plate was negatively charged, however, the electrons were repelled. According to Fleming, this explained why no current flowed when the plate was connected to the negative terminal of the battery.

Using a variation of Edison's lamp, Fleming had devised a "rectifier"—a device to convert alternating current into direct current. He had surrounded an incandescent filament with a metal wall. Since current flowed from the heated filament to the wall only when the wall was positivey charged, one-half of each cycle of alternating current passed through the tube. And this half cycle always flowed in the same direction—from filament to plate. Fleming called his rectifier tube a "valve," since it was like a tap that controls the flow of a fluid. Rights to the Fleming valve had been purchased by the Marconi Company.

Lee realized that he, too, had been making use of the Edison effect without knowing it. True, they had been pursuing different goals, he and Fleming. The Englishman saw it as a means of converting alternating current into direct current, while Lee had been using the same phenomenon for the detection of Hertzian waves.

"You see," he told Babcock, "The Edison effect does not depend on gas as a medium to transmit electric current. The free flow of electrons to the positively charged plate is the important thing. That's why the empty tube gave as good results as those that were gas filled. We no longer have to pump gas into our bulbs."

Babcock was perplexed. "But it's the increased or lowered resistance of the gas that controls the flow of current from the carbon filament to the platinum plate," he pointed out. "If we have no gas, we have no medium of control."

Lee laughed. "You don't understand," he said. "The gas isn't necessary. Our antenna is wired to the platinum plate. So is the positive terminal of our 'B' battery. Therefore the plate is always positively charged. Whatever wireless signals are picked up are transmitted to the plate and alter its positive charge slightly. This increases or decreases the flow of electrons from the filament to the plate, and in this way the current flowing through the tube is made to vary in accordance with the wireless signals."

Babcock understood now and grinned. Like Lee, he was well aware that they were in the process of making scientific history, and he enjoyed being part of it. He even suggested a name for the tube. "Why not call it an *Audion*," he said. "I looked up the word *audio*. It's Greek, and it means 'to hear.' Since the bulb's purpose is to help us hear wireless better, I thought it might be a proper name." Lee agreed that it was an excellent name.

While he now understood the principle of the new tube-receiver, Lee was still perplexed by its failure to measure up to its open flame predecessor. In the closing weeks of 1904,

he and Babcock worked feverishly to find the source of the trouble.

They wired the Audion into their receiving circuit and tested it in a dozen different ways. A heavier "B" battery was substituted, various transformers were introduced to "step up" the voltage, and the aerial wire was lengthened. Nothing seemed to work.

In a sudden burst of inspiration, Lee unhooked the aerial from the platinum electrode. As if by magic, the signal in his headset grew louder. It was bizarre, for the antenna was not even connected to the bulb! Lee held the antenna wire at different points near the circuit. He found that as he moved the wire closer to the bulb without actually touching the platinum electrode terminal the signal grew stronger. Finally, he held it directly against the glass itself and was amazed at the sharpness and clarity of reception.

What was the reason? Lee admitted to Babcock that he was not sure. "But I suspect that when the aerial is wired to the platinum plate, some of the wave energy is wasted," he said. "Since the platinum is also connected to the telephone-battery circuit, much of the signal undoubtedly 'leaks' off through this circuit and disappears into the ground."

Next, Lee attached the antenna to the glass wall of the lamp. He accomplished it by the simple expedient of wrapping a piece of tin foil around the outside of the Audion and tucking the bare end of the aerial wire under the foil. It worked better than any of the previous receivers.

He was gripped by a sense of excitement now, greater than he had ever known. A combination of hard work and fortunate accident had led to a discovery that might very well revolutionize the whole field of wireless!

So far, no one but he and Babcock knew about the Audion. And Babcock could be trusted to keep quiet until they had finished their experiments.

Lee was so keyed up that he could think only of the new

bulb. Day and night his brain whirled restlessly as he tried to devise additional ways of improving it.

In disconnecting the antenna wire from the platinum plate and attaching it to the glass itself he in effect had invented a *third* electrode for the Audion. The signals flowing from the aerial to this new electrode "controlled" the flow of electrons from the hot filament to the plate. They were a "trigger" governing the high-voltage current from the "B" battery. Variations in the strength of the signal instantly caused proportionate changes in the current flow from filament to plate.

The Audion was thus like a rifle in which a gentle squeeze on the trigger sets off enormous explosive force in the gun itself. Not only did it act as a sensitive receiver of Hertzian waves, but it also *multiplied* the effect of these waves. It was an "amplifier" tube which in theory could increase the strength of a wireless signal thousands, even millions of times!

All during the spring and summer of 1905 Lee intensified his efforts to ready the Audion for commercial use. The tin foil wrapped around the outside of the tube with the antenna wire tucked precariously underneath troubled him. Sometimes, the wire would slip out in the middle of an experiment. It was a minor defect; yet Lee realized that it was a clumsy and unreliable way of connecting the aerial. By late fall he had worked out an ingenious plan: why not introduce the third electrode directly into the bulb itself instead of attaching it to the glass outside? Not only would it be a neater, more practical way of doing it, but the tube's effectiveness might even be increased.

Lee had Babcock take a small piece of platinum and perforate it with a great number of holes. He explained to his assistant that when incoming signals gave a positive charge to the third electrode the holes would allow electrons from the filament to *pass through* the perforated metal and find their way to the desired destination—the solid platinum plate.

The perforated platinum was given to McCandless with instructions to insert it inside the glass tube, with a wire terminal outside, so it could be connected to the antenna.

The reliable McCandless followed specifications precisely. The new device contained the perforated plate and the solid plate with the carbon filament located in the middle. Lee's theory proved to be sound. The introduction of the third electrode inside the Audion made it work even more efficiently.

But he was still not wholly satisfied. Platinum was expensive, and perforating it was difficult work. Why use platinum at all? Wouldn't it be simpler and cheaper to use a tiny grid-iron arrangement as the third electrode—a simple piece of wire bent back and forth? Furthermore, he realized now that the grid would be more effective if placed *between* the filament and the platinum plate. Since its purpose was to control the flow of current from the former to the latter, it would be a more logical arrangement than having the filament as the middle electrode.

The new design was sent to McCandless. When the bulb came back, Lee tested it carefully. It performed better than anything preceding it.

In the early months of 1906, Lee filed nearly a dozen patent applications covering every phase of his Audion work. Among these was a plan to use the tube as an amplifying device for long-distance standard telephony. His reasoning was simple: If the Audion could be used to boost the strength of wireless signals, why couldn't it also be used as an amplifier of regular telephone signals?

Having worked in the Western Electric research department, he knew that one of the key problems in telephone engineering was the loss of signal strength as current from the telephone transmitter traveled over the wires to the receiver. Such losses were inconsequential in short-distance calls, but as distance increased, they became so great that the signal eventually faded out altogether. For this reason the tele-

phone company had been unable to establish an effective system of long-distance communication, although millions of dollars had gone into research on the problem.

The telephone engineers had sought to establish a "repeater" system by hooking up telephone receivers to transmitters at regular intervals. In this way they hoped to renew the strength of the signal over long distances. The effort had proved worthless. Sound distortion resulting from repeated conversion of the same signal into sound and back again could not be eliminated. As a result, speech became unintelligible after being relayed over a relatively short distance.

Lee was convinced that the Audion provided a solution. Instead of using receiver-transmitter "repeaters" to reamplify the sound, why not amplify the electric current itself? Audions, installed every few miles along a telephone line, would boost the power of the signal just as it was beginning to lose strength. In this way, an electrical impulse originating in a telephone transmitter could be amplified constantly until it reached its terminal point. Only then would it be converted into sound. This would eliminate the problem of sound distortion and actually make it possible to telephone clear across the country!

Once the patent applications were filed, Lee felt the time was ripe to introduce the Audion commercially. As the chief engineer of the American De Forest Wireless Telegraph Company, he had the authority to make all technical decisions. Therefore he instructed his subordinates to put through an order with McCandless for the manufacture of a large quantity of Audions and informed Abe White of his action. The tubes were to be installed in all De Forest receiving stations in place of the electrolytic receivers. Lee then departed for England to supervise the installation of several new stations on the British coast.

He returned three weeks later to discover that his order had been countermanded.

Angrily, he demanded an explanation. Abe White in-

formed him that the order had not been put through because the company was short of funds.

"How can this be, when you've been boasting about the success of our commercial operations?" he replied incredulously.

"You can believe it or not as you see fit," White replied coldly. "Nevertheless, that's the situation. I can tell you now, in fact, that the company is bankrupt."

It was like being struck in the face, hard. Lee was speechless for a long moment, but when he regained his composure and tried to find out what had happened, White refused to discuss the matter.

"Very well," Lee said. "You can take it up with my attorney."

He immediately engaged the services of a lawyer who conducted an investigation. The full story was worse than anything he could have imagined. Several months before, Abe White and some accomplices on the board of directors had launched a reckless promotion scheme to sell as much stock as possible. Then they had milked the company through an old stock manipulator's trick: They had organized a new "dummy" corporation called "United Wireless Telegraph Company" and quietly transferred all the assets of the De Forest company to it, leaving all the debts on the books of the old corporation, which was now an empty shell.

The looting by the company directors was unscrupulous in every respect. But it was the betrayal by Abe White that Lee felt most deeply. Disillusioned and sick at heart, he asked his lawyer for advice and was told that while he could bring the matter to the courts, it would be a long and costly fight. The alternative was to resign from the company and try to negotiate with White and the others for a settlement.

Lee chose the latter course.

Because he wanted to have no more personal dealings with White and the others, he had the lawyer conduct all negotiations on his behalf. The company treasury was virtually

empty now, so Lee was forced to surrender his stock interest for one thousand dollars—a pitiful reward for his years of creative effort and hard work. Of this sum, he had to pay his lawyer five hundred dollars.

Of far greater moment was the matter of patent claims. Trusting Abe White implicitly, Lee had assigned all his patent rights to the American De Forest Wireless Telegraph Company. More than forty patents were involved. White and the others insisted that these rights legally belonged to them. Lee's attorney threatened White with a suit. But he confidentially advised his client that they were sure to lose.

"Ask them, then, to let me retain the rights to my latest invention—the Audion," Lee pleaded. "It's little enough, considering that they have robbed me of my property and my dignity."

The lawyer promised to see what could be done. The next morning he called Lee to inform him that White and his cronies had magnanimously agreed to allow Lee to keep the Audion patents on condition that he not press a suit for rights to the earlier inventions. Even in his bitterness, Lee had to smile. It was perfectly clear that White didn't have the faintest notion of the potential value of the Audion.

In the fall of 1906 Lee and the American De Forest Company's officers signed a general agreement releasing each other from all future claims.

Lee immediately moved his personal belongings out of the office and laboratory which the company had assigned to him. With his five hundred dollars he set up a small laboratory on the top floor of Manhattan's Parker Building, at 19th Street and Fourth Avenue.

He was thirty-three now. After five years of work he found himself as penniless as he had been when starting out on his career. But there was one difference: he was now armed with a small glass tube and a conviction that it could help him conquer space.

10

Early Radio

Once more Lee turned to the discouraging task of seeking financial backing. His plan was to organize a new company devoted exclusively to wireless telephony—or *radio,* as American engineers had begun to call the wireless transmission of speech to distinguish it from wireless telegraphy.

In July of 1906, prior to his resignation from the company, he had introduced the Audion to the scientific world in a paper read at a meeting of the American Institute of Electrical Engineers. He described the Audion principle and explained why he felt it held the key to wireless telephony. As a result, several technical journals carried articles based on his paper.

Lee hoped that the publicity would win potential backers to his cause, but he was doomed to disappointment. There were rumors of a financial crisis, and money had suddenly become tight. Few investors were in a position to back risky new ventures.

Lee was reduced to canvassing fellow alumni in his Yale class. After weeks of effort he managed to obtain loans totaling four hundred dollars. It was a pittance, but it was a start. He immediately filed papers organizing a new corporation to be known as the De Forest Radio Telephone Company.

One afternoon he received a visit from a Mrs. John Hogan and her son Jack. The Hogans had heard of Lee through a

mutual friend who was one of his Yale classmates. Explaining that she had heard he was looking for backing, Mrs. Hogan asked if he would agree to accept several hundred dollars from the Hogan family. What's more, she added, her husband would be happy to help him raise additional funds from friends and business associates!

Lee was astonished. Was he being made the victim of an elaborate practical joke? But as Mrs. Hogan continued talking, he realized that she was in deadly earnest.

There was one condition. Her son Jack, who was seventeen, planned to enroll at the Sheffield Scientific School, and she wanted him to have a taste of scientific research before matriculating at Yale. Could Dr. De Forest employ him as a laboratory assistant?

Lee was flattered. Recalling his own unsuccessful try to get work in Nikola Tesla's laboratory, he spoke kindly to the boy. Jack Hogan turned out to be surprisingly well informed. He had read everything he could find on electricity and was particularly interested in wireless.

"If you don't mind getting your hands dirty, you have a job—starting next Monday," Lee told him. The lad grinned his appreciation while Mrs. Hogan thanked Lee profusely.

While he missed the help of an experienced man like Clifford Babcock, Lee found young Hogan willing and enthusiastic. The boy did everything from wiring simple circuits to running messages and sweeping up the laboratory floor. He was so quick to learn that in a short time he was helping Lee with important radio experiments.

Aside from Jack Hogan, Lee saw few people. He continued to lead his lonely bachelor's existence in the apartment on Riverside Drive, in spite of the pleas of his mother and sister to cultivate a more active social life.

