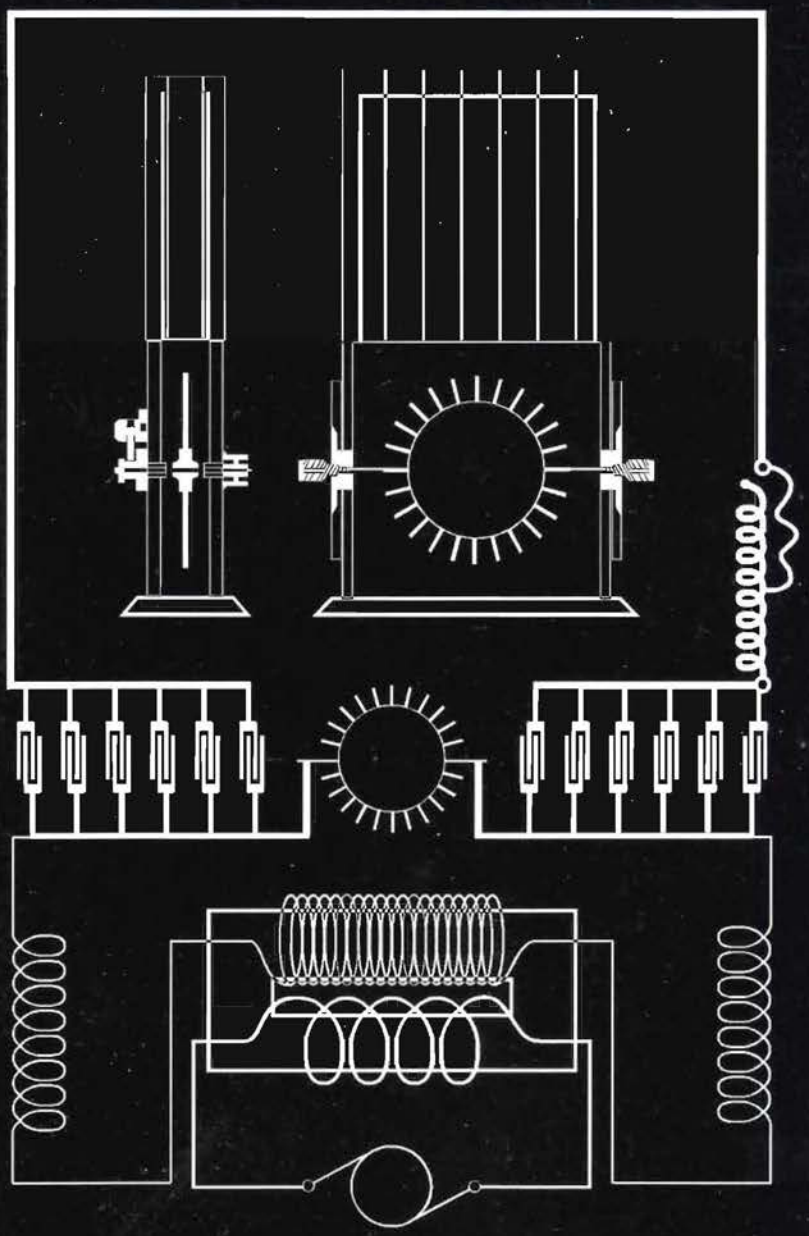
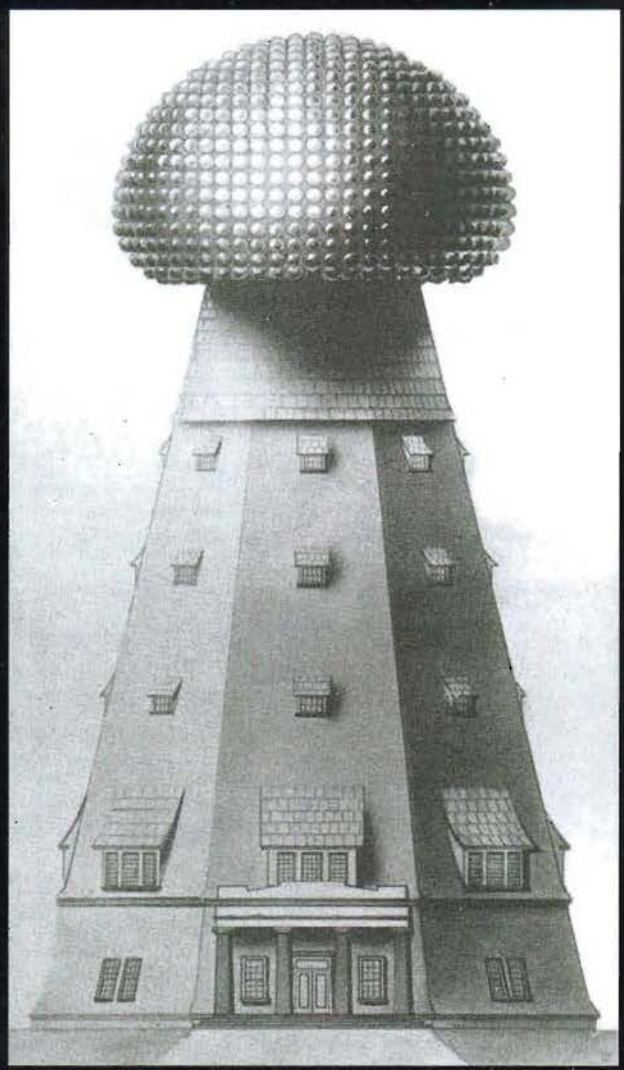
NIKOLA TESLA

On His Work With Alternating Currents

and Their Application to Wireless Telegraphy, Telephony, and Transmission of Power

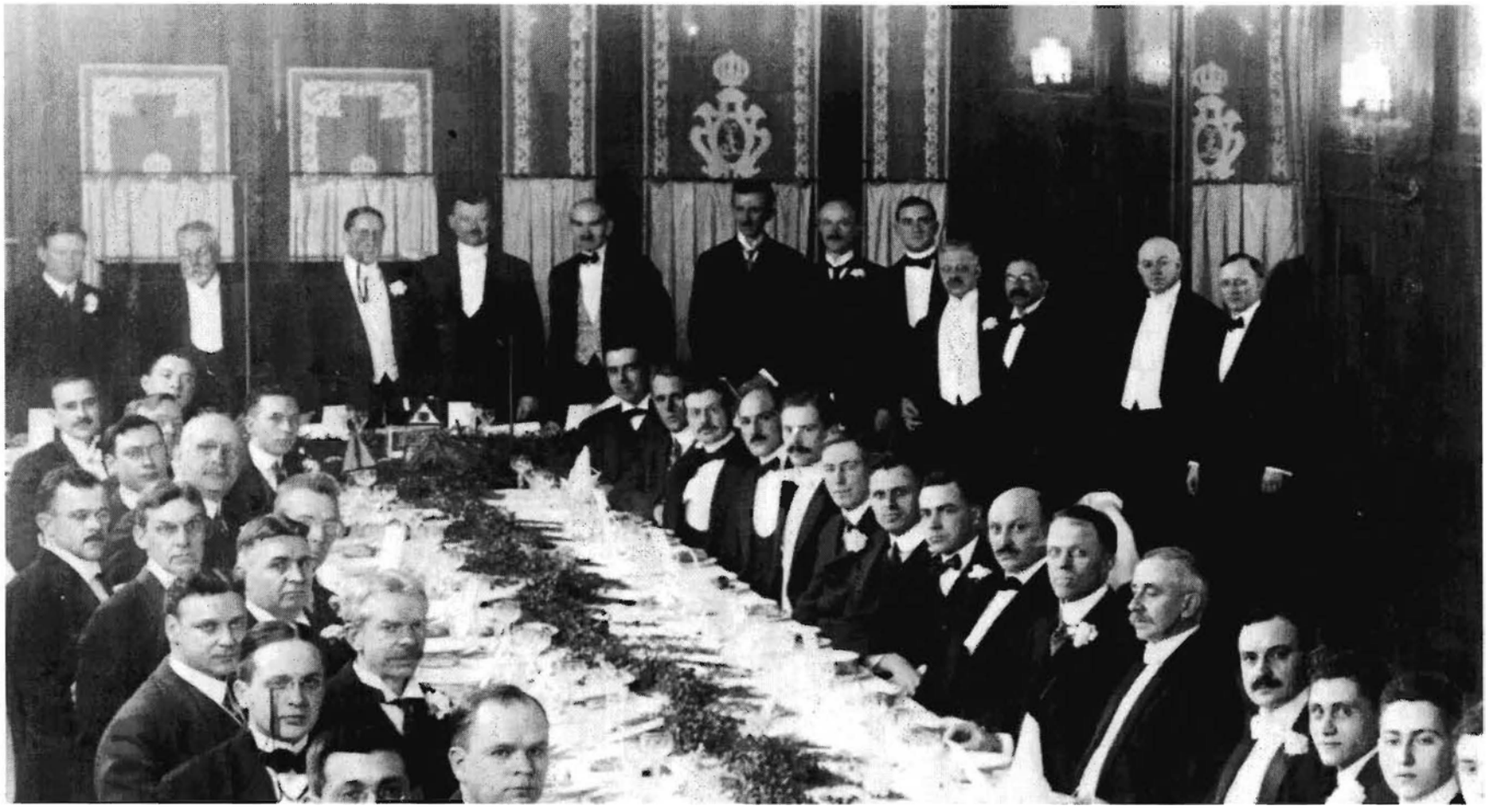
Leland I. Anderson, Editor





TWENTY FIRST CENTURY BOOKS BRECKENRIDGE, COLORADO

NIKOLA TESLA ON HIS WORK WITH ALTERNATING CURRENTS



Second banquet meeting of the Institute of Radio Engineers (now part of the Institute of Electrical Engineers) at Luchow's in New York City, April 24, 1915.

Photo by C.A. Schere
Smithsonian Institution

Standing at back from left,

George W. Pierce	Ferdinand Braun	John Stone Stone	Jonathan Zenneck	Lee de Forest	Nikola Tesla	Fritz Lowenstein	Alfred N. Goldsmith	Ernst F.W. Alexanderson
Tesla refers to these contemporaries in the interview at pages:								
not mentioned	103	16, 124	16, 133	100		178, 179	not mentioned	24, 171

Tesla Presents Series
1

NIKOLA TESLA ON HIS WORK WITH ALTERNATING CURRENTS AND THEIR APPLICATION TO WIRELESS TELEGRAPHY, TELEPHONY, AND TRANSMISSION OF POWER

An Extended Interview

Leland Anderson, Editor

2002

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This work is dedicated to the late
D. Jordan, Professor emeritus
of American history, University of
Minnesota, who pressed his students
to the review of legal records in
historical research. few
tstc::mans, librarians, and archivists
L¥,VHJL. the of
materials. . . . Yet the law, in one
way or is the basis of most
institutions-political, social, cultural,
economic. . . . It is unfortunately
a truism that graduate students
are seldom introduced to
materials."*

* "In Search of Legal Records," American Archivist, Vol. No. 4 (Oct. 1970).

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PREFACE

The surfacing of the transcript for this pre-hearing interview with Nikola by his legal counsel in 1916 resulted from an intensive search in archives of legal firms, some now and others later acquired by contemporary interests. The interview was precipitated by numerous pending court cases as the fledgling radio industry entered a period of fierce competition. Tesla's counsel believed the interview necessary not only in order to prepare for the pressing of own claims against the Marconi Company, but also to protect his own patent interests when called to expert-witness testimony in the upcoming litigation foray pitting as adversaries a plethora of new communications companies their captive radio pioneers.

A case prompting this interview, one of dozens to reach judicial review, was "Marconi Wireless Telegraph Company of America v. Atlantic Communication Company, *et al*." Atlantic owned and operated the large radio station at Sayville, Long Island. The proceedings opened in 1915 with the calling of expert witnesses including Ferdinand Braun and Nikola Tesla. The specter of war had cast its shadow over Europe, and Count George von Arco, who had also been called, was detained because of services to the German Army in the use of asphyxiating gases and other deadly inventions perfected by him.

The text of this interview was, of course, never intended for publication. Counsel, concerned primarily with the protection of Tesla's patent interests, asks questions almost exclusively relating to the priority of his patents and their application. Tesla candidly discusses his contenders while presenting a thorough history of his work with alternating currents as applied to wireless transmission. In this document, he describes experimental methods, and apparatus used in laboratories at New York City, Colorado Springs, and on Long Island.

Most of the photographs accompanying this interview are in good condition, but those of schematic and mechanical drawings have suffered some decay with time. These may be the only form of the drawings extant and are reproduced with as much fidelity as possible. For better clarity, five illustrations are reprinted from the February and May 1913 issues of the *Electrical Experimenter* magazine, Copyright © Gernsback Publications, where they subsequently appeared. These are figures 66, 67, 79, 81 and 82.

Although the interview spanned several days, it is presented in this work as though it was given at one time; all references to interruptions and resumptions have been removed. The text is printed in standard typewriter pica type, unjustified, in the style of hearing proceedings of that period. No alterations have been made in Tesla's remarks except for 'clean-up' additions, typically references to photographs and diagrams, and fill-in words necessitated by occasional rambling and incomplete sentence structure. These additions are provided in brackets [ ]. Helpful notes are also cued to the text in brackets.

L.I.A.

INTRODUCTION

What I am going to show you) step 1?J step) is how I proceeded until I finally realized my dream....

Nikola Tesla

You are holding in your hands one of the most remarkable documents in the history of electrical science. Seldom, in technical research, has such a treasure of descriptive commentary and historical documentation been discovered. This book is a veritable Rosetta stone for deciphering and translating the technical thoughts of one of the world's most distinguished engineering scientists since Archimedes. It describes electrical experiments which took place nearly 100 years ago-but have yet to be replicated.

So astonishing are its contents that it will take one's breath away!

Here, in Tesla's own words, we find descriptions (couched in the language of 19th century physics) for electrical phenomena that lack satisfactory explanation in the language of modern technical analysis. Tesla tells you how to construct a "magnifying transmitter" (that arcane instrument for global power transmission),* but it will be up to you to discover what instruments Tesla was employing, what his procedures were, how he conceptualized what he proceeded, where he performed his historic experiments, when key results were obtained, and how he arrived at his conclusions.

Tesla, himself, was awe-struck with the results of his experiments. He expressed astonishment then at what he later asserts is experimentally verifiable. Listen to the words he uses in this interview to describe the electrical phenomena to his attorney: "magnificent," "it was a marvelous sight," "a wonderful thing," "practically the lamp of Aladdin," "a tremendous display," "glorious," "so marvelous that one would be almost afraid to talk about them . . ." An Edmund Spencer or a John Milton could be no more eloquent. One of Shakespeare's characters once said, "Give me discourse, and I will enchant thine ear." Tesla does no less, even in a legal briefing. He weaves the gossamer web of enchantment which yet holds our technical imagination and draws us in, nearly 80 years after a stenographer recorded his spoken words!

Who was Nikola Tesla?

In 1896, at the Franklin Institute in Philadelphia, Lord Kelvin said, "Tesla has contributed more to electrical science than any man up to his time." After showering words of praise upon the inventor before a meeting of the Royal Society in London in 1892, Lord Rayleigh declared that Tesla possessed a great gift for electrical discovery. Fortunately, the text of Tesla's speech has been preserved and republished.[1,2,3] He was one of the earliest scientists to understand the distinction between lumped and distributed resonance and the first to patent voltage magnification by standing waves.

* It may just be that there *is* enough information present to solve the puzzle of the magnifying transmitter. The reader will have to dig for himself.

The unit of magnetic induction is named in honor of Tesla. It is commonly understood by power engineers that he was the inventor of the induction motor utilizing the rotating field and the AC polyphase power distribution throughout the civilized world.* However, most electrical engineers are unaware that, as late as 1943, he (not Marconi†) was recognized by the U.S. Court as having priority of radio." Even fewer computer scientists are aware that, when attempted to patent digital logic gates World War II, U.S. Parent Office Tesla's turn-of-the-century priority in the electrical implementation of logic secure communications, control systems, and robotics. As a a monopoly on digital logic in was unable to be secured in the 1950s.

Tesla served the electrical engineering profession in its highest offices. In the early 1890s, was elected as of the Institute of now of Electrical and At Graham Bell was its president. Tesla two as and, a one his laboratory technicians at the Colorado Springs experiments served as first vice-president of the Institute of Radio when it was formed 1903. This was the now, famous consulting engineer Fritz Lowenstein. the grid biased amplifier (for which he received the sum of $150,000 from AT&T in 1918),[4] the and electrical and mechanical devices. His two with comments on the propagation of ground waves by Zenneck and sky waves by Austin, appeared in February and June issues of IRE Proceedings, the year of this interv It be that of the AIEE, the American Association for the Advancement of Science, and a dozen other professional societies. He received over 13 honorary from such distinguished institutions as Columbia, and the Universities of Paris, Prague, and Sofia.

Recently, another fascinating fact about has come to all it is now known that he was nominated for an *undivided* Nobel prize in physics in 1937.[5] Tesla's nominator, Ehernhaft, of Vienna, had previously nominated Albert Einstein for the Nobel

* Charles E. Scott, of the AIEE has said, evolution of electric power from the discovery of Faraday in 1831 to the initial great installation of the polyphase system in 1896 Niagara Falls] is undoubtedly the most tremendous event in *all* history." *[Electrical Engineering*, August, 1943 (Vol. 62, 8), pp. 351-355.]

† Although it took the courts decades to figure out, the facts were well understood by technical men of the day. Robert H. Marriott, the first president of the IRE, once said that Marconi had, ". . . played the of a demonstrator and sales engineer. A money getting company was formed, which in attempting to obtain a monopoly, set out to to everybody that Marconi was inventor and that they that patent on to a monopoly." *[Radio oroaat·asT.* December. 1 (Vol. 8, No. 2), 159-162.]

Tesla had the remarkable talent of charming and astonishing his admirers while at the same time enraging his enemies—the phenomenon continuing to the present day. It is unfortunate that, despite several current popular biographies, there still exists no definitive technical authority, other than his own scattered publications, to consult on the scientific issues of his intriguing and colorful scientific career. Consider the adulation bestowed upon him by Lord Kelvin, Hermann von Helmholtz, Sir William Crookes, Lord Rayleigh, Sir James Dewer, Robert Millikan, Sir James Fleming, B.A. Behrend, A.E. Kennally, L.W. Austin, W.H. Bragg, Ferdinand Braun, Jonathan Zenneck, E.W.E Alexanderson, J.S. Stone, Vannevar Bush, W.H. Eccles, Edwin H. Armstrong (who served as a pallbearer at Tesla's funeral, as did Alexanderson), and notably Albert Einstein, Ernest Rutherford, Arthur Compton, and Neils Bohr. There are a number of Nobel laureates, Royal Society fellows, IEEE presidents and fellows, and university [illegible] in that collection. one, since Franklin, had so stirred the scientific and engineering world.

1893, Thomas Commerford Martin, the third president of the AIEE (1888-1889), edited and published a remarkable collection of Tesla's contemporary lectures. It is in print today, and a century now it will still be considered an unparalleled classic in scientific literature to be read along with Franklin's *letters*, Priestly's *history*, Faraday's *researches in electricity*, Maxwell's *treatise*, Hertz's *electric waves*, and Heaviside's *electrical papers*. In 1919, 26 years after publishing the work on Tesla, Martin wrote,

> Tesla's influence may truly be said to have marked an epoch in the progress of electrical science. Very little data, however, has been procurable that is descriptive of his later researches, and more is the pity from the historical standpoint. Tesla has not finished. The world waits expectantly for each fresh touch of his vitalizing thought upon the big electrical problem of the age. [6]

Unlike most of the aforementioned scientists, Dr so it is appropriate to call him—had no financial support to fall back on from a faculty position or research institute. His ideas had to support themselves and him in the technical marketplace. It is not surprising, therefore, that he felt no compulsion to share further technical details in the open literature day. For these must dig (and dig, and dig) through the patent literature, only enough is [illegible] to make it to one "skilled in the art."

Readers will also be struck with Tesla's lighter side. His sense of humor and his quick wit shine through when he describes his 1893 RF demonstration before the public at the Sixteenth Convention of the National Electric Light Association in St. Louis, where he was distinguished as honorary member: "There was a stampede in the two upper galleries and they all rushed out. They thought it was some part of the devil's work." (p. 87) His humor is also evident in his description of the influence that his demonstrations had upon the Royal Institution in London in 1892: "The scientists simply did not know where they were when they saw it." (p. 95)

Tesla could also be sarcastic: "The greatest men of science have told me [the Tesla was my best achievement. . . . For instance, a man fills this space with hydrogen; he employs all instrumentalities, everything that is necessary, but calls it a new wireless system—*I cannot stop it.* Another man puts in a kind of gap. *He gets a Nobel prize for it.*... The inventive effort involved is about a 30-year old mule is capable." (p. 48)

Electrical History

For those deeply active in technical evaluation of historic research, it is a source of intense frustration and shattering disappointment to find "a new book" or even have a television "documentary" appear, only to that the authors (a) didn't the technical aspects of their subject sufficiently to understand the were, and (b) ,.,,,continue to perpetuate unsubstantiated popularized assertions, and errors at victory balls' and not at the scene battle. This is especially true addressing topics in the realm of RF, antennas, and distributed circuits (i.e., radio) merely an academic knowledge of electronics or Maxwell's to livelihood It leads one to conclude no reliable history of can be written until those with adequate technical training and their time and effort to the subject.

But this 1s a breath of fresh air. It sets straight a region of the radio history puzzle which has been incongruous for over nine decades. When we saw these pages, our first impulse was to start an immediate replicate apparatus, search for partially disclosed concepts and missing pieces, clarify issues, and execute a technical analysis.

We believe that this document will considerable along as well by a broad c rh-n of investigators. introduction is not an to discuss such pursuits. Instead, we invite the reader to consider the wonderful personal narrative which will be him.

Feel the pathos in as famous system of four-tuned circuits: *Every wireless message that has ever been transmitted to af!J distance has been transmitted lry this apparatus; there is no other way.* Twenty-seven more years would pass the highest courts of the land would echo in proceedings would em:enre the acid test for any radio For this reason, Tesla, not Hertz, Marconi, or De Forest has been given the title *inventor Of radio.* "innovation" and "invention." How strange that, even at this late date, there what happened. are those that still don't understand

Surprises from Tesla

Tesla has never lost the magical touch. Roy Even today, exactly 100 years after his lecture at the a te engineering skill still has power to surprise and delight in is a fresh glimpse of his life's work. Those us that have toiled with RF technology, and electromagnetic radiation and propagation owe a debt to Anderson, one of the world's leading authorities on Tesla, publishing this It is absolutelyWe no doubt 1t 1s to join *Ivfy Inventions; Patents, and Articles; Und Sein Inventions, Researches and Writings, Colorado Springs Notes* as a member of the historic "canonical Tesla publications." Anyone doing a serious technical evaluation must turn to works.

Return to 1916

It is important to grasp the pulse of society at the time of this interview. In your mind's eye, return to the era of 1916. A Princeton history professor named Woodrow Wilson, the same age as will be re-elected to lead the country. War has been raging in Europe for the past 18 months. Lusitania has been sunk. Within a year, the U.S. would declare war on Germany and more than 100,000 young Americans would go "over there" never to return home to their loved ones. Berlin is writing songs, 24 states have voted-in prohibition, and Ford has produced his millionth automobile. Motorized taxies have just appeared on the streets of New York, and electricity made possible the new skyscrapers that now begin to dominate the city's skyline.

Mount Wilson, California, the new 100-inch telescope is completion. In Europe, Albert Einstein has introduced the general of relativity, and astronomer Arthur Stanley Eddington is quietly preparing expeditions to off the coast and Brazil to test the theory during a solar eclipse. Consultant Stone Stone has completed his term as president of the IRE, and Harvard Professor Kennelly has stepped into the position-he had previously served as president of the AIEE The IRE now 1,000 members. Dr. Zenneck's treatise on wireless telegraphy has just appeared, and he will soon be held "under arrest" at Ellis Island for the duration of WWI. Zenneck would later serve as vice-president of the IRE during 1933.

At Bell Labs, John has just shown that single-sideband transmission is mathematically possible. The transcontinental telephone link has just been demonstrated between Alexander Graham Bell in and Thomas A. Watson in San Francisco, and wireless service between the U.S. and Japan has been inaugurated. In 1916 the electromagnetic spectrum is populated only by amateurs and commercial telegraph stations. There is yet no commercial AM broadcasting, although Frank Conrad, who would be vice-president of the IRE 11 years later, has just an amateur station. It would become Westinghouse's KDKA in November, 1920.

Tesla has recently published "Some in *American.* He has proposed that the Secretary of Defense create a Defense Science Looking toward the future, he publishes an essay called, "The World to be Created by Electricity." E. Taylor Jones and W.M. Jones have published, *Philosophical Magazine* erroneous circuit analyses of Tesla coils. Lawrence's proteges at Berkeley would declare, in pages of Nineteen one of E.O. "cannot be treated usefully by mathematics." the *Physical* Tesla coils

Tesla prophesies
population, not just that radio-controlled and missiles soon expose the
Tesla's new st the military, to the horrors of war. In 1916, *Scientific American*
hands, and Hugo automobile speedometer, the tower at Shoreham Island) will pass from his
Springs experiments. Gernsback's magazine, *Electrical Experimenter* will contemplate his Colorado
Princes Lwoff-Parlaghy entertains Tesla New Yorkialites, and
her painting of Tesla appears in *The* It will later appear on the cover of *Time*
July 20, 1931).

A Visit to a Law Office

As an unseen guest, you have been ushered into an oaJ:e-d.eC<)rated law office New York City. Before you sits Nikola Tesla, now 60 years old, bushy black hair, slight wrinkles beginning to form arot"""""" his piercing light blue-grey possesses a winning smile and a firm handshake. He wears no jewelry or watch a somewhat high-pitched, reedy voice, and ..... .·.·, and convincingly. He is the cosmopolitan New Yorker in his speech, manner, He numerous drawings, papcr:s. and photographs for reference

Across a wooden attorney. His demeanor is tJ.L\Juc""ua<t1 and serious, his questions are penetrating, manner is deliberate. He is aware professional and reputation international regard esteemed gentleman that upon him, and he is understanding every that he can turn to his in the dramatic contests at law which will soon occur. present with is a stenographer, providing the formalities being an accurate written tra1nsc:r1i:1ticm of every thought which soon unfold. The ....,....,,,,...,L_....., over, the counselor begins to speak.

K.L. Corum* J.F. Corum, Ph.D.†
and April 4, 1992

References:

(1) *Inventions, Researches and Writings of Nikola Tesla,* The Electrical Engineer, New York, 1893; ch. 27, pp. 123 and 198-293, with Alternate Currents of High Potential and High Frequency" by Tesla, book has been and is available from several sources.

(2) Nikolik, N., eds., *Nikola Tesla: Lectures, Patents and Articles*, Nikola Tesla Museum, Beograd, Yugoslavia, 1956; ch. 3, "Experiments with Alternate Currents of High Potential and High Frequency" by Tesla, pp. L48-L106.

(3) *with Alternate Currents of High Potential and High Frequenry,* McGraw Publishing Co., New York, 1904, 162 pp.

(4) Discussion of Some Foundations of Modern Radio-Electronic Technology," Comments by Espenschied, *Proceedings of the IRE*, July, 1959 (Vol. 47, No. 7), pp. 1254, 1256.

(5) Crawford, J.L., and Ullrich, R., University of California, 1987.

(6) Martin, *The Story of Electricity*, The Story of Electricity 1919,

* Thornton, Hew Hampshire

† Battelle, Columbus, Ohio

It was evident to me that wireless transmission of energy, if it could ever be accomplished, is not an invention; it is an art. Bell's telephone, Edison's phonograph, or my induction motor were inventions, but the wireless transmission of energy is an art that requires a great many inventions in combination.

We are living on a planet that is rushing through space; this planet is partly conducting and partly insulating. If it were all conducting, or if it were all insulating, we could not transmit energy without wire. It is only because it is partly conducting and partly insulating that a glorious future for man is reserved through the application of this art.

The steps to be taken which I recognized then as absolutely necessary were, first, that I had to produce electric oscillations of the required character. Now, granted that I had them, it still remained to be shown how these oscillations could be transformed into some sort of vibratory energy cap- able of penetrating into the distance.

Therefore, the second step was the transformation of these oscillations into such form of energy as would go to a distance. To develop methods of and apparatus for reception, to collect the energy at any point, was the third step. The fourth step was to isolate the energy. If I simply transmitted energy in all directions without regard to its use, then that energy would be simply lost in space, and it would be no economical system. Con- sequently, I had to devise means to isolate that energy, and this problem again presented itself in two aspects, active and passive; that is, I had to make the transmitter noninterfer- ing, and I had to make it noninterferable. Those are not two identical problems, but both had to be solved. Finally, as to the fifth step, I found that we could never transmit energy, or construct our machines and apply them with understanding, unless we discovered the laws according to which this energy flows through the planet, laws which would enable us to calculate accurately the energy we are to receive at any point, and to design our machines to suit the work.

In reviewing these objectives, what I am going to show you, step by step, is how I proceeded until I finally realized my dream, and, in 1899, produced a transmitter of greater power than probably all the combined transmitters put up today, and, furthermore, perfected an apparatus by which unlimited energy can be transmitted very economically, thousands of horsepower if necessary, from one small, compact plant, much smaller than that at Sayville or Tuckerton.[*]

* Editorial note: The large German-owned radio station at Sayville, Long Island, was constructed by Telefunken (Geselleschaft fur Drahtlose Telegraphie) a few years prior to WWI for communication with a station at Nauen, near Berlin. Suspected of rendering non-neutral service at the outbreak of hostilities, it was taken over by the U.S. Navy Department in July, 1915. The great Tuckerton, New Jersey, radio station was built by the Homag Company (Hochfrequenz-Maschinen

The drawing [. 1] shows the first s toward the evolution of a generator, or transmitter, which be used to flash energy to distances, under practical and economical conditions. This machine was described me in U.S. Patent 447, 0, of March 10, 89 .

It was the first frequency alternator that was exhibited, and with ch tests were made c, although I had made alternators of frequency, as I said before, as far back as 1888. This was a machine from which I could from 10,000 to 20,000 cycles. We used to say, in old times, "alternations"; this term has been loose employed

There been an impression produced that my early machines were rather experimental; but as a matter of fact, the design and construction of machines was my specialty and, prior to undertaking this, I had spent e years in doing nothing but designing machines Therefore, the results which I machine, and which I before the world in 1891, are results a machine that I could not, with all my present and experience, and all the devices of the art, improve one-half of one percent. And any other engineer' no matter who he be, would have that same hard time as myself because in this I embodied every little device that was available. I utilized to the full and the maximum out of the materials. I had the lowest armature resis tance which could be obta , I had the lowest self-induction, I had the t periphery I had the greatest output, far than any alternator that has ever been built since that time. In fact, I united this machine features which no other that has been des since has ever combined

Furthermore, the currents I deve were ly sinu l. That have been known to other , that the currents should be sinusoidal, because that follows from certain theoretical researches; but remember that I had invented the "rotat ic field," the very product of that field was based on the use of ities which wax and wane alternately in accordance with the law of the sine as, I have out in a paper read before the American Institute of Electrical 1888, when I presented my induction motor before that Therefore, done in this machine that could be done to by every possible device known to engineering

Aktiengesellschaft fur Drahtlose Telegraphie) for the Compagnie Generale de Te sans Fil of France, but the German firm delayed transferring ownership after the outbreak of hostilities. It, too, was taken over by the U.S. Navy Department, September, 1915. (See: Howeth, L.S., History of Communitions-Electronics in the United States Navy, U.S. ing Office, 1963; pp. 225• 526.) Tesla was a technical consultant to the Tuckerton station and received monthly royalty payments on its operation until it was taken over by the U.S. Navy Department.