One day he learned that two new neighbors had moved into the apartment next door. They turned out to be an attractive dark-haired girl named Nora Blatch and her widowed mother, Harriet Stanton Blatch. Miss Blatch was a

quiet-spoken, serious-minded young lady in her twenties. When Lee met her in the hallway, he greeted her politely; and on one occasion they even paused to chat briefly on the landing. He discovered that she was a graduate of Cornell University—the only woman to have received a civil engineering degree from that institution—and was now working in the New York City Engineer's Office.

In the following weeks he thought a great deal about Nora Blatch, and there were times when he found himself on the verge of asking her to go out with him. But at the last minute the painful memories of Jessie Wallace rose up to renew his old fears of emotional involvement, and he found himself incapable of taking the step.

In the meantime, Lee, with young Hogan's help, had begun work on an important new project—the construction of a carbon arc transmitter.

The principle of the electric arc was not new. It had been used for lighting purposes for many years. An *arc* was simply a luminous flame of electricity leaping, or *arcing*, from one conductor to another. The flame was curved like the arc of a circle. In the carbon arc the conductors, or electrodes, were made of carbon. Although the flame seemed to be leaping through empty space, it was actually the gases in the air that served as a conductor.

Researchers had found that the arcing between the carbon electrodes was capable of radiating wireless waves. Lee realized at once that for voice transmission, an arc was far superior to a spark. It was capable of radiating a continuous succession of waves whereas a spark transmitter emitted waves in short, flashing bursts. In addition, an arc circuit required less power and was cheaper to construct.

While Lee had known of the carbon arc experiments from the first, he had been cautious about building an arc transmitter. An engineer named Poulsen had already filed for a broad patent. Lee was convinced that by constructing such equipment he would be guilty of patent infringement. How-

ever, in the fall of 1906, he learned from a scientific journal that a French scientist had preceded Poulsen. If that were true, no infringement of valid patent claims was involved. To make certain, he checked with McFarlane Moore, a fellow engineer who was considered an expert in such matters. Moore assured him that he was on safe ground.

Lee immediately got to work constructing a crude carbon-arc transmitter which would be powered by a 220-volt direct-current source. The apparatus would also include a microphone circuit for voice transmission.

While working on the new transmitter, Lee explained to young Hogan how it would function. The principle was the same as in wireless telegraphy, he pointed out, except that the carbon arc would take the place of the spark gap. Since an arc generated a continuous succession of Hertzian waves, speaking into the microphone would constantly change the resistance of the circuit. Accordingly, a larger or smaller part of the voice current would arc across the electrode at any one moment. The result would be the emission of continuous waves of changing strength, or *amplitude*.

When the waves were picked up in the receiving antenna and led to the grid electrode in the Audion, they would regulate the current flowing through the tube, Lee continued. This constantly changing current would then be converted into sound waves in the telephone headset. It was as simple as that.

On December 31, 1906, the transmitter and receiver were ready. Lee and the boy moved the two pieces of equipment to opposite ends of the tiny laboratory. Jack donned the earphones and switched on the Audion receiving set. At the transmitter across the room, Lee cleared his throat nervously and spoke into the microphone: "Jack, I would like you to pick up some sandwiches and coffee for lunch."

He glanced across the laboratory at the boy's face. Young Hogan's eyes had widened and his mouth was agape. Lee spoke again, inquiring about the clarity of the signal. So

overawed was the lad by the miracle he was witnessing, that it was several seconds before he understood Lee's question. At last, he removed the earphones and called across the laboratory, "It works, Dr. De Forest! It works! I could hear your voice clearly."

Lee calmed the youngster down, and they switched positions. Jack picked up the microphone and began to speak into it. Through the earphones, Lee could hear his words distinctly: "I can hardly wait to tell my mother and father about this. Do you suppose I can invite them up here to listen to this machine one of these days?"

They spent the rest of the day playing with the fabulous new toy they had built. It was astonishing how clear human speech sounded. Toward the end of the afternoon, Lee cranked up his old Columbia phonograph, put a record on the turntable and set the transmitter microphone near the horn. Then he and Jack took turns listening to the receiver. Every note was distinguishable!

When at last they locked up the laboratory and walked down the stairs and out into the winter's night, Lee felt excited and fatigued by the day's momentous events. He bid his young assistant good night and a Happy New Year. "The coming year will be an important one," he said. "But for now we can both do with some rest."

As he walked down the street to the subway station, he noted that snow was falling and a strong wind was beginning to whip the flakes into small drifts along the sides of the buildings. He was wearing only a light topcoat and the cold was piercing; still, he felt as if spring had already come and he was basking in the glow of a warm, yellow sun.

Lee took the subway train uptown. In the hallway of his building, he ran into Nora Blatch who was on her way out to mail some letters. He wished her a Happy New Year and was about to enter his apartment when suddenly he felt lightheaded and bold. Almost before he knew it, he found himself asking her if she had plans for the evening. She re-

plied with the faint trace of a smile that she had no plans. In that case, would she care to have dinner at a restaurant with him? She hesitated briefly, then said yes.

They had a huge dinner at a modest little German restaurant. Afterward, they talked about their respective work, and Lee told her about the important triumph he had scored that day. "So you see, I have good reason to celebrate tonight," he confessed with almost boyish enthusiasm. Nora asked many questions about the wireless telephone and listened in fascination as he outlined his future plans.

She wanted to know why he felt radio was such an important advance over wireless telegraphy. "For one thing, it doesn't require a skilled operator," he replied. "All you have to do is press a button and speak into the microphone or listen at an earphone. Also, atmospheric disturbance doesn't affect radio as much as the telegraph, for one is able to distinguish the human voice through a great amount of static."

Did he really feel that radio eventually would replace the standard wire telephone? she wanted to know.

"Not at all," he replied. "The fundamental advantage of wireless telephony is not that one person can speak with another without wires, although that too is important—especially for ships. The truly amazing thing is that a single transmission can be heard by hundreds, even thousands of people with individual receivers. It's called 'broadcasting.' Think of it! News, music, even plays can be heard by a multitude who may not otherwise have the chance, ever. Why, radio can cause space to shrivel and turn the whole country, even half the planet, into a single, huge auditorium."

Before the evening was over, Nora was caught up on the wings of his own enthusiasm. He invited her to visit his laboratory, and she promised she would come. He asked her to go to a concert with him the following Saturday night, and she said yes to that, too.

Lee and the girl began to see each other regularly. She had a keen engineer's mind and swiftly caught on to the prin-

ciples of wireless. Since young Jack Hogan was due to enroll at Yale in the fall, Lee knew he would need another assistant. So he offered the job to Nora, for he could think of no more pleasant arrangement than to have her work with him.

"I can't afford to pay you much of a salary," he told her humbly. "But if the transmitter is a success, as I expect it to be, I want you to share in the rewards." Her eyes shining, Nora agreed to his offer. She resigned her job at the city engineer's office and joined Lee and Hogan in the laboratory.

In the following months, Lee and Nora worked side by side. Because of her training and experience in engineering methods, she proved to be a tower of support. On many occasions she came up with ingenious solutions to laboratory problems that surprised even Lee. When Jack Hogan left in September, Nora became his entire "staff." By now she was so involved in the work that she could talk of nothing else.

When he took her out for dinner or to a concert on evenings or week ends she insisted on discussing wireless. Lee, who was by now head over heels in love, jokingly remarked one evening that she seemed more interested in his laboratory than in him. Nora did not see the humor. She frowned without replying, but for the rest of the evening she was cool and distant.

By the following day, she appeared to have forgiven him. But Lee could not help reflecting that the arrangement with Nora had its disadvantages as well as its benefits. Perhaps it was not wise to combine work and love, he speculated. Was it fair to expect a young lady with whom he was associated on a professional basis from nine to six to suddenly alter her role in the evening to that of romantic companion? Would it eventually put a strain on their relationship? As the weeks passed, the thread of doubt in his mind seemed to grow stronger.

Early in February of 1907 Lee began a series of experimental "broadcasts" from the Parker Building laboratory to test the range of the new carbon arc transmitter. Since wire-

less telegraph stations now dotted the metropolitan area, he asked listeners to call him if they received his broadcasts. In the following days and weeks he was swamped by telephone calls from naval operators at the Brooklyn Navy Yard and others who, surprisingly enough, were able to receive distinguishable voice signals on their electrolytic receiver installations.

At first the broadcasts consisted of informal chatter and the reading of old speeches. Then Lee hit on the notion of transmitting phonograph music. This led to another idea: He constructed a second arc transmitter and took it to the Cahill Telharmonium Company, a small independent firm specializing in the distribution of music by wire to halls and restaurants around the city. The Cahill brothers, owners of the firm, agreed to let him string an antenna wire to a flagpole on the roof and connect his equipment to their regular music circuit. In this way he was able to test the effects of having two stations broadcast simultaneously. He found that by carefully adjusting each transmitter to radiate waves of a different frequency, the signals did not interfere or "jam" each other as had been the case at the International Yacht Races.

Soon, the broadcasts began attracting attention from the newspapers. Even more important, accounts appeared in the technical magazines hailing Lee's pioneering efforts in wireless telephony.

However, the lack of financial backing remained a major problem. Some weeks after the broadcasts began, he received a visit from James Dunlap Smith and J. J. Thompkins, two former stock salesmen for the American De Forest Wireless Telegraph Company. Like Lee, they had quit after observing the financial machinations of White and his cohorts. Now, having seen articles about Lee's latest work in radio, they were anxious to team up with him.

The De Forest Radio Telephone Company was soon transformed into a larger organization known as the Radio Tele-

phone Company with stock capitalized at two million dollars. It was agreed that Smith would serve as president. He and Thompkins threw themselves wholeheartedly into the campaign to raise funds. It was not easy in these early months, for the fears of financial panic had turned out to be real enough. Already, crowds of frightened depositors were lining up in front of some of New York's leading banks. Nevertheless, with the help of Jack Hogan's father, enough backing was secured to enable Lee to carry on his development work on a modest scale. One of the backers was Captain Samuel E. Darby who was elected chairman of the board of the new company.

In June the first real break came. A wealthy publisher and yachtsman, Commodore W. R. Huntington of Elyria, Ohio, had read about Lee's work and was interested in equipping his boat *Thelma* with a radiotelephone to report a series of yacht races to be held on Lake Erie in July.

Lee immediately rushed to Ohio to complete the arrangements. He was delighted to learn that the Commodore, who had strong contacts with the Navy, planned to send a full account of the trial to high-ranking naval officers, including Admiral Evans, commanding officer of the North Atlantic Fleet.

The *Thelma* thus became the first craft in the world to be equipped with a radiotelephone. During the week of July 15, she followed the competing yachts around the course while reporters telephoned graphic accounts of the regatta to shore stations exactly as the event occurred.

In spite of a low antenna on the *Thelma*, the reports from the yacht could be heard four miles away. Newspaper stories contained references to the experiment and expressed "astonishment" at the "clearness and fidelity of the reproduction."

The efforts aboard the *Thelma* paid off. Early in September, Lee was called in by the Navy and asked to supply radiotelephone test installations for two battleships of the North Atlantic Fleet, the *Connecticut* and *Virginia!* It was a major

triumph. He dropped everything, hired additional assistants and set up temporary headquarters at the Brooklyn Navy Yard where the battleships were docked. While the equipment was being installed, he was visited by Admiral Evans, a blunt-speaking, competent officer who promised that if the test was successful "big things are in store for you."

The following week the battleships steamed out of the Navy Yard headed for New England waters. For the better part of a week the radiotelephones were tested under every conceivable condition.

Afterward, Lee received a complete report of the trials. He learned that a record of twenty-two miles had been established for ship-to-ship voice communication!

A few days later, the Navy announced that because of the success of the tests, it was ordering equipment for an entire flotilla which was soon to leave on a globe-circling cruise. The ships included sixteen battleships, six destroyers and two auxiliary vessels.

Since there was an almost impossibly short time in which to manufacture and install the apparatus, Lee's laboratory force worked day and night, almost without sleep, to complete the assignment. After weeks of back-breaking effort, the last equipment was crated and shipped to Hampton Roads, Virginia, where the fleet was docked. Three assistants accompanied Lee on the trip south to install the transmitters and receivers on shipboard. Nora remained in New York to look after things there.

The Navy project was barely completed when the Radio Telephone Company received a rush order from the Army for two radiotelephone units for the Signal Corps. Lee sighed and wearily turned his attention to the new undertaking, wondering if things would ever get back to normal again. Developments had been so swift that he found it hard to convince himself that they weren't part of a vast, confusing dream.

A week before Christmas, the Army apparatus was com-

pleted and installed. Lee was able at last to look forward to a much-needed rest. He wrote to New Haven and invited his mother and brother Charlie to come to New York to spend the Christmas holidays with him. Mary, who was now married to the Reverend Philip Ralph, a Yale Divinity School graduate, had made plans to spend the holidays with her husband's family.

Lee introduced his folks to Nora and her mother. He had referred to Nora in several of his letters to his mother but had not otherwise indicated that they were tacitly engaged.

On Christmas Eve, Lee proposed marriage to Nora Blatch and she accepted. The following day they announced their plans to their families.

Six weeks later, on February 14, 1908, Lee and Nora took a train to Greenwich, Connecticut, and were married at a quiet ceremony by a justice of the peace. Only members of their immediate families attended the wedding. The next morning, in a cold, dreary rain, the couple embarked on the *Carmania* for England and a European honeymoon.