(No Model.)

N. TESLA.

METHOD OF OPERATING ARC LAMPS.

No. 447,920. Patented Mar. 10, 1891.

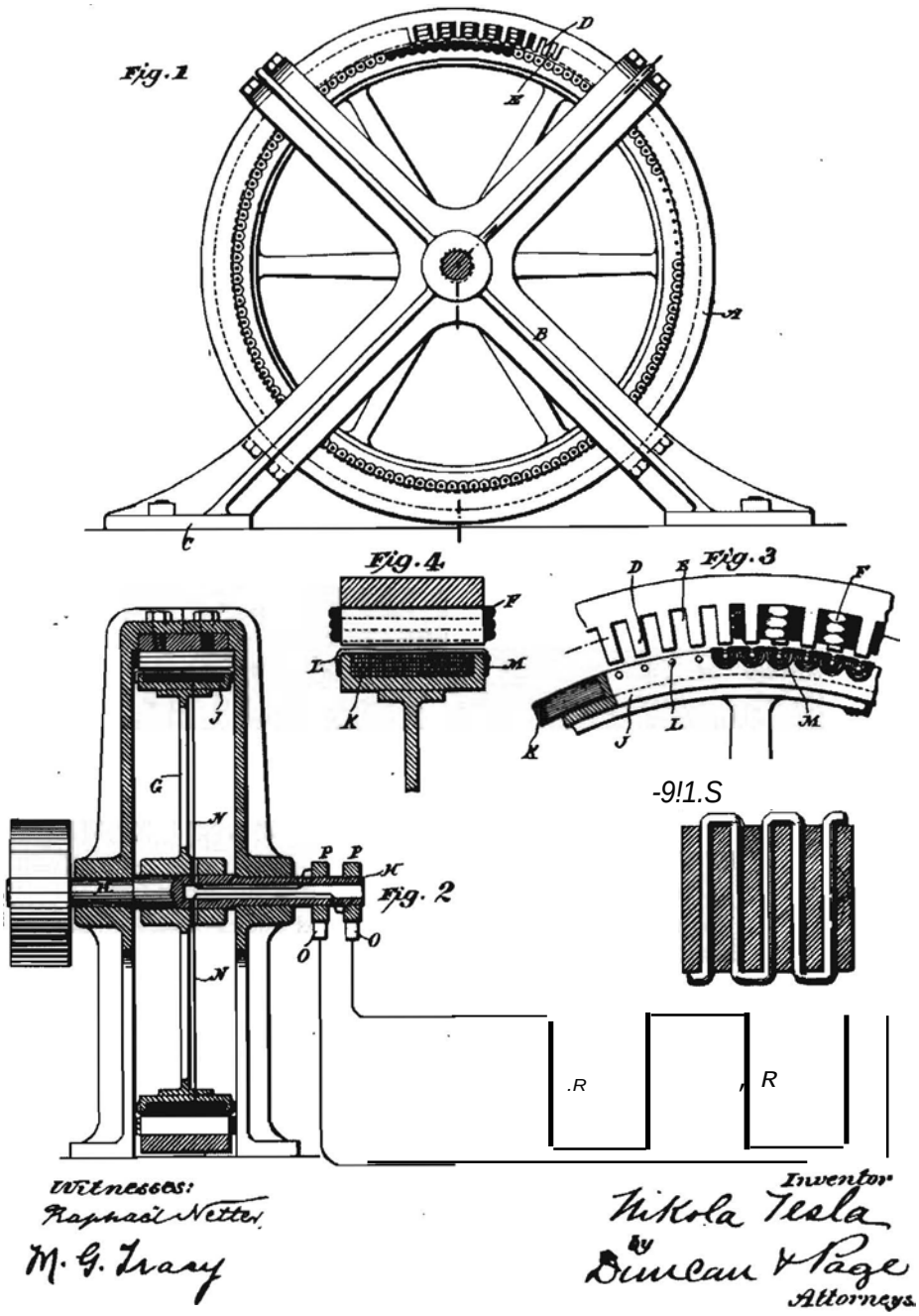


Figure 1.
Diagrammatic illustration of first high frequency alternator with 384 poles, patent application filed October 1, 1890, also in book Inventions, Researches and Writings of Nikola Tesla" by T.C. Martin, published by the Electrical Engineer, New York, 1893, Figs. 199-203, pp. 375-376.

Re to the . 1], I employed a ring of the finest iron, and a steel disc with a peculiarly arranged r , of rotat at 1,400 feet per second, safely. No such veloci has ever been in any alternator. I had, furthermore, an armature resistance in this of only 0.5 ohm. If I would have had, say, 6 ohms, which is typical of such an alternator, the machine would have been burned out. Even at 0.5 ohm, I had a hard time to it when I really had the resonant rise.

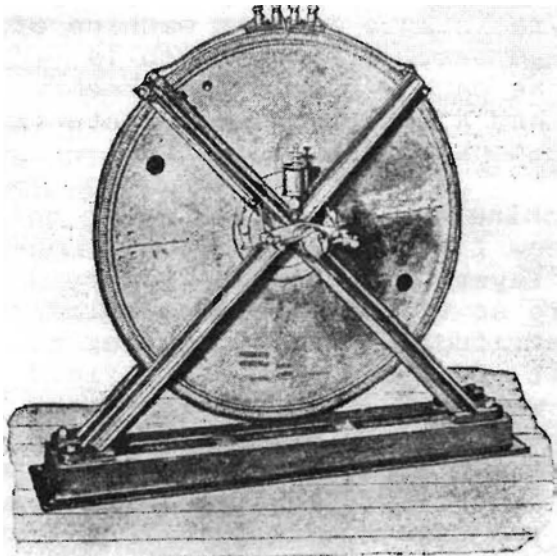
I used a trick [in this] which enabled me to a , and you will see how I accomplished I constructed my rotor with just one layer of thin wire, and by a special process I baked this wire so that it formed a sol mass with the rotor, and the force, no matter how h the , could not tear it off. Then I made my field very small. The result of this was that I had a tremendous ventilation which enabled me to put the field a current of 25 or 30 amperes per square millimeter, and out of the armature I could easily take 30 amperes per square millimeter. You know, in des , if you take out four to four-and-one-half amperes per square mill , that is a performance. I defy anyone to take out of the conductor [of these conventional machines] more than five or six amperes per square millimeter. But, I des this so that I could have 30 amperes per llimeter in the armature and 30 amperes per millimeter in the field on account of the great ventilation

So, therefore, when I show this , I have shown the most ne in wireless that has ever been produced up to this date. People, of to use a turbine, but that is a If I had had a turbine to s done much better. Later on, however, I will show you a machine which I designed specifically for the turbine. I have recently heard that, as a result of [emphasis Tesla , [*] reported that to just the same machine which I exhibited in 1893, with which I showed s to Helmholtz, and which was a of s known all the world over from pictures; have been for years and years but exper this particular field.

This machine 2] was exh ted before the American Institute of Electrical , where I showed my first experiments, and these experiments, as I shall state in a few

* Editorial note: Reference is to John V.L. Hogar, at that time chief research engineer, National Electric Signaling Company, who was one of the driving forces in the of the Institute of Radio Engineers, later its ident in 920. The refers to the work of the General Electric Company's Steinmetz, Berg and Alexanderson, in collaboration with Fes of the National Elect Signaling Company, leading to the production of successful alternators operating to 60 kHz at 100 kW

words, I obtained some striking results, which were the starting point of this whole development.



Fw. 97.

Figure 2.
Photographic view of alternator [shown in Fig. 1]. Illustration from Martin book, Fig. 97, p. 153.

Unfortunately, that [Fig. 2] is a reproduction from the only picture I have. This machine was destroyed in the fire that annihilated my laboratory in the Spring of 1895, and I had nothing left of it but a little piece. That photograph [was] taken from an old, very poor print; but it shows the general arrangement of the machine.

This machine I operated at Columbia College with about 5,000 cycles; later on I attained 23,000 cycles running it at a higher speed, and it was in every way a most satisfactory piece of apparatus. It was used by me in experiments with wireless telephony, telegraphy, and all sorts of experiments until it was destroyed.

When I published the results with this machine, I did not have the courage to run it as high as I wanted to so I operated only at about 3,000 or 3,600 revolutions and then I could get out of it approximately 4 kilowatts. But I could easily get out of it 12 or 13 kilowatts later on.

This large output was only made possible through the tremendous ventilation. I remember that at Columbia College, Mr. [Gano] Dunn, who is now Vice-President of the White Company, I believe, and who was assisting me in the lecture, forgot to turn off the current in the field when the machine was stopped, and if I had not shut it off, the field would have burned out. This high output I could only get through this artifice.

It was a fine machine, and I really do not see how anybody could produce a better device for the purposes of

radio telegraphy. There is no such thing. I have designed other machines which are, perhaps, better in some respects. This machine is extremely serviceable.

There were two striking results which I showed in my lecture at Columbia College, and I will illustrate them because I wish to show these various ideas from their starting point.

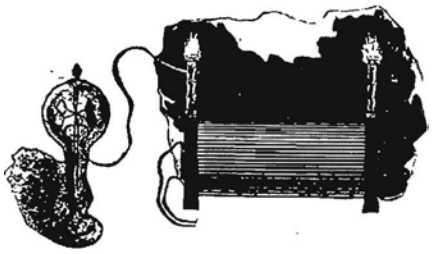


FIG. 114.

FIG. 11.1.

Figure 3.
Light and motive devices operated from this alternator in novel manner. Illustration from Martin book, Figs. 114 and 115, p. 177.

The first result [Fig. 3] was one of the experiments which I at that time showed in a public lecture, motive devices operated by merely connecting them to one terminal of a source of oscillations -- a high frequency coil. I have often been told that my most important results in invention was the demonstration of the practicability of transmitting energy over one wire; because, once we can transmit energy over one wire we can use also the earth, for the earth is equivalent to a large conductor -- a better conductor than copper wire. This was one of the results I got, but the most striking one I will show you now.

This second result [Fig. 4] shows how energy goes through space without any wire. That was a most striking experiment which was repeated all the world over and was published in thousands and thousands of papers. There is a field produced -- of high frequency -- and in this field I hold two tubes of glass in my hands. These glass tubes spring into powerful light. That was an experiment which carried the whole world by storm; but to me it was the first evidence that I was conveying energy to a distance, and it was a tremendous spur to my imagination and to my energy to develop what I had started.

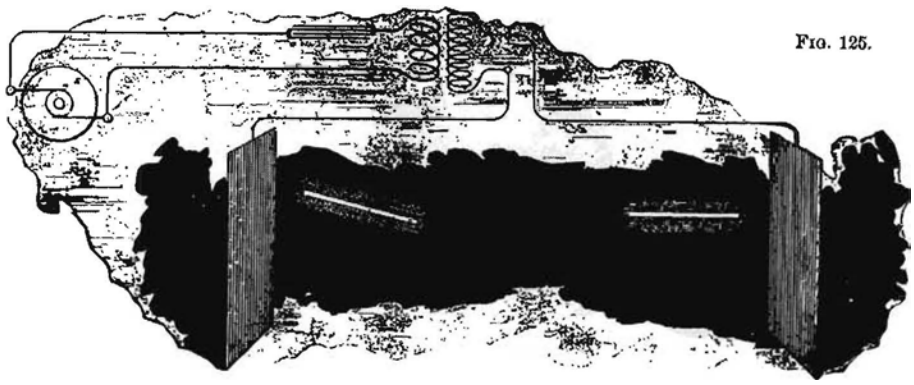


Figure 4.
Most striking results obtained -- vacuum tubes lighted in alternating electrostatic field. Illustrated in Martin book, Fig. 125, p. 188.

II. Experiments with Wireless Telegraphy and Telephony

Tesla

[Diag. 1 of Fig. 5] shows how I used this machine which I have described in my first efforts toward wireless. These experiments were all performed in my laboratory on Grand Streetr but they were subsequently very much refined and carried on in a different way.

Counsel

What date was that?

Tesla

That was in 1891, to my to and to lecture before the s societies there, the Institution and the Institution of Electrical I had a wire run out through the , and on the roof all sorts of devices to const this capacity [shown in the diagrams as an elevated square] The first s was to connect this alternator [shown the agrams as a rcle] with one terminal to the water p and the other end to the antenna.
I had already my lecture at Columbia Col that I could transmit energy through one wire; therefore, I was prepared to find that a current of cons strength could be passed through this wire here the alternator to the elevated , was insulated. My idea at that time was that I would disturb the electrical equilibrium in the ions of the earth, and the equilibrium being disturbed, this could then be ized to bring into operation in any way some instrument. That was what we would now call, s y, ssing forced ions of very high frequency on an antenna. We have introduced the term "antenna" since that time.

The second was as shown [in . 2 of Fig. 5]. You will notice that I have inserted a coil in the circu The necessity for that arose from the fact that I could not get a capacity big enough to tune the prope to the frequency of the alternator. I had in the beginning a very large and you will note that in my expositions of that , from 1891 to 1893, I insisted on the very largest capac that could be because, accordto my which has since, of course, been confirmed, the amount of current that flows such a system is proportionate to that capacity. Therefore, as the effect in the distance is to that current, I had to use a b capacity; but not having a in the building I introduced an coil to tune the s down to the frequency of the that from the ground connection this circuit, , the coil, and

antenna, would have the natural of the dynamo. Next I recognized the necess of introducing a means of adjusting, and it is this [shown in Diag. 3 of . 5].

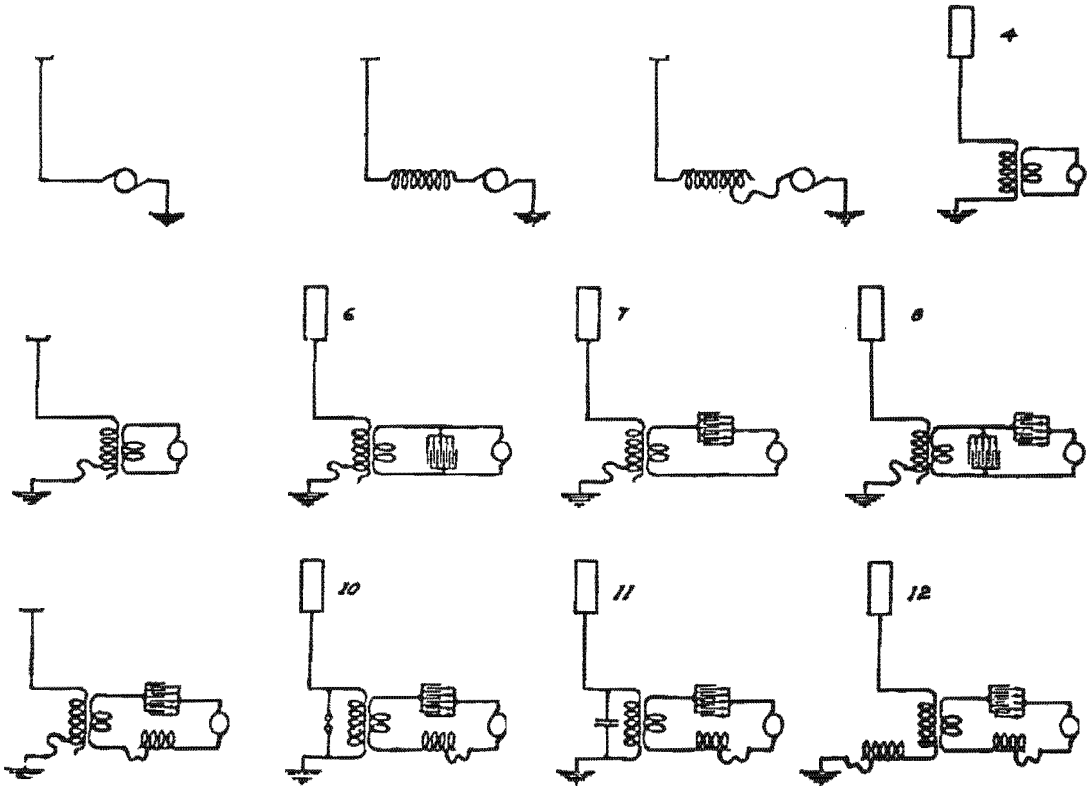


Figure 5.
Illustrating various ways of **the first** AOA1ml!ATI<ts at the a high frequency a1ternator in Street Laboratory: 1891-1893.

Now, I found that notwi I tuned this system successfully, I could not this antenna or these "cans," as we called them at that time, charged su high. But it occurred to me that if I transformed the current and raised the tension of the dynamo in a transformer, I could then charge the antenna to a and produce a greater displacement of electri That resulted in an arrangement like this [. 4 of 5], in I have dynamo supply a a second current of higher potential, and tune and ust the conditions so that this conductor [connecting the antenna to the transfor- mer], the secondary of the , is aga tuned to the the was a fine ; it is the one s that is absolutely essential, because on in the fewest instances can the power of a or be taken up without transformation.

Then, of course, I introduced for convenience the improvement [an coil, shown in . 5, Fig. 5]. adjustable That was the fifth

In order to increase the current in the primary, I adopted an liary condenser ci t [shown in Diag. 6, . 5]. This auxiliary circuit I have, the way, already illustrated in a which was to me in 1891 [U.S. Pat. No. 454,622]. The condenser has the effect of magnifying very much the current, this magnification being proportionate to the ratio of the inductance to the resistance of the circuit, and that rat was very great so I a strong current which enabled to greatly magnify the current in the antenna.

In the next step 7, . 5], I have again f something, but it was not drawn up right.[*] I put a condenser in se s with the primary That is exactly the way operated at Columbia College. At Columbia Col I had an adjustable condenser, purchased from W. Marshall, with very small , which I used in with an inductance coil, and the secondary I was then operating exhibited all the phenomena which have been described in the lecture.

In [Diag. 8, Fig. 5] I show another modification which has certain virtues. I introduced ustable condensers here, with which I could, first, counteract the self-inductance of the dynamo in one circuit, then raise the tension in the reso nant circuit, and then tune the secondary of the sys tern to the same vibration.

In [. 9, Fig. 5], as you see, I came to this arrange ment where I have an ustable inductance and adjustable condenser in the primary, and an ustable coil in the secondary or antenna circuit. That is now a arrangement, and it is very and practical.

In the meantime, as I was deve all this, I had already struck a new line of effort toward producing vibrations; namely, I had developed a system ing me to take ordinary current of any and transform it into any of vibrations I desired, either or undamped. I will dwe l on this [later], but I want to say now that I also operated an arrangement as shown here [Diag. 10, Fig. SJ . I bridged the secondary with an air gap. This I did in studying harmonics. I found that sometimes I could a very strong harmon , particularly, for instance, the third harmonic was often very strong. By this I work with the fundamental tone and with a harmonic, and I made some interesting observations which later on led me to very important inventions.

* Editorial note: Tesla refers adj table primary inductance rather than an adjustable secondary inductance as shown.

[Diag. 11, Fig. 5 is a similar sposition in which I introduced an adjustable condenser, and had the same arrangement in primary

And lly, [Diag. 12, Fig. 5] one of the most common ans which I have been us later in other laboratories - an ustable inductance in the antenna circuit, and an adjustable condenser and ustable in the pr imary circuit.

Counse l

Will you describe, Mr. Tesla, just how far these went into use, and how far they were shown and to others?

Te la

At the on] Grand Street, I had in following men: Mr. Anthony Sz , a electrician and wire man who had been a France and came over in 1884 or 1885, I do not recall now. Then there was Mr. F.W. Clark, a very skilled mechanic, formerly in the of Brown & Sharpe. Bes s these were Mr. Leonhardt, a young Hungari an Paul Noyes, a former employee of the Gordon Press where I him while I was my arc l was city at that tim by the Hierge There was also a man by the name of David sell, a German-American glass blower.

At the time I made these experiments, there were very few of the el that since made a success with wireless in , who would have known much about these things anyway. They had seen me run the up the building they had seen me operate continuous with those machines. I had shown them wonderful results, and had told them all the time that I was going to transmit energy without wire telephone, te , run cars and l s at any distance and that these were the toward s end. How much these men could tell, in the l of the present knowledge, that, of course, I am unable to say; but, certainly, I had of witnesses to follow my and to know what I had been doing.

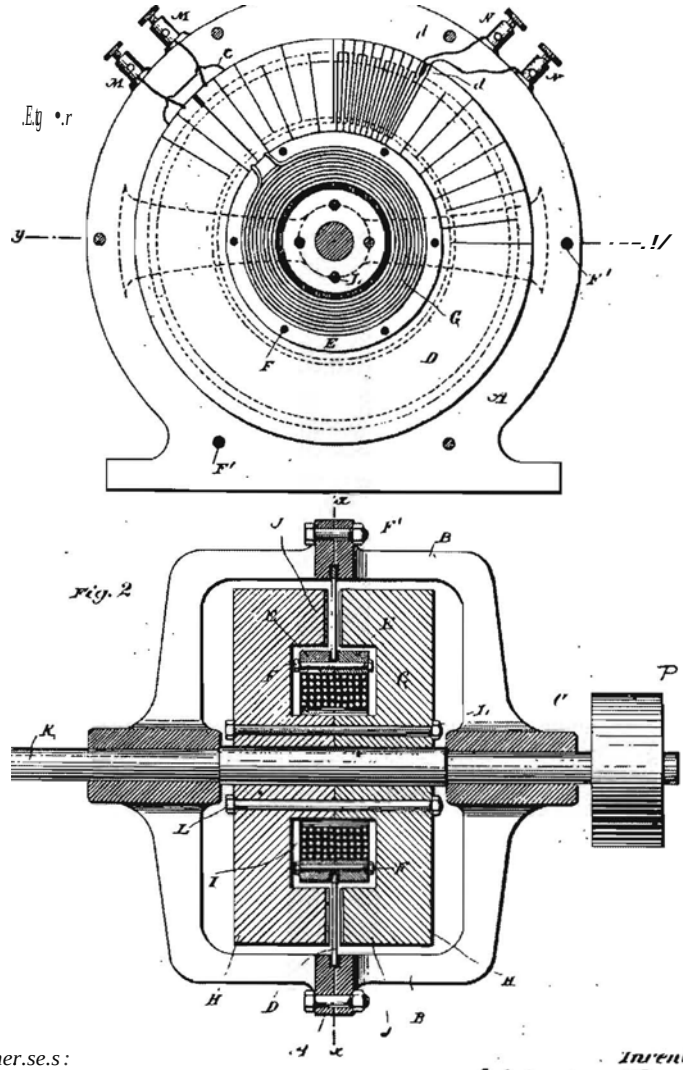
This . 6] I was building while I was carrying on the first machine. As you will note, I had s the wire from the armature. I had taken the f st steel I could and constructed a machine with oppos poles, with what we call a " ff" field, and had done away all moving wire. I intended to connect a turbine and run s machine at a very speed, which I thought might be up to 20,000 revolutions. The armature conductors were sposed in this f and the 1 that was

(No Model.) 2 Sbeets.:....sbeet 1.

N. TESLA.

ALTERNATING ELECTRIC CURRENT GENERATOR.

No. 447,921. Patented Mar. l_O, 1891.



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& 8. .

Inventor
Nikola Tesla
by
Duncan & Page
Attorneys.

Figure 6.
Diagrammatic illustration of the second machine built with no wire on the rotating part, designed for turbine drive, taken from U.S. Patent No. 447,921 of March 10, 1891. Application filed November 15, 1890.

exciting the magnet was the conductors, as seen in this drawing, I had two wires for the and two wires for the conductors. Usually, however, I had six binding posts because I had two ts splaced in the armature.

I have and years in des and I have never lt one machine but that the saw it complimented me on its ss and the s of my design. men were students; not know how to do it. made a machine which had an internal resistance of 6 ohms and to raise the tension one hundred fold. the resistance of my ne was 1/40 of an ohm on wanted to make a short conductor and made a conductor many feet The wire in my machine was but 4 feet So, you see, I had in this machine the t thoughts of design. It could not be any more because I had gone to the 1 ng; limit of tensile st , limit of air space, limit of copper, 1 of every other material. This ne I have used for many years with great success, and I have discovered many, facts in connection wireless by its means, and some of these facts I will tell you.

Counsel

What has happened to that machine?

Tesla

I used it for years and years; used it 1 recently That machine must still be in existence, but with the only fference that I have the number of s. It was to do away with the spark gap. That was an idea that I conceived sometime 1892, but it dragged on 1 a later period. My idea was to construct a machine with a n small number of poles, rotate it at an enormous , and thus generate sudden impulses ch would the same effect as the arc discharge i my so-called "Tesla transformer." ly, s machine had 64 poles. Then [in 1901] I reduced them to 32, and to 16, and that form I have with it any osci lations, continuous trains or undamped oscillations of I desired. That is done a process not yet well only so far that electri ans have produced higher harmonics from low fundamentals; but in that case they have a very small energy. Now, I have perfected a scheme enabling me to take, for , s machine, which will **give** me 3,000 or 4,000 oscillations, and from these oscillations 100,000 [oscillations], and there will be a continuous train of waves.

Counsel

During what years was this machine used?

Tesla

This machine was lt in 189 . I used it continuously certainly, until 1905 or 1906.

Counsel

When was it you reduced the number of poles?

Tesla

I reduced the number of es, I think, in 1901. But then I reduced it for the purpose of currents of higher frequency f had a number of poles, could not realize my because these poles would come in quick succession and ce a rate of change comparable to the rate of change is obtainable by the discharge of a condenser owing to a sudden break of the electric. That is to say, a blow. It has to be a blow, see. I had to place my poles comparatively far , then run them at excessive speed and generate ly few impulses, but each of those impulses are of such tremendous intensity that the dynamo is ical short-ci ted. That gave me a blow which replaced the arc. And then, of course, there to be perfected a scheme enabl me to the energy of the alternator in the most economical manner, in harmonics. That is not known, at least I have not seen ing of that kind in literature, and I bel that if anybody would attempt it without the devices which I have invented, he could not get much of the energy in harmonics.

Counsel

What was the output of that machine in its original form?

Tesla

The of the machine was about 8 kilowatts; but, observe, I did not [then] have the turbine [patented in 1913]. If I had had the turbine, I could have run this machine [at] 20,000 revolutions, and then I would have had a [significantly h] output

[The machine] had a stationary armature and no wire. It was of the finest steel, all stationary, and the current was taken from stat terminals. [It] is the final type which, after all these yea other electricians have come

Counsel

How fast did you run that before you reduced the number of poles?

Tesla

Up to 12,000 [revolutions]. I used this machine in transmission of signals, particularly with the telephone, in a great many investigations, and I discovered a way, for instance, of measuring accurately capacities employing this machine. You know that, normally, the capacity of an antenna cannot be measured very closely. The ablest men [in the art] -- Prof. Zenneck and Prof. Stone -- know how it is. But, with the scheme I have developed, I could measure any capacity. With an antenna of 1,000 centimeters, I can very easily read half a centimeter. [*] There is no method known which would

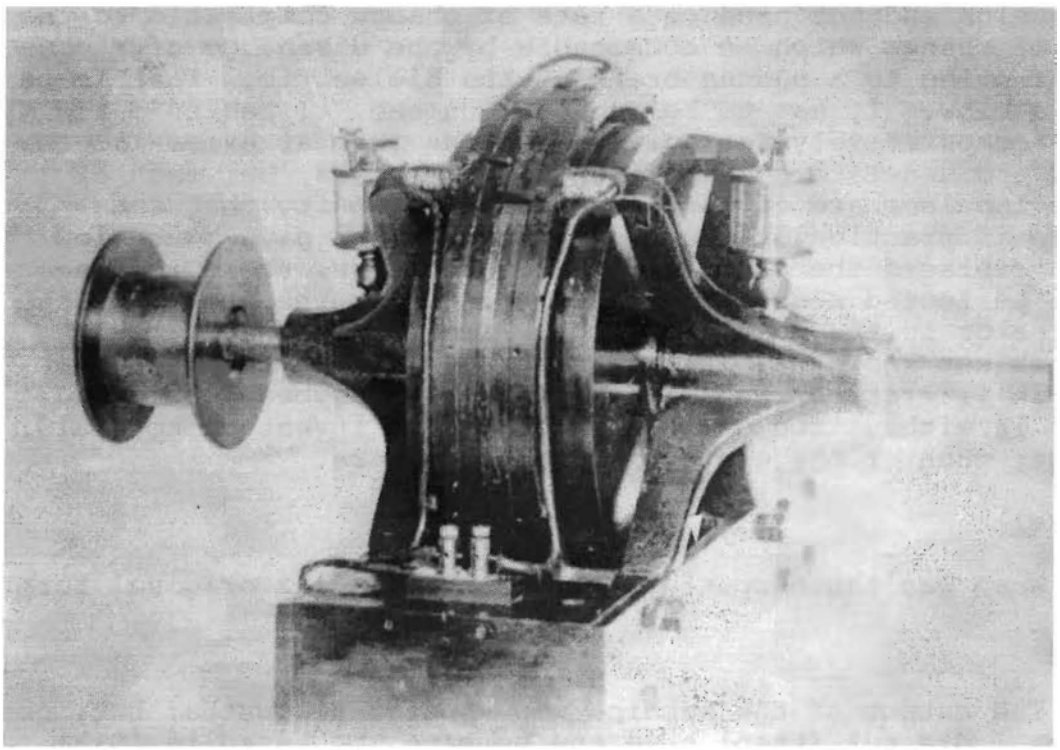

Figure 7.
Photograph of machine covered by U.S. Patent No. 447,921 of March 10, 1891. Application filed November 15, 1890.

* Editorial note: Capacitance values expressed in centimeters are in electrostatic units; to convert from centimeters to picofarads, multiply by 10/9. Thus, in the situation described, with an antenna of 0.0011 microfarad, Tesla could read an increment of 0.55 picofarad.

enable an expert to read as closely as that. I used this machine in as these. It was a very fine of apparatus for all sorts of wireless demonstrations.

In those years, of course, I was developing the princ s. I have shown that five s had to be accomplished before wireless was an art, a real art that could be applied scientifically.

. 7] shows this machine as it actually was. You notice here a wire [point to the] a solid, thick wire. In the form that you see the machine here, I used it for developing harmonics, and in this case I had a condenser soldered to the alternator so that I would a system of no resistance, y. The resistance in my alternator was 1/40 of an ohm. I made a pr -- that seen here -- the resistance of which was also I combined it the condenser and tuned it so that I a current of tremendous volume in that circuit, and then I operated it with the secondary

. 8 shows] another machine. This is the third machine which I built, a larger one. This machine is described by me in the U.S. Patent No. 447,921 of March 10, 1891. It was constructed early in 1891.

Then I made a On my from [in 1892], I took it in a little changed ion in next at 35 South Fifth Avenue. In this , I had the same kind of what we call a "stiff" field -- and in that Ia sc to rotate, which was cut out in a proper way so as to give me a zig-zag conductor. I wanted to have a very l rotor, and thought that this form, rotating, the in [a] plane force, would be a very one to experiment with. The machine was of very much larger capacity; it was built with 480 s, and I could get from it, at comparatively low 30,000 cycles per I could get, in fact, more. This machine was also de fire. Of these three machines which I have the second one was saved from my labo 1895. [*]

* Editorial note: Fig. 7 is from a photograph taken after the laboratory fire. Another machine, which had been on loan to Westinghouse Electric & Manufacturing Company, also escaped the laboratory fire. See Appendix I, Fig. A1-1, for a 1938 photograph.