11

The Troubled Years

Lee and Nora had planned their European visit as a combination business trip and honeymoon. The extraordinary publicity Lee had received from equipping Admiral Evans' round-the-world fleet had stirred great interest abroad.

French, German and Italian officials had written asking for demonstrations of the Audion and arc transmitter. Accordingly, the De Forest's luggage included two complete sets of radiotelephone transmitters and receivers.

After docking in England they went to Paris where they arranged with French Army officials to give a demonstration of the new equipment at the Eiffel Tower Military Station. A Colonel Ferrié, Chief of Radio for the French government, had strung a giant antenna almost to the top of the Tower itself. The lead wire extended to a small wooden experimental shack located two hundred feet from the southeast corner of the world-famous steel-ribbed structure. Assisted by Nora and several of Colonel Ferrié's men, Lee installed the carbon arc transmitter in the shack.

A small army of French government officials as well as representatives of a half dozen other European nations were on hand to witness the test. Wireless telegraph operators throughout France had been alerted to keep their receivers open. Newspapers and wire services assigned reporters to

cover the event, both at the transmitting shack and at various receiving stations.

The plan was to transmit phonograph music by clamping a carbon microphone next to the speaker horn, just as in the early New York broadcasts. Finally, all was ready. Lee switched on the transmitter and simultaneously instructed Nora to start the phonograph. Music poured out of the speaker and filled the tiny, crowded shack.

All night long Lee and Nora took turns feeding records to the phonograph. At last, near dawn, they shut down the transmitter and returned wearily to their hotel to await the results.

At nine o'clock Colonel Ferrié appeared wearing a broad grin. They ordered breakfast and settled back to listen to his report.

"The news is excellent," he told them. "So many wireless stations have telegraphed to say your signal was heard that it is difficult to keep count. Doubtlessly, many more will report by post. Already, however, we know the music was received at stations up to one hundred and fifty miles from Paris! It is a cause for rejoicing."

Two days later, Lee and Nora received a further report from Ferrié. Stations on the Mediterranean Coast near Marseille, a distance of nearly five hundred miles, had picked up the Eiffel Tower signal!

Before leaving Paris, Lee received a cablegram from Captain Darby in New York. As a result of the French demonstration, the Italian government had ordered four sets of radiotelephone equipment. The shipment would be on its way to Italy within two weeks. REMAIN IN EUROPE TO INSTALL, Darby's message advised.

While waiting, the De Forests visited Germany, where they met the leading scientists engaged in wireless work and gave additional demonstrations of the arc transmitter and Audion equipment. In each city, the newspapers carried banner stories and interviews.

From Germany they went to Spezia, Italy, to meet the shipment from New York. The equipment was uncrated, installed and tested for five weeks, during which time they were beset by Italian reporters who wrote lengthy accounts about "the American De Forest who has outstripped the great Marconi in perfecting wireless telephony."

Their next stop was Rome, where they were able to relax at last and take in the sights. A ceremony was held in their honor, and they were presented with a check from the Italian government in payment for the four installations at Spezia.

While in Rome Lee received a copy of an English technical magazine containing an article by John Ambrose Fleming. The English scientist claimed the three-electrode or "triode" Audion was merely a variation of his own two-electrode vacuum rectifier tube, the rights to which had been purchased by the Marconi Company. Lee angrily showed the article to Nora.

She smiled. "You should accept it as a compliment," she said. "It means your vacuum tube is making a greater impact than we suspected."

But Lee was not ready to dismiss the Fleming matter casually. Between visits to the Coliseum and other points of historic and cultural interest in Rome, he wrote a reply to the magazine, the *London Electrician*. In this article he explained in detail the difference between Fleming's rectifier "valve," whose sole function was to change alternating current into intermittent direct current, and the De Forest triode tube which served as a sensitive detector of radio waves and amplifier for magnifying the waves far beyond their original strength.

Early in June of 1908, Lee returned to New York alone, while Nora remained in England for a visit with her English relatives. What had started out as an ordinary business and honeymoon trip had actually developed into a triumphal tour.

Lee arrived home to find Captain Darby swamped with

orders for Audion tubes and radiotelephone equipment. However, under Darby's efficient direction, manufacturing facilities had been expanded considerably. The laboratory had been moved from the Parker Building to larger quarters in the Metropolitan Life Building at Fourth Avenue and 23rd Street; a factory had been opened in Newark; and more workers had been hired. Even so, the company had to maintain round-the-clock shifts to try to keep up with the demand for radio equipment. It was hard for Lee to realize that in a few short months he had succeeded in revolutionizing the wireless field!

When Nora returned from Europe she insisted on going back to work in the laboratory. Lee tried to talk her out of it. He recalled only too distinctly the doubts that had arisen in his mind about the wisdom of such an arrangement during their courtship. By now he had come to feel even more strongly about the matter, and he had hoped that after their marriage Nora would come around to his point of view.

He feared that in returning to the laboratory his bride would become so involved in work again that it would create a real strain on their emotional relationship. In truth, he was old-fashioned enough to want a real home and a family —including a wife who would cook his meals and give him all the little attentions his mother had given his father. And he felt that as long as Nora was working, she would not have the time or the desire to become such a mate. He discussed the issue candidly with her, but she protested almost tearfully that she did not intend to be merely a housewife. In the end, he gave in unhappily and allowed her to go back to work "for a while."

They also disagreed on where to make their home. Nora preferred to remain in an apartment, close to the laboratory, but Lee, who had dreams of a home of his own, found a highly desirable site at Spuyten Duyvil on the shores of the beautiful Hudson River and made plans to build a house.

Reluctantly, Nora went along with it. "I want to name our home *Riverlure*," Lee told her.

In the fall of 1908, Captain Darby discussed with Lee the need to establish a factory to produce their own electrical condensers, for none of the commercial firms seemed able to meet their specifications. Lee gave his approval. Since the transmitter and receiver factory was in Newark, it was agreed that the condenser facilities should also be there. A factory site was soon rented and machines installed.

In Europe Nora had learned about a new type of condenser developed by a Polish scientist, Moskicki, and asked to be put in charge of the work in Newark, so she could follow through on this condenser. Lee protested that it would take too much of her time. But she argued that since she had given in on the house, he should not stand in her way now. In order to avoid a bitter disagreement, Lee surrendered.

Three months later, in January, 1909, Nora announced that she was expecting a baby in June. Lee's heart leaped with joy, for not only did the prospect of impending fatherhood delight him, but he felt that now at last she would listen to reason and give up work.

He was doomed to disappointment. Nora protested that it was much too soon for her to discontinue her duties at the condenser factory. Working would occupy her days and keep her from worrying, she pointed out. Indeed, her only problem was commuting between New York City and Newark; it took a great deal of time and was a drain on her energy. Why couldn't she stay in Milford, a small town near Newark? After all, it would only be a temporary arrangement.

Lee frowned. Already he had discovered that he was incapable of mustering the determination to stand his ground in an argument with Nora. Now he tried once more. He pleaded feebly with her, but she refused to budge. In the end it was he who gave in again.

Nora rented a cottage in Milford while Lee continued to live in his old bachelor apartment on Riverside Drive. In

the meantime, he gave orders to a contractor to complete their new house at Spuyten Duyvil as soon as possible, hoping that once they moved into Riverlure Nora's interest in working would abate. During those spring months he saw his wife only occasionally—usually when he had to travel to the Newark factories on business.

In late spring, Lee's problems were complicated by a new and unexpected development in the Radio Telephone Company. With the demands for Audion tubes and other radio equipment continuing to mount daily, the corporation's financial structure seemed eminently sound. The books showed a sizable cash reserve, and neither Lee nor Captain Darby had reason to suspect that the picture was anything but bright.

Then in May, at a meeting of the company's directors, Jim Smith, the president, unexpectedly submitted his resignation as an officer and director. He calmly announced that the company was $40,000 in debt and that there was virtually no cash left in the treasury. Having dropped this bombshell, he proceeded to close his desk and walk out of the company's offices. With him went J. J. Thompkins.

Lee and Captain Darby were aghast. Lee, who had barely recovered from the perfidy of Abe White, felt as if a deep wound had been torn open. Darby immediately launched an investigation of the company's records. He soon discovered that Smith and Thompkins, taking a leaf from White's book, had picked the Radio Telephone Company clean. Instead of selling the stock from the company treasury, they had sold off their own private shares and pocketed the proceeds. This was a violation of law.

Captain Darby and Lee proposed to the other directors that the matter be turned over to the United States attorney at once. "These men should be prosecuted and put behind bars," declared Darby.

The directors hesitated. They feared that bad publicity would shake the public's faith in the company and damage

it permanently. It would be far better, they agreed, to reorganize the firm under a different name, float a bond issue and start out fresh. After much deliberation, Lee and Darby reluctantly agreed.

A new company was formed known as the North American Wireless Corporation which took over the assets of the Radio Telephone Company and issued shares in exchange for the old stock. At the same time, the Radio Telephone Company was continued as a "paper" corporation, with Lee as majority stockholder, since it held the patent rights to the Audion and Lee's other recent inventions.

During the weeks of stress brought on by Smith's defalcation, the chasm in the De Forest marriage widened. Nora insisted on remaining on in Milford even after she was forced to stop working. Nora's mother went there to stay with her until the baby was born.

On June 19 Lee received an urgent telephone call from Mrs. Blatch informing him that Nora had given birth to a little girl. She was named Harriet, after her grandmother.

Lee rushed to Milford. His eyes grew misty as he gazed down at the tiny, red-faced sleeping infant. He wanted to plead with Nora to give up the cottage and return to New York as soon as she was able; but pride, mingled perhaps with a sense of his past inadequacy in persuading her, restrained him.

He went back to the city, gloomy and depressed. Nora remained in Milford for the rest of the summer. In late September, they agreed on a formal separation.

Afterward, Lee could not help asking himself what had gone wrong. Where had they failed, Nora and he? Earlier, he had attributed their marital difficulties solely to her insistence on working, for all of their arguments seemed to have centered on this issue. Yet now he began to wonder whether the reason wasn't more basic. Had Nora given in to him and become a housewife, would they have had a better marriage? He wasn't sure. Perhaps both of them had been

too selfish, too unconcerned with each other's needs and intolerant of each other's weaknesses. Their marriage had not been a partnership, but rather an association of two strong-minded people, each determined on forcing the other to submit to his will.

The following week he went up to New Haven to visit his mother. He told her what had happened. Mrs. De Forest received the sad news with sympathy. "When I was a little girl in Iowa," she said gently, "I used to marvel at the way the wheat stalks would bend when a strong wind blew. That was their secret of survival. I often think husbands and wives should take a lesson from the wheat. Unless both are willing to bend a little when the winds come, their marriage is doomed to destruction."

Lee saw the wisdom of his mother's words. He could not help speculating what might have been had Nora and he learned this lesson earlier.

In this period of despair, Lee plunged once more into his work. Foremost was the task of building a solid foundation for the new company. Lee and Darby decided that in order to restore confidence among their stockholders and the financial community, an effort should be made to dramatize the potential which the new medium of radio held out for the future.

Passing by the Metropolitan Opera House one day, Lee was suddenly seized with an inspiration. Why not broadcast grand opera? True, the audience would be limited to a small handful of professional and amateur wireless operators, but what better way was there to demonstrate the value of radio as a broadcasting medium than to show how it could be used to bring fine music to the masses?

It was a fantastic notion, for he did not have the vaguest reason to believe that the Metropolitan Opera people would go along with it; yet Darby agreed it was worth a try.

Lee obtained an interview with Andreas Dippel, the assistant director of the Metropolitan Opera, and explained

what he had in mind. Not only was Dippel receptive but he even suggested that the broadcast might be enhanced if it featured the world's leading tenor—Enrico Caruso.

Caruso! The name was already legendary. Transmitting his golden voice on wireless would guarantee international attention. Lee began at once to carry out the technical arrangements. Just recently, the opera management had ordered a new type of acousticon microphone installed by the National Dictograph Company on the stage of the Metropolitan so the performances could be carried by regular wire telephone circuit to the various offices in the building. Since the microphone was capable of picking up sound from everywhere on stage and in the orchestra pit, it was exactly what Lee needed. He obtained permission to "feed off" the telephone circuit installed by National Dictograph. Next, a small carbon-arc transmitter was installed in the attic of the opera house, and a temporary bamboo mast was lashed to one of the short flagpoles on the roof. An antenna wire attached to the bamboo led down through a ventilator to the transmitter.

The broadcast was planned for the night of January 13, 1910. A double bill was scheduled—*Cavalleria Rusticana* and *I Pagliacci*, the opera in which Caruso had immortalized the role of Canio.

Captain Darby notified the press, and as curtain time neared, reporters were stationed at various radiotelephone receiving installations throughout the city; several were even on board a ship docked in the Hudson River.

Finally, while manning the transmitter station in the attic, Lee heard through his telephone receiver the opening notes of the overture to *Cavalleria*. Completely absorbed, he listened as the performance began and the arias came over the telephone wire, almost as clearly as if he himself were seated in the audience downstairs. It went through without a hitch, and before he knew it the short one-act opera was over and it was intermission time.

Then the curtain went up for the second time. Soon he heard the magnificent sounds of Caruso's powerful voice in *Pagliacci* as he sang of his grief at his betrayal by his wife Nedda. And then it was over, and wave after wave of applause came pouring through the telephone receiver. Lee knew then that it was an experience he would carry with him as long as he lived.

Every station tuned in to the broadcast had received the signals clearly. The next day newspapers throughout the country carried lengthy reports of the pioneering venture. So impressed was the music world that Lee easily obtained permission from Oscar Hammerstein, impresario of the Manhattan Opera Company, to do a special broadcast of the famous contralto Mme. Mazarin singing the "La Habanera" aria from *Carmen.*

In spite of the tremendous success of the opera broadcasts, the financial affairs of the North American Wireless Company went from bad to worse. The debt and fiscal confusion resulting from Smith's looting of the treasury of the predecessor company hung over Lee and Captain Darby like a dark cloud. Business had fallen off, the firm had trouble obtaining credit, and a number of employees had to be laid off.

Therefore, when they were offered a contract by the Army Signal Corps in the spring of 1910 to equip two transports on the West Coast, they jumped at the opportunity. Lee immediately left for Seattle where one of the ships was docked. There he spent several weeks supervising the installation. From Seattle he proceeded to San Francisco to equip the second transport.

It was his first visit to California, and he found San Francisco a delightful, fascinating city. He made friends among some of the leading engineers and physicists in the San Francisco area. One of these was Cyril F. Elwell, chief engineer and a stockholder in a new communications firm

named Federal Telegraph Company at Palo Alto, a short distance from San Francisco.

Elwell tried to persuade Lee to join the company. He offered him an excellent salary and free reign to do research. It was a tempting offer, but Lee felt that his first loyalty was to Darby. Shortly afterward he received a discouraging letter from Darby informing him that the North American Telegraph Company was in worse shape than ever.

As soon as he finished the San Francisco installation, Lee rushed east to discuss the situation with Captain Darby and the others. The books showed a huge deficit and little hope for the future, in spite of the recent Army contract.

Two choices faced them. They could file voluntary bankruptcy proceedings, or they could restrict operations and cut expenses to the bone in anticipation of a future miracle that would put the company on its feet again.

After many hours of deliberation, the directors decided on the latter course. This meant that Lee's role as chief engineer was now little more than an official title. He told Captain Darby of Elwell's offer. "Accept it, Lee, by all means," Darby urged. "You can't do any good here until the situation changes. If it does, and if you want to come back, you can always do so."

In spite of Darby's advice, Lee hesitated. A prolonged stay in California would mean being three thousand miles away from his little daughter. He adored her, and ever since the separation from Nora, his life had centered on the week ends when he could see tiny Harriet. During the weeks in California the separation from the baby had created a terrible void in his life.

Yet he could see no other solution. Remaining in New York held out the prospect of a penniless, purposeless existence. Perhaps, he told himself, after a few months in California he could convince his employers to give him a short leave of absence to go east and see Harriet. And there was always the possibility, as Darby had pointed out, that the

picture might change and he would have reason to return to New York permanently.

With a heavy heart and the recurrent sense of failure that had dogged him from childhood, Lee entrained once more for California to join the Federal Telegraph Company as a research engineer.

12

California Interlude

Lee was happy in Palo Alto. He was drawing three hundred dollars a month, and for the first time in years he felt unburdened by the nagging business worries that had complicated his life in the East. By now, too, he was reconciled to the fact that his life with Nora was over. She had asked for a divorce, and he had agreed.

Beach Thompson, president of the Federal Telegraph Company, assigned Lee to a small laboratory and told him he was free to select his own area of research. It was like a dream come true—the opportunity to work on problems of his own choosing, untroubled by commercial pressures, free to requisition whatever equipment was needed. His assistant was Charles Logwood, an ingenious, resourceful mechanic who in many ways reminded Lee of his old assistant Clifford Babcock.

Lee made a down payment on a small cottage in Palo Alto and sent for his mother to come and stay with him. His brother Charles had been married the previous year, and Mrs. De Forest had been living alone in New Haven. Since she had relatives in California and the climate was sunny and pleasant, Lee was convinced that it would be a wonderful place for her to spend her declining years. Within a few weeks after her arrival, she had managed to transform the cottage into a cozy, attractive home for her son.

From the first, Lee had recognized the Audion's tremendous potential as an amplifier not only of radio waves but of wire telephone and telegraph signals as well. And his patent applications had been filed with this in mind.

Yet, in spite of the superb results the Audion had given as a detector and amplifier of radio waves, he had never really tested its ultimate magnification ability.

In this respect, he viewed the Audion as a kind of lever. Make a lever long enough and find a place to stand, a physics teacher had once told him, and it was theoretically possible to move the earth. Lee had seen at once the analogy between the lever and his three-electrode tube, for he was convinced that in theory the Audion's amplification properties were limitless.

But to translate the theory into practice would require time —time to think, to experiment, to "find a place to stand." And in New York time had been a prohibitively expensive luxury.

In Palo Alto things were different. Now he had not only the necessary facilities and technical help but the time.

Early in 1912, Lee decided to find out just how far he could go in using the Audion as an amplifier. The problem was not entirely divorced from the activities of his new employer, the Federal Telegraph Company, for among other things, the firm operated a busy and profitable commercial telegraph service to Hawaii and along the Pacific Coast.

To speed up the rate of message transmission and reception, the company was experimenting with the "telegraphone," a machine that magnetically recorded sound on fine steel wire. Under the proposed system, operators would punch Morse code messages on long strips of paper tape, already in use for cable transmission, then transmit these taped messages at high speed over the telegraph wires.

Telegraphones at the receiving end would record these signals. The steel wire would then be rerun at a rate slow enough to permit an operator listening to the telegraphone headphone to transcribe the recorded messages on his type-

writer. In this way, the message traffic over a single telegraph wire could be multiplied.

However, there was one obstacle. Long-distance telegraph signals were so weak that they could not be recorded satisfactorily on the telegraphone. Lee saw immediately that Federal's difficulty was only a single aspect of the over-all problem of signal amplification that plagued the telephone and wireless industries as well as the telegraph companies. He pointed this out to Thompson and Elwell and described his plan to use the Audion to develop amplification apparatus that might be used in all areas of electrical communications. They gave him permission to go ahead.

At Lee's direction, Charles Logwood rigged up a standard wire telephone circuit in the laboratory. Between the transmitter and receiver Lee interposed a simple Audion circuit using an "A" battery to heat the filament and a "B" battery to provide voltage and give a positive charge to the platinum plate.

The weak telephone signals from the transmitter proceeded to the Audion grid where they controlled the electrical flow from the filament to the plate. The resulting plate or "output" current then went to the telephone receiver to be converted into sound waves.

In his first experiments, Lee used as a "B" battery the 18-volt storage battery that had become a standard power source for his Audion radio receivers. He was not surprised to find that even this initial amplification of the telephone signal was quite good. But Logwood, who had never worked with triode vacuum tubes before, was astonished at the result and could not understand why Lee failed to react with more enthusiasm to what he considered a major triumph. "We've just started," Lee told him calmly. "Wait and see."

Next, they boosted the power by substituting a 22-volt battery for the "B" source. A slight magnification in the telephone receiver signal was noted. In the past, Lee had refrained from using anything more powerful than 22 volts

for fear of blowing out the Audion; but now he continued to build up the voltage step-by-step.

Between 30 and 40 volts, a blue haze began to develop in the tube. There was a sharp drop in power. From past experience Lee knew that the hazing was due to the small amount of air which remained in the tube after it was exhausted. This air turned to gas under the influence of the high voltage.

Suddenly, an idea struck him like a thunderbolt. Suppose that instead of using a single Audion as an amplifier they used two—or even three! And suppose they fed the current from the platinum "output" plate of the first to the grid or "controlling" electrode of the second, then did the same with a third, and so on. They would thus have developed a "tandem" or cascade of Audions. And by treating this circuit of tubes as a unit, they might be able to double or even triple the voltage without risking a tube blowout.

Logwood hurriedly wired a second Audion in the circuit according to Lee's instructions. Forty-four volts from the "B" source were now fed into the two-tube Audion "cascade." The negative terminal of the "B" battery was wired to the carbon filament of the first Audion, while the positive terminal was connected to the platinum plate of the second.

Logwood spoke into the telephone transmitter. The signal Lee heard in the receiver was stronger than anything they had produced before. He examined the Audions carefully and could not detect even a faint sign of hazing.

Now he knew they were on the right track. They gradually increased the power—50, 60, 70, 80 volts! Not until they hit a voltage of 90 did the bulbs begin to develop the cloudy telltale blue tinge.

By now the amplification was so strong that the standard telephone receiver they had been using was no longer satisfactory. Lee obtained a small loudspeaker and wired it into the circuit in place of the headset. Even the slightest whisper in the transmitter seemed to pour out of the speaker horn with a roar that filled every corner of the small laboratory.

But Lee still was not satisfied. He wondered if a more complete vacuum in the Audions themselves would give even better results. They had been using tubes manufactured by McCandless and shipped from New York. It was Logwood who suggested that they go to someone experienced in making x-ray tubes, since such equipment required a high degree of skill and precision.

In San Francisco, they located a Mr. Lamont, who specialized in manufacturing such tubes. He agreed to re-exhaust McCandless' bulbs, using the identical process given to his x-ray glassware.

The repumped Audions were superior to any Lee had ever used. He found he was now able to boost the power input to more than a hundred volts. In order to test the amplification, he and Logwood hit on the simple scheme of placing the loudspeaker in the open window of the laboratory and walking down the block until they could no longer hear the signal. After noting the distance in "blocks" they boosted the voltage for another test. At first small crowds, usually neighborhood youngsters, followed curiously to see what was going on; but soon they learned to accept as normal the strange sight of grown men strolling leisurely down a block, cocking an ear to catch a distant sound, then writing earnestly in a little black notebook.

By adding a third tube to the Audion "cascade" Lee managed to magnify the signal so strongly that sounds spoken into the telephone transmitter could be heard over the loudspeaker two blocks away! The power was now up to 120 volts, yet Lamont's re-exhausted tubes showed no hazing. Nevertheless, Lee decided to call a halt at this point, since he felt that for all practical purposes there was nothing more to be gained by boosting the signal further.

In the following weeks Lee, Logwood and another young engineer named Herbert Van Etten, who was now assigned to Lee's laboratory, worked hard to refine the apparatus. One day, Lee speculated aloud that it might be possible to make

one vacuum tube do the work of two. Suppose, he conjectured, instead of using tubes in tandem, they were to feed the output current from a single Audion plate back into the grid of the same tube. What amplification would such an arrangement give? Logwood and Van Etten agreed that it would make an interesting experiment.

The effect was startling. As soon as the current was turned on they were astonished to hear a whistling noise emanating from the loudspeaker. It was a queer piece of business this, something they had never encountered before. Even Lee could not explain it at first. What was strangest of all was that the sound did not die out but continued. It was beautiful, a clear note, cleaner and purer than any they had ever obtained before. Fascinated, they played around with the circuit and found that by varying the voltage they could actually change the pitch of the note.

Lee began to analyze the phenomenon. Clearly, what they had discovered was a feedback principle that caused the current in the Audion circuit to "oscillate," or vibrate back and forth at a high, fixed frequency. This accounted for the steady pitch in the sound they had heard. What was equally important was that the high-frequency oscillation was apparently feeding on itself. Therefore it was *self-regenerating*, or continuous.

With a start, Lee realized that he had stumbled on a phenomenal discovery. If this continuous high-frequency oscillating current could be fed to a transmitting antenna instead of a loudspeaker, it would radiate continuous high-frequency Hertzian waves. And by varying the voltage through the use of a microphone, voice or music could be imposed on the continuous waves which could then be used for radio transmission.

It was an amazing idea. The carbon arc and the spark transmitter, after all, were nothing more than devices to radiate continuous high-frequency waves. The arc was superior to the spark because it produced steadier waves.

But here was a system of radiating continuous waves that was incomparably more efficient and sensitive than anything that had ever been used before.

Logwood and Van Etten were as excited as Lee. Of course, to design a transmitter based on the oscillating Audion principle would require time and effort. And for the moment their energies were completely absorbed in perfecting the telephone amplifier. Nevertheless, Lee instructed Van Etten to prepare a detailed diagram and description of their oscillating circuit to be filed away for future reference.

While working on his amplification and oscillating experiments, Lee reported his progress regularly to Beach Thompson. Originally, the president of Federal had given him the widest latitude in selecting his research problems; yet Lee feared that as the months passed Thompson might begin to resent the time and expense invested in experiments that did not bring an immediate financial return to the company. However, Beach Thompson was an unusual man.

"We're a small company competing against giants," he told Lee. "The most important product we have to offer is imagination—new ideas. Some of these experiments may have no practical use as far as Federal is concerned, although I am convinced your amplification principle will prove a major contribution in our telegraphy work. In any case, I believe strongly in giving free reign to genius, for we never know when it will lead us to the pot of gold at the end of the rainbow. Your only obligation is to give the company free access to any discoveries that can be applied to telegraphy. All the other rights to your inventions will remain with you."

Lee could not help thinking how sorely the world of science and industry needed other leaders with the imagination and vision of a Beach Thompson.

In the late winter of 1912, Lee sat down and wrote a long letter to John Stone, a friend in New York. Stone was an electrical engineer, one of the most respected in the East.

They had met several years before, at engineering conferences. In his letter Lee described in detail what he had accomplished with the Audion as a telephone amplifier and asked if Stone felt that any purpose would be served in laying the matter before the executives of the telephone industry.