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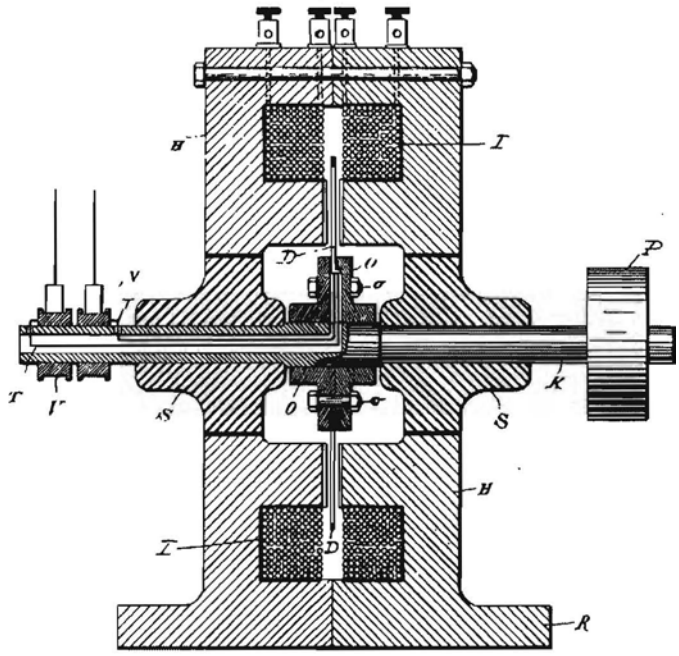
N. TESLA.

ALTERNATING ELECTRIC CURRENT GENERATOR.

No. 447,921. Patented Mar. 10, 1891.

Fig. 3



Witnesses:
Ernest Hopkinson
Frank B. Murphy.

Inventor
Nikola Tesla
by Duncan & Page
Attorneys.

Figure 8.
Diagrammatic drawing of the third and larger machine with 480 poles, taken from U.S. Patent No. 447,921.

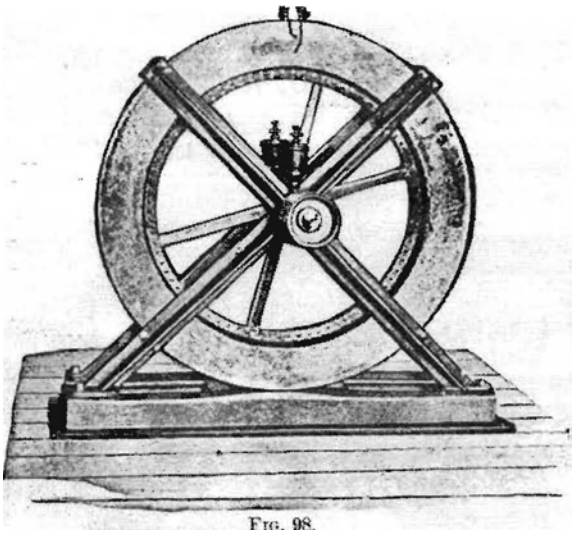


Figure 9.
Photographic view of alternator covered by U.S. **Patent No. 447,921. Illustrated in Martin book, Fig. 98, p. 154.**

[Fig. 9] is a photographic representation of the machine, but it is not so apparent that it was a machine of much larger capacity. I could get out if it readily 25 kilowatts.

Those are not the only machines I built. I constructed quite a number of other high frequency machines. Some of these were obviously small, and I built them chiefly for scientific investigations and for use in connection with receiving circuits.

One of my ideas was to generate at the receiving station oscillations of a certain frequency, and then combine them with an incoming oscillation to obtain beats. And later on, in 1898, I worked this idea into an invention which has been called a "telautomaton,n and which has begun to be appreciated because Congress voted a certain expenditure of money, $750,000, for that machine which I vainly attempted to persuade them to accept.[*] I perfected the machine in 1898, and tried everything in my power to have it adopted; but, everybody was ridiculing my efforts. Everybody said it is impracticable, and after my patent expired only a few months ago, Congress appropriated this sum and I have now the pleasure of simply looking on when others are using my inventions, which I could not persuade people to adopt. This is usually so.

[Fig. 10] shows a type of small alternator, one of two forms which I will show you, that from the constructive point of view, is rather poor. I will admit that. But, it was

* Editorial note: For further remarks on attempts to persuade the U.S. Navy Department to fund the idea, see p. 158.

convenient for me to construct it that way. You see, the magnetic circuit is constituted by the laminated core here, [and] there is an exciting coil. In this picture you will also note the field wires, and the rotor is indicated. With this machine I could get 200,000 cycles per second,[*] very readily, but the output was very small. It was used mostly for telephonic work and for scientific investigations.

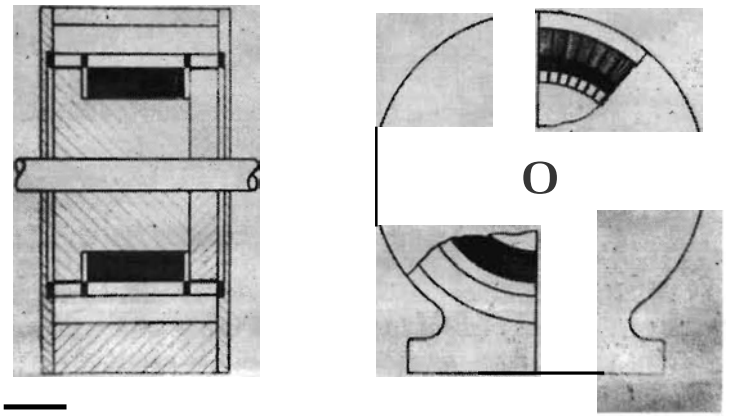


Figure 10.
Small alternator of very high frequency built for purposes of investigation, chiefly in conjunction with receivers. Drawing. Measurement purposes.

This [Fig. 11], if you please, is another small machine which I built, and with it I also obtained a very high number of cycles. You see how that was made. Here [field] I have 8 laminated magnets, and the circuit was formed through here, you see. On the rotating part I had 9 projections so that if,

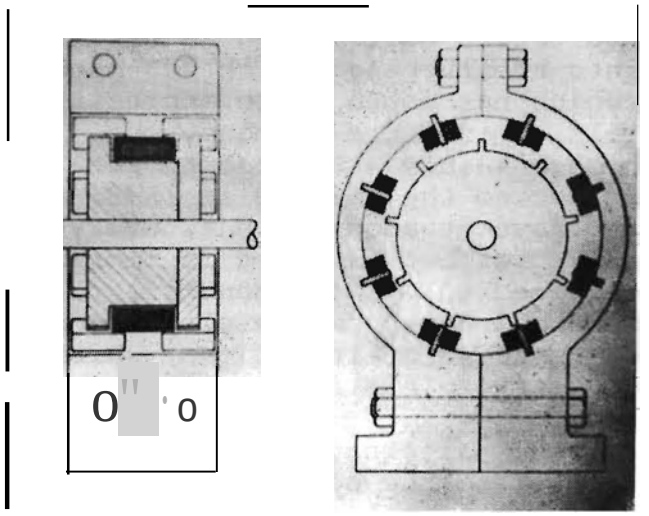


Figure 11.
Another small high-frequency alternator of different construction intended for the same purposes. Drawing. Mercury interrupters, 1898.

* Editorial note: This was accomplished by having the number of field magnets differing from the number of armature projections by one. For the general case, the number of field magnets and armature projections must have an even-odd relation.

for tance, this armature was rotated, say, in the clockwise direction, then the ts will come successively into also in the lockwise direction.[*] But, as you will readily note, I had a very small electromotive force, for the reason that the inductance of seven coils while one was the electromotive force. However, [the] inductance I could overcome resonance, in properly ust capacity, so was no objection, and the machine was extremely serviceable. This machine s, by one revolution 72 impulses 72 , there are 8 poles and 9 projections. That means 8 x 9 = 72. And, of course, being small, light, and balanced, I could rotate it a very great speed and get a very h frequency

Counsel

In what patent was that shown?

Tesla

This was disclosed in my patents on mercury interrupters which were published in 1898. You will find the same idea in my mercury interrupters I used 7 streams of mercury, and 8 projections. In fact, in one I have constructed, I used 25 projectect 24 streams, and I could get a very frequency and unobta e with a very high frequency dynamo. which is

The machines which I have described so far were all of the ; that is, insofar as the mode of fie ex-citation was concerned.

[Fig. 12] shows another type of machine which was patented by me before I had conceived the princ of iting a machine, not rect current, but by current of fferent phase producing a whirl magnetic field, and then rotat in that field an armature and generating currents in the same. This .. has been taken up later by a very able German engineer, Mr. Gol , and today it is known as the Goldschmidt machine. Of course, mentions me at all, and I suppose is in wireless as in love and war. But, I gave the of these machines, and I had several of them with which continuously.

There is s to be [about this type of machine]. When you rotate the armature in the direction of the rotat s, but a velocity, then it is a machine which has the field excited by a simple alternating current;

* Editorial note: For the case where the number of field magnets is 8 and the number of armature projections is 7, resulting in 56 impulses revolution, and the armature is rotated in the clockwise direction, the magnets will come success into play in the counter-clockwise direction.

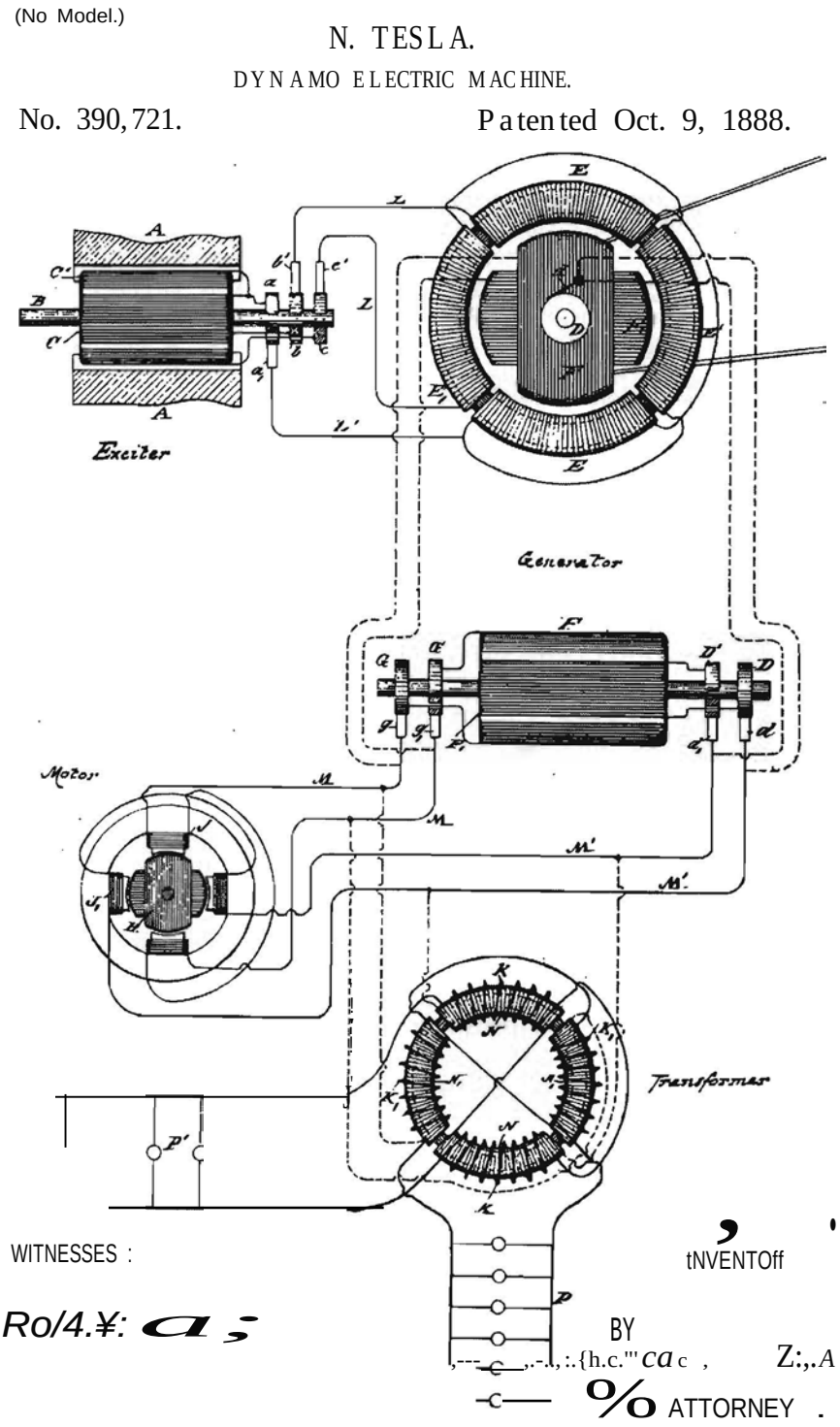


Figure 12.
Diagrammatic illustration of another type of machine with rotating magnetic field excitation, as described in U.S. Patent No. 390,721 of October 9, 1888. Application filed April 28, 1888.

when you rotate it in the other direction, then the rotat field really comes in, and you obtain a higher frequency. you rotate the field just as fast one way If rotated the other way, you have then, for as the armature s example, the frequency

The objection to s machine I found to lie in the fact that the current is not strictly s You see, when flux in the f varies harmon there are two inductions; one is the induction due to the motion of the wire across the field and the other is the induction to that taking place a static transformer. This latter is proportional to the sine, the other is onal to the square of the s , and the result is that we get a little storted curve. Nevertheless, the is applicable, and [it] has been ied Golds commercial machine.

Now I am to a very wonderful discovery which made in connection with high frequency alternators, and I do not believe that there is a man in the cal profession today who dreams about it; not one. This scovery to me that, without further provision, was impossible to use frequency alternator in wireless work that required any kind of fineness; and I made this scovery in the following way. I was operating with three alternators in my laboratory at 35 South Fifth Avenue. I would run [any] one o the machines, tune a circuit, then go around the ci and the hum of the alternator in my tuned circuit, and from this note the intens of could judge the of the devices that I was using. That was a very convenient way; I did it cont I most between the 1 on South the Hotel Gerlach on 27th Street, near Sixth Avenue, where I was s p

While I was ca on this work I was perfecting methods and for attunement, and I noticed that lly could not get as results as before. I could not understand this. But after a few of invest , one happened that I was a note on the of the Gerlach could not get hum of the alternator. I was giving it up, when all of a sudden out it rang very sharp and clear, and was off , as though a wire had been broken. s to myself, a has been broken some- where in the ci t and went down to the laboratory where I examined all care lly. But eve was in order. Then the idea flashed upon me that my circuit was sharply attuned, and the alternator was not one but many frequencies; the alternator was all changing speed, like every alternator does. It does not one frequency, it s many frequencies.

Now, I solved that problem in 1898, and I will tell you how I solved it. I said to myself, here is a generator that gives a dozen different frequencies, but very closely related. They follow one another in succession. How am I going to get selectivity, and at the same time have a perfect response? I solved this through what I term the principle of individualization. An ordinary circuit has one characteristic; it responds to a certain note. An individual has more than one characteristic; [he] comprises many in combination. Similarly, I combine several circuits and depend on the cooperation of these circuits to operate my device.

My first step was to tune several circuits very closely together, so closely that they would pick up [any] of the frequencies within the range of the change of the alternator [speed], and I operated with all these circuits on my receiver. The moment I used that kind of a circuit, I found that I got very clearly the note of the alternator because my receiver was responding to any of the frequencies which were produced. On the other hand, when foreign frequencies would come in to disturb, I would only get a partial effect, as my normal effect was due to all the frequencies combined, whereas the outside effect was due to just the one frequency. I presented the same principle in a lecture before the New York Academy of Sciences on April 6, 1897, but which was not published.

There were certain steps to be accomplished, [however,] before the wireless could be on a really practical and scientific basis. The next step to accomplish, after all had been done, was to design an apparatus which will exactly suit the earth; that is, which will give the proper wavelengths suitable for it, and will also be in all other respects adapted to the physical conditions of the globe on which we live, and to the place on which the plant is erected. The earth is not a sphere; it is an oblate spheroid, owing to the effect of centrifugal force. Now, it makes all the difference whether a scientifically correct apparatus is placed in a northern region, near the pole, or near the equator, because the length of the conductor is not the same.

In the account of the experiments and machines which I [have earlier shown], I hope I have proved that those machines represented the farthest advancement in the art, not only of that time but of the present day. Not that I would say I was a better designer -- nothing would be further from my mind. I simply mean that my followers did not require the limitations of frequency, and I have stuck to those designs which were most efficient. Alexanderson said,

> "We are compelled to go to the very frequencies that you [i.e., Tesla] used in your earlier demonstrations."

There were reasons why I made machines of low frequency

in my experimental work, why I stuck to these frequencies which I have used in my early lectures and public demonstrations. Firstly, because such a machine can be efficiently built for high output, which a machine for 200,000 cannot. Secondly, the waves which are generated were less absorbed because they are of lower frequency. They went to greater distance; the effects were greater. But there was still a third reason: Whenever I received the effects of a transmitter, one of the most convenient and simplest ways [to detect them] was to apply a magnetic field to currents generated in a conductor, and when I did so, the low frequency gave audible notes.

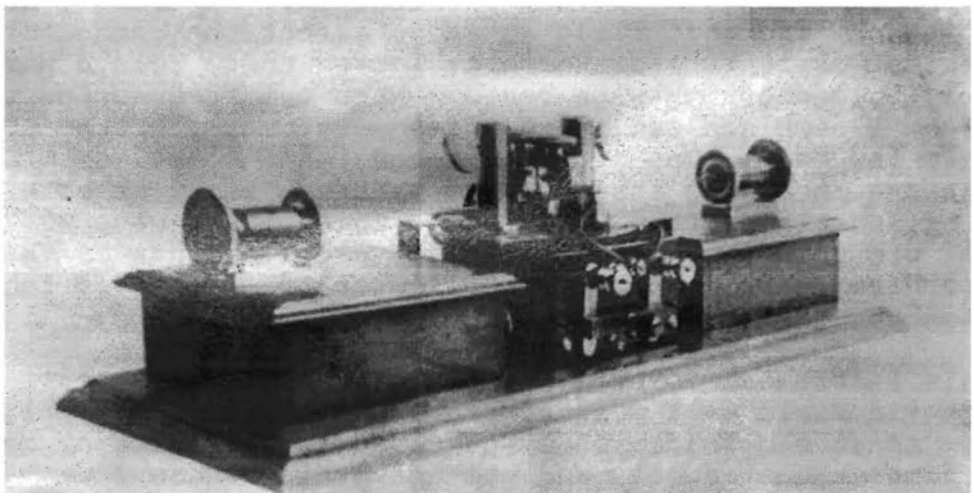


Figure 13.
Instrument to receive radio waves of 1896-1899 structure.

One of the simplest devices I used in my experiments between my laboratory on South Fifth Avenue and [at] the Gerlach Hotel, and other places in and outside the city, was an instrument constructed in 1896 with a magnet which sometimes was so designed as to give me a very intense magnetic field up to 20,000 lines per square centimeter. In this [field] I placed a conductor, a wire or a coil, and then I would get a note which I amplified and intensified in many ways. From the characteristics of the audible note, I would immediately judge the quality of my apparatus.

When I speak of an audible note, I mean a note audible in a telephone as produced by the diaphragm of a telephone, or by a vibrating wire within the range of audibility.

[Fig. 13] shows the general arrangement of [the receiving] apparatus.[*] Two condensers are the boxes at each end,

* Editorial note: Also see discussion in association with Fig. 94, p. 162.

and in the center a coil, or two coils, according to necessity, with which I produced a strong magnetic field and [placed] in it a wire. These condensers and the wire form a circuit which I tune. The condensers are of comparatively large capacity because my conductor is so short. I usually would transform the current in the receiving circuit and make as close a connection as possible and then tune the circuit to the vibrations. I would also mechanically tune the wire, according to the frequency, to the same note or to a fundamental.

This machine was suitable for transportation. I could put it under my arm with a couple of batteries. I had relays, which were very big, in which I produced (for stationary work) a very intense magnetic field so as to affect the conductor by the feeblest current. Furthermore, I used these relays particularly in connection with beats. When the frequencies were very high, I combined two frequencies very nearly alike. That gave me a low beat. One of the frequencies I sometimes produced at the receiving station, and at other times at both the receiving and transmitting stations. This always gave me the means of producing an audible note. I used machines of this character from 1892, but this specific instrument in my labo- ratory on Houston Street.

This instrument comprising a magnet and chord or coil in the magnetic field -- I mean a wire or coil in the magnetic field -- is an old academic device, used in all sorts of demonstrations at the schools and the university where I was studying. My professor of physics has had similar instruments with an adjustable spring and magnet, and I have employed them in assisting him. There is nothing novel in the idea. The only novelty was that I kept my alternation low and I made this arrangement with conductors to tune.

It was very convenient for producing audible effects because, if I used other forms of a receiver, I had a reading which was not at once translatable. If I listened to a note, I could immediately tell the quality of the transmission. For instance, I would tune a circuit in my laboratory, take it out to another building, and I would receive the signals; and from the quality of the signals I would see how I was progressing.

Counsel

In the experiments that you have spoken of with the instrument of which the picture is shown [as Fig. 13], what were the distances between the transmitting and receiving stations?

Tesla

The distance at that time, and I think the greatest distance at which I ever received signals from the Houston Street

laboratory, was from Houston laboratory to West Point. That is, I think, a stance of about 30 miles. This was prior to 1897 when Lord Kelvin came to my laboratory. In 1898 I made certain demon before the Examiner-in-Chief of the Patent Office, Mr. See and it was upon showing him the practicabi lity of transmiss patents were granted to me.

Counsel

At that experiment were you at the Houston Street end or at the West Point end?

Tesla

In that continuous of oscil-lations and went with the instrument to West Point. I did s two or three s. There were no s s actually en. I s the note, that was for me just the same.

Counsel

That is to say, you not make and break the circuit?

Tesla

No, and I did not receive any signals but I did receive the audible notes in telephone receiver

Counsel

At West Point?

Tesla

Yes, in or about the year 1897.

Counsel

And did the continuous tran ssion thus received start from Houston Street?

Tesla

Yes.

Counsel

Was one of your employees there?

Tesla

Yes, the employees knew that I was running the apparatus

On frequent occas s, I would a to make and break the circuit. Then found it was much s er to just let the apparatus run and the notes.

Counsel

What was the distance between transmi ssion and reception?

Tesla

That was the distance from my laboratory on Houston Street to the Gerlach Hotel.

Counsel

Is this instrument [Fig. 13] the same general type which is coll ly known as a string galvanometer?
oquial

Tes

No, it is not. Such a scientific instrument is used in the schools, for instance, in various kinds of demonstrations

Counsel

In 13], is that [wire) shown on the apparatus in series in the , and is it in of the ?

Tesla

Yes. had a coil, or a s wire, in the field -- it made no fference. It was the react of the currents on the f ld that produced the note.

Counsel

What is the furthest distance from your source of transmission that you u the apparatus of this character?

Tesla

I think I used this once at the Western Union Building -- on the roof -- in company with Mr. Alfred K. Brown. That would be a stance of 2 miles.

Counsel

What was character of the recepti on?

Tesla

Just the alternator was run and you could hear the note of the same when rcuit and st was tuned to

the same frequency

Counsel

Did you hear it?

Tesla

You could hear it all over the place

Counsel

You mean you did not have to have your ear in the telephone to hear it?

Tesla

No, not at all; I could hear it from a distance. The vibrations were very vigorous

Counsel

About when was that?

Tesla

That must have been either late 1896 or early in 1897.

Counsel

What was the frequency of alternation that you were using?

Tesla

The [illegible] might have been something like I should say - in the neighborhood of 5,000.

Counsel

Was there [illegible] hidden about these uses, or were [illegible] open so that anyone could use them?

Tesla

There were thousands of people, [illegible] shed men of all kinds, from [illegible] and greatest artists and scientists in the [illegible] down to some old chums of mine [illegible] mechanics, to whom my laboratory was always open. I showed it to [illegible]; I talked [illegible] about it.

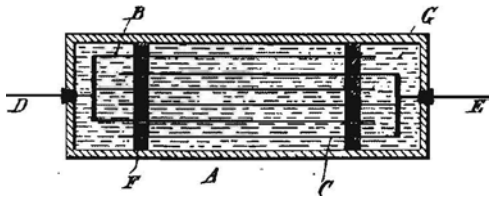
lia Model.)

N. TESLA.

ELECTRIC AL CONDE NSE R.

No. 464,667. Patented Deo. 8, 1891.

>J'!/·1



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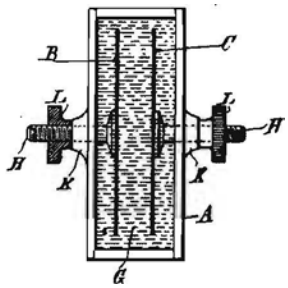

Witnesses:
Raphael Netter
Frank B. Murphy.

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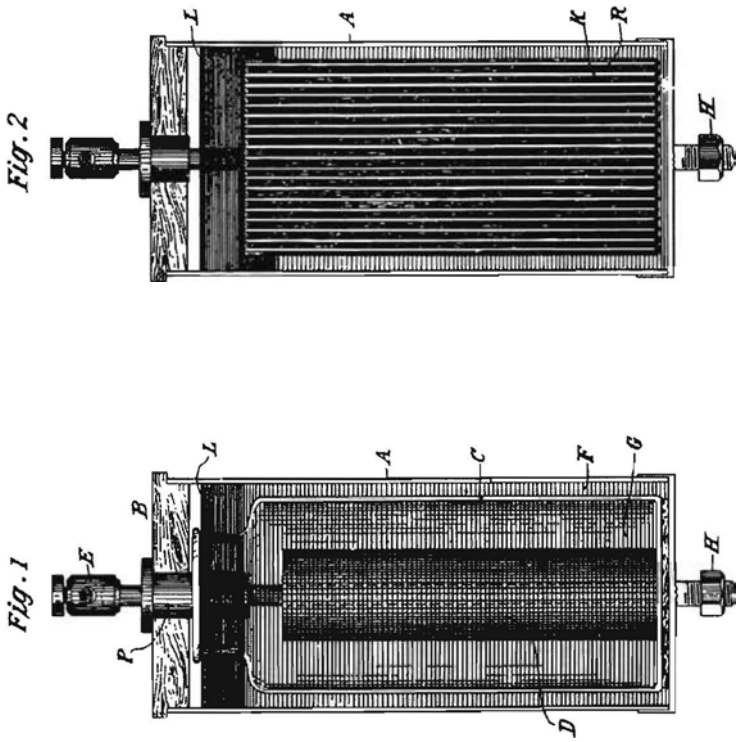
Figure 14.
Construction described in U.S. Patent No. 464,667 of December 8, 1891. Application filed August 1, 1891.

. (No Model.)

N. TESLA.

ELECTRICAL CONDENSER.

No. 567,818. Patented Sept. 15, 1896.



WITNESSES

Raphael Netter

Harry W. Cusper

INVENTOR

Nikola Tesla

BY

Kerr, Curtis & Page

ATTORNEYS

Figure 15.
Forms described in U.S. Patent No. 567,818 of September 15, 1896.
Application filed June 17, 1896.

Counsel

When you said, "5,000," did you mean cycles or alternations?

Tesla

I mean cycles. On another occasion I have also operated going a little further into showing the reactions of high frequency currents upon magnetic fields -- I have operated motors, and at that time I have stated what frequencies had to be used in order to produce these rotations, which are, of course, due to reactions of the currents on the field. I have pointed out, in the Martin book, that they should be from 5,000 to 10,000.

I would like to proceed, without going into details making this too hard to follow. I would like to have this simply a clean story with only the salient facts pointed out, and not a maze of little details which would complicate it and spoil the harmony. Proceeding, then,

[Fig. 14] shows a form of condenser in which I have boiled out all the air bubbles, and the next drawing [Fig. 15] shows another form.

I have made a notable advance in this condenser, with which I have operated in my laboratory on Houston Street and in experiments at my wireless station in Colorado. This is the most efficient form of condenser known, showing practically no loss whatever. And it is only with this condenser that really very fine results are obtainable because, even if we employ mica condensers immersed in oil, or glass of the best kind coated with tinfoil, we do not get the results which we get with this condenser, and they are obtained by substituting electrolyte for the metallic coatings as before. I used electrolytes which were especially adapted for that, and cheap -- for instance, like a solution of ordinary salt. It is cheap and readily obtainable.

[Fig. 16] shows a type of this kind of condenser in finished form as I used them in my laboratories. There were many of these adapted to be secured on the bottom. They were readily transportable. Occasionally, I took some of these condensers with me when I experimented.

[Fig. 17] shows another improved form of condenser. I do not have a photograph of a finished apparatus and this is a sketch that was made in 1896 shortly before a condenser of this kind was constructed. That was a condenser intended for high electric pressure and the insulation was obtained through the air. It was built for 500 atmospheres air pressure safely. There is a reference in my writings where I point out

the use of compressed air, and therefore there was no creative effort involved in any patent in that direction by Fessenden and others.

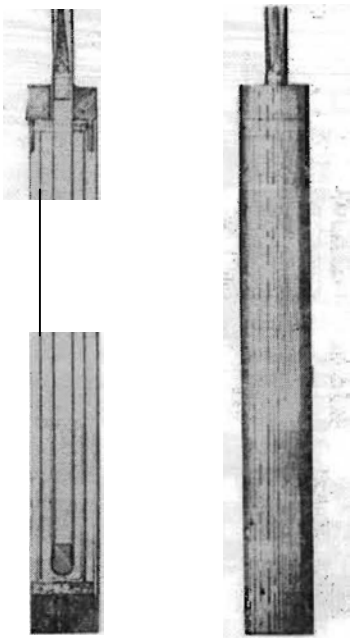


Figure 16.
Improved form of electrolyte condenser as used in laboratories on 35 S. Fifth Avenue and 46 E. Houston Street.

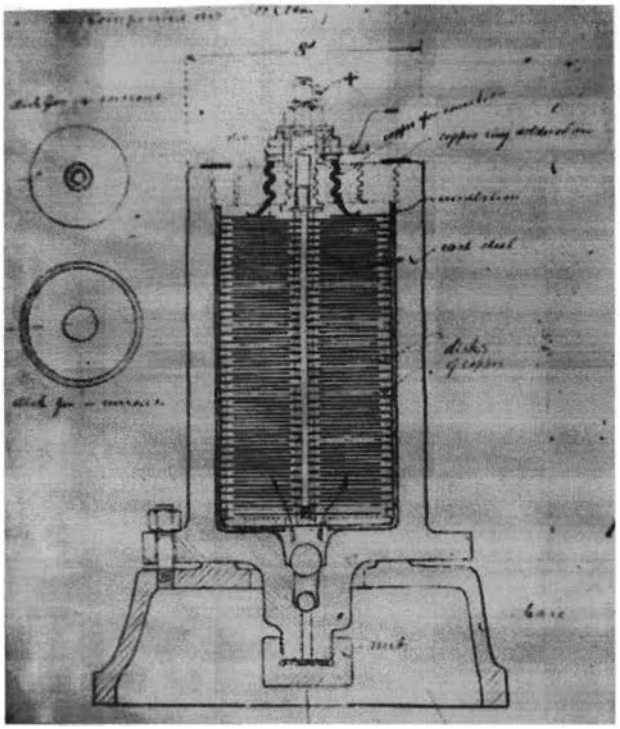


Figure 17.
Form of condenser with air under great pressure as dielectric used at the same period, subsequently patented by others.

The apparatus shown by the drawing [Fig. 18] which I designed and installed was for years employed to practice this process of manufacture. This process is [now] universally adopted; everybody uses it. There are millions and millions involved in it. If I could only get one cent for every apparatus that is manufactured in accordance with my invention, I could erect a building like the Woolworth and not feel the expense.[*] Everybody uses it, but nobody says thanks. That was arranged for what was called a vacuum pressure process.

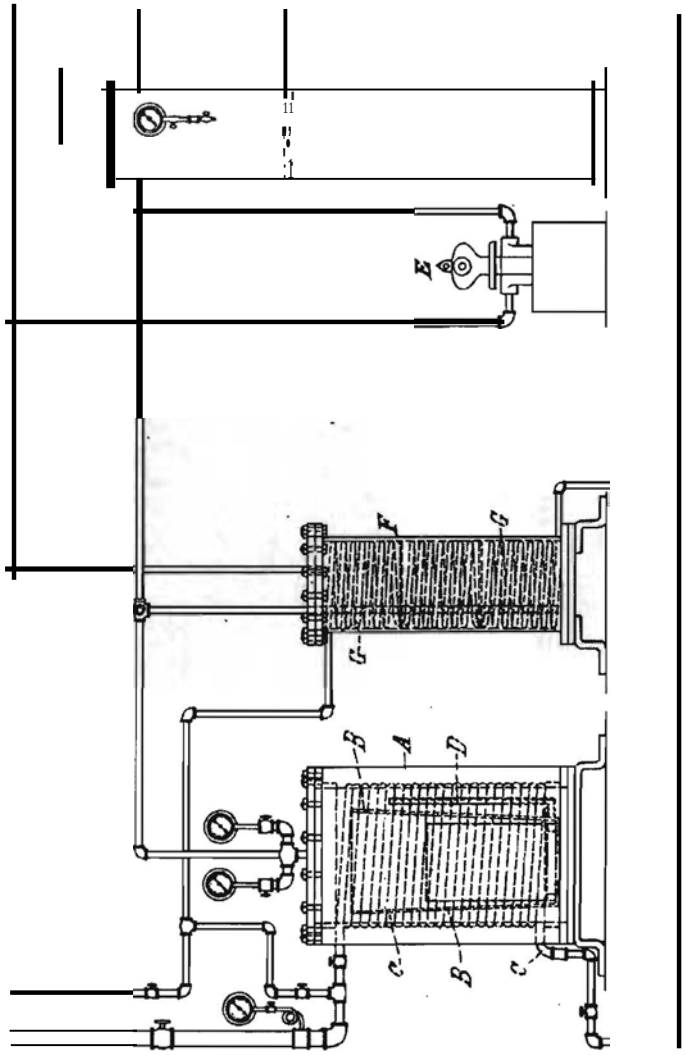
* Editorial note: At the time of this interview, Tesla had shortly before removed his offices from the Woolworth Building where they had been established for one year.

(No Model.)

N. TESLA.

MANUFACTURE OF ELECTRICAL CONDENSERS, COILS, &c.

No. 677,671. Patented Feb. 23, 1897.



WITNESSES

Edwin B. Hopkinson,

Benjamin Miller,

INVENTOR

Nikola Tesla

Y/7

ATTORNEYS.

Figure 18.
Apparatus for manufacture of condensers and coils to exclude air as described in U.S. Patent No. 577,671 of February *23,* 1897. Application filed November 5, 1896. The whole manufacture is now dependent on this or similar processes, and many patents have been secured by others.

Steinmetz says,

"No, I have found a better way. I just the thing in kerosene "

It is thin and penetrates in the inside and, of course, he s a patent

I am [next] coming to a in my life which was very fruitful. I was absorbed in the development of a new type of generator. The solution, which enables me to use the high frequency alternator ical , was not yet found at that time. I saw that the high was not usable for any finer work.We were toward perfection and that if we attained it, the alternator would be s y thrown away as an absolute useless rument. That was my conviction, and I to results I subsequently reached with the alternator in another way. To this end I built a many machines of a novel , which I called oscillators -- mechani electri oscillators it is with these that my best results in the investigations of these le to wireless in many of phases, were obtained

III. Mechanical and Electrical Oscillators

Tesla

The photograph [Fig. 19] shows my earliest experimental oscillator which I used to generate electrical vibrations.

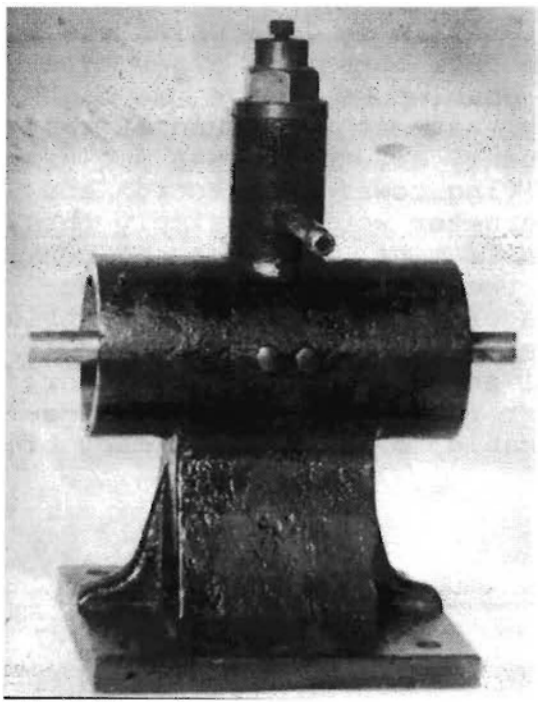


Figure 19.
Simple mechanical oscillator used in first experiments.

My first efforts were to produce this vibratory mechanical motion, then attach to this system an electrical generator; that is, I would attach a conductor to it and vibrate it in a magnetic field. That was the first step in the evolution of the idea. The machine is shown here without any attachment.

The drawing [Fig. 20] illustrates the next advance in the evolution of the idea. I have produced isochronous oscillation, and now I am applying considerable power to the piston to develop energy in this electric system. It is the energy of the mechanical system which produces the electrical energy in the circuit, but the vibration is controlled by the tremendous force of the air spring against which the small impressed force is nothing. In this manner, then, I first obtained isochronous electrical oscillations, which no transmitter made today furnishes except my own.

The drawing [Fig. 21] illustrates the next improvement. I conceived the idea, instead of using a mechanical air spring

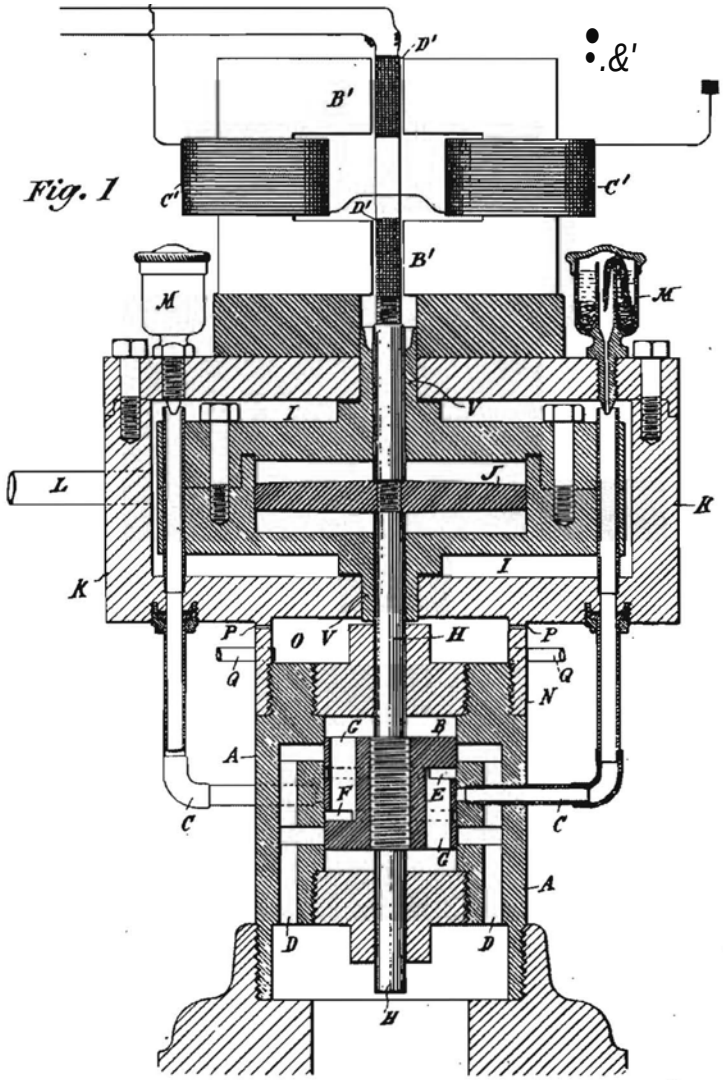
(.No Model.) 2 Sheets-Sheet 1.

N. TESLA.

ELECTRIO GE NER ATOR.

No. 611,916. Patented Jan. 2, 1894.

Fig. 1



Witnesses
Raphael Netter
R. F. Gaylord

Inventor
Nikola Tesla
By his Attorneys
Duncan & Page.

Figure 20.
Mechanical oscillator with air spring combined with electric generator as shown in U.S. Patent No. 511,916 of January 2, 1894. Application filed August 19, 1893.

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N. TESLA.

ELECTRIO GENERATOR.

No. 511,916. Patented Ja.n. 2, 1894.

FIG. 2

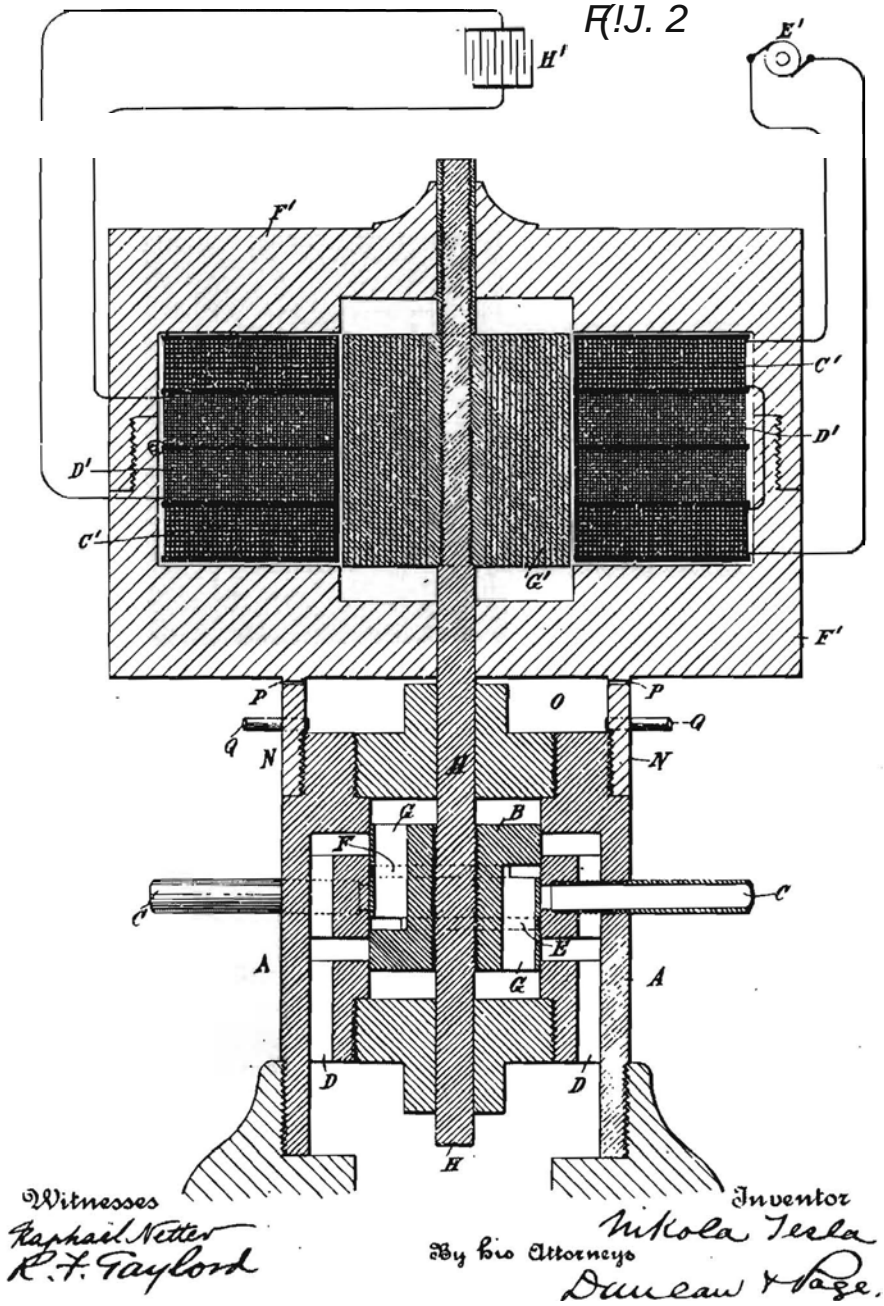


Figure 21.
Another mechanical oscillator with controlling electromagnetic system described in U.S. Patent No. 511,916 of January 2, 1894. Application filed August 19, 1893.

for exercising the controlling force, to obtain it electrically. Boiling water was employed to keep the temperature of the air spring perfectly constant and the oscillations isochronous. I constructed an electromagnetic field so that it could be used for isochronous control. This invention I also exhibited at the Chicago World's Fair where scientific men, Helmholtz and others, saw it. The magnetic field [of the] core generates currents in the coils. Two coils are used for excitation and two for induction. I connect a condenser to the latter and adjust the period of the electromagnetic system, comprising the condenser and the self-inductance, so that it is just suitable for the conditions under which I wish to operate. Then the magnetic system, having a constant period of vibration, controls the admission of the fluid to the piston, and when I use the currents I find them perfectly isochronous. I can run a clock with them and it will show correct time. The vibrations obtained in this way would not vary one-millionth of a second in a thousand years.

The photograph [Fig. 22] shows another form which I also exhibited at the Chicago World's Fair. There is a round coil, you see, in the field; on the other side is another such coil. I performed very curious experiments with this machine. For instance, among other things, I produced direct currents without commutation.

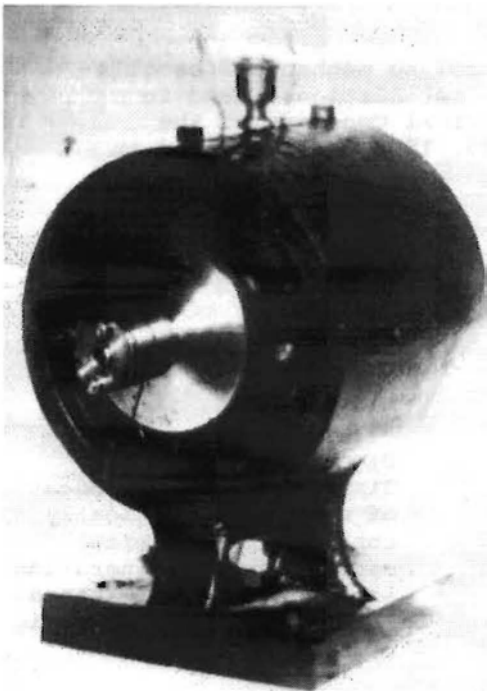


Figure 22.
Another type of small mechanical electromagnetically controlled mechanical oscillator.

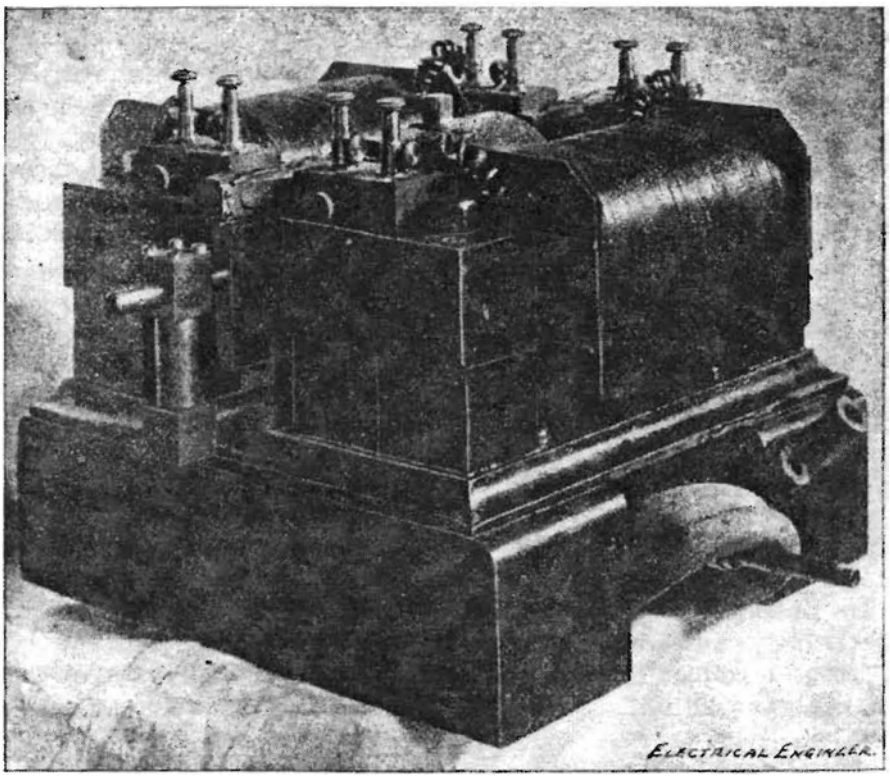
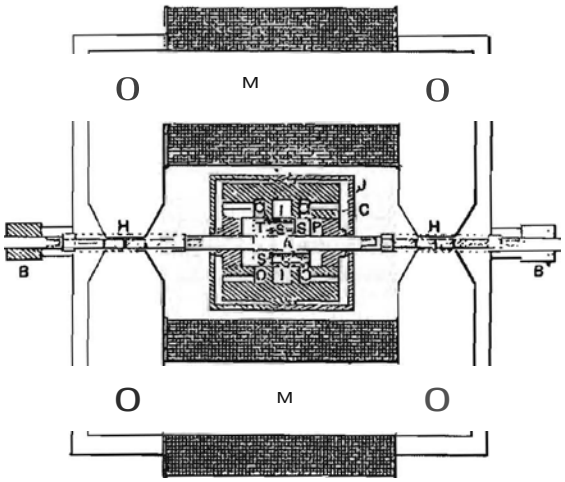


Figure 23.
Large electromagnetically controlled mechanical oscillator for generating isochronous oscillations, used in demonstration before the Electrical Congress at the Chicago World's Fair, August 25, 1893. Illustrated in Martin book, Fig. 312, p. 490.



Fxa.31S.

Figure 24.
Diagrammatic representation of electro-magnetically controlled mechanical oscillator for generating isochronous oscillations. Shown in Martin book, Fig. 313, p. 491.

Here [Fig. 23) is, I might say, the first corrunercial oscillator which I designed and constructed and which was exhibited at the Chicago World's Fair. With this, I also performed many experiments. As you will observe, I have a powerful magnet in two parts for producing a strong field on both sides, and in it are conductors which are vibrated by an engine in the center.

That [Fig. 24], as you see, diagramatically represents the arrangement. Here [at the center] is my little engine, and here [at H and M] are the conductors and the magnets producing a very strong field. I observed very curious phenomena with this machine, which I subsequently turned to great advantage.

We are now coming to a form of machine which was on an industrial scale.

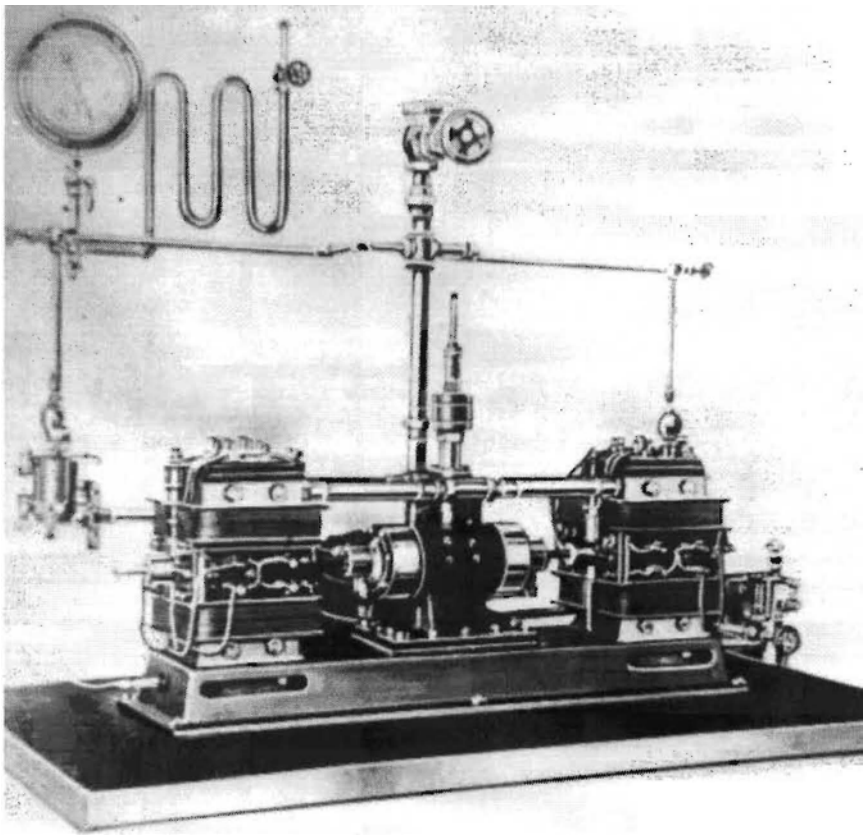


Figure 25.
Double compound mechanical and electrical oscillator for generating current of perfect, constant, dynamo frequency of 10 horsepower. (Article by Martin [Tesla's Oscillator and Other Inventions"], Century Magazine, April 1895, Fig. *2*, p. 921.) (Built in 1893.)

With this one [shown in Fig. 25], I operated normally in my laboratory at 35 South Fifth Avenue. It was primarily installed there. The Babcock and Wilcox people had the kindness of specially constructing a boiler for me which could stand a pressure of 1,000 pounds. This machine was capable of developing up to 10 horsepower. It was, as you see, composed of two magnets or magnetic fields and a compound engine for imparting vibration to the conductors in the fields. It was controlled by an isochronous oscillator and, in addition, I tuned the electromagnetic system when I operated .

Counsel

What frequencies were developed?

Tesla

Those were low frequencies, but I will tell you how I solved the problem of high frequencies.

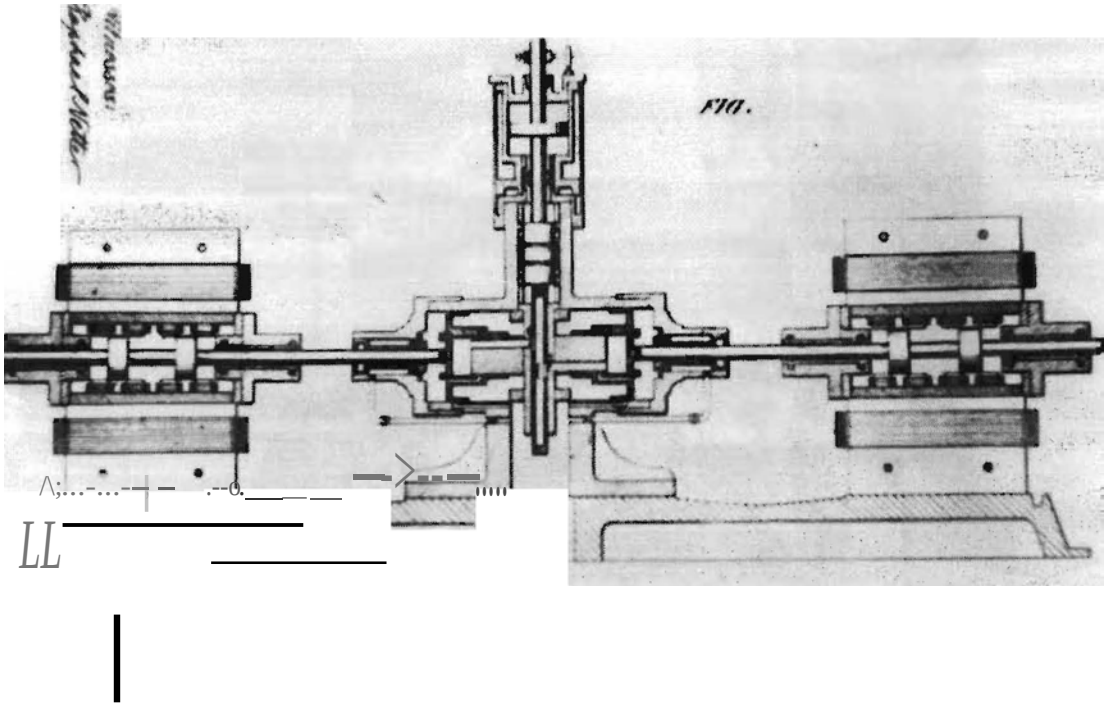


Figure 26.
Diagrammatic representation of double compound mechanical and electrical oscillator for generating currents of perfectly constant dynamo frequency. Shows mechanical and electrical parts.

Counsel

When was that machine developed, Mr. Tesla?

Tesla

This machine was built in 1893 and was operated until May 1895, when a fire destroyed my laboratory. You will appreciate better this photograph [Fig. 25] if I show this drawing [Fig. 26] that was made for the patent specification at that period.

I come now to a large machine which was built in my laboratory on Houston Street. Immediately after the destruction of my laboratory by fire, the first thing I did was to design this oscillator [shown in Fig. 27]. I was still recognizing

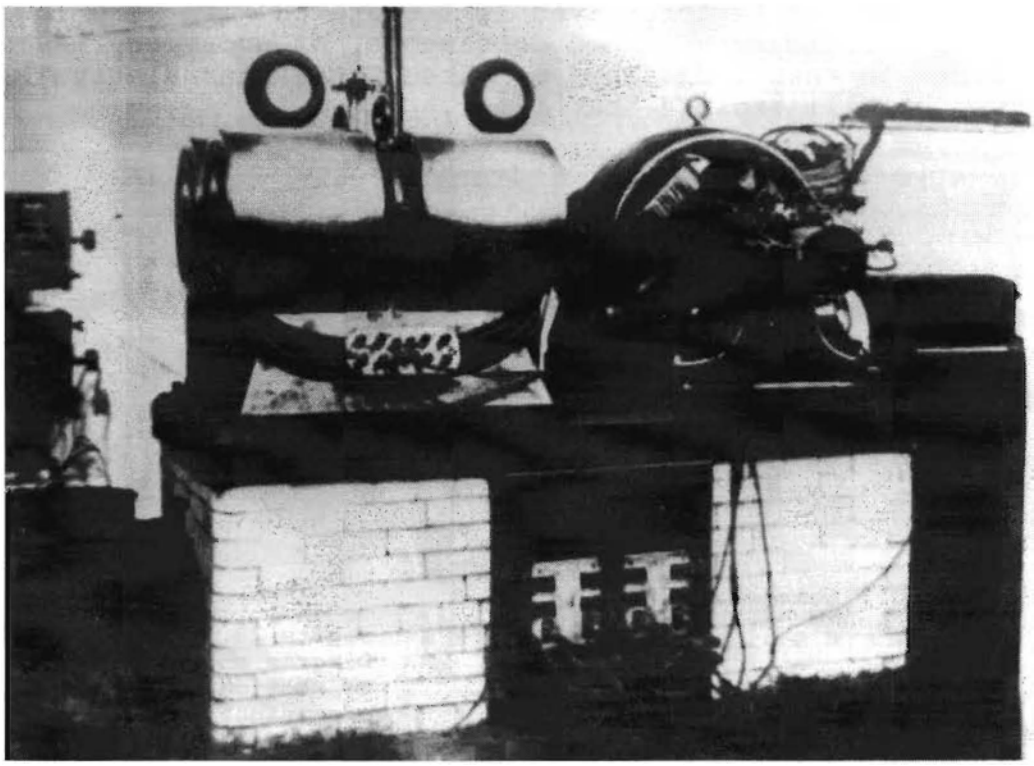


Figure 27.
Large mechanical and electrical oscillator with four vibrating parts installed in the laboratory at 46 E. Houston Street, for furnishing isochronous currents of desired wave frequencies, phases, and beats.

the absolute necessity of producing isochronous oscillations, and I could not get it with the alternator, so I constructed this machine. That was all a very expensive piece of work. It comprised four engines. Those four engines were put in pairs and there was an isochronous controller in the center, and furthermore, that controller was so arranged that I could set two pairs of engines to any phase or produce any beat I desired. Usually I operated quarter phase; that is, I generated currents of 90° displacement.

By the way, now, for the first time you see my apparatus on Houston Street, which I used for obtaining oscillations, damped and undamped as well. But, it is necessary to state that while others, who had been using my apparatus, but without my experience, have produced with it damped oscillations, my oscillations were almost invariably continuous, or undamped, because my circuits were so designed that they had a very small damping factor. Even if I operated with very low frequencies, I always obtained continuous, or undamped, waves for the reason that I designed my circuits as nonradiative circuits. I will explain that later.

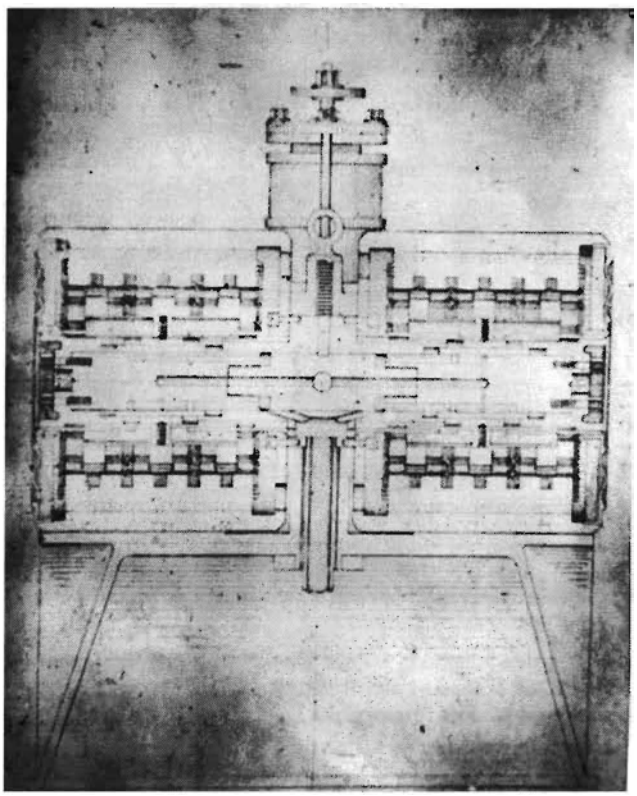


Figure 28.
Diagram showing length of section of large mechanical and electrical oscillator.

In this diagram [Fig. 28) I show the general arrangement of these engines installed in the laboratory at 46 East Houston Street. There were four, with four vibrating parts installed for furnishing isochronous currents of desired wave frequencies, phases, and beats.