By return mail John Stone replied that the Audion amplifier sounded so promising that if Lee desired he personally would sound out his friend John J. Carty, vice-president of the American Telephone and Telegraph Company in New York. Lee could hardly have wished for more. He immediately wrote Stone authorizing him to undertake the negotiations with Carty.

Stone wasted no time. Within ten days he informed Lee that he had made arrangements for a demonstration of the Audion amplifier before engineers of the Western Electric Company. The test was to take place in the Bell Telephone Laboratories in New York. The date and time were left open, subject to Lee's convenience. Overjoyed, Lee made arrangements to take time off from his job to make a hurried trip back east.

Then disaster struck.

One afternoon in late March, two men called at the offices of the Federal Telegraph Company and asked for Mr. De Forest. They were ushered into his laboratory, where they requested him to step outside so they could talk privately. In the hall, they quietly informed him that they were United States marshals with an order from the federal judge in San Francisco for his arrest!

Lee was stunned. "On what charge?" he asked at last in a voice that was close to breaking.

"This will explain it, sir," one of the marshals replied, handing Lee a court order. Through glazed eyes, he read the charge "... use of the mails to defraud ..."

He protested that there was some mistake, but they assured him politely that it was no mistake. He was immedi-

ately taken to San Francisco and arraigned before the court. Bail was set at ten thousand dollars. He was given until midnight to post bond.

Although confused and in a state of near-shock at the unbelievable sequence of events, Lee asked for permission to call Beach Thompson, president of Federal Telegraph. The call was put through. Brokenly, he explained what had happened and was told to try not to worry. "The company will do everything in its power to help," Thompson assured him.

Within a few hours, his employer had made arrangements with two wealthy members of the board of directors to post bond. Lee was released from custody and told that he would be duly informed when a trial date was set.

When Lee arrived at the cottage, his mother immediately sensed that something was wrong, but he tried to evade her questions. However, she was not to be put off, and finally he confessed that there had been some legal difficulty due to a "misunderstanding." He assured her that it would be straightened out in short order and urged her not to worry.

That night he got no sleep.

The next day Thompson asked him whether he had retained counsel. Lee replied that he didn't feel he needed a lawyer just yet. "It will all be cleared up, I'm certain of it," he told his employer naïvely.

Thompson exploded. "Lee, don't be a damn fool," he said. "You need someone to represent you."

Lee argued that his innocence would prove itself. Thompson replied: "Nonsense. Guilt or innocence has nothing to do with hiring an attorney." At last he prevailed upon Lee to let the company lawyers represent him for the time being.

"But I have no funds except my salary," Lee informed him.

"I said nothing about money," Thompson replied. "The company will take care of it."

Federal's lawyers were able to uncover some of the facts. They found out that warrants had been issued for Lee,

Captain Darby, Jim Smith, J. J. Thompkins and E. E. Burlingame, another principal of the North American Wireless Company.

The accusation of fraud against Lee and Darby stemmed from the sale of stock in the Audion, an invention which the government claimed had no value whatsoever.

Similar charges had been brought against Smith and Thompkins, in addition to which they were accused of defrauding Radio Telephone Company stockholders by pocketing the proceeds of stock shares.

E. E. Burlingame was the company officer who had actually organized the North American Wireless Company as a successor to the Radio Telephone Company. He had been arrested on counts similar to those brought against Lee and Darby as well as a charge of using irregular procedures in establishing the new corporation.

Lee was frankly relieved when he learned the nature of the charges against him. He knew he was innocent, and he felt that so did everyone else who had ever had any dealings with him. Why, even officials of the Marconi Company, his strongest competitor, could be subpoenaed, if need be, to testify to the value of the Audion.

The very fact that John Ambrose Fleming had complained over the years that the Audion was an adaptation of his own diode rectifier, the standard tube in Marconi equipment, was itself implicit proof that the experts did not agree with the government's contention that the Audion "had no value whatsoever." Furthermore, there were recent documented reports that the Marconi operators had begun secretly to substitute Audions for diode rectifiers in their sets. This was an even stronger indication that the triode was considered of legitimate value in wireless circles.

Thus armed with a deep sense of conviction in his own ability to disprove the government's case, Lee convinced himself that once the matter reached the courts and the facts were presented, he would be swiftly vindicated.

In this somewhat improved frame of mind, he returned to his laboratory to make the final adjustments on the Audion amplifier in preparation for the demonstration in New York.

Late in September, Lee obtained a leave of absence from the company. He packed his experimental equipment and took a train to New York, thrilled at the prospect of seeing his tiny daughter Harriet again. John Stone met him at the station and invited him to make his headquarters at the Fine Arts Club, where he himself was living.

As soon as John Carty was informed of Lee's arrival he arranged to have a small room set aside in the Bell Telephone Laboratories on West Street. Here, Lee set up his apparatus and tested it privately for Stone who was frank to admit his astonishment at what Lee had accomplished in his short time in California.

Lee also told him about the "oscillating Audion" effect he had discovered and began to explain what it could mean for radio transmission. Stone saw the implications immediately. "It could revolutionize the wireless industry, Lee," he said thoughtfully.

On the afternoon set for the amplifier tests, a corps of Western Electric and Bell Laboratory engineers crowded into the small demonstration room. They were mildly skeptical that Lee De Forest, whose professional career had been tied up with wireless, could have developed a system of interest to telephone men, but they were willing to be shown.

Since Lee recognized that the fundamental concern of the engineers was with signal amplification that could be applied to a telephone receiver, he had temporarily discarded the loudspeaker in favor of headphones. As the demonstration proceeded, the engineers' initial apathy turned to interest and then to enthusiasm. Lee gave each member of the group a chance to don the headset. He dropped a handkerchief a few inches away from the transmitter. The result was a resounding thud in their ears that caused them to blink in amazement.

Then he used a dozen different techniques to demonstrate the clarity and sensitivity of the equipment. He spoke into the transmitter, played music and even whistled to show the absence of sound distortion.

"You see, gentlemen," he explained. "By installing these Audion amplifiers at intervals in your telephone circuit, they serve as 'repeaters.' They boost the current to compensate for losses due to the distance the signal has traveled."

The engineers asked many questions. How high a voltage could be used without burning out the tubes? Would it be possible to transmit a signal from New York to California without distortion? How expensive were the Audions?

Lee answered all the questions patiently. He pointed out that in a "cascade" circuit there was theoretically no limit to the number of tubes that could be wired together or to the voltage that could be applied. Signal distortion over a distance of thousands of miles would be so minimal as to be unnoticeable to the human ear. And as far as cost was concerned, he assured them that if manufactured in quantity his vacuum tubes could be turned out for less than a dollar apiece.

Satisfied with these answers, the telephone company engineers requested Lee to leave his apparatus for a few days. He agreed and they promised that he would hear from them shortly.

During the following weeks Lee had little to do but travel about New York City renewing friendships and spending many hours in the technical libraries reading the books and scientific journals he had not been able to find in California.

After their divorce, Nora had moved back to her old apartment on Riverside Drive and gotten an engineering job. Now, each morning, after Nora left for work, Lee visited with his little daughter and spent a joyful hour or two watching her have breakfast and being bathed by her nurse.

One evening an acquaintance, Emil Simon, asked Lee to join him at the Grand Opera House, where a tuneful musical

named the *Quaker Girl* was playing. Simon knew many members of the company, and afterward they went backstage. One of the singers immediately caught Lee's eye. She was a stunningly beautiful girl whom Simon introduced as Mary Mayo. Lee invited her to dinner.

During the next few weeks, Lee saw Mary Mayo often. They went out to dinner and concerts and spent many quiet afternoons strolling in Central Park. Soon he found himself deeply in love.

Meanwhile, he still had not heard from the telephone company. John Stone made inquiries but was told that no decision had yet been made.

By December, Lee realized he could not remain in New York much longer and retain his job with the Federal Telegraph Company. He empowered John Stone to act as his agent in case the telephone company gave intimations that it wanted to acquire telephone rights to the Audion amplifier. They agreed that $500,000 would be a fair asking price.

A few days before Christmas, Lee asked Mary Mayo to marry him. It had been a whirlwind courtship and proposal, but she accepted without hesitation. They were married in late January and left immediately for San Francisco.

Lee was heartened by the warmth with which his mother accepted his bride into their home. During the early months of 1913, he happily settled down to the routine of married life and to his experiments with Logwood and Van Etten in the Federal laboratories.

By early spring the letters from John Stone indicated that there was still no news from Carty and the telephone people. Lee was discouraged. He tried to hide his disappointment from Mary and his mother but did a bad job of it.

Toward the end of April he received an unexpected letter from the American Telegraphone Company's New York offices. They had heard of the Audion amplifier and were interested in combining it with a special type of recorder and reproducer which they were hoping could be synchronized

with motion picture film. Their goal: the development of talking motion pictures.

They offered to pay his way to New York and to set him up in a laboratory to conduct experiments. Although he was happy in Palo Alto, Lee could not help feeling that it was a wonderful opportunity. Mary missed New York and was anxious to return, and he was desperately anxious to see his little daughter. Moreover, a trial date on the fraud charges had been set for late fall, and since the case was to be heard in New York, he realized that sooner or later he would have to return to prepare for his defense.

However, Lee's mother was not anxious to leave California. During her year there, Mrs. De Forest had established a new life for herself and had developed close friendships with a number of distant relatives in the San Francisco area. A family conference was held and it was decided that she should remain on the West Coast.

Early in May, Lee and Mary returned to New York City.

13

Time of Trial

The house Lee had planned at Spuyten Duyvil had been completed long ago but never occupied. Upon their arrival in New York he arranged with the bank holding the mortgage on Riverlure to move in until such time as he could make regular payments or a purchaser could be found.

Lacking cash, they furnished their new home scantily with furniture bought on the installment plan and set up housekeeping. Mary, who had become a good cook under Mrs. De Forest's tutelage, undertook her duties conscientiously and worked hard to make the large sprawling house a homey place in which to live.

Lee's "laboratory" turned out to be the Biograph motion picture studio on 14th Street. Here he worked alone on the talking picture project. The American Telegraphone Company officials, it developed, were not nearly as generous as their letter had indicated, for the weekly salary they paid was far less than he had expected.

Nevertheless, Lee threw himself into the project wholeheartedly. The idea was a fairly simple one. Using the telegraphone which recorded sounds magnetically on steel wire, he was to work out a system of signal amplification in conjunction with his Audion circuit. At the same time, the telegraphone wire was to run over a large pulley attached to the socket spindle of a motion picture projector, so that

when the wire traveled from one spindle to the other it would synchronize perfectly with the progress of the picture film.

In a matter of weeks Lee succeeded in devising the pulley arrangement and amplification system the Telegraphone officials had sought. He constructed a working model, using a secondhand projector, and brought it up to the company officials. Instead of enthusiasm, he was greeted with total apathy. Apparently, the company had lost interest. Furthermore, he was informed that his salary was being discontinued!

He pleaded that the talking picture machine could mean a fortune, but his arguments fell on deaf ears. Discouraged, yet unwilling to lay aside the project on which he had worked so hard, he got permission from the Biograph studio manager to finish testing the machine on his own. By this time he and Mary were so short of funds that she pawned her ring and he his watch in order to buy food.

One day in August Sidney Meyers, a dapper young lawyer, visited Lee at the studio. He claimed that he represented business interests who desired to acquire long-distance telephone rights to the Audion amplifier. Lee was immediately on his guard, for he knew that these rights could only be of interest to the American Telephone and Telegraph Company. He asked Meyers bluntly if he represented the telephone company. The attorney shook his head vehemently and declared, "On my word of honor as a gentleman, I assure you that my clients are *not* the American Telephone and Telegraph Company."

Satisfied with this assurance, Lee asked him how much he was prepared to pay, recalling that he and John Stone had agreed on $500,000 as the price for the rights. He was shocked when Meyers informed him that his principals were willing to pay $50,000—"take it or leave it."

Under other circumstances Lee would have shown Meyers the door. But he knew that since the patent rights

were held by the Radio Telephone Company which was in desperate straits, he was not free to ignore any offer—no matter how unrealistic. Besides he had learned recently that there was a real danger that the assets of Radio Telephone and its parent corporation, North American Wireless, might have to be sold at auction to cover back taxes. The assets included the patents. If this happened it was highly possible that all the patent rights—including those covering the Audion—would be sold for a song. Meyers apparently had done his homework well, for he made it clear that he knew all about the financial condition of the companies. "We know you are in a corner," he told Lee triumphantly. "Under the circumstances you can't very well ignore our offer."

Hurried meetings of the stockholders of both companies were held and Meyers' proposition was discussed. It was reluctantly approved.

Captain Darby was directed to prepare an agreement assigning the Audion telephone rights to Sidney Meyers. In return, the attorney turned over his certified personal check for $50,000.

A few days later the truth leaked out. Meyers' clients turned out to be none other than the American Telephone and Telegraph Company. Lee further discovered that the telephone company had actually appropriated $500,000 to purchase the long-distance rights if it should have proven necessary. Thus Meyers had saved his client $450,000! Lee observed bitterly to Darby that the American Telephone and Telegraph Company executives, in trading on Sidney Meyers' "word of honor as a gentleman," had obtained quite a bargain indeed.

Lee could not help wondering at the perversity of a fate that had doomed him so often to be a victim at the hands of others. Yet, was it merely bad luck—an unfortunate combination of misplaced trust and preoccupation with his own work that had brought about his misfortunes? Or was it an inadequacy deep within himself that was the real problem?