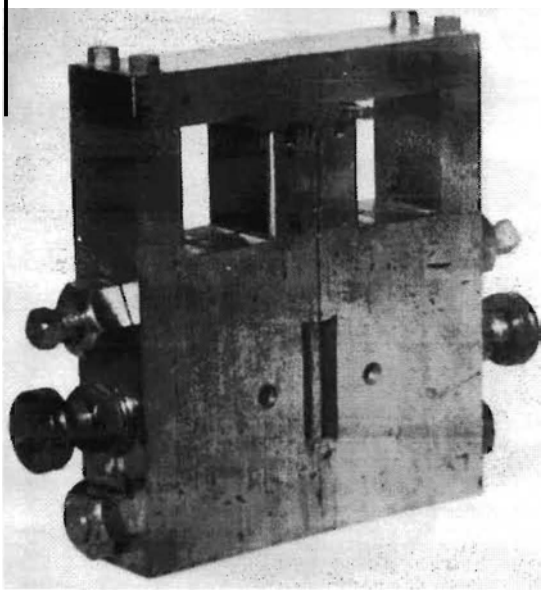


Figure 29.
Small hiqh frequency mechanical and electrical oscillator used in many investigations.

That oscillator [Fig. 29] was one of high frequency for isochronous work, and I used it in many ways. The machine, you see, comprised a magnetic frame. The energizing coil, which is removed, produced a strong magnetic field in this region. I calculated the dimensions of the field to make it as intense as possible. There was a powerful tongue of steel which carried a conductor at the extreme end. When it was vibrated, it generated oscillations in the wire. The tongue was so rigid that a special arrangement was provided for giving it a blow; then it would start, and the air pressure would keep it going. The vibrating mechanical system would fall into synchronism with the electrical, and I would get isochronous currents from it. That was a machine of high frequency that emitted a note about like a mosquito. It was something like 4,000 or 5,000. It gave a pitch nearly that of my alternator of the [first] type which I have described.

Of course this device was not intended for a big output, but simply to give me, when operating in connection with receiving circuits, isochronous currents. The excursions of the tongue were so small that one could not see it oscillate, but when the finger was pressed against it the vibration was felt.

This drawing [Fig. 30] shows the construction in detail. Here is the field coil, here are the conductors in the intense field, the valves for air supply, and the stops for limiting vibration. The stronger the field was excited, the [stronger] the vibrations became, but just the same, while the amplitude changed, the isochronism was not disturbed.

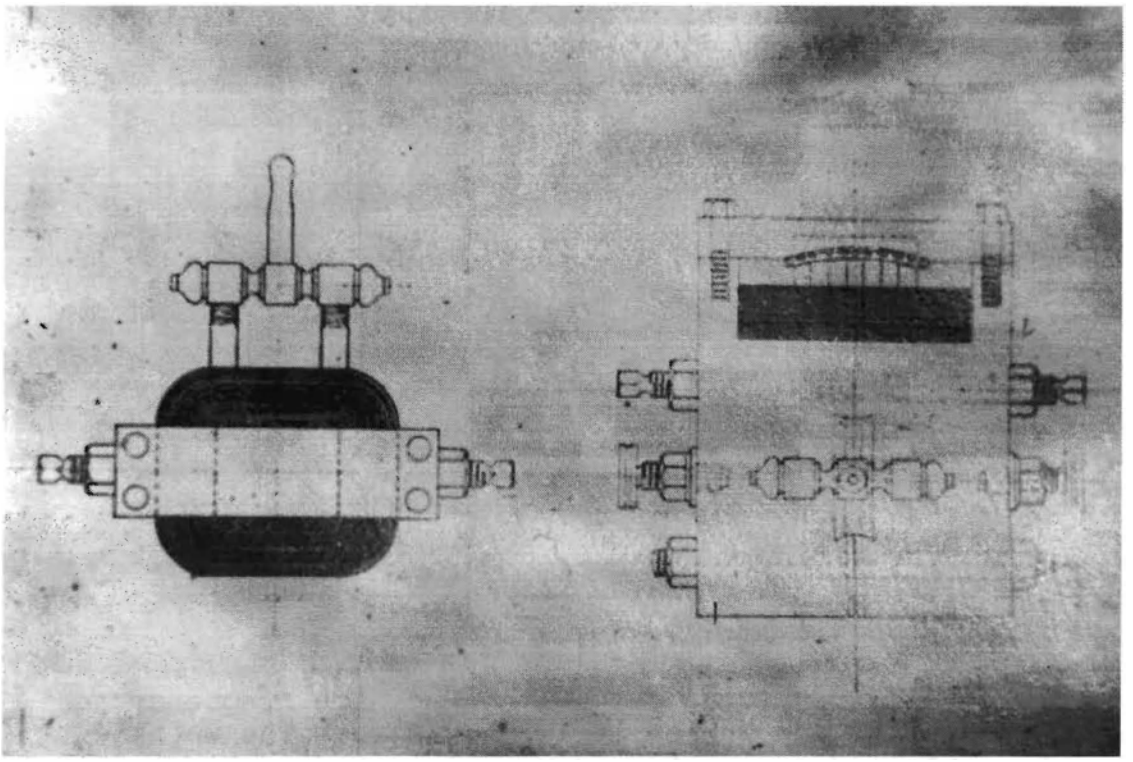


Figure 30.
Diagrammatic representation of small high frequency mechanical and electrical oscillator used in many investigations.

I want to say now why these machines were the means of obtaining the best results in my wireless work. The machine at the Houston Street laboratory with which I could obtain any difference of phase, as well as that machine at 35 South Fifth Avenue, were the means of running a motor in perfect isochronism. That is, if I connected a synchronous motor to these machines and drove it with currents of different phase, I obtained an absolutely uniform rotation -- constant in time -- and when I coupled this motor directly to an alternator, I obtained from the latter currents of absolutely constant frequency, all the more readily as I tuned the circuit of the alternator to the same frequency.

These machines I have described in a general way only. The work has covered years, and it would take a long time to explain all about them. They enabled me to operate in whatever I did with currents of constant frequency, and the small

alternators in my experiments were dr in this way. While this work was going on, I was perfect other ways of generating electric oscillations of absolutely constant frequency which were then not [illegible] in the art.

IV. Apparatus for Transfo:rma.tion by Condenser Discharges; Damped Waves

Tesla

This work [. 31] was begun already in 1889. This of is identified with my name as certain as the law of gravitation is with that of Newton. I know that some have claimed that Professor [Elihu] Thomson also invented the so-called Tesla coil, but those feeble chirps ne'er went beyond Swampscott. Professor Thomson is an odd sort of man; very ingenious, but he never was a wireless ; he never could be. Moreover, to realize that this le is The greatest men of science have told me that this was my best and, in connection with this [to schematics of . 31], I may say that a lot of liberties have been taken. For instance, a man fills this space [break D] with hydrogen; he all my instrumentalities, that is necessary, but calls it a new wireless the Poulsen arc. I cannot Another man here [to space between self-inductive lines kind of gap -- he a Nobel My name is not mentioned Still another man s here [conductor B] a mercury[-arc] rectifier. That is my friend [Peter} Hewitt. But, as a matter of fact, those devices have nothing to do with the performance

If these men knew what I do, would not touch my arrangements; would leave my as it is. Marconi puts in here [break D] two wheels. one wheel; he shows two. And he says, "See what s when the wheels are a wonderful s!" What is the wonderful Why, when the teeth of the wheels pass one another, the currents are broken and That is the wonderful thing that ? The f could not make anything else happen unless he broke his own laws. So, in this way, invention debased, prostituted, more in connection with my s than in anything else. Not a ves of invention as a creative effort is in the thousands of s that you see under the name of other a ves of invent It is exactly like in car which 6,000 have been taken out; but all are constructed and exactly the same way. The inventive effort involved is about the same as that of which a 30 mule is This is a fact.

This is one of most beautiful ever in the way of apparatus: I take a of any kind. With the generator I charge a condenser. Then I di the condenser under conditions which result in the of vibrations. it was known since Lord Kelvin that the condenser

(lf o Model.)

N. TESLA.

METHOD OF AND APPARATUS FOR ELECTRICAL CONVERSION AND DISTRIBUTIO N.

No. 462,41 Pa.tented Nov. 3, 1891.

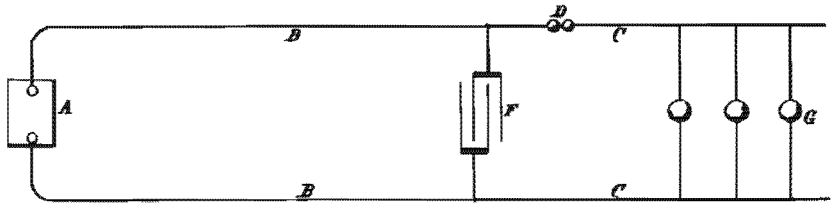
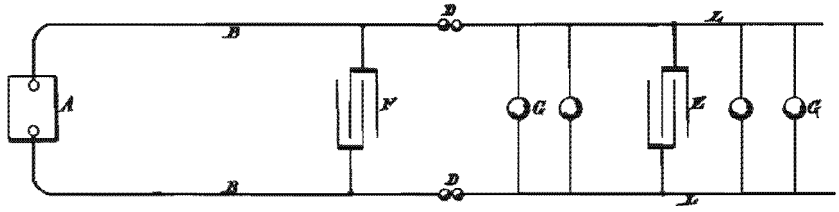


Fig. 2.



Witnesses:
Raphael Netter
Frank B. Murphy.

Inventor
Nikola Tesla
by Duncan & Page.
Attorneys.

Figure 31.
Method of transformation of electrical oscillatory condenser discharges described in U.S. Patent No. of November 3, 1891. Application filed February 4, 1891. Announcement of this invention was made in Tesla's lecture before the American Institute of Electrical Engineers at Columbia College, 20, 1891, where it was predicted that this afforded vast and would play an important in the future. Illustrated and described in Martin book, Figs. and 127, pp. 191-194.

discharge would give this vibration, but I perfected my apparatus to such a degree that it became an instrument utilizable in the arts, in a much broader way than Lord Kelvin had contemplated as possible. In fact, years afterwards when Lord Kelvin honored me by presenting to the British Association one of my oscillators of a perfected form, he said that it was "a wonderful development and destined to be of great importance."

[Returning to a discussion of Fig. 31J, [EJ is supposed to be a condenser. That [A] is the generator. Now then, supposing that this is a generator of steady pressure. I can obtain oscillations of any frequency I desire. I can make them damped or undamped. I can make them of one direction or alternating in direction as I choose. At G are devices which operate -- lamps, or anything else. Some experimenters who have gone after me have found a difficulty. They said,

"No, we cannot produce a constant train of oscillations."

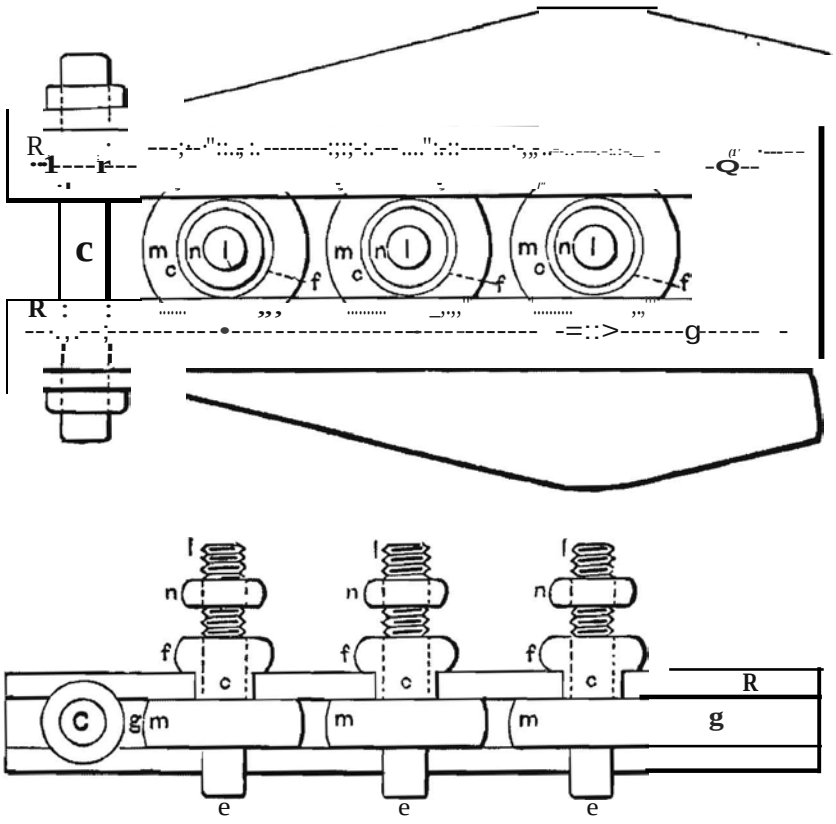


Figure 32.
Quenched spark gap. (Tesla at that time pointed out the future of quenching and showed that oscillations can be maintained without a spark being visible to the naked eye between the knobs.) Illustrated in Martin book, Figs. 135 and 136, p. 211.

Well, it is not my fault. I never have had the slightest difficulty. I produced constant oscillations and I have described how I produced them. Anyone who has no more than my own skill can do it.

This [Fig. 32] is another improvement in that particular device, which was the weakness of the invention and which I tried to eliminate. This device incorporated many spark gaps in series. It had a peculiar feature; namely, through the great number of gaps, I was able, as I have pointed out in my writings, to produce oscillations without even a spark being visible between the knobs. This device is now known in the art as the "quenched spark gap." Professor Wein has formulated a beautiful theory about it, which I understand has netted him the Nobel prize. Wein's theories are admirable. The only trouble is that he has overlooked one very important fact. It is this: If the apparatus is properly designed and operated, there is no use for the quenched gap, for the oscillations are continuous anyway. The radio men who came after me had the problem before them of making a bell sound, and they immersed it in mercury. Now, you know mercury is heavy. When they struck their bell, the mercury did not permit it to vibrate long because it took away all the energy. I put my bell in a vacuum and make it vibrate for hours. I have designed circuits in connection with an enterprise in 1898 for transmission of energy which, once started, would vibrate three years, and even after that the oscillations could still be detected. Professor Wein's theory is very beautiful, but it really has no practical meaning. It will become useless as soon as the inefficient apparatus of the day, with antennae that radiate energy rapidly, [are] replaced by a scientifically designed oscillator which does not give out energy except when it gets up to a tremendous electromagnetic momentum.

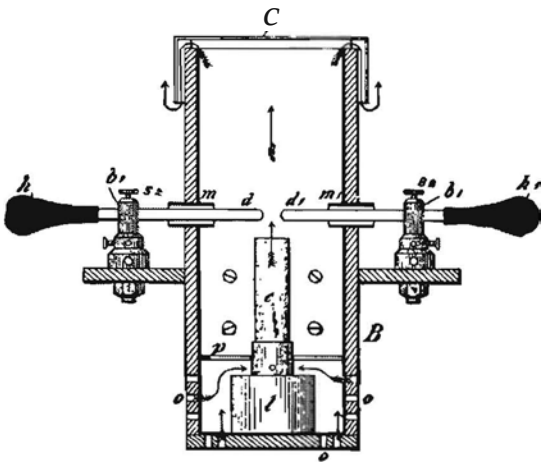


FIG. 107.

Figure 33.
The discharger working in an atmosphere, chiefly consisting of hydrogen, still further weakened by heat. The use of hydrogen in this connection has been claimed as a discovery and patented. Presented in Tesla's lectures before the Franklin Institute and the National Electric Light Association. Martin book, Fig. 167, pp. 307-308.

In this form of break [the atmosphere in which the arc was ing. was mostly hydrogen, and with this device I experiments before the Franklin Institute and the National Electric Light As ion in St. Louis. has been used by Poulsen and is now called "Poulsen arc" and "Poulsen system " But, of course, there is no ion in I am on record with prior publ ions, and besides, the hydrogen does not have any other effect that it lowers the tension under which the device can operate. It has the disadvantage of rical or dis waves, and the impulses not best suited for ng.

s [34 is the apparatus used in the cago Exposition of 1893, at which time I explained for the first time to Professor Helmholtz my for transmitting energy. After I had shown Professor Helmholtz and other scientific men there certain , he asked me,

"Now, what is all this intended for?"

I told him I was trying to develop an apparatus for transmit- energy without wire for telegraphy, telephony, and other purposes. When I explained to Professor ltz the whole idea, I said,

"Excellency, do you think that my plan is realizable?"

He ied,

"Why, certainly it is, but first you must produce the apparatus."

I started then and there to produce the apparatus.

Counsel

Was that conversation at the Chicago Exposition? la

Yes. a ion which was built especially for my inventions and discoveries. I be- 1 Professor Wedding was there and some other s ists whom I cannot remember now. I showed Professor Helmholtz my vacuum tubes and performed many other experiments

Counsel

Will you describe this apparatus in a le more detail?

r No Model.)

N. TESLA.

MEANS FOR GENERATING ELECTRIC CURRENTS.

No. 614,168. Patented Feb. 6, 1894.

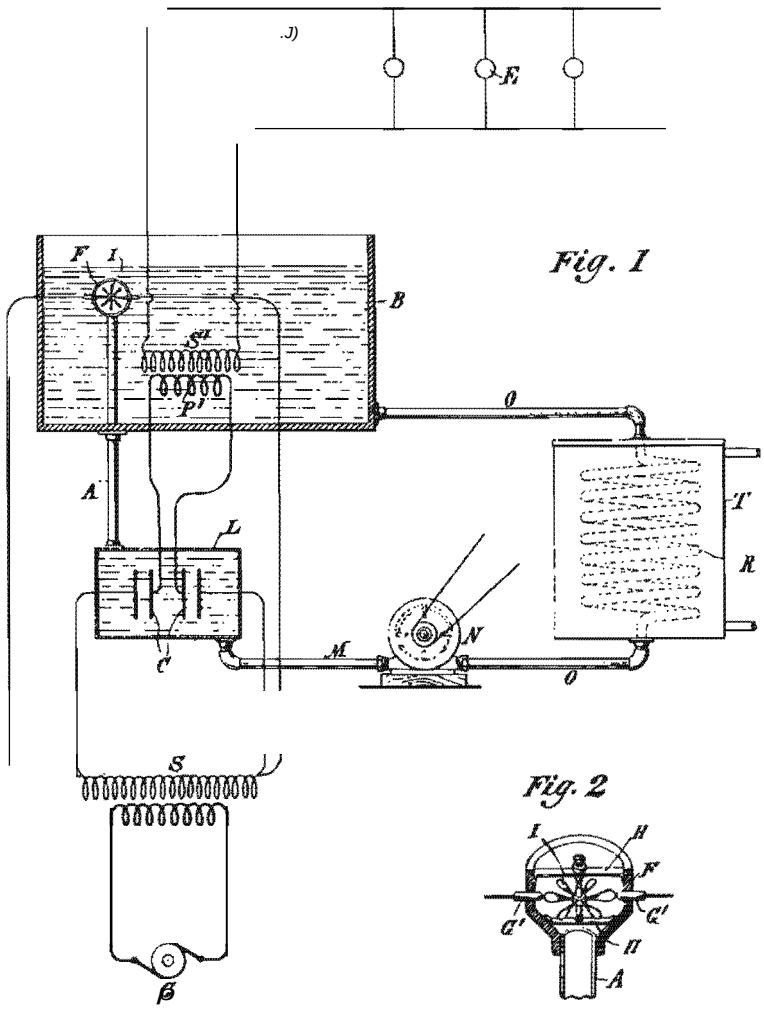


Fig. 1

Fig. 2

Witnesses
Raphael Netter
James H. Gaither

Inventor
Nikola Tesla
By his Attorneys
Duncan Page

Figure 34.
Oscillatory apparatus with interrupter in oil. Exhibited in the **Chicago** Exposition of 1893 before Helmholtz. Described in U.S. Patent **No. 514**,168 of February 6, 1894. Application filed August 2, 1893.

Tesla

The apparatus [Fig. 34], as you see, comprised primary and secondary coils immersed in a large tank of oil. The break was automatically effected by means of a turbine. The oil was circulated by a pump, and the current [i.e., stream flow] of oil drove the turbine which effected the make and break. Owing to the fact that the oil used was a very good insulator, rapidly flowing and of great dielectric strength, these make-and-break points were very close together, and the arcs extremely short. The effects were accordingly more intense. Here [T in Diag. 1 of Fig. 34] is a cooler through which the oil was circulated. The oil was forced through the gaps at great speed, and as it flowed out it was supplied again to the tank and the current driving the turbine.

Counsel

That device [Diag. 2 of Fig. 34] you call a turbine?

Tesla

Yes. It had vanes like those of a propeller and constituted a rotary break in the circuit.

Counsel

What was your prime source [of power]?

Tesla

The primary source was an alternator with a frequency of 133 cycles and, if I recollect rightly, the pressure [at the secondary] was about 20,000 volts. I may have had 10,000 volts. I am not sure what it was, but it must have been certainly from 10,000 to 20,000 volts -- within that range.

Counsel

I notice you have two sets of transformers in there marked S and S', have you not?

Tesla

This [S'] is my oscillatory circuit. That [SJ is the transformer from which the condenser was charged. Here [at S] we had 20,000 volts, or whatever it was, from the commercial transformer and here [at S'] is my secondary which generated the high frequency currents. The rotary gap is shown in detail [Diag. 2 of Fig. 34].

I had a special reason for showing this. To meet that great man Helmholtz and other scientific men, and to bring

before them for the first time the results of years of previous labor, was an important moment in my life -- particularly because Professor Helmholtz gave me the assurance himself that what I explained to him was realizable, provided that I could produce the apparatus. I was very much encouraged.

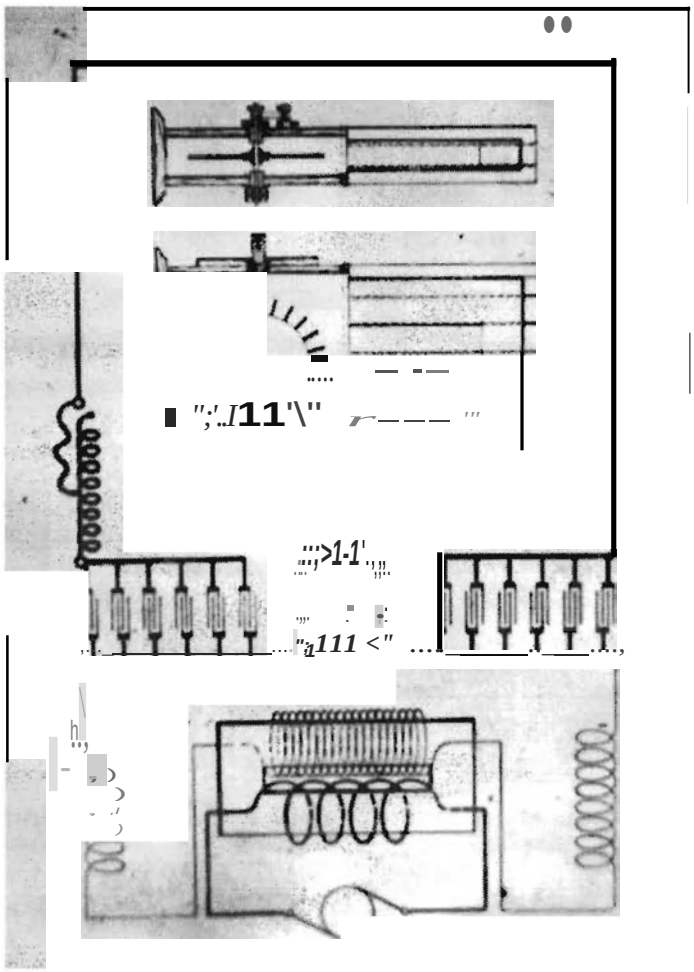


Figure 35. **Apparatus with mechanical break as installed on a large scale in the laboratory at 35 So. Fifth Avenue and subsequently at 46 E. Houston Street. Described in U.S. Patent No. 645,576 of March 20, 1900. Application filed September 2, 1897.**

This [Fig. 35] is the apparatus I had at 35 South Fifth Avenue and also Houston Street. It shows the whole arrangement as I had it for the demonstration of effects which I investigated.[*] This cable you see [square loop in top half of Fig. 35] is stretched around the hall. These are my condensers. There is the mechanically operated break, and that is a transformer charged from the generator. That is the way I had it for the production of current effects which were rather of damped character because, at that period, I used circuits of great activity which radiated rapidly. In the Houston Street laboratory, I could take in my hands a coil

* Editorial note: This diagram is not provided in the referenced patent.

tuned to my body and collect 3/4 re in the room without connection, and I have often disillusioned my vis to such effects. Sometimes, I would flames shooting out from my head and run a motor in my hands, or light six or e lamps could not understand festations of energy and thought that it was a transmiss of power. I told them that these were wonderful, but that a system of transmission, based on the same principle, was absolutely worthless. It was a transmission by e ic waves. The solution in a different direction. I am showing you s [diagram] s y as a typical form of of that pe and if you go over the 1 of the present you will find that the newest arrangements have nothing better to show.

Counsel

What was the ma and break frequency you got from that apparatus?

Tes

It was 5,000, 6,000 -- sometimes r still. I had two oppositely rotating discs which Iwill show and with which I could have y, 15,000 or 18,000.

Counsel

What wave frequencie s did you develop?

Tesla

Icould from a few thousand up to a million per second, if I wanted.

Counsel

What did you actually use?

Tesla

In these demonstrat , which I showed these effects, these most powerful e fects that were [in] the s of New York at that time, I operated with frequencies from 30,000 to 80,000. At that time I could ck up a wire, 1 it up, and tell what the vibration would be, without any test, because I was experimenting day and night

This [Fig. 36] is a form of break which I in working with alternators. I recognized that it was of tremendous advantage to break at the peak of the wave. If I used just an ordinary , it would make and bre the current at

(No Model.) i Sheets-Sheet 2.

N. TESLA.

APPARATUS FOR PRODUCING ELECTRICAL CURRENTS OF HIGH FREQUENCY.

No: 668,180. Patented Sept. 22, 1896.

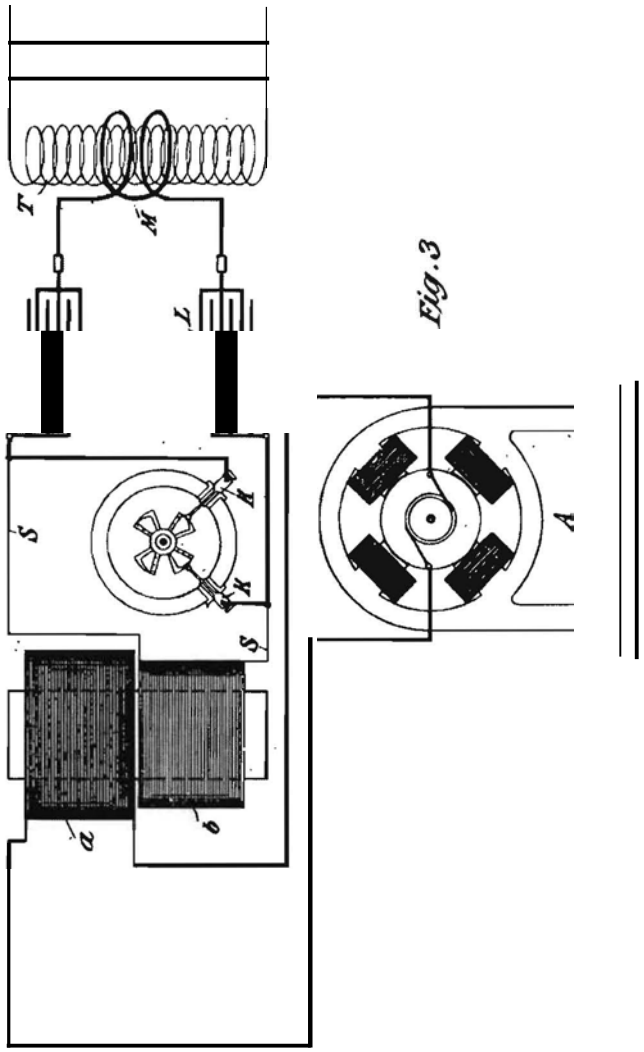


Fig. 3

WITNESSES:
Edwin B. Hopkinson.
Benjamin Jarvis Jr.

Nikola Tesla INVENTOR

Kerr, Curtis & Page, ATTORNEYS

Figure 36.
Isochronous mechanical break used in the laboratory at 35 South Fifth Avenue. Described in U.S. Patent Nos. 568,179 and 568,180 of September 22, 1896. Applications filed July 6 and 9, 1896. (Diagram taken from Patent No. 568,180.)

low as well as high points of the wave. Of this apparatus I had two forms; one in which I drove the break right from the shaft of the dynamo and the other in which I drove it with an isochronous motor. Then, by a movement of these knobs (K K), I would make the adjustments so that the makes would occur exactly at the top of the wave. That is a form of break which is embodied in hundreds of patents and used now extensively.

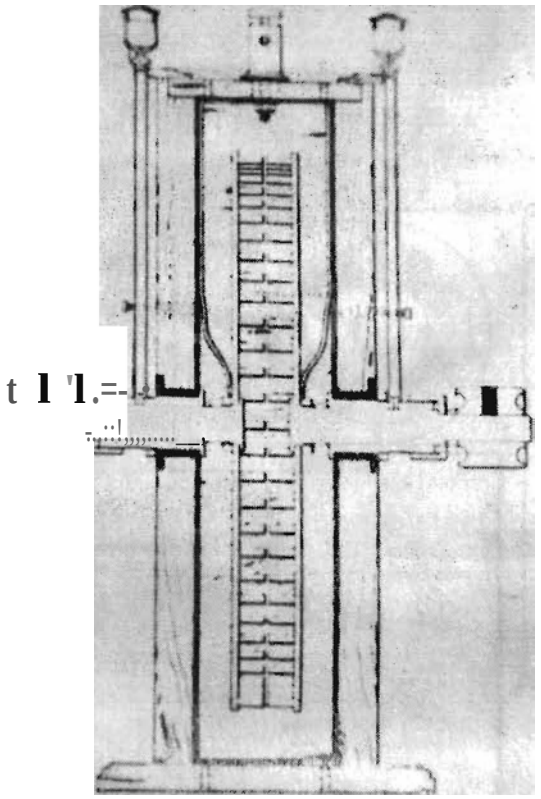


Figure 37.
Mechanical break with two oppositely rotating discs used for the purpose of increasing the number of breaks and alternating the oscillations practically undamped. (Subsequently patented by others.)

Here [Fig. 37] I show an apparatus that was installed in the Houston Street laboratory prior to the other break because I wanted to get as high a number of impulses as possible. The drawing dates from the spring of 1896. It is a break with which I could reach from 15,000 to 18,000 interruptions per second. I used it very much until later I found it was not necessary.

That is the innocent device which Marconi thought a great invention.

Counsel

This is also a rotary gap?

Tesla

Yes, and it consists of two scs of a with teeth of side. were rotated by two motors in opposite y rotated they alternately closed and t. In some tances I used an uneven number of teeth on one and even number on the other so that I as many breaks as I desired. I will show you later an more perfect than s one, and of a different kind, in which I have 24 contacts, and 25 rotat elements that established the contact and broke it, so that by one I 24 25, or 600 interruptions [per revolution].

Counsel

Whenever you say "the break", you mean "a spark gap"?

Tesla

Yes; otherwise I use the term "circuit controller," prefe rably

This [Fig. 38] illustrates another deve in a dif- ferent direct In order to increase number of breaks, I employed currents of different I had in my labora- tory, permanent ly, a and could phases between; that is, from apart, I could obtain four phases, 45 Here is an shown as I had it, working with three [60 , and could obtain six phases, 30 apart], and later on I had one with four s [45 apart, and could obtain e phases 22 1/2 You see, as I mult ied the number of the s, I the number of the fundamental scharges.

Counsel

What is the date of this apparatus?

Tesla

I in the 35 South Fifth Avenue labo remember that gave entertainments to several sc ific soc s and it was then present there. know on one occasion there was the Society of Architects, and another, the Electrotherapeutic Soc and then I had dis- tingu men like Mark Twain and Joseph Jefferson I gave them a demonstration which was published in Martin's article in the _____ of il 1895, I know on these occasions I used a two-phase arrangement Later on I made it four phase. That apparatus existed, therefore, prior to the destruction of my laboratory in 1895.

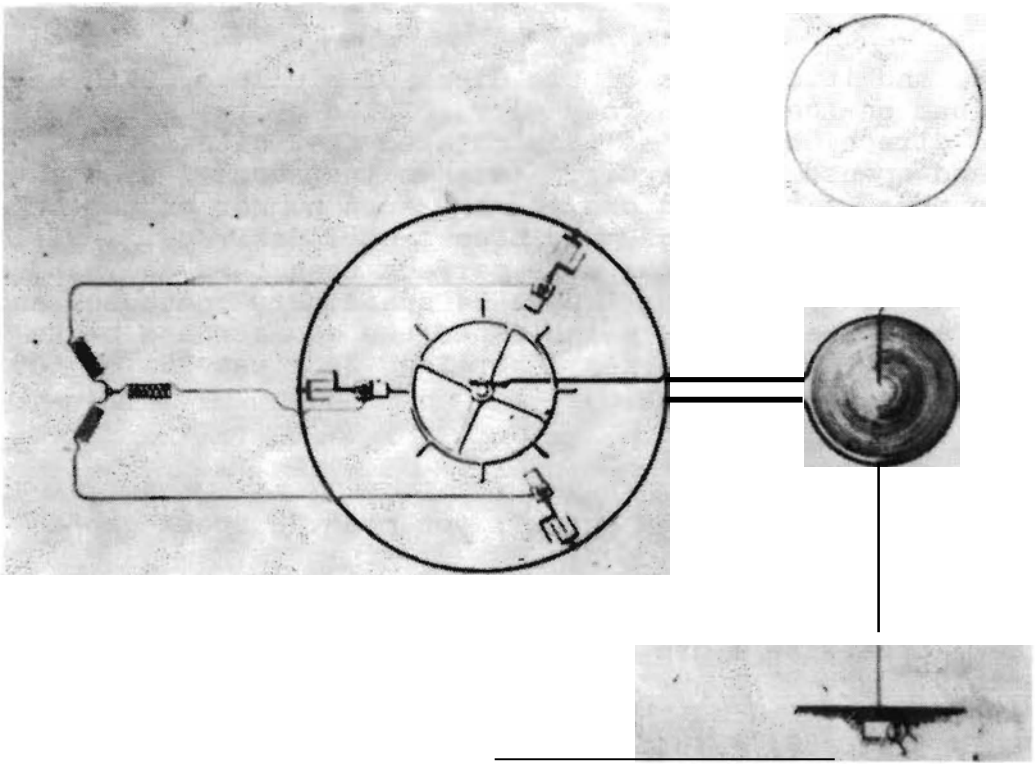


Figure 38.
Use of multi-phase generator with mechanical break. Experiments in the laboratory at 35 So. Fifth Avenue and subsequently.

Counsel

Do you recall any publication in which this diagram was illustrated?

Tesla

I made no publication, and I vividly remember that when I installed my apparatus on Long Island I had an arrangement with four transformers and four phases 45 apart. After I had been using this apparatus there, several years afterwards, I ran across a patent, I believe held by the General Electric Company, describing precisely the same arrangement.[*] It was a similar experience as with that patent of Fessenden on the compressed air condenser. Any time I want to use these improvements all I need to do is to produce my records and that will settle the patents.

Counsel

When was that drawing [Fig. 38]?

* Editorial note: Tesla refers to U.S. Patent No. 996,580 dated June 27, 1911, of Charles Green with assignment to G.E.; application filed September 30, 1907.

la

This is from an old patent drawing which was made by Mr. Netter.

Counsel

But that not go to patent?

Tesla

No. I have hundreds of inventions that were to be paten but The expense was too and I could not do it. This form of with two and four phases was used prior to the destruction of my laboratory in 1895, and it was instal on a scale with four phases in my plant on Island with which I was to telephone around the world, but that is a long story.

Counsel

In that use you made of it at your , was that connected up as shown there [. 38], to an antenna?

la

I used the s, yes, in with the antenna too, but this is from a drawing in ch an antenna is shown; I mean, I used in every connection. [Fig. 38] il- lustrates an antenna with my tran circuit, but the apparatus was used in all my work, in all my investigations

Counsel

And when this was connected and used in an antenna, did you use it as in other instances -- go off and listen to the notes which you received?

Tesla

Oh, certai But I remember that, bes this, I had fferent nds of apparatus Then I had a sensibly damped wave because at that time I still was laboring under the same difficult s as some do this day -- I had not learned how to produce a circuit which would give me, with very few fundamental impulses, a perfectly cont s wave. That came with the perfection of the devices. When I came to my experiments Colorado, I could take my apparatus in like that and get a tinuous undamped wave, con- individual s almost without except , between

Counsel

Speaking of your not having perfectly undamped waves at that time, you were referring to that character of circuit?

Tesla

Yes, but with another kind of circuit I could, of course. The advantage of this apparatus was the delivering of energy at short intervals whereby one could increase activity, and with this scheme I was able to perform all of those wonderful experiments which have been reprinted from time to time in the technical papers. I would take energy out of a circuit at rates of hundreds or thousands of horsepower. In Colorado, I reached 18 million horsepower activities, but that was always by this device: Energy stored in the condenser and discharged in an inconceivably small interval of time. You could not produce that activity with an undamped wave. The damped wave is of advantage because it gives you, with a generator of 1 kilowatt, an activity of 2,000, 3,000, 4,000, or 5,000 kilowatts; whereas, if you have a continuous or undamped wave, 1 kilowatt gives you only wave energy at the rate of 1 kilowatt and nothing more. That is the reason why the system with a quenched gap has become popular.

I have refined this so that I have been able to take energy out of engines by drawing on their momentum. For instance, if the engine is of 200 horsepower, I take the energy out for a minute interval of time, at a rate of 5,000 or 6,000 horsepower, then I store [it] in a condenser and discharge the same at the rate of several millions of horsepower. That is how these wonderful effects are produced. The condenser is the most wonderful instrument, as I have stated in my writings, because it enables us to attain greater activities than are practical with explosives. There is no limit to the energy which you can develop with a condenser. There is a limit to the energy which you can develop with an explosive.

A common experiment, for instance, in my laboratory on Houston Street, was to pass through a coil energy at a rate of several thousand horsepower, put a piece of thick tinfoil on a stick, and approach it to that coil. The tinfoil would melt, and would not only melt, but while it was still in that form, it would be evaporated and the whole process took place in so small an interval of time that it was like a cannon shot. Instantly I put it there, there was an explosion. That was a striking experiment. It simply showed the power of the condenser, and at that time I was so reckless that in order to demonstrate to my visitors that my theories were correct, I would stick my head into that coil and I was not hurt; but, I would not do it now.

[Fig. 39] shows a four-phase machine which was furnished me by the Westinghouse Electric Company at the close of 1895. My laboratory burned out in May, and I urged my friend, Mr. Albert Schmidt, who was the Superintendent, to give me this alternator as soon as possible. He worked day and night until he got it out, and he certainly did notable work because while the machine was rated at 30 horsepower, I have run it at 150 horsepower.

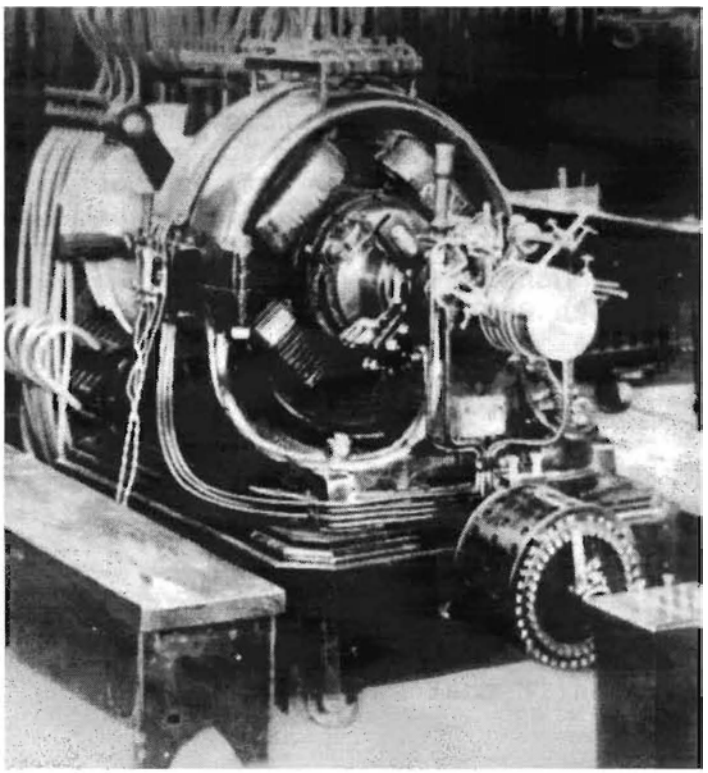


Figure 39.
Apparatus furnishing direct currents of high tension, producing undamped electrical oscillations of high frequency. (This is also shown in [Fig. 27]). Apparatus built in 1895.

By the way, and this is a painful reflection, it was Schmidt and I who developed this type of frame and this general arrangement which is universally adopted now -- a base, with the magnets cast below, split at the center line, and a corresponding upper part. That is now used everywhere. I remember years ago, some of my friends, Messrs. Crocker and Wheeler, started with those long magnets and I told them, "The sooner you throw these away and adopt this construction, the better it will be for you." They have got it now; it is all right.

Counsel

How is this machine [Fig. 39] shown in connection with that?

Tesla

This dynamo [Fig. 39], you see, is a two-phase machine; that is, I develop from it currents of two-phase. Now, there are four transformers, you see them down here [lower left of Fig. 39], that furnish the primary energy. From these two phases I develop four phases. [However,] this involves something else which I have referred to before; namely, an arrangement which enables me to produce from these alternating currents direct currents and undamped -- absolutely undamped isochronous oscillations of any period I like.

This is accomplished in the following manner: The secondaries of the four transformers could each develop 44,000 volts. They were specially built for me by the Westinghouse Company. They could, however, be connected in such a way
that each would give 11,000 volts, and then I would take these 11,000 volts and these four phases and commutate them by a commutator consisting of aluminum plates, or aluminum segments, which were rotated in synchronism with the alternator. Then I obtained a continuous pressure; that is, direct current of a tension of 44,000 volts, and with these 44,000 volts I charged my condensers. Then by discharging the condensers, either through a stationary gap or through a gap with a mechanical interrupter, I obtained any frequency I desired, and perfectly undamped waves. This arrangement was installed in 1901 in my wireless plant at Long Island, with which I was to telephone around **the** world.

Counsel

Who built that machine?

Tesla

The Westinghouse Company, [under direction of] Mr. Albert Schmidt, Superintendent. It was especially built for me and furnished to my laboratory on Houston Street.

While I was with the Westinghouse Company, I did two things in addition to bringing my motors to them. I had discovered that Bessemer steel was a much better material for transformers and motors than the soft iron which was previously used. When I came to Pittsburgh, my motors gave results which their motors could not at first produce, and I told them that I had used Bessemer steel. I discovered, in following up the analysis of the steels which were used, that the Bessemer was not steel but really soft iron. The Westinghouse people then adopted my suggestion. At first, Mr. Shallenberger and other electricians there objected very much, but I persuaded them and when the transformers were built we found that we could get 2 1/2 times the output we got before.

The Westinghouse people kept a secret for a time and no one understood how they could make transformers, but all was to use the Bessemer steel, on my sugges on, instead of the soft iron the General Electric and other people used. Mr. Westinghouse e ally requested me to join efforts with Mr. Schmidt and the des of his machines, and we did so. We evolved this design, introduced the ready-made coils, which are pressed on the armature, and other improvements. I took a couple of s out with Mr. Schmidt, and Mr. Westinghouse was very nice about it. I nk he compensated me with $10,000, or something like that, for my suggestions.

Counsel

You have of the use of that machine at Houston Street. In what way was it used?

Tesla

I used s machine, as I said, either to alternat currents and then interrupt them with a cal break at high peaks of the wave; or, I used alternat currents and interrupted them with an i ng break ng a number of teeth. Or, I generated continuous currents commutating the tension ternating currents of transformer. At that time I had two transformers from which I obtained a constant sure, the condenser, and produced undamped waves of any frequency I wanted. As to the machine here [. 39], that is the way it was arranged It was for the generat of continuous elec tromotive force and production of waves -- from 1895 and on.

Counsel

What sort of apparatus was it connected up to for the purpose of absorbing these waves?

Tesla

I was same as shown here [. 38). It was connected to the condensers, and these condensers were discharged through a primary which excited the ; the antenna was i in the secondary. At other s we scha the condensers rectly so that I could use antenna without the secondary

Counsel

In the same way did you note the operat ion of these waves?

Tesla

We did, of course, only in most cases the instrument of reception was different. When I operated with these continuous, or undamped, waves, generated in this way, usually went to high frequencies. I did operate [at] a very few thousand, but that gave me a smaller output Such a machine you have to operate at high frequencies to power.

Counsel

What do you mean frequencies?

Te

I mean frequencies of 30,000, 40,000, 50,000, or some-th 1 that.

Counsel

And by means of that , you undamped waves of frequency about 50,000 into that antenna at Houston Street in 1895?

Tesla

No, not in 1895. Late in 1895 the machine was furnished and I began to operate in early 1896. That when I to operate.

Counsel

Then you did this, that I speak of, 1896?

Tesla

Yes, from 1896 to 1899, right along

Counsel

When you used s like that in your antenna, was your antenna tuned or untuned?

Te l

I could not use it untuned. That would be absurd.

Counse I

What form of device did you use, and where did you use it, for the of these oscillations or waves in the antenna?

Tesla

I suppose I had hundreds of devices, but the first device that I used, and it was very successful, was an improvement on the bolometer. I met Professor Langley in 1892 at the Royal Institution. He said to me, after I had delivered a lecture, that they were all proud of me. I spoke to him of the bolom- eter, and remarked that it was a beautiful instrument. I then said,

> "Professor Langley, I have a suggestion for making an improvement in the bolometer, if you will embody it in the principle."

I explained to him how the bolometer could be improved. Professor Langley was very much interested and wrote in his notebook what I suggested. I used what I have termed a small-mass resistance, but of much smaller mass than in the bolometer of Langley, and of much smaller mass than that of any of the devices which have been recorded in patents issued since. Those are clumsy things. I used masses that were not a millionth of the smallest mass described in any of the patents, or in the publications. With such an instrument, I operated, for instance, in West Point -- I received signals from my laboratory on Houston Street in West Point.

Counsel

This was then the machine that you used when working with West Point?

Tesla

I operated once or twice with it at that distance, but usually as I was investigating in the city. My work at that time was to prepare for the development of a commercial plant, and with me the question was not to transmit signals, but to see what intensity I could get to put me in position to calculate out my apparatus, the dimensions and the forms, before I began the undertaking. It was nothing but preparatory work for the construction of a commercial plant, and I demonstrated its practicability through my experiments, a plant which was to accomplish much more than all others.

Counsel

What was the horsepower activity in the oscillating circuits when you used this machine?

Tesla

Usually something like 50 horsepower, and I would get, I should say, approximately 30 horsepower in the antenna; that

is, I would get 30 horsepower in the oscillating rcuit.

Counse 1

I understood a little while ago when you made the statement of using several thousand horsepower put a conden-ser, you could take out of the condenser a mill horsepower. I if you the same condition with s machine.

Tesla

Yes; I charged the condenser with 40,000 When it was charged full, I discharged it suddenly, a short circuit which gave me a very rapid rate of oscillation. Let us suppose that I had stored in the condenser 10 watts. Then, for such a wave there is a flux of energy of (4 x 04)2, s is multiplied by and the of 100,000. You see, it may go into thousands or millions of horsepower.

Counsel

What I wanted to get at was, did that depend upon the suddenness of the discharge?

Tesla

Yes. It is merely the electrical le driver or a hammer. You accumulate energy a long distance and then you del th a tremendous suddenness. The distance ch the mass moves is small -- the pressure immense.

Counsel

Did you find that that was the best condition for trans-tt energy without the use of wire?

Tesla

No, I did not use that method when I was transmitting energy. I used on in the production of those freaks for which I have been called a magician. If I had used merely undamped waves, I would have been an ordinary e ian like everybody else.

Counsel

You have referred to some delicate
Did you any trouble with struments
static? . those burning out on account
of

Tesla

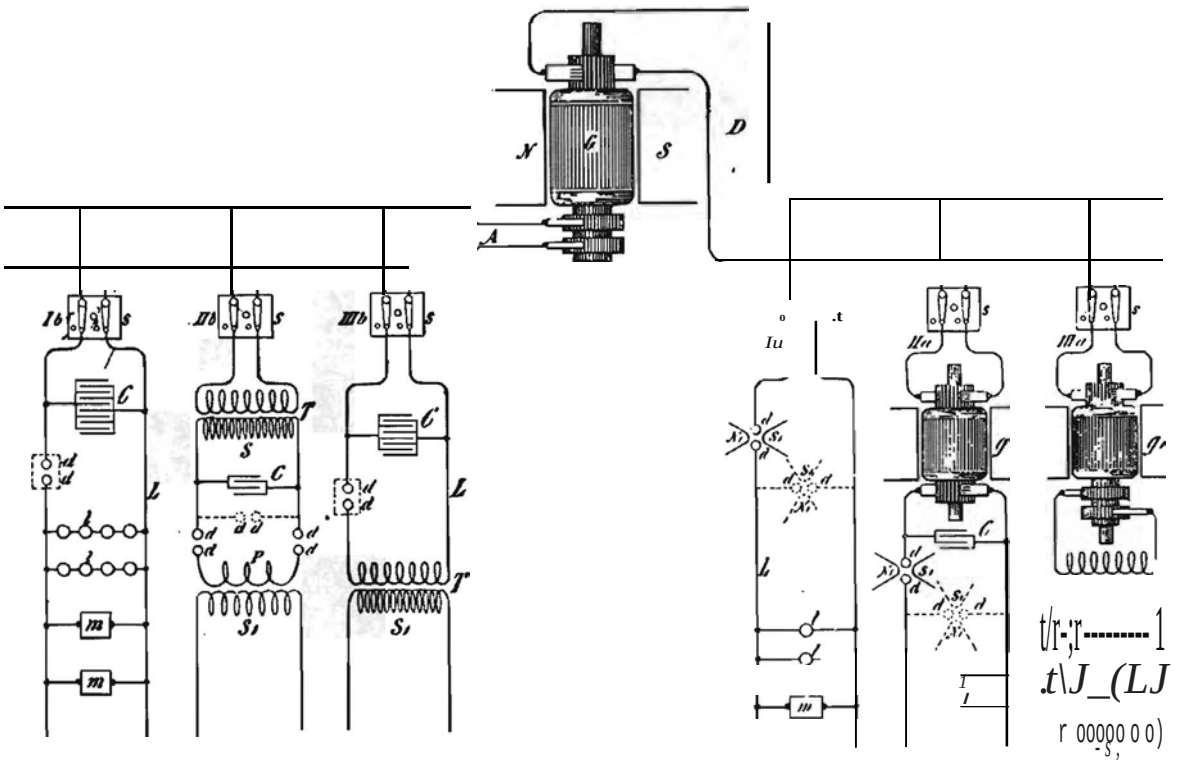
My dear sir, I burned out so many instruments before I discovered what was the matter with them! They burned out instantly until I learned how to make them so that they could not burn out. Yes, that was a great trouble in the beginning.

Counsel

Did you succeed in getting them so they would not burn out?

Tesla

Yes. If lightning struck close by, it would not burn out my instrument that has a millionth of the smallest mass used in the instruments of others.



Fm. 165.

Figure 40.
Apparatus and method of conversion by condenser discharges applicable to both alternating and direct currents. Described in lectures before the Franklin Institute and the National Electric Light Association early in 1893. Illustrated in Martin book, Fig. 165, pp. 302-317.

This [Fig. 40] is a systematic representation of the various ways which I gave in my lecture before the Franklin

Institute and the National Electric Light Association, embodying the general arrangements for the obtainment of continuous waves, undamped or damped waves, from direct and alternating current supply. On the one side [right] you have direct, on the other side alternating current supply. Some electricians have had difficulties in operating some of this apparatus. I had none. I can take an ordinary circuit of 50 volts and produce from it absolutely undamped oscillations and never have the slightest difficulty about it.

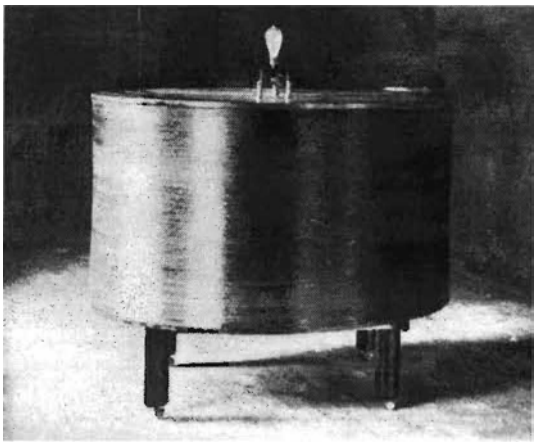


Figure 41.
Illustrating one of the early experiments with a tuned transformer in the laboratory at 35 So. Fifth Avenue.

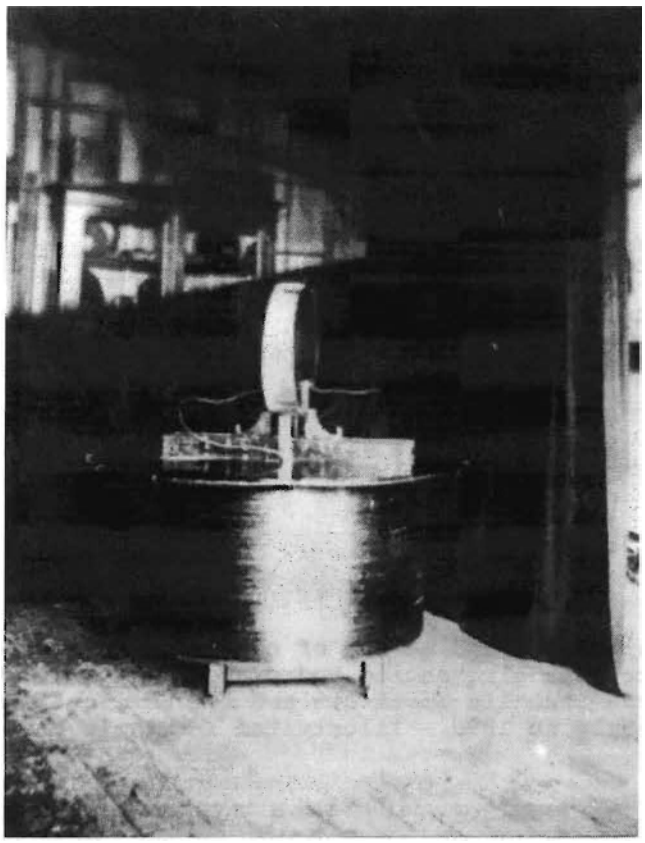


Figure 42.
Another experiment illustrating one of the early experiments with a tuned transformer in the laboratory at 35 So. Fifth Avenue. (Article by Martin ["Tesla's Oscillator and Other Inventions"'], Century Magazine, April 1895, Fig. 9, p. 926.)

Now I come to a few pieces of apparatus which I used the Houston Street and the South Fifth Avenue labo-
ratory r have here 41] what you might call a tuning
coil. Iemp usually another secondary and had my con-
densers on the table. You see one of the coils in action.
This is a tuned which responds to e c
waves which are the room.

Counsel

This is be used as a receiver of waves?

Te

Yes.

Th s t shown in Fig. 42] was used in the labo-
ratory on Fifth Avenue. Here [large rcular sc pos
tioned on coil] is the tuning table with the condensers,
a thick , and another secondary wire. Somet s I would
operate with two and I would tune the first circuit
to one and the to the other. Here [re to cabi-
nets in back of room] you see some of my historical apparatus.
Professor Fairf ld Osborn[*] came once to my laboratory and
said to me, "Why on earth do you keep in 's laboratory?"
I had all of this apparatus, 400 pieces, absolutely priceless,
and offered to take it over to the Museum. But I did not
heed s advice, and it is gone.

* Editorial note: Fairfield Osborn, Dean, of Pure Science,
Columbia College in of New York. Osborn wrote lege President
Seth Low in part, "I have upon my mind two
matters which to very rst is connected
with Mr. Hill with Mr. New York. have
is considered the mathematician in this
country, and seems to be little doubt that Mr. is elec-
trician. They both are in a measure connected with Columbia through Mr. Hill's
lectures here, and the fact that Mr. Tesla at Professor upin's and Pro-
fessor Crocker's invitat his first electrical lecture in Columbia. So
that we have already establ a sympathetic relation with these men. I
spent an afternoon recently with Tesla, and regard him as one of most dis
tinguishec men I have ever met. I happened to meet Professor Crocker shortly
afterwards, and learned from him that he had spoken to you in regard giving
Tesla an Honorary I would like to support this in the most earnest
manner. Poulton [. of at Oxford] tells me that Tesla was covered
with honors while in England France. We certainly must not allow other
University to anticipate us in honoring a man who lives under our very walls
In response to this, President Low recommended, in a letter dated 5,
1894, to the Trustees, that the honorary degree of LL.D. should be conferred on
Tesla. The degree was awarded in June, 1894.

Source: Columbia University Archives

Counsel

Where were the waves sent from?

Tesla

The whole room was energized by electromagnetic waves and the receiver responded at any place in the hall. The hall was bigger than this room [shown in Fig. 42], twice as long, and anywhere the intensity of action was the same. These discs [vertical, on top of tuning table] were, I think, about 14 or 15 inches in diameter, and you could see the streamers [shown as white between the discs] anywhere in the room. In a hall twice as long as this, wherever I placed the instrument, it would respond to the electromagnetic waves.

Counsel

In this particular instance you are speaking of, the waves were generated right there at 35 South Fifth Avenue?

Tesla

Yes.

Counsel

Was that the apparatus in which you had the primaries running entirely around the room?

Tesla

Yes. This was shown to many people and societies.

This [Fig. 43] shows the first single step I made toward the evolution of an apparatus which, given primary oscillations, will transform them into oscillations capable of penetrating the medium. That experiment, which was marvelous at the time it was performed, was shown for the first time in 1894. I remember the incident perfectly. I called Mr. Edward Adams, the banker, to come and see it, and he was the first man to observe it and to hear my explanation of what it meant.

This coil, which I have subsequently shown in my patents Nos. 645,576 and 649,621, in the form of a spiral, was, as you see, [earlier] in the form of a cone. The idea was to put the coil, with reference to the primary, in an inductive connection which was not close -- we call it now a loose coupling -- but free to permit a great resonant rise. That was the first single step, as I say, toward the evolution of an invention which I have called my "magnifying transmitter." That means, a circuit connected to ground and to the antenna, of a tremendous electromagnetic momentum and small damping factor, with

all the conditions so determined that an immense accumulation of electrical energy can take place.

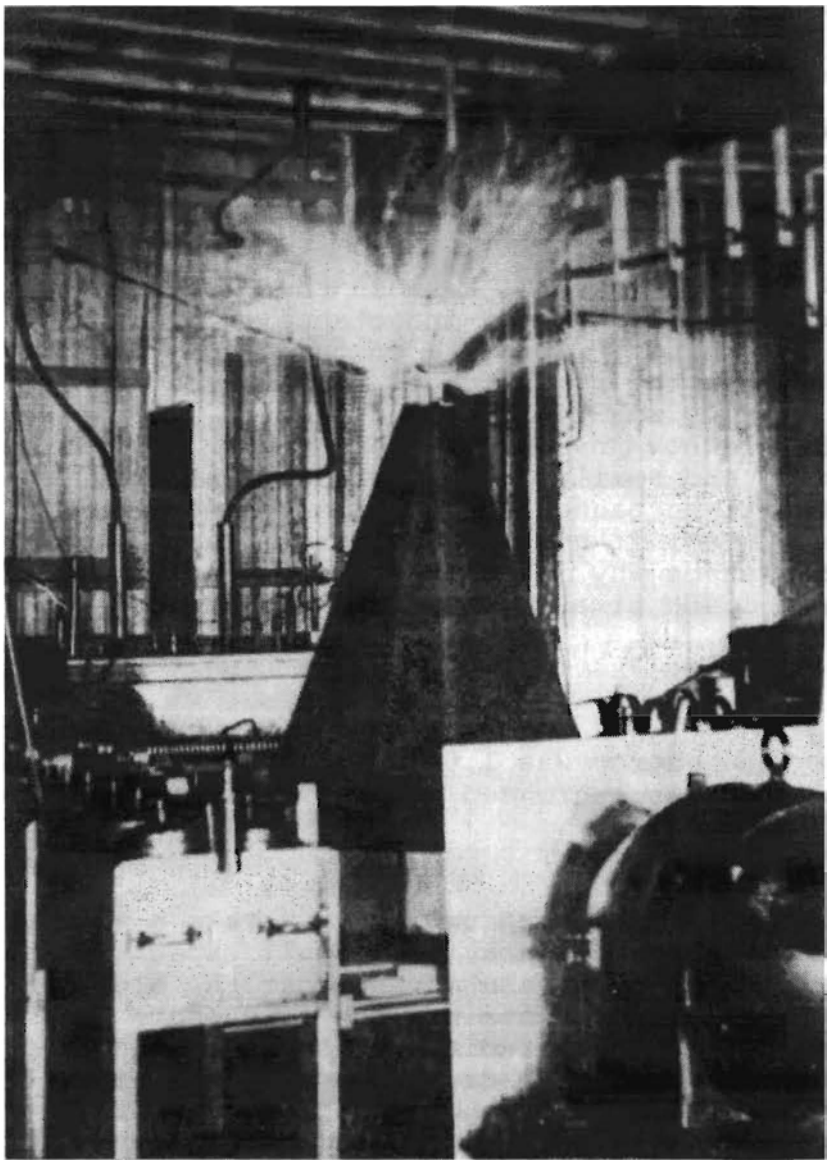


Figure 43.
Apparatus in action illustrating the first step in the evolution of the magnifying transmitter in the laboratory at 35 So. Fifth Avenue. (Article by Martin ["Tesla's Oscillator and Other Inventions"], Century Magazine, April 1895, Fig. 15, p. 932.)

It was along this line that I finally arrived at the results described in my article in the Century Magazine of June 1900. [Fig. 43] shows an alternator; not the alternator that was furnished for my laboratory on Houston Street -- that was another one, [but] at 35 South Fifth Avenue [and] operated on the same principle. Here [lower left] are the condensers,

primary, and all the rest. The discharge there was 5 or 6 feet, comparatively small to what I subsequently obtained. I have produced discharges of 100 feet, and could produce some of 1,000 feet if necessary, with the greatest facility.