True, his entire life had been one of honest dedication to the task at hand. And all his life he had taken it for granted that others were equally honest and equally dedicated. Now, however, he began to ask himself whether his total submersion in work—an involvement with *things* instead of *people*—was not actually due to a fear of people and a consequent inability to understand them.

Was his work, then, merely a refuge? Was he blinded to the nature of human frailties because in reality he was unconcerned with human beings? Could this be why he had failed so often not only in his evaluation of business associates but in his judgments and understanding of those whom he had once loved, like Jessica Wallace and Nora?

For Lee, introspection of this sort was painful, particularly because he knew by now that there were no ready answers. Perhaps someday, he told himself, he would be able to face himself honestly and discover the truth.

In spite of Lee's disgust at Meyers' deception, the check for $50,000 proved a godsend. Working with Darby, Lee soon reorganized the Radio Telephone Company under a new name, The Radio Telephone and Telegraph Company. New stock was issued to stockholders in exchange for shares in the former corporation.

An empty two-story loft in Highbridge, not far from Spuyten Duyvil, was rented; in a matter of weeks research and manufacturing operations were resumed once more. Lee wrote to Logwood asking if he would like to come east as his assistant. Logwood packed his luggage and came eagerly. By fall, the prospects for the company looked brighter than they had in years.

In spite of the rebirth of the firm, a dark cloud still hung over Lee's future. The November date set for the fraud trial was approaching rapidly, and as yet he had done nothing to prepare for his defense. The Federal Telegraph Company lawyers had been out of the case ever since he had left California. And during the spring and summer months of

grinding poverty he and Mary had not been able to afford a decent meal, let alone a good attorney.

Mary wanted to know why part of the $50,000 for the telephone amplifier rights could not be used to pay for legal fees. Lee patiently explained that it belonged to the Radio Telephone Company, not to him as an individual.

One morning a few weeks before the trial was to begin, he received an unexpected call from an attorney, Howard Deming, asking permission to represent him. Lee explained that he had no funds, but Deming replied that he was not to worry about money. "Your Yale classmates are attending to that," he said.

Lee was astounded. He had not discussed or corresponded with his fellow alumni about his difficulties. Upon further questioning he learned something that warmed his heart and almost brought tears to his eyes.

A number of his classmates, having learned of his predicament, had quietly established a "De Forest Defense Fund." They had succeeded in collecting $2,500 and retained Deming, who had a reputation as an active, crusading young lawyer.

With only a short time left until the trial, Lee and Deming began to prepare a defense. The government's case hinged on the contention that the Audion was a worthless, fraudulent device. Since Deming knew nothing of radio or electricity, Lee spent a number of evenings giving his attorney an intensive "course" in wireless.

Once he completed his "basic training," Howard Deming swung into action like a general. He prepared a lengthy brief describing the scientific value of the triode vacuum tube and its application. Seeking an independent expert to testify on behalf of the Audion, he got in touch with the Marconi Company, Lee's stanchest competitor. In spite of past rivalry, the firm did not wait to receive a subpoena but voluntarily transported at its own expense one of its employees from Mexico to testify to the Audion's worth.

A number of Lee's former assistants were brought in as witnesses on the practical value of the discovery and on his character and honesty. Engineers and patent experts were called upon to testify as to Lee's excellent reputation in the engineering field.

Shortly before Thanksgiving the trial opened in New York's Federal Court. All the defendants were present with their counsel. The federal prosecutor, Robert Stephenson, delivered a sharply worded attack on the Audion and on Lee. He charged that fraud had been committed through the sale of stock in the Radio Telephone Company and North American Wireless inasmuch as the "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—not even a good lamp." At this point Stephenson contemptuously held up to the jury one of the little bulbs.

"De Forest has said in many newspapers," Stephenson declared, "that it would be possible to transmit the human voice across the Atlantic before many years! Based on these absurd and deliberately misleading statements of De Forest, the misguided public, Your Honor, has been persuaded to purchase stock, paying as high as ten and twenty dollars a share!"

The prosecutor ended his impassioned attack by urging that Lee and the other defendants "be given the limit of the law and be sent to the federal penitentiary."

For six dreary weeks, the trial dragged on. A parade of witnesses were heard and a spate of evidence given.

On the last day of the year, the case went to the jury. The judge explained the various charges and was careful to differentiate between those brought against Lee and Darby and the additional counts against the other three defendants.

The jury retired to the jury room shortly after noon. It stayed out for thirteen hours. Then, at two o'clock in the morning, the members filed back in and took their seats.

Lee felt his heart beating violently and his breath coming in loud, heavy rasps. However, he noticed one face in the jury smiling kindly at him, and he felt a deep sense of relief.

The verdict was announced.

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

"De Forest, Darby—*not guilty.*"

Smith and Thompkins were sentenced to ten years in Atlanta Penitentiary. Burlingame was given five years.

In the early hours of the morning Lee called Mary at home to tell her the news. She broke down and cried over the telephone.

With the black cloud of prosecution swept away, Lee and his associates settled down to the task of building up the new Radio Telephone and Telegraph Company. He was amazed at how rapidly the radio field had expanded during his brief stay in California. The demand for equipment seemed insatiable, and it was all the company could do to expand its manufacturing facilities fast enough.

Since Lee was now drawing a salary again, he set as one of his first goals the repayment of the $2,500 contributed by his Yale classmates. He and Mary pared their living expenses to the bone and each week set aside a fixed sum toward their "repayment fund." Within nine months, Lee was able to send a check for the full amount to the fund's chairman, George Parmly Day. With it went a letter expressing heartfelt gratitude for the class's demonstration of friendship in his time of trial.

In August of 1914 the sound of guns echoed through Europe. A world war had broken out. Wireless, until now a subject of incidental experimental interest to military and naval officers, suddenly found itself in the spotlight. The Allied armies began to order such large quantities of tubes and amplifying apparatus from Lee's company that sales to nonmilitary customers had to be restricted.

Now, however, a new legal entanglement developed. For some time, Lee had continued to receive reports that oper-

ators for the Marconi Company had been infringing on the Audion patents by using the three-electrode tubes in their sets in place of the Fleming valve. This, despite the oft-repeated public charges by Fleming that the triode was merely an offshoot of his own diode.

In view of the Marconi Company's generous cooperation during his trial, Lee was content to overlook the infringement. But toward the end of 1914, attorneys for Marconi—apparently instigated by Fleming—informed Lee and Captain Darby that they planned to file suit against the Radio Telephone and Telegraph Company for infringing on the Fleming valve.

A meeting was held between lawyers for both companies. Darby told the Marconi attorneys that if such a suit were brought, he would bring a countersuit against the Marconi Company for infringing on the Audion patents. An attempt was made to reach an amicable agreement, for Lee and Darby had no wish to waste time and expense in a complex legal battle. But the terms desired by the Marconi lawyers were so outrageous that the conference fell apart. Shortly afterward, both companies filed claims against each other.

Late in 1914 the case came to court. The attorney for Marconi did an astonishing thing: he immediately withdrew Fleming's charges and admitted that his company had been guilty of infringement! Apparently, having looked into the matter more thoroughly, he had concluded that his client's claims were groundless.

Philip Farnsworth, the attorney hired by Darby, immediately moved for an injunction to permanently prohibit the Marconi Company from infringing on the Audion patent. But the judge, who was clearly confused by the scientific aspects of the controversy, decreed that since the Marconi Company had honestly admitted its sins and repented, it should not be punished. And he proceeded to deny the injunction.

Then he stated that it was his belief that the Fleming valve was an amplifier, and since Fleming had patented his diode before Lee's triode, the Audion was actually an infringement on the diode. He thereupon prohibited the Radio Telephone and Telegraph Company from making, using or selling Audions! *In effect, the judge had ruled that the Marconi Company was the wronged party, in spite of its attorney's own clear admission to the contrary.*

Outraged by this gross miscarriage of justice, Lee and Darby appealed the case. The decision on the appeal was a ruling which prohibited both companies from making and selling tubes without the other's consent. As a result, a complex, inefficient arrangement was worked out to cover future production and sales of Audions.

One day, Lee and Darby were surprised to receive a visit from Sidney Meyers, the attorney for the telephone company. Meyers, obviously embarrassed by his earlier deception, laid his cards on the table this time. He explained that his company was now interested in acquiring additional license rights under the Audion patents to cover radio signaling. His offer: $10,000.

Lee and Darby laughed bitterly at the telephone company's generosity. "Since 'gentlemanly honor' is not a matter under consideration this time, let us deal as buyer and seller," Lee declared. "The price is $100,000—'take it or leave it.'"

Sidney Meyers flushed a deep red. He started to argue that the price was too high, but Lee and Darby were adamant. The attorney kept raising his offer. Finally, they compromised on $90,000. Patent assignment papers were drawn up giving the telephone company rights to manufacture Audions for use in radio receivers.

Because of the legal expense of the Marconi suit, the $90,000 loomed large in the company treasury. It enabled Lee and Darby to undertake much-needed expansion of manufacturing and laboratory facilities. They acquired their

own tube factory and pumps and built a 125-foot transmission tower at Highbridge, for Lee decided he was now ready to begin development of the Audion as an oscillating transmitter.

In the spring of 1915 Lee interrupted his work to go to San Francisco to visit his mother and to attend the Panama-Pacific International Exposition being held there. Darby had arranged for a modest display of De Forest Audions and other equipment at the fair. Nearby, in the same Hall of Electricity, was the American Telephone and Telegraph Company exhibit.

The telephone company had just opened its transcontinental telephone line, made possible through the use of Lee's Audion amplifier. It was obviously proud of the achievement, for virtually the entire exhibit was devoted to the miracle of long-distance telephony. Several times each day a lecture was delivered in a small amphitheatre by a telephone representative who explained in popular language the history of the transcontinental line.

At the close of each lecture, visitors were given a chance to listen to the sound of a person speaking across the country from New York City. Then they were handed a neat little booklet entitled

THE STORY OF A GREAT ACHIEVEMENT

Telephone Communication from Coast to Coast

Yet at no point, either in the lecture or in the booklet, was a single word mentioned about the role of the Audion in making long-distance telephony possible. Lee was angry and embittered. He felt it was unfair of the company to give the impression that its engineers had been wholly responsible for the accomplishment—especially since it had used deceit in acquiring the wire rights to the Audion in the first place.

That evening, Lee studied the booklet carefully and sat up half the night preparing one of his own. In size, color and

format, it was to be the exact duplicate of the telephone company's publication. The title was to read:

THE STORY OF A GREAT ACHIEVEMENT

Which Made Telephone Communication from Coast to Coast Possible.

In the text, Lee described the unsuccessful twenty-year attempt of the telephone engineers to devise a long-distance system. Then he explained in detail the history of the Audion and how it enabled engineers to boost a telephone signal for cross-country transmission.

He located a firm of printers who agreed to turn out the booklet within twenty-four hours. The following day, attendants at the De Forest booth began handing out thousands of copies of the pamphlet to sight-seers, many of whom had just come from the American Telephone exhibit!

Back in New York, Lee resumed work on the oscillating transmitter. With Logwood's help he constructed test apparatus consisting of a microphone unit connected to an Audion oscillator which in turn was wired to an antenna in the new transmitting tower. Once again, as he had done years before, Lee called on wireless station operators in the metropolitan area to help by serving as a test audience.

Within minutes after his first "broadcast," the laboratory phone was kept busy with calls from stations in Manhattan and the Bronx, as well as from Bridgeport, Connecticut, and New Jersey. The quality of reception was excellent, better than anything that had been achieved with the carbon arc, the operators reported. They lauded the range and clarity of speech and demanded to know when the new "transmitting gadget" would be put on the market.

To test the oscillator further, Lee and Logwood constructed a second transmitter and brought it to the Columbia Gramophone Building on 38th Street with a simple proposition: if Columbia would let them install the transmitter in

their building and furnish free records, Lee would give the company a "credit" before each playing. The company agreed enthusiastically.

For the next few months, the transmitter in the Columbia building broadcast steadily, with Lee as chief announcer. On Election Night, he dispensed with the usual musical program to bring his audience election bulletins from the editorial offices of the *New York American*.

By the end of 1916 Lee's broadcasting career came to an abrupt end. With the United States headed toward war against Germany, the government ordered the shutdown of all amateur and most commercial radio activities. The Highbridge antenna was cut and officially sealed.

But the broadcasts had served their purpose. Almost overnight, the oscillating Audion began to replace the spark gap and carbon arc for radio transmission, just as a decade ago the same tube had suddenly made the electrolytic receiver obsolete. Indeed, to Lee, his little triode vacuum tube by now was beginning to take on the characteristics of a precocious child whose own parent was no longer able to foresee where its future might lead.

In April of the following year, just as America entered the war, Lee and Darby were approached once more by the American Telephone Company, which now sought to purchase the oscillating rights to the Audion. After several weeks of bickering, the price was set at a quarter of a million dollars. So pleased were the directors of the Radio Telephone and Telegraph Company that as a gesture of appreciation to Lee they renamed the firm the De Forest Radio Telephone and Telegraph Company.

14

Talking Pictures

The year 1919 was a critical one in Lee De Forest's life. The end of the war had brought vast changes to the radio industry, with profound effects on Lee's own thinking. Wireless had once been the exclusive province of a handful of individual researchers and pioneers; now it was assuming the dimensions of a big business.

Marconi had sold his independent company to three of the large electrical companies, which now were known as the Radio Corporation of America. The giants Westinghouse Electric and General Electric had begun to move into radio swiftly; Westinghouse had even set up a broadcasting station to transmit regular programs of music and news, a project in which Lee had shown the way. American Telephone and Telegraph, with receiving, transmission and telephone rights to the Audion, now exercised enormous control over commercial radio.