Counsel

Mr. Tesla, at that point, what did you mean by electromagnetic momentum?

Tesla

I mean that you have to have in the circuit, inertia. You have to have a large self-inductance in order that you may accomplish two things: First, a comparatively low frequency, which will reduce the radiation of the electromagnetic waves to a comparatively small value, and second, a great resonant effect. That is not possible in an antenna, for instance, of large capacity and small self-inductance. A large capacity and small self-inductance is the poorest kind of circuit which can be constructed; it gives a very small resonant effect. That was the reason why in my experiments in Colorado the energies were 1,000 times greater than in the present antennae.

Counsel

You say the energy was 1,000 times greater. Do you mean that the voltage was increased, or the current, or both?

Tesla

Yes [both]. To be more explicit, I take a very large self-inductance and a comparatively small capacity, which I have constructed in a certain way so that the electricity cannot leak out. I thus obtain a low frequency; but, as you know, the electromagnetic radiation is proportionate to the square root of the capacity divided by the self-induction. I do not permit the energy to go out; I accumulate in that circuit a tremendous energy. When the high potential is attained, if I want to give off electromagnetic waves, I do so, but I prefer to reduce those waves in quantity and pass a current into the earth, because electromagnetic wave energy is not recoverable while that [earth] current is entirely recoverable, being the energy stored in an elastic system.

Counsel

What elastic system do you refer to?

Tesla

I mean this: If you pass a current into a circuit with

large self-induction, and no radiation takes place, and you have a low resistance, there is no possibility of this energy getting out into space; therefore, the impressed impulses accumulate.

Counsel

Let's see if I understand this correctly. If you have radiation or electromagnetic waves going from your system, the energy is wasted?

Tesla

Absolutely wasted. From my circuit you can get either electromagnetic waves, 90 percent of electromagnetic waves if you like, and 10 percent in the current energy that passes through the earth. Or, you can reverse the process and get 10 percent of the energy in electromagnetic waves and 90 percent in energy of the current that passes through the earth.

It is just like this: I have invented a knife. The knife can cut with the sharp edge. I tell the man who applies my invention, you must cut with the sharp edge. I know perfectly well you can cut butter with the blunt edge, but my knife is not intended for this. You must not make the antenna give off 90 percent in electromagnetic and 10 percent in current waves, because the electromagnetic waves are lost by the time you are a few arcs around the planet, while the current travels to the uttermost distance of the globe and can be recovered.

This view, by the way, is now confirmed. Note, for instance, the mathematical treatise of Sommerfeld,[*] who shows that my theory is correct, that I was right in my explanations of the phenomena, and that the profession was completely misled. This is the reason why these followers of mine in high frequency currents have made a mistake. They wanted to make high frequency alternators of 200,000 cycles with the idea that they would produce electromagnetic waves, 90 percent in electromagnetic waves and the rest in current energy. I only used low alternations, and I produced 90 percent in current energy and only 10 percent in electromagnetic waves, which are wasted, and that is why I got my results.

* Editorial note: Sommerfeld, Arnold N., "Uber die Ausbreitung der Wellen in der drahtlosen Telegraphie," Annalen der Physik, March 16, 1909 (Vol. 28, No. 4), pp. 665-736.

V. Apparatus for Transformation by Condenser Discharges; Continuous Waves

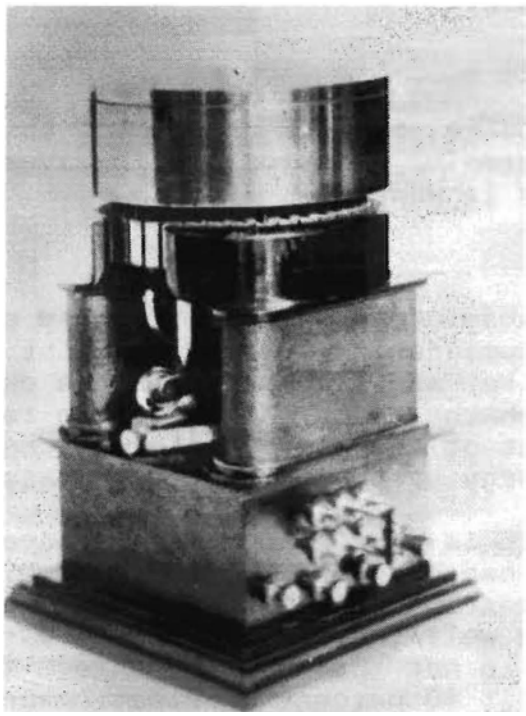


Figure 44.
One of the many forms of mercury circuit controllers described in various U.S. Patents.

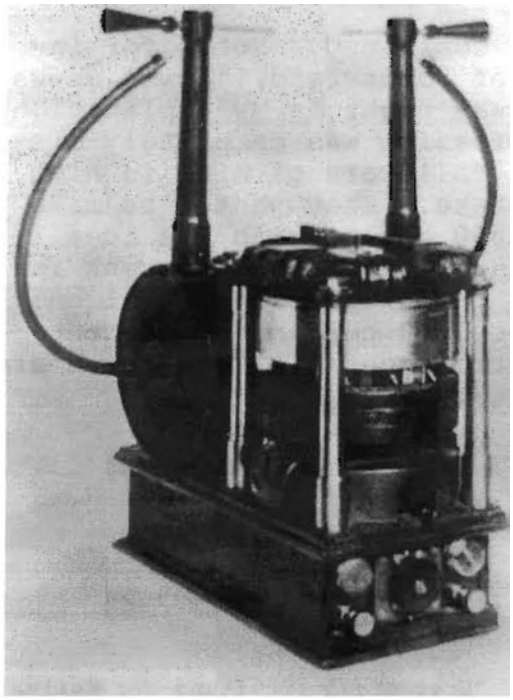


Figure 45.
Hermetically enclosed mercury circuit controller with compact oscillatory transformer. Described in U.S. Patent No. 609,245 of August 16, 1898.

Figure 44 (verso).
One of the many forms of mercury circuit controllers. Described in U.S. Patent Nos.:

609,245	of August	16,	1898,	application filed	December	2, 1897
609,246		,			February	28, 1898
609,247		",		"	March	12,
609,248		",		"	"	
609,249	"	",	"	"		
609,251		",			June	3, 1897
611,719	" October	4,			December	10, 1897
613,735	" November	8,	"			19, 1898.

Tesla

This [Fig. 44] shows a further in the direction of perfect a way of making and bre the current, and illustrates one the simplest forms of my apparatus, which was special built with a mercury interrupter inside capable of cons That was from an ordinary circuit y and could stand a current of 20 or 25 amperes. It was a very compact instrument. I had dozens these instruments, obtained ei on the same; were all is in 1898.

The next thing was to enclose the mercury break hermetically [Fig. 45]. You see, here [46, overleaf] is a motor, especially designed rotating this ley.

In this [referring to the sectional diagram] cross is a jet of mercury, and there are teeth running around which make and break the current. The whole is encased hermetically. Here I have a German-silver cup that is ckel plated on the ins , and there is a d magnet outs which holds the mercury jet stat while the pulley rotates. I could this instrument about 2,000 cycles very nicely, and was a machine that would an of about 1 ki It was a fairly effi instrument, per- 80 percent of the energy of the was obtained in the secondary.

Here [Fig. 47] come to another That was another solution of the of currents of very high frequency. An rnator was difficult to construct; if one went into too h , became inefficient and worthless. But, in this way, I was able to any frequency up to 200,000 per second, or more, in a perfectly reliable manner, and I could a couple of kilowatts output very easily.[*] That was especially built for telegraphy, te , and similar experiments.

* Editorial note: In the article, "Dr. Nikola Tesla and His Achievements" Samuel Cohen, appearing in the Electrical Experimenter magazine, February 19 (pp. 712, 713,), figure 4 shows an interrupter having a similar external appearance and it is described as handling 50 horsepower (37 kilowatts).

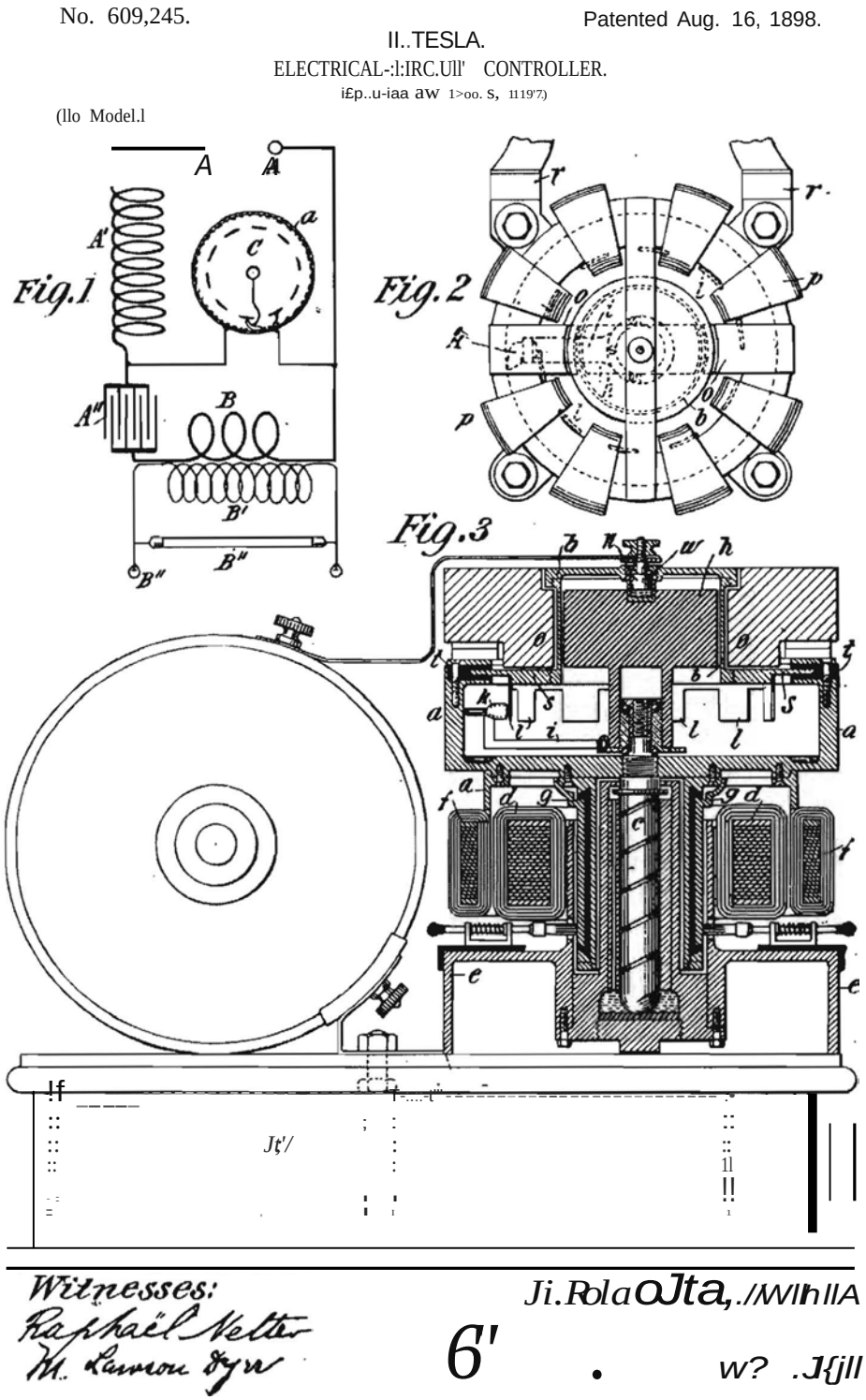


Figure 46.
Diagrammatic illustrations of hermetically enclosed mercury break described in U.S. Patent No. 609,245 of August 16, 1898.

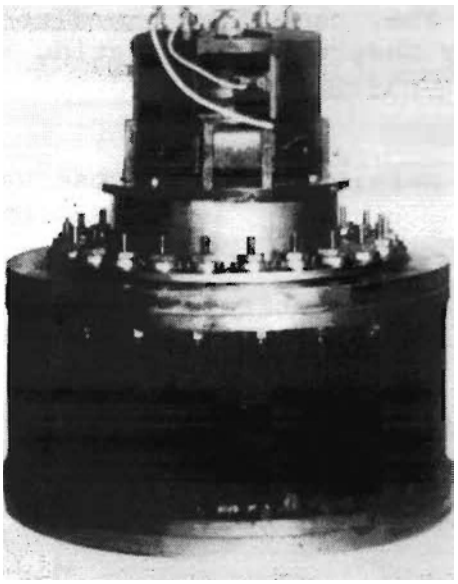


Figure 47.
Large mercury circuit controller of high frequency (telegraphic and telephonic experiments) .

The arrangement was simply this. I had a number of studs with cups which were insulated, 24 if I recollect rightly. In the interior was a mechanism that lifted the mercury, threw it into these cups, and from these studs there were thus 24 little streamlets of mercury going out.[*] In the meantime, the same motor drove a system with 25 contact points, so that for each revolution I got a product of 24 times 25 impulses, and when I passed these impulses through a primary, and excited with it a secondary, I got in the latter complete waves of that frequency.

Counsel

What frequency, then, did you get in your secondary?

Tesla

Oh, I could get in this, 600 per revolution.

Counsel

You mean 600 trains?

Tesla

No, 600 waves. Assume then, 600 impulses per revolution and suppose that I rotated it 100 times per second [6,000 RPM]; then I would get 600 times 100, or 60,000 primary

* Editorial note: This controller mechanism is described in Tesla U.S. Patent No. 611,719.

impulses [per second], and in the secondary a frequency of 60,000 complete cycles. The primary impulses were unidirectional. They came from the direct current source, but in the secondary they were alternating -- full waves.

Counsel

How persistent were those waves?

Tesla

They were entirely persistent. I had 60,000 per second absolutely undamped waves; they could not be damped.

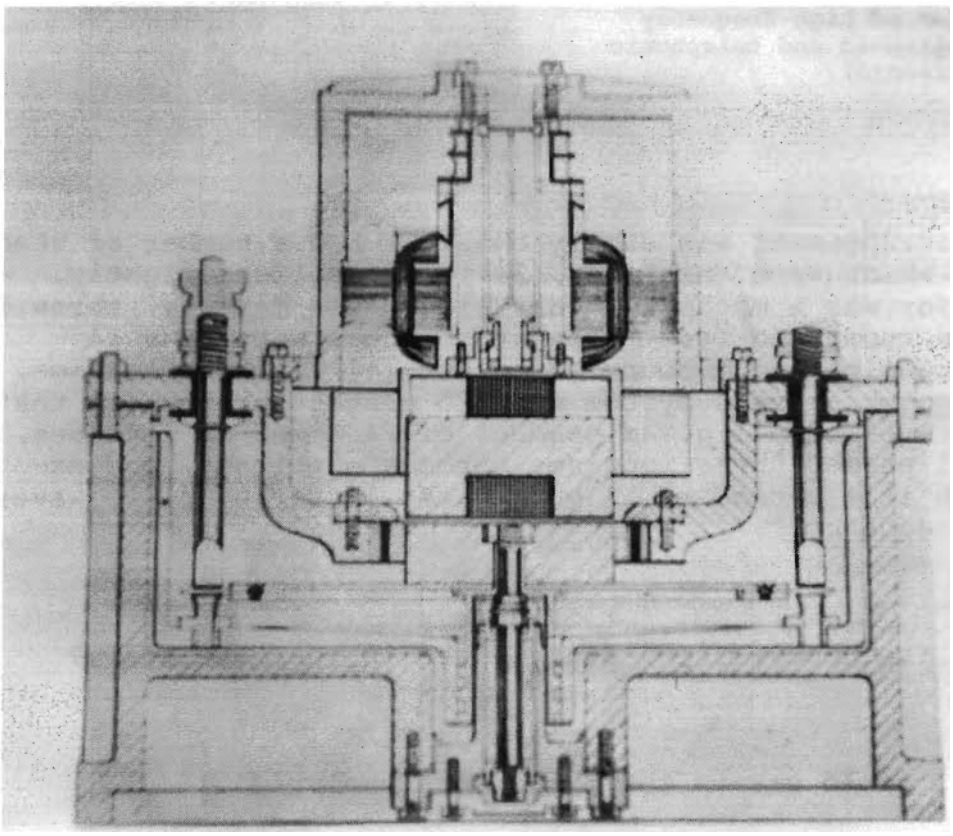


Figure 48.
Drawing Interior arrangement of large mercury circuit controller of very high frequency. (1899)

I want to show you [Fig. 48] the general arrangement in such an instrument, except that this does not exactly illustrate the interior of the other one [Fig. 47]. But, you can readily see a pump that takes the mercury up, and then the mercury flows out against this stud, and as these arms rotate they break the mercury stream and interrupt the current.

That [Fig. 48) was another type. I had probably 50 or 60 different instruments; in fact, I spent a little fortune on these devices, but some of them have been very valuable, and I do not know but that they will take an important place in the art. They are used very extensively.

The other day, some time ago, a German concern, in recognition of my inventions, made me a present of a very nicely developed interrupter which they had been manufacturing along the lines of my patents. My patents expired; they used the inventions and built up a business, and felt that at least they ought to give me one instrument, and they did. It was very nice.

Counsel

This then, as operated by you, produced undamped waves. Will you tell us just what use you made of it?

Tesla

Oh, I used it just exactly as I used the high frequency alternators. I would energize the primary circuit, and then in the secondary connect the antenna. You see, with an apparatus about 18 inches in diameter, I could get 2 kilowatts in undamped waves.

Counsel

When was this?

Tesla

These instruments all were made, practically all -- I had perhaps 40 or 50 of them -- prior to 1899. When I came to my plant on Long Island, I did some further work on them, but I used the old casings and simply changed the interior construction.

There was one construction I had, a very fine thing in which I did not produce any streams. It was so devised that the mercury filled these pockets, and I had 24 little droplets coming out of these places. Then, on the other hand, I had curved arms running around and forcing mercury out under small pressure due to a difference in the length of two columns in the curved arm. I had just the drops meeting, and there was no mercury flowing out in reality. There was simply mercury touching mercury, the contacts being at a distance of about 1/64 inch. These devices worked very well indeed. I have this little instrument from Germany -- of course the Germans do everything so thoroughly -- it is very reliable. I can pass through it regularly 20 amperes, and it works well -- no trouble at all. This [Fig. 48) is a little bit different in

construction but, as I say, my patents described many forms. I have spent a lot of gray matter in developing these instruments.

This [Fig. 49] I must show you, because that was a transformer of the high frequency type which I used. I could not employ ordinary transformers, and I built something special. I had my primary on the outside, and inside was the secondary. That enabled me to use thick wires in the two circuits and put them in a loose inductive connection. I had two of these transformers. They were made late in 1896, and I remember that with one of these transformers I showed experiments to Lord Kelvin. He was interested in this form of transformer and I explained to him why I departed from the usual arrangement. That instrument was simply one of the accessories in the equipment of my plant.

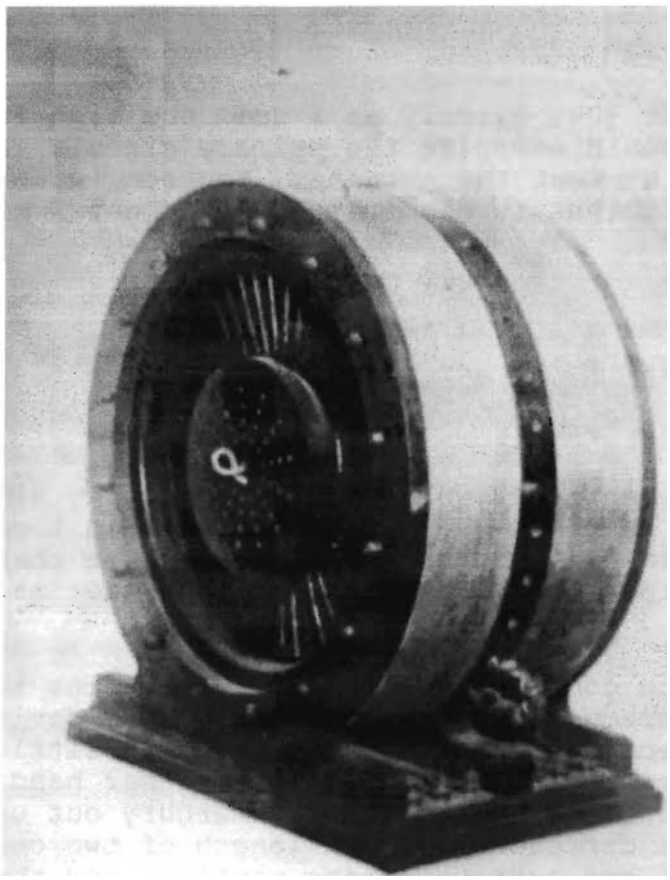


Figure 49.
Special type of high frequency transformer. Houston Street laboratory; later in Colorado. Tesla article, "The Transmission of Electric Energy Without Wires," Electrical World and Engineer, March 5, 1904, pp. 429-431. Made in 1896.

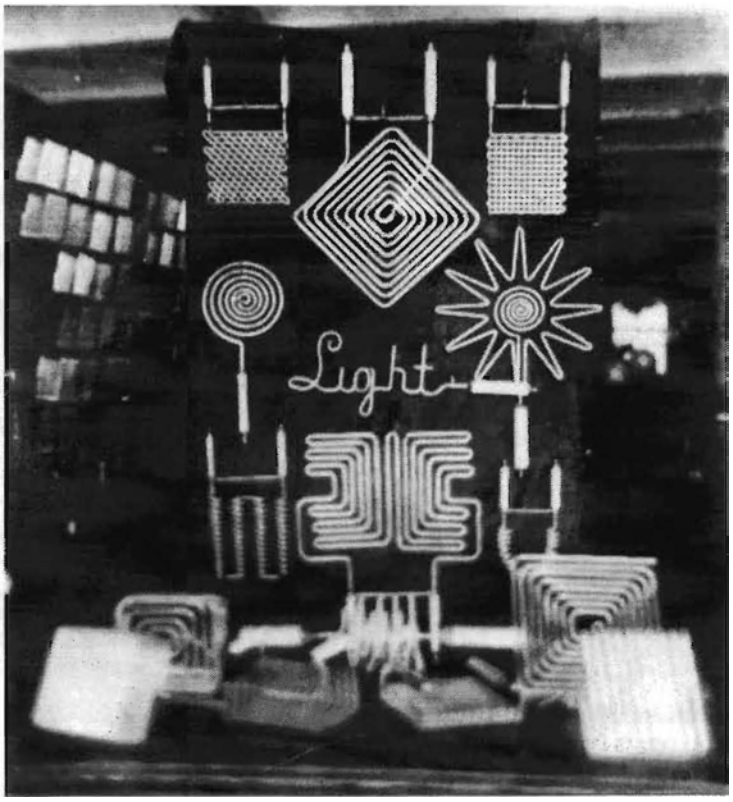


Figure 50.
Illustrating forms of vacuum tubes.

This [Fig. 50] does not refer to wireless telegraphy, but it does refer to wireless transmission of energy. These [upper] are forms of tubes I used, and these [on table] are the forms that I proposed to use in a larger plant when transmitting energy. This is, in fact, the ideal application of the transmission of wireless energy because the lighting can be effected in isolated places at a much smaller cost than is possible by any other method known. I also believe that nowhere as yet has a source of illumination been produced, neither the tungsten or the mercury arc nor anything else, which has the efficiency in light production that my tubes have; but they can only be used to produce light on a large scale, and that project, unfortunately, has not yet been carried out; but I think it will.

This [Fig. 51] is the transmitter which was already so far developed that I obtained discharges of 16 feet and a tension of 4 million volts. The secondary [flat spiral] usually connects to the antenna, and this [coil on vertical stand] is another tuning coil to adjust the oscillations to a low frequency. Now, it is a mere matter of proportioning this circuit to the antenna in order to transmit, with the same apparatus I built in 1895, 1896, and 1897, messages across the Atlantic with the greatest facility. I will agree at any time

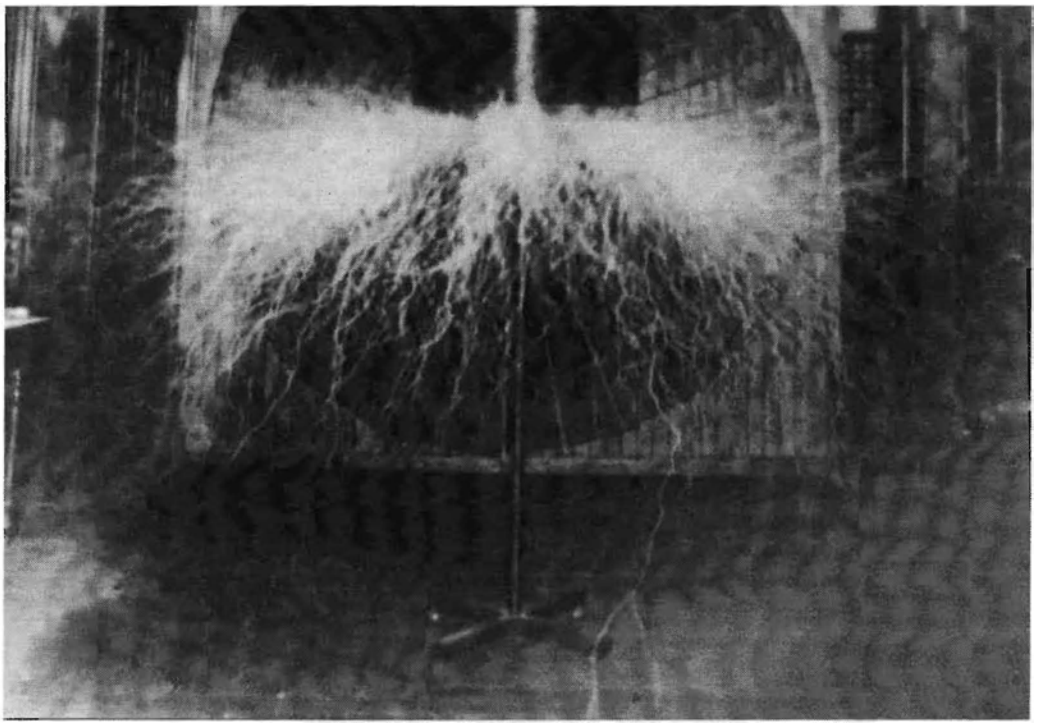


Figure 51.
Resonant wireless transmitting circuit. (Described in Electrical Review, New York, March 29, 1899, pp. 193-197, 204, and Electrical Review, London, May 5, 1899, pp. 730-733.)

to construct an apparatus exactly as I have described at that time and, without the slightest change, I will effect transmission across the Atlantic as easily as rolling off a log.

Counsel

Is that a spark apparatus?

Tesla

Yes, in this instance it was a spark apparatus; but I operated it also without a spark, with alternating current. I operated it with damped waves or with undamped waves. But remember that I had a system with small capacity, large self-induction -- no outflow of energy. Energy could not radiate; that is the reason why I got this tremendous pressure which you cannot get in an antenna which radiates too much energy in electromagnetic waves.

Counsel

Mr. Tesla, speaking about that apparatus you said that the energy could not get out. How was the transmission then made, as for instance, across the Atlantic, or elsewhere? Is it through these earth currents that you spoke of?

Tesla

Yes, of course, through the earth currents. If I s y generated electromagnetic waves, I would be in the same box that Marconi is in, or anybody else; I would have to use an awful lot of power and I would not be able to across. I would have to use a bigger apparatus. But, if I adapt s apparatus to the antenna in the way I want to , there is no difficulty of transmitting across the Atlantic with s very same apparatus.

I understand that ion Company made recently, a suit, an Pickard [*] me about it -- [where] they constructed a coil according to my ons, and then te -- ▮ 't know, 200, 300, or 400 miles. When Pickard told me about that, I saw that did not make the test You see, they should have obtained the low frequency by us more primary energy, by more condensers, but they did not do that; only used the which I specified in my patent which was , I unders , 0.04 microfarad. should have added to the condenser [additional] ty and got down to a lower frequency with a r then could have te across the Atlantic. Why not? The same ap- paratus is in all of these These stations, every one of them, have the spiral form. [See Appendix I, . 2.J

Counsel

Pickard not understand your disclosures, then, did he?

Tesla

Excuse me, he understood them perfectly.

Counsel

But he did not embody them in the apparatus?

Te la

He did not do the as I would have done it, I will admit that; but, then, there are artists, and then there are others.

* Editorial note: Greenleaf Whittier Apparatus Company. Pickard, grandnephew of poet leaf Whittier. Beginning in 1903, he i ated using mineral and is identified with introducing the "crystal" detector. At and designer with the interview, he was a research

John Green- s as detectors
the time of this Wireless Specialty

Counsel

I do not yet get quite clear just what the effect is of keeping the energy from leaking out from the antenna.

Tesla

Well, sir, I have given you the simplest mathematical formula which, of course, experts are perfectly familiar with. You are not. Now, let me explain.

If we put it in an equation, we will have on one side the decrement of the antenna, and on the other the resistance of the antenna multiplied by the square root of the capacity divided by the self-induction. [*]

Counsel

Yes, I understand. I have heard of that formula; but I do not understand how transmission is effected unless there is radiation.

Tesla

This is a very important thing. We will come to that; I will explain it later.

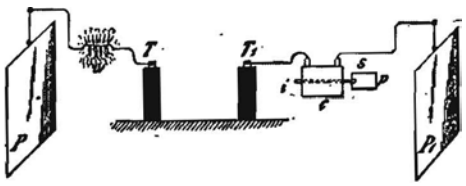


FIG. 175.

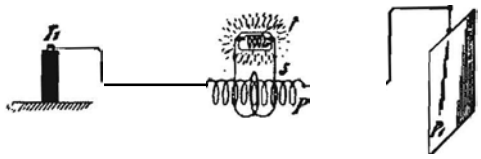


FIG. 176.

Figure 52.
Experiments illustrating transmission and transformation of energy through one wire made in demonstrations before the Franklin Institute and the National Electric Light Association in 1893. Illustrations from Martin book, Figs. 175 and 176, pp. 328, 329.

Here [Fig. 52) are illustrated the first experiments I demonstrated in public, in my lectures in the United States, forming the original striking departures -- the first primary steps I made in operating devices, when I showed this new principle of conversion. I passed a current of high tension through one wire, then I reduced the pressure in a secondary; that is now a very common practice.

* Editorial note: See, for example, Zenneck, Jonathan, Wireless Telegraphy, McGraw-Hill, 1915, p. 165.

I<n:. 1!1D. FIG. 191. FtG. \!)2.

Figure 53.
Some of the most striking experiments with vacuum tubes and lamps shown before the Franklin Institute and the National Electric Light Association in 1893. Martin book, Figs. 190, 191, and 192, pp. 358, 359.

These were the most striking results I showed in the transmission of energy in my lectures before mentioned. You see how far I have gone into the mastery of electrical vibrations in 1893. I stand here [Martin's Fig. 190] in the hall, holding a lamp in my hand, and the energy transmitted lights it. Here again [Fig. 191] I hold a phosphorescent bulb in my hand, and here [Fig. 192] a vacuum tube.