In view of these developments, the wireless field to which Lee had devoted twenty years of his life had begun to lose some of its appeal for him. He could continue, of course, to devote his exclusive efforts to the needs of the De Forest Company, but the prospect of serving as a full-time business executive appalled him.

He still considered himself an inventor, and an inventor must search for new fields to explore and conquer. As far as

radio was concerned, he was convinced that most of the basic work had been accomplished. He felt that while there would be technical improvements in the future, the fundamental principles would remain the same; whatever advances would be made would be done largely by the teams of bright young engineers working in the well-equipped laboratories of the giant companies.

For his own part, Lee felt no desire to compete with the great corporations. To do so would mean working almost entirely along commercial lines rather than seeking out new problems to solve simply because the problems themselves were challenging.

Lee's personal life, too, was undergoing grave stresses and strains at this time. Early in 1919, after seven years of marriage, Mary learned she was going to have a baby. As the months wore on, she began to suffer from growing periods of depression. In a desperate effort to ease her mental state she turned to drink. Lee tried to convince himself that it was due to her pregnancy, for he had heard that women soon to give birth often suffer from emotional upheavals. And while it was true that at times in the past Mary had drunk heavily, particularly during periods of extreme tension, her dependence on alcohol now began to take on the dimensions of a serious problem. Nevertheless, Lee prayed that once the baby was born, she would be able to straighten herself out.

On September 30, 1919, Mary gave birth to a little girl. They named her Eleanor. For the first few weeks after returning home with the baby, Mary did not touch a drop. Lee was jubilant, and he began to look forward to some of the delights of fatherhood that had been denied him when his first daughter was born. In spite of the fact that he had visited his beloved Harriet regularly down through the years —a practice he continued after Eleanor was born—he had never deluded himself that these periodic visits afforded the full pleasures of parenthood.

Lee's joy was short-lived. When tiny Eleanor was two

months old, Mary's fits of depression returned; once again she was seized with the terrible compulsion to find relief in liquor. Dismayed, Lee took her to medical experts, but they held out little encouragement.

"I'll be blunt, Dr. De Forest," one physician told him. "Many of us in the medical profession now recognize alcoholism as a disease. But as yet there is no cure. There is a sanitarium I know of where she can go for temporary help. However, unless she herself has the strength and determination to overcome her 'problem,' I fear I can offer no permanent solution."

Lee was at a loss to know what to do. When he suggested that she enter a sanitarium for a few weeks of "rest," Mary broke down and became so distraught that he had to give up the idea. He hired a nurse to care for the baby, but that did not solve Mary's problem nor alleviate his own sense of despair and disillusionment. Most of all, he felt a compelling need to escape, to plunge himself wholeheartedly into some major new task that would help take his mind off his unhappiness at home.

Early in 1920 he found the challenge he was looking for.

One day, while getting rid of some old laboratory equipment, he came across the "talking motion picture" machine he had developed for American Telegraphone. Recalling that long, sweltering summer seven years earlier when he and Mary had lived a hand-to-mouth existence so he could complete the device, he could not help smiling bitterly to himself. It had been another wasted effort, he mused—one of many in his life.

American Telegraphone had lost interest in the project, and with the revival of his own fortunes, Lee had put the machine aside and forgotten about it. Now, however, he began to examine the projector with the curious recollection of someone looking at a memento in a dusty attic.

Actually, the machine had worked reasonably well. By running the steel telegraphone wire, magnetized with re-

corded sound, over a pulley attached to the socket spindle of the film projector, he had managed to achieve satisfactory synchronization between sound and motion picture film. The main trouble, he recalled, was in the tendency of the film to break easily. When this happened it was almost impossible to restore perfect synchronization. The images in the film would then be mouthing words that had no relation to the sound.

A second problem had been the difficulty of editing the magnetized wire and the film at the same time. It was a problem of achieving split-second timing between sound and picture. And while he had succeeded with the short test films prepared at the Biograph studio, the task had proved so time-consuming that it was questionable whether such a system would prove commercially practicable.

As Lee thought about the problem, he found his interest reviving. Clearly, the answer was to develop a system of synchronizing sound and picture so that the harmony between the two would be retained permanently. The only way to do this was to eliminate either the magnetized wire or the film and bring the sound and picture together in a single inseparable medium.

For a number of weeks Lee continued to ponder the question. He read every piece of technical literature he could lay his hands on that concerned talking pictures. There was not much, even though many men had been working on it. He learned that Thomas Alva Edison had once suggested a system, but this simply involved the playing of a phonograph record simultaneously with a motion picture, so that in principle it was similar to the machine he had built for American Telegraphone.

Lee decided to approach the problem logically. He concluded at once that if either the magnetized steel "sound" wire or the film had to be eliminated, it would have to be the former. While there were other techniques of recording and reproducing sound—such as the phonograph record or

punched tape—there was no way to record visual images except on film.

His next conclusion followed logically: the sound would have to be impressed in the film itself in such a way that as each tiny picture frame passed through the projector a simultaneous segment of sound accompanied it. Thus, if the film stopped, the sound would stop at the same precise point. If the film broke and had to be respliced the sound would remain in perfect synchronization. And if it was necessary to eliminate or edit portions of a film, the sound, too, would be edited automatically.

But how could it be done?

Out of his curious inventor's gift for amalgamating instinct and knowledge came an inspired clue. Plumbing the depths of experience and memory, he suddenly recalled the Welsbach burner experiment of his Chicago days. It had happened twenty years before, yet he could remember it vividly —perhaps because it was the signpost that had first pointed him in the direction of the Audion.

He and Ed Smythe had noticed that whenever their primitive spark transmitter was operated in the room, the light from the burner flame changed intensity. They had first suspected that the Hertzian waves were responsible, but it had turned out to be nothing more than the *sound waves* from the crackling noise of the spark.

That was the hint he had been seeking!

Why couldn't he rig up sensitive apparatus that would convert sound waves into varying intensities of light? This light source could then be utilized to make a "sound record" by exposing it to motion picture film.

Once he had established the basic principle his restless brain began to spin out the mechanical details almost without conscious effort on his part. He could not use a Welsbach burner because an open flame was hard to control. But suppose he took a tube and filled it with some sort of gas that would cause it to glow when an electric voltage was applied

—similar to the mercury and nitrogen lamps that had long been in use for lighting purposes. And suppose further that he connected this "glow tube" to a standard Audion-microphone transmitter circuit.

Sound waves picked up by the microphone would be converted into a varying electric current, amplified by the Audion circuit and fed to the glow tube. The constantly changing voltage would cause corresponding changes in the amount of light given off by the glow tube. By focusing the light through a narrow slit onto the edge of a film while it ran through a motion picture camera, the light would show up as a pattern of black and white densities on the film. And this "sound track" would synchronize perfectly with the images photographed at the instant the sound was picked up in the transmitter.

To project the talking picture, a reverse process would be employed. As the film ran through a motion picture projector, a steady beam of light would be focused on the narrow sound track. The amount of light coming through the film would vary according to the changing density of the track and would then be made to strike a photoelectric cell, which converted light into electric current. The photoelectric cell had been developed some years before, and Lee was well acquainted with the principle. It was simply a vacuum tube shaped like an Audion and coated with a light-sensitive material like potassium or cesium. When light struck the tube the metallic coating gave off electrons which were picked up by a loop of wire inside the tube. The flow of electrons produced a current.

The varying intensity of the light shining through the sound track would produce a weak but varying flow of current in the photoelectric cell. The current would then be fed into an Audion amplifier and greatly magnified for use in a theatre loudspeaker.

In spite of the simplicity of the scheme Lee could not help feeling a sense of amazement at how quickly the details

had fallen into place once he devised the fundamental principle. Moreover, he felt an additional sense of satisfaction in the knowledge that quite unintentionally he had discovered still another use for his precious Audion tube.

With the compulsive energy that had been a lifelong characteristic, he now threw himself completely into the project. He got in touch with Theodore Case in Auburn, New York, who had developed an improved photoelectric cell, and ordered a number of tubes from him. Case, curious as to why the cells were needed, came down to see him, and Lee explained in precise detail his plan for talking motion pictures. Intrigued, Case agreed to help, and at Lee's request went to work devising a glow tube containing a mixture of argon and helium gas which proved to be better than anything then available in its ability to respond sensitively to voltage changes.

Lee, having dropped all his activities at De Forest Radio to devote full attention to sound-on-film, worked night and day to construct an experimental machine. Meanwhile, word had leaked out to the newspapers, and several carried stories about his new undertaking.

By November of 1922, he was satisfied that the apparatus was ready for testing. Dr. Hugo Riesenfeld, musical director of the Paramount Theatres, had read of his work and now offered to lend a fully equipped movie studio and the services of a cameraman. Lee gratefully accepted. Riesenfeld also supplied a number of musical acts for "screen tests."

Since the grinding noise of a camera presented no problem in silent films, the manufacturers of motion picture equipment had never taken the trouble to soundproof them. But for Lee's purposes it was disastrous. Therefore, he and the cameraman hit on the idea of enclosing the machines in a telephone booth during the actual filming. With Lee in the booth serving as director, the cameraman, Harry Owens, cranked away as a singer, violinist and ballroom dance team took turns performing.

Two days later the film was developed, printed and ready for projection. Lee, Riesenfeld, Owens and Theodore Case composed the entire audience in the projection room. A loudspeaker had been hooked up behind the screen. The lights were switched off and the film began to run.

The sound poured out of the loudspeaker with a clarity that surprised even Lee. "Why the singing and music seem to be coming from the screen itself!" Owens exclaimed.

"Yes," said Lee. "That's the illusion we want to give."

The film was only ten minutes long, but Riesenfeld muttered appreciatively and Case gave Lee a hearty slap on the back by way of congratulations.

Lee had the film rerun several more times and studied it carefully. He discovered something he hadn't noticed before: the sound and visual portion were very slightly out of synchronization. Suddenly it dawned on him that he had overlooked an important factor. Since light traveled much faster than sound, there would be a time lag between the image and the sound, because of the extra time needed for the sound waves to travel to the pickup microphone during the filming and to cover the distance from the loudspeaker to the audience while the picture was being shown.

For the next few weeks Lee worked hard to iron out this wrinkle. Finally he hit on a simple solution. Instead of recording sound and picture on the same negative, why not record them separately? Then the two could be printed together on the positive used for actual projection. In this way the sound track could be set slightly ahead of the visual portion of the film to compensate for the time lag. By a simple mathematical process, Lee calculated that the sound would have to be moved up twenty-four frames for perfect synchronization. Furthermore, he soon realized that the device of recording sound and image on separate negatives held other advantages, too. It would make possible all sorts of unusual techniques, such as dubbing in special sound effects, inserting a singer's voice while an actor mouthed the lyrics

during musical sequences, and the substitution of foreign dialogue for films to be shown abroad.

Lee decided to name his new invention *Phonofilm.* Toward the end of 1923 he organized the De Forest Phonofilm Corporation and the De Forest Patent Holding Company to handle commercial development of the system.

After months of refining his apparatus Lee informed Riesenfeld that he was ready to present Phonofilm to the public. The musical director arranged to have Owens film a number of leading stage acts. First they photographed a sequence featuring an actor named Henry Cass who described Phonofilm briefly. Then came a monologue and a song by vaudeville star Eddie Cantor, followed by forty minutes of additional comedy, songs and dances.

In early April, 1923, the film was shown at a preview before the New York Electrical Society. The auditorium was jammed. The lights went down and the film began to unreel. Except for occasional bursts of laughter at a joke spoken on screen, the audience of engineers sat in rapt silence, their attention glued to the miracle unfolding before them. As the lights came on the applause was resounding. Afterward, the engineers crowded around Lee and asked dozens of questions about his invention.

On April 12, Riesenfeld presented the same film at Paramount's Rivoli Theatre on Broadway. It was the first time in history that a talking picture was shown on a commercial screen. The audience was so enthralled that when the show was over they applauded, cheered and stamped their feet for a full five minutes.

15

Return to the West

Encouraged by the initial success at the Rivoli, Lee and Riesenfeld embarked on a campaign to sell the Phonofilm idea to other theatres. By 1924 they managed to convince more than thirty independent theatre owners from Cleveland to Florida that talking pictures were the wave of the future. Phonofilm sound equipment was installed in all these houses.

An actor named Arthur Donaldson approached Lee with the idea of producing a feature film in Swedish. Lee jumped at the proposal and even agreed to provide some of the financing. The result was an original film entitled *Domen,* which ran forty minutes and had a cast of thirteen. It was such a hit in Sweden that an English version was made. The picture was released to Phonofilm-equipped theatres in the United States under the title "Retribution" and played to standing room audiences.

During the presidential election campaign of 1924, Lee got a sudden inspiration. Why not have one of the candidates deliver a political speech on Phonofilm? John W. Davis, the Democratic nominee, accepted the proposal and presented three addresses on "What is Honesty in Government?" Although Davis lost the election to Calvin Coolidge, the films received wide publicity in the newspapers and aroused great public attention.

By now, Riesenfeld's 48th Street studio was producing

several short sound films a week. But Lee, directing his sights toward the future, realized that it was not enough. If talking pictures were really to take hold, the major film producers and theatre chains would have to be persuaded to get behind the idea.

With Riesenfeld's help he contacted the leading motion picture executives, including Sam and Harry Warner, heads of Warner Brothers, and William Fox, president of the mighty Fox motion picture chain. These men looked at Lee and Riesenfeld as if they were out of their minds. Why should anyone be interested in sound pictures? they asked incredulously. People go to the movies to *see*, not to hear!

"There will be *no* talking pictures in *my* theaters," William Fox decreed flatly.

Lee tried to prevail on the movie magnates to keep an open mind until they had had a chance to view a sample film, but this plea was ignored. "The public does not want sound movies," he was told brusquely.

The stubborn shortsightedness of the men who ran America's multimillion-dollar motion picture industry was a shocking revelation to Lee. And in addition to his failure to make headway with them he was running into serious financial problems. Since the beginning, he had financed the development of Phonofilm out of his own funds. With the big movie chains unanimous in their opposition to talking pictures, he was faced with a critical choice: either give up Phonofilm or sell his controlling interest in De Forest Radio to get the money to go on with sound-on-film development in the hope that eventually they would come around.

Lee decided to leave the radio company that bore his name.

A syndicate of Detroit businessmen announced that it was prepared to pay a very large sum for his stock. Lee accepted, praying that he had made the right choice.

At this time, his home difficulties, too, were reaching a climactic point. On December 1, 1924, Mary gave birth to a

second daughter—a lovely little girl named Marilyn. However, she continued to drink, even more heavily than before. No longer able to tolerate the situation, Lee left her. But he returned to Riverlure a short time later when Mary promised to give up alcohol. She kept to her resolution for a few months, then lost control again. A final separation resulted, followed by arrangements for a divorce.

In June of 1926, on his thirtieth anniversary of graduation, Lee was informed by his alma mater, Yale University, that he had been named to receive an honorary Doctor of Science degree. He went up to New Haven to attend the commencement exercises, but his heart was heavy and he simply could not summon the enthusiasm which the occasion demanded. After he stepped up to the podium to receive his degree, the president delivered an encomium to his pioneering work in radio, but the words seemed to have a hollow echo in Lee's ears.

He returned from New Haven to learn that a revolution was being set in motion in the movie industry. The once mighty Warner Brothers empire, now tottering on the brink of financial disaster, had decided on a desperate gamble. It planned to release a John Barrymore motion picture entitled "Don Juan" which would feature recorded musical accompaniment! Following the picture itself, there would a series of "shorts"—vaudeville acts with voice and music. The sound was to be supplied by phonograph records synchronized with the film projector—the old Edison principle that Lee had discarded five years before.

For two months Warner Brothers conducted an unremitting advertising campaign to "sell" the public on talking pictures. In August, a flamboyant opening was held at New York's Warner Theatre on Broadway. Crowds began lining up early in the morning to obtain tickets to the matinee performance. The presentation was a spectacular success.

Every movie company now jumped on the bandwagon. And suddenly the motion picture industry was sound-con-

scious—nearly three years after Lee had vainly tried to convince its leaders that the public was eager for talking pictures.

The leading electrical equipment companies lost no time in getting into the race. Western Electric, which had supplie the Warner Brothers' sound equipment, promoted its synchronized disk machines, while RCA and General Electric hurriedly undertook to develop a sound-on-film system similar to Lee's.

Once again Lee tried to sell the big chains on Phonofilm—a system which had been refined and commercially tested—but he was unsuccessful. Now that they were convinced that sound films were the thing of the future they had lost no time in signing contracts with the major electrical companies.

One morning Lee was thunderstruck to read in the newspapers that Fox Theatres had purchased rights to a talking picture system allegedly developed by his old colleague Theodore Case, to whom he had confided all the details of Phonofilm. Upon further investigation, he learned that the "Case system"—which had been dubbed "Movietone"—was identical with Phonofilm in almost every respect.

Angry and dismayed, he filed a patent infringement suit. A Fox business agent named Cortland Smith rushed over and paid Lee $100,000 for a three-month option to buy control of Phonofilm, claiming that Fox was unaware of the real origin of the Case system. Smith promised that when the option was exercised, Lee would receive an additional $2,000,000 in payment for full patent rights.

Ninety days passed, but the company failed to use its option. Lee began proceedings against Fox and threatened suit against the other companies that had infringed on his Phonofilm patents. It was a hopeless task. Almost completely drained of funds by his heavy investment in Phonofilm, he knew full well that he did not have the capital to wage a long, expensive court fight. His giant competitors knew it

too. They indicated bluntly that they were prepared to drag out the suit for years, if necessary.

Reluctantly, Lee agreed to settle out of court. He was offered $10,000 and finally agreed to accept $60,000.

His Phonofilm adventure had come to an end.

One evening Lee received a telegram from Palo Alto informing him that his mother had died. The sad news was not unexpected, for her health had been failing in recent months. Yet at eighty she had remained as alert and clear-minded as ever. He rushed to San Francisco to attend the funeral. Afterward there was a quiet reunion with Charles and Mary and their families.

He returned to New York restless and despondent, feeling as if he had been cut loose from life itself. In an attempt to find his roots again he buried himself in his laboratory, surrounded by his precious circuits and batteries. There he resumed work on a dozen little projects that he had begun but never completed, including an idea for an improved photoelectric cell and an ultrasensitive diffraction microphone. But at fifty-six he was like a man on an island, lonely and uncertain—even uncaring—about the future.

In the spring of 1930 he received word that he had been chosen President of the Institute of Radio Engineers. Still at loose ends, he took a train to Toronto where the annual convention was being held that year. After the installation ceremony, he delivered the presidential address and received a thunderous standing ovation. However, instead of returning to New York he decided to proceed to California for a brief rest. He hoped that in the sunny, relaxed atmosphere of the Pacific Coast he might find, for a few weeks at least, the sense of peace and contentment he had discovered there once before.

He visited his friends and relatives in San Francisco and went on to Los Angeles, where he also had several distant cousins. Among them was the motion picture actress Bebe

Daniels, who was descended on her mother's side from David Curtis De Forest, founder of the family scholarship at Yale.

One evening Bebe invited him to a swimming party at her Santa Monica beach house. Among the guests was a charming young woman who seemed vaguely familiar. When he learned her name was Marie Mosquini, he recognized her as an actress he had seen in many silent films. She had played with Harold Lloyd, Bebe Daniels, Janet Gaynor and had been Will Rogers' leading lady in some thirty pictures.

They talked at great length about acting, films, radio and a dozen other varied subjects. Lee found her clever, articulate and surprisingly well informed. He decided to prolong his stay in California.

During the next six weeks they saw each other almost constantly. For Lee, life suddenly had begun to take on meaning once more.

In September, he proposed to Marie.

They were married two weeks later and decided to make their home in Los Angeles.

16

The Peaceful Years

The years seemed to speed by now. They were busy, work-filled years, crowned with a radiant personal happiness Lee had never known before. He and Marie lived quietly in a comfortably furnished home in Hollywood, only a few minutes away from his laboratory on the fourteenth floor of a giant building in the heart of the film capital's hyperactive business area.

The projects that demanded his attention seemed endless: devices for improving sound reproduction on film; a new type of loudspeaker; the development of an Audion high-frequency machine to be used by physicians for diathermy treatment.

Almost monthly he found himself filing patents covering new uses for the Audion. Indeed, a new name—*electronics*—was soon coined to define the burgeoning applications of the vacuum tube for science and industry.

Toward the end of the nineteen-thirties, Lee was inexorably drawn to a new field of electronic communications—*television*. Beginning in 1935 he filed ten patent applications for inventions associated with television reception and transmission. One of these, a radial-scanning device, was to serve as the ancestor of a vital new system of sea and air navigation known as *radar*.

Lee carefully avoided efforts by friends and associates to

get him involved in the commercial development of his latest inventions. Following the collapse of the Phonofilm venture, he had spent many hours reflecting on his long, stormy career and had come to the conclusion that the true reward of the inventor was in the satisfaction of meeting the challenge itself. As a result, he now adhered to a policy of selling patent rights to RCA, Bell Telephone and other companies instead of seeking to exploit them himself. In this way he was left free to go on immediately to other research problems.

Lee's life with Marie was supremely happy. They took long vacations together, camping in the magnificent state and national parks in California or skiing at the many fine winter resorts that dotted the Pacific Northwest. Several times during the year Lee visited his daughters, and during vacations they came to stay for several weeks with him and Marie.

With the entrance of the United States into World War II, Lee found his talents in demand on behalf of the war effort. Bell Telephone Laboratories, which was engaged in confidential military research, asked Lee to help solve aviation instrumentation problems. He agreed. Under the terms of the contract, Bell Telephone opened and equipped a special laboratory in Los Angeles and placed it at his disposal. Out of his efforts during those war years came a number of improved aircraft instruments, including flying speed and course indicators and devices for accurately determining a plane's altitude.

In 1943, a decision of the United States Supreme Court brought a smile of quiet satisfaction to Lee's lips. Some twenty-five years after the beginning of the long and painful legal wrangling over John Ambrose Fleming's charge that the three-electrode Audion was really an infringement on his own diode rectifier tube, the Supreme Court held Fleming's patent invalid and ruled that Lee's claims had been justified all along! While the victory coming at this late date

was little more than academic, Lee could not help feeling a sense of personal vindication.

Following the end of World War II there were new and extensive uses for the versatile Audion. Among these were the introduction of amazing new types of automated machinery and computers that performed tasks thought unbelievable a few years earlier, and the development of instrumentation for guided missiles and rockets.

At times, when he was in a philosophical mood, Lee could not help feeling a vague sense of guilt at his own role in the march of science and engineering during the past half century. It was hard to believe how far man had advanced technologically, and yet man's progress in human relations, in learning to control his own destructive instincts, seemed to lag far behind.

It sometimes seemed to Lee that the invention of the Audion and other new devices and scientific discoveries like nuclear fission merely hastened mankind's march toward disorder and self-annihilation. He thought of how a large part of the radio and television industry had been corrupted by advertising and commercial influences and felt appalled.

Yet on sober re-reflection he could take comfort in the fact that as long as man retained his questing spirit, his desire for self-knowledge, there would always be hope. In time to come, perhaps, the dream of a world in which society is able to conquer its own shortcomings would be realized. And perhaps in that struggle for self-elevation the marvelous new devices which he and others had placed at man's disposal would actually help quicken the march toward a peaceful, humane world.

In spite of age, Lee continued to retain a youthful, vigorous look. Although his hair had turned silvery white, his bushy eyebrows remained dark and his skin was smooth and pink, features that belied his advanced years. Moreover, his boundless energy and springy step helped add to the illusion of youth.

In 1943, Lee wrote a book entitled *Television Today and Tomorrow*, in which he forecast with amazing accuracy the tremendous influence of television on man's thinking. As he observed his seventy-fifth birthday, he embarked on a more ambitious venture—the preparation of his autobiography. With Marie's help, the manuscript was completed within two years. It was published in 1950, under the title *Father of Radio*.

In these years, Lee found himself the recipient of many new honors. He had already received a number of important distinctions, including the Cross of the Legion of Honor of France, in acknowledgement of the Audion's contribution in wartime. Now, the American Institute of Electrical Engineers conferred its Edison Medal on him, and colleges and universities named him to receive additional honorary degrees.

In 1952, as he approached his eightieth year, he was honored with a testimonial dinner at New York's Waldorf-Astoria Hotel which was attended by leading figures in all walks of life. The main address was delivered by Herbert Hoover, former President of the United States.

Four years later, on the fiftieth anniversary of the Audion, a plaque was unveiled at 229 Fourth Avenue, Manhattan, the building where Lee had invented the three-element vacuum tube. He was also given an award by the National Association of Broadcasters as the "originator of modern electronics."

One evening in 1957 Lee and Marie were spending a quiet evening in their Hollywood home when he began to complain of pains in his chest. A doctor was summoned and Lee was taken to the hospital. The diagnosis disclosed that he had suffered a heart attack.

For the next few weeks Marie forced him to remain in bed, in spite of his protests that he had too much to do in the laboratory to allow himself to be made a "chronic invalid." When finally he was up and around again, he insisted on going back to work, but the doctor decreed that the time had

come for him to give up the demanding daily routine he had been following for so many decades. Lee pleaded and argued, but Marie and the physician were adamant.

Just a few weeks before his heart attack he had filed a patent application for his latest invention, a new type of automatic device for telephone dialing. It was to be the last of an inventive career that had spanned fifty-seven years. During that time Lee had amassed an astonishing total of more than three hundred patents!

The years that followed were quiet, inactive ones, punctuated by frequent visits from his daughters. Occasionally he was invited to deliver a speech somewhere or to receive a new honor, but for the most part his time was spent with Marie in their Hollywood home.

On the evening of June 30, 1961, Lee and Marie were in their music room listening to classical recordings. Lee declared that he was feeling tired and closed his eyes to take a brief nap. His face wore an expression of utter peace and contentment. Later, when Marie tried to wake him to go to bed, he did not stir.

Lee De Forest was dead at the age of eighty-seven.

The news of his passing was featured on the front pages of newspapers throughout the world. Three days later—on July 3—a simple funeral service was held at San Fernando Mission, just a few miles from downtown Los Angeles.

Today, leading scientists hail the Audion as a monumental invention whose magnitude is touched only two or three times in a century. The Nobel Prize–winning physicist I. I. Rabi has described it as "ranking with the greatest of all time."

In spite of new scientific developments, the De Forest three-element Audion continues to remain the foundation on which all modern communications and electronics rest. It glows as a symbol of one man's courage, determination and stubborn faith in his own personal star.

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