These experiments, I remember, were made in St. Louis. There was a hall with 6,000 or 7,000 people. When I explained how I had shown a phosphorescent bulb to Lord Kelvin in England, and told them that the bulb was going to spring into light, and the current was turned on and it did burst into light, there was a stampede in the two upper galleries and they all rushed out. They thought it was some part of the devil's work, and ran out. That was the way my experiments were received.

VI. Colorado Experiments

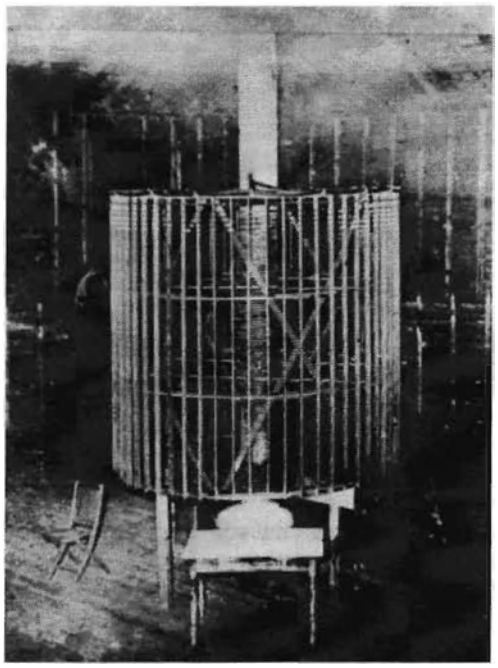


Figure 54 (left).
Experiment showing the lighting of incandescent lamps by energy transmitted through one wire with more powerful apparatus.

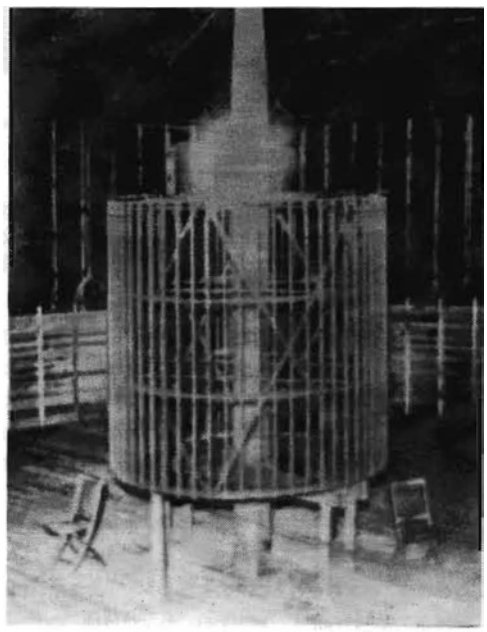


Figure 55 (right).
Still more striking experiment with the same apparatus in which a lamp is lighted at the extreme end of a coil. (Article "The Problem of Increasing Human Energy," Century Magazine, June 1900, Fig. 3, p. 186.)

Tesla

Here [Fig. 54] I show that I have advanced further, much further. This is an experiment in Colorado [*], and as you see, five or six lamps are lighted -- no capacity, just simply a coil into which the current passes. I have not the time to do justice to these photographs now.

This [Fig. 55] is a wonderful result, showing a further perfection. To give an idea of the power of all these oscillations, I put a lamp on the end of a coil, nothing else, and it is lighted to full brilliance just by reason of the fact that it has a minute capacity, only 4 or 5 centimeters [4.4 or 5.5 picofarads]; that is enough to light it.

* Editorial note: For comments on the Colorado experiments appearing in earlier sections, see pp. 32, 61, 62, 74, and 82 (Fig. 49 caption); in later sections, see pp. 130, 137, 145, 146, 163, 167, 170, 172-175, and 179.

Counsel

Where is the other coil?

Tesla

You see it [in the background of] this picture. The coil here is 51 feet in diameter.

Counsel

A wire around the room?

Tesla

No, it is a coil. That [in the picture background] is my secondary. That is the coil which connects to the antenna, you see. But this smaller coil stands free, entirely free, in the center of the big one.

Counsel

Is this apparatus shown here the receiver; that is, is the glow that we see there the indication of received energy?

Tesla

Yes, but that is the energy supplied through one wire. That is, I am now describing various effects. I meant to lead up from the transmission over one [wire] to the transmission

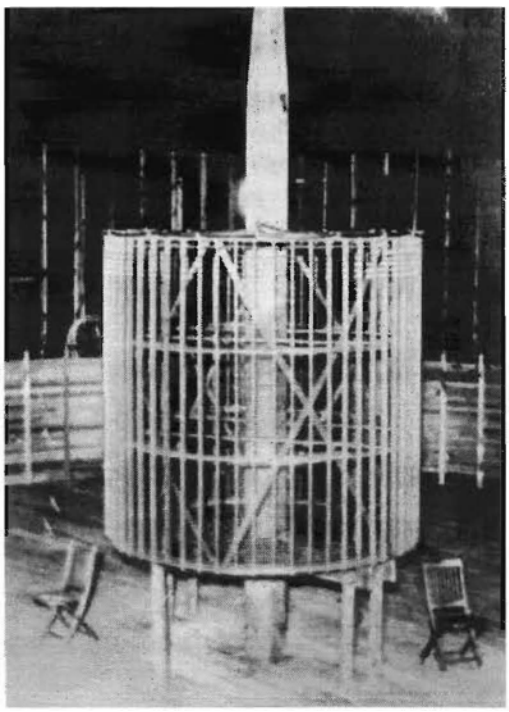


Figure 56.
Illustrating another experiment with the same apparatus in which the coil is not directly connected to the source of oscillations, but receives the effect inductively from a distance. [Note: the wire lead used to connect the resonator to the ground plate is absent.]

through the earth. This is transmission through one wire, but shows what a marvelous oscillation takes place in the circuit when one can light a lamp at the end without any capacity, just a bulb.

I measured the capacity of the bulb. The capacity was 2 or 3 centimeters [2.2 - 3.3 picofarads], at most, and in order to light a lamp with a capacity of 2 or 3 centimeters, you can appreciate what a tremendous vibration that must have been.

This [Fig. 56] is another experiment, another effect. Here is a coil absolutely disconnected from everything else. I transmit electromagnetic energy to it. There is a lamp at the end and that lamp lights. There is no connection to the coil whatever.

Counsel

And from what source does that coil get its energy?

Tesla

From a [primary] circuit that is 51 feet in diameter, and goes all around. Some of these experiments have been described in my article in the Century Magazine, June 1900.

This [Fig. 57] shows the general arrangement of the apparatus. That [middle upper-left], you see here, is a coil 51 feet in diameter; it is my secondary. That is not a thin wire; it is a very thick cable. It is a coil about 9 feet high. This wire goes up to the antenna. Here [lower half] are my condensers, and the transformers behind. There is my self-inductance [with wooden-handle crank], and all the rest.

Now you see [in Fig. 58) another thing. I have a number of coils here. Notice the coil in the center. These are coils which I have tuned to various frequencies; that is, to harmonics. They receive electromagnetic energy by induction, and you see the enormous discharge from the center coil, although it is unconnected and at a distance of many feet from the primary.

Counsel

Were those spark generators?

Tesla

I used the spark method and continuous, or undamped, oscillations. I had for their generation ordinary current of 133 cycles and also a street railway current of 550 or 600 volts, from which I produced undamped waves.

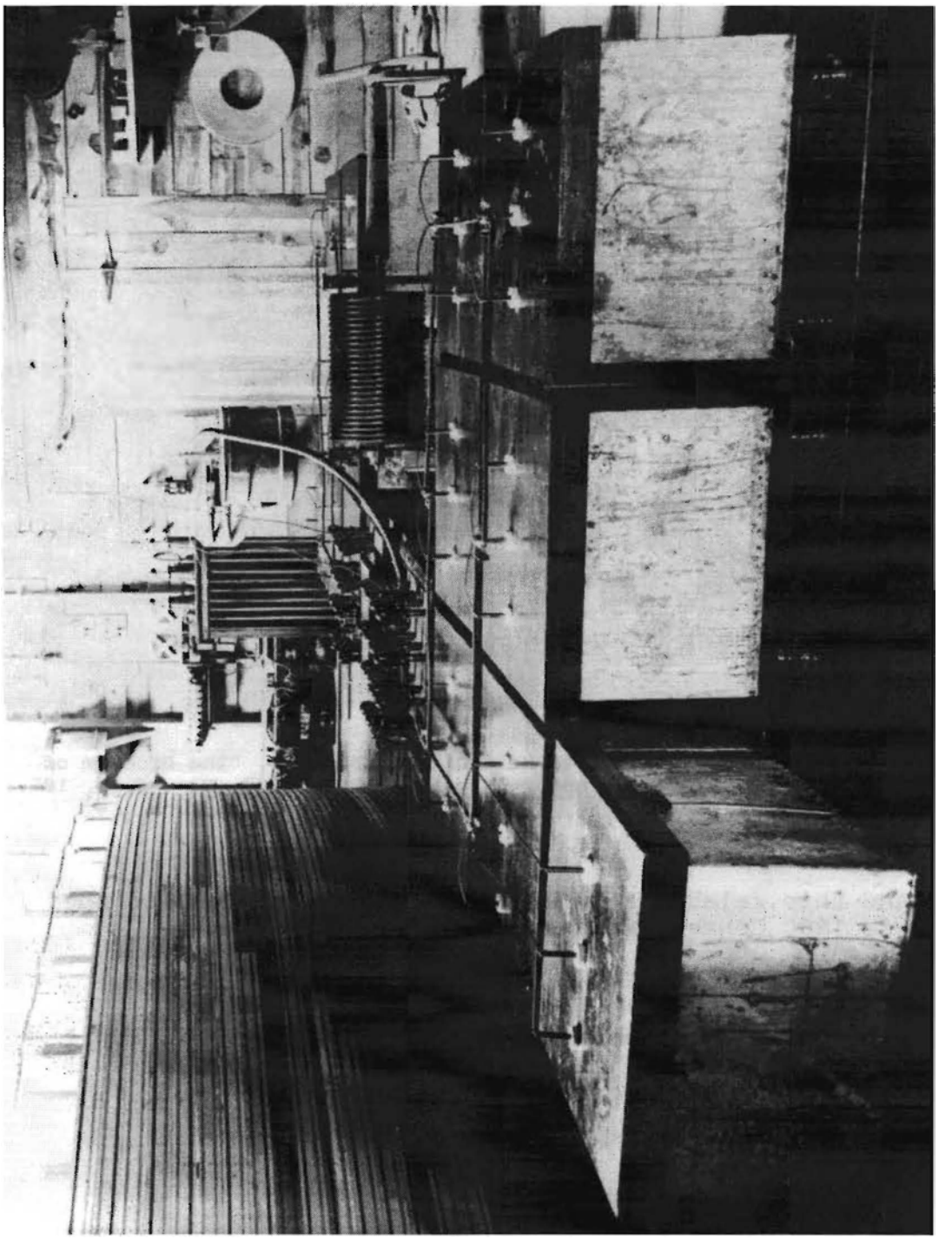


Figure 57.
Oscillating apparatus on large scale with which the preceding experiments were made. Coil at left, 51 feet in diameter, forms part of the magnifying transmitter. (Article, "The Problem of Increasing Human Energy," Century Magazine, June 1900, Fig. 6, p. 188.)

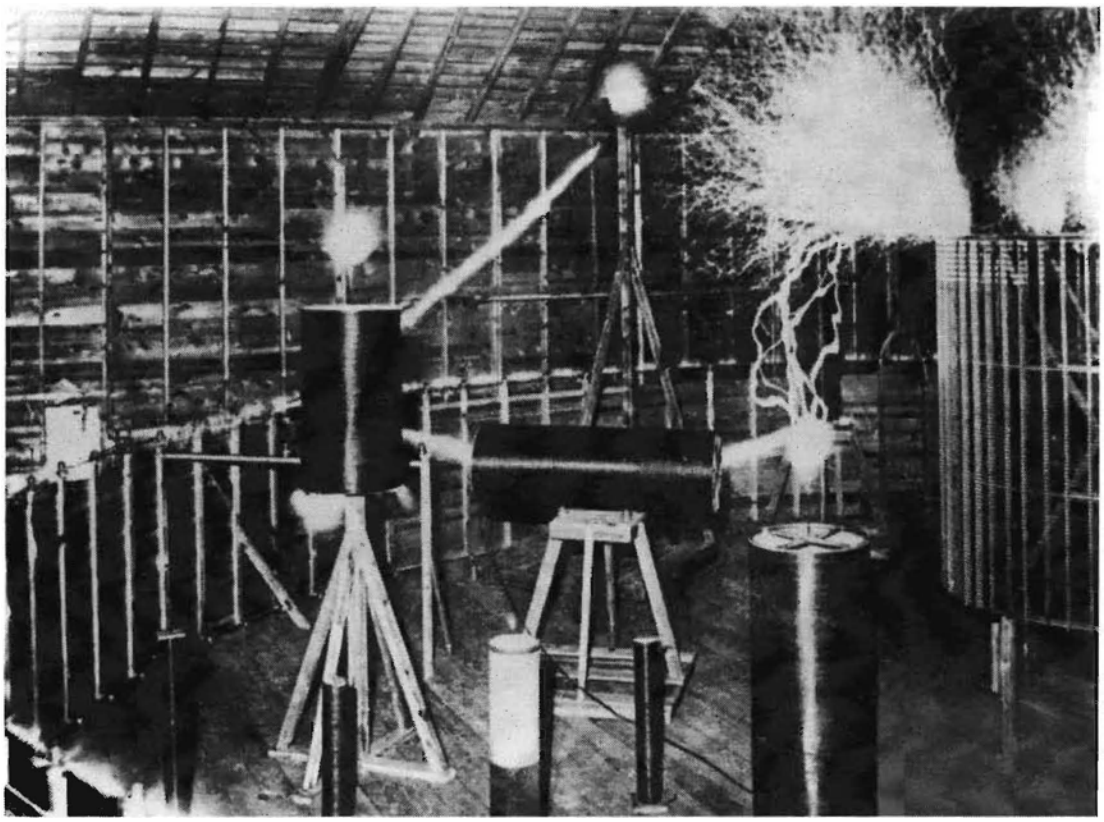


Figure 58.
Experiment with coils tuned to harmonics. (Artic:le, "The Problem of Increasing Buman Energy," Century Magazine, June 1900, Fig. 5, p. 187.)

Counsel

And this relates to the experiments that are described in the June 1900 Century Magazine?

Tesla

Yes, those experiments of powerful discharges which I showed you were mostly performed in this way, with a few primary impulses and superimposed quicker vibrations.

Counsel

But they were spark discharges?

Tesla

They were spark discharges because, as I said before, working with damped waves we can produce wonderful effects. Operating with undamped waves, we have to stick to the actual capacity of the machine.

Figure 59.
Transmission of energy with tuned system by induction. (Article, "The Problem of Increasing Human Energy," Century Magazine, June 1900, Fig. 7, p. 189.)

This [shown in Fig. 59] is transmission of energy by induction. Here is a tuned circuit, you see, out in the field with three incandescent lamps and a condenser. The energy is transmitted inductively, from the oscillator. In this case,
I have the primary supply circuit, the energizing condenser

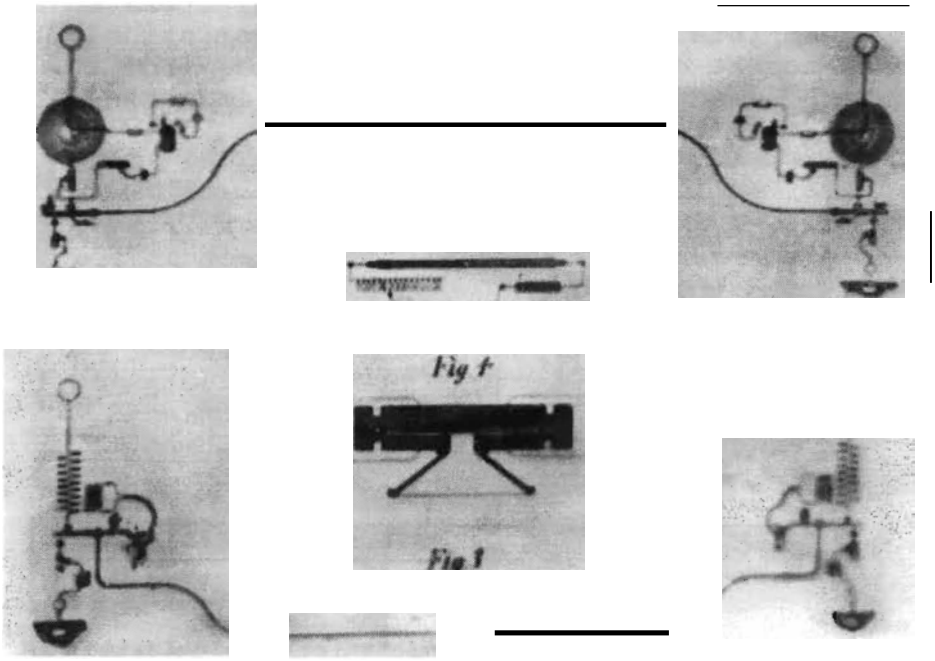
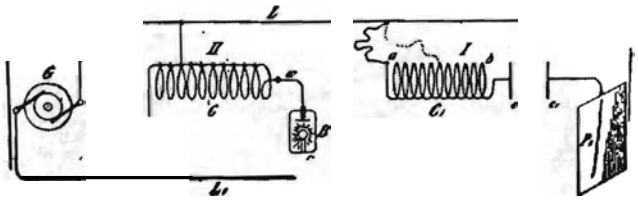


Figure 60.
Application of the one-wire principle to the transmission of telegraphic and telephonic messages. (1896-1897)

circuit, the primary inducing circuit, and the secondary in the field as in the fourth circuit, all tuned -- four circuits in resonance.

Here [Fig. 60), from a drawing for a patent application not pursued, are shown arrangements in single-wire transmission. All of these arrangements date back to 1896, 1897, and 1898.



Fm. 184.

Figure 61.
Illustrating experiment with high frequency alternator and tuned circuit having adjustable inductance and capacity as described in lecture before the Franklin Institute and the National Electric Light Association in February and March 1893. Illustrated in Martin book, Fig. 184, p. 344. (See Chapter, "On Electrical Resonance.")

Here [Fig. 61] is a diagram which was published on my lectures before the Franklin Institute and the National Electric Light Association. There I first alliterated and described a complete system of wireless transmission. I show here a generator at one side, a line extending from it, a capacity which is adjustable, as well as an inductance.

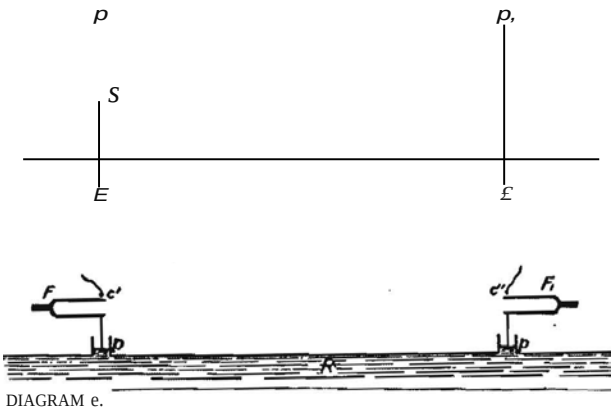


DIAGRAM e.

Figure 62.
Wireless transmission demonstrated, mechanically elucidated, as demonstrated before the Franklin Institute and the National Electric Light Association in February and March 1893. (Article, "The Problem of Increasing Human Energy," Century Magazine, June 1900, Diag. C, p. 206.) Illustrated in Martin book, Fig. 185, p. 348. (See Chapter, "On Electrical Resonance.")

I had, preliminarily to the article in the Century Magazine, to explain, in a popular way, the language of the wireless men; and my friends, R.U. Johnson, and R. Watson Gilder, wanted it explained in the simplest possible manner. This diagram [Fig. 62, top] illustrates the wireless system as I have described it in my lecture and this one, below, its mechanical analogue which I put in for the benefit of the Century Magazine readers.

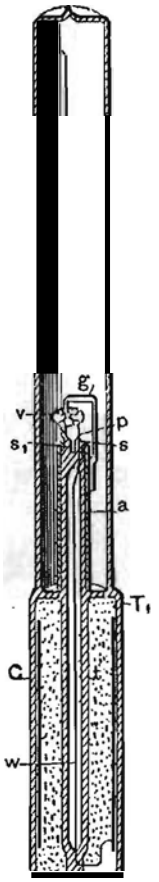


Figure 63.
Striking experiment in the transmission of energy by electromagnetic waves. Demonstrated in lectures before the Institution of Electrical Engineers and the Royal Institution, London, in February 1892. Illustrated in Martin book, Fig. 164, p. 288.

I show two illustrations now. This [Fig. 63], the first one, is to illustrate what I have already partially explained. The experiment was shown before the Institution of Electrical Engineers and the Royal Institution in London in 1892; I will illustrate [next] another experiment which I performed in Colorado in 1899 or 1900. That [Fig. 63] is the time where I take a glass tube, hold it in my hand, with nothing nearby. I create electromagnetic energy in the room, and I operate a little fan in that tube by the electromagnetic waves -- a wonderful thing. The scientists simply did not know where they were when they saw it.

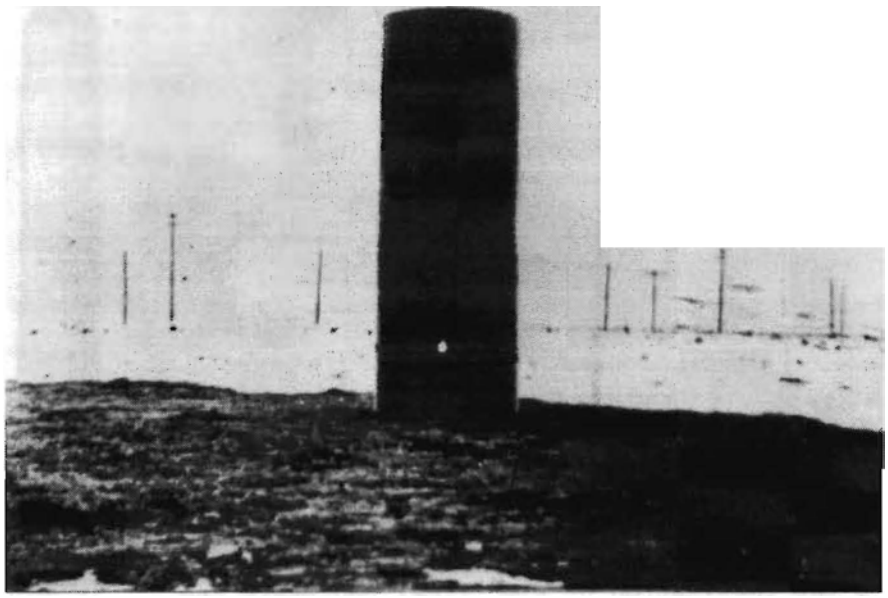


Figure 64.
Another less impressive but infinitely more important experiment in the transmission of energy performed in 1899.

Now I will show you [Fig. 64] the other experiment. How is that experiment performed? Here is a coil, without any antenna, no capacity whatever; just a simple, plain coil. It is placed at a distance from the transmitter and is connected to the ground. I have tuned it so that it forms the fourth circuit of a system of concatenated tuned circuits, and I have another secondary coil here which is likewise tuned, and I light a little lamp. That little lamp is nothing spectacular, nothing that would impress the scientific imagination, but that experiment which I showed you before, while wonderful, was worthless. It never in the world could lead to any development. It was so because of the fact that I employed agen- cies which were condemned from the very beginning as worth- less. But this, here, is a great experiment, marking an epoch in the evolution of the art.

Note that I connect a coil to the ground, impress powerful oscillations on the earth, and draw energy from it. This

coil I can put at the antipodes if I have my system properly devel it makes absolutely no ference whether it is there or 10 feet from my t That is the difference between the two experiments.

Counsel

When was that last one?

Tesla

That was in Colorado in 1899 -- at the close of 1899, that last experiment. And the other one was in 1892 before the Institution of Electrical Engineers in London.

sel

The difference between those two experiments last de was that the first one in 1892 had no grounding?

Te la

No grounding

Counsel

In the second, the l was grounded?

Te la

In the second the coil was grounded, and the was not that of electromagnetic waves, which is wasted; it was the energy of a current through the that the effect. This transmission was effic ; the other one was worthless.

Counsel

How far was that coil [Fig. 64], in Colorado, from the circuit?

Tesla

That was out in the field. I cannot tell you. The very same was illustrated the Century Magazine of June 1900 and I know when I wrote it that I gave full iculars.[*]

* Editorial note: Neither the text, nor the caption for Fig. 4, p. 186 of the Century Magazine article of June 1900, carry distance information.

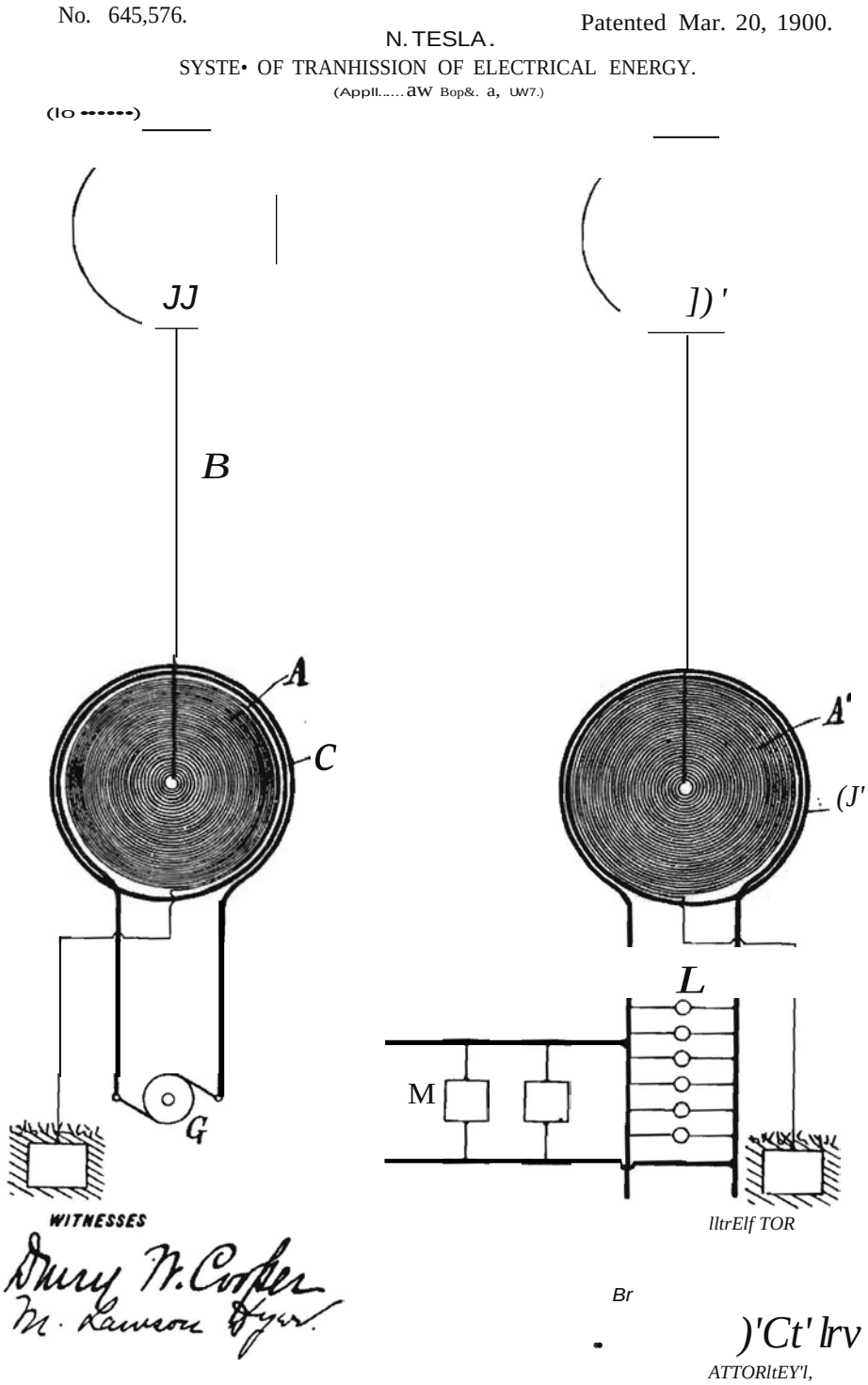


Figure 65.
Perfected system of wireless transmission with four tuned circuits. Described in U.S. Patent Nos. 645,576 of March 20, 1900 and 649,621 of May 15, 1900. Applications filed September 2, 1897.

Here [. 65] is my completed wireless system. That was published first in my Belgium patent in 1898. I clearly remember that the when I received it I entertained the present King rt] in my laboratory [August 1898] and explained to him the system.

There [at left] is my primary source of energy, which produces arbitrary oscillations of any kind. This antenna, you see, is grounded; no break in the connection. These two circuits are tuned to a definite frequency, which was arbitrarily adopted. The dynamo supplies oscillats which have been settled upon beforehand, of low frequency, of course, and the ci t is excited in the manner I have described.

Here [at right] I have the receiving circuit, similarly connected to ground and to an antenna. Then I have a second tuned ci t in which are inc the operating devices.

There is an important thing which is not known to engineers, which I want to point out. I have, the evolution of the whole system, always laid stress that whenever my frequency currents are employed, no matter how many circuits there are, those circuits are all to be tuned, preferab to same note.

In one of these s [i.e., No. 645,576] I described a transmitter giving minutely the dimensions of the coil, of the condenser, in connection with it.

There is one [other] important point. I have insisted on the tuning of all circuits but, you see, often have maintained that if a certain thing is not will not work, and all that. There is no truth in such statements. That circuit, and that, and that one must be attuned; this is an indispensable condition for t ssion; but it is not essential to tune this fourth circuit. As a matter of fact, in certain instances I have obtained a better result without tuning the fourth c it when I tuned it, and I will tell you the reason That is not known to engineers

If you take this fourth circuit [C'] entire away, and leave only that circuit here, the antenna and the ground connection, then that is the for the flow of the current in this rece Any other circuit you bring near to that the antenna will draw energy from it and tend to pull the oscillat in the latter circuit and diminish the resonant rise. No matter what you link to the antenna ci , and how you link it, the energy you take away that circuit will always being frictional, to diminish the resonant rise. Now the art con- sists in reducing as much as the energy necessary for the signal, and in that of as

the auction of Dr. De Forest, and of such devices, is in the proper direction, rational, and good. But the ideal condition s that you should have here a which only requires pressure and no current; and once you have a device which does not need any current but merely acts by pressure and has no internal capac , so that there will be no current in the circuit, then that is the ideal receiver.

There are two ways in which you can if you have a receiver of that One is , closely, your working circuit with the primary excited circuit. The other is by 1 it loosely, and then working up the pressure by resonance. You will find that you can do much better, if you have such a , to the necessary pressure by turns, than by resonant rise, because if you want to excite it by resonance you have to link a few 1 ; start a very low electromotive force and work.it up. But, if you have such a device as I have de you can obtain any pressure you 1 by a few turns. I have invented such an instrument and have demonstrated its efficacy

Quod erat demonstrandum.

But, I usually do tune the fourth I am trying to point out an error existing simply in the present ture of radio telegraphy and telephony litera-

Counsel

One moment before you leave that -- you have spoken of the as illustrated here of low frequency; what did you mean by that?

sla

In my s, frequencies were fied ranqinc all the way from about 1,000 per second up to 200,000 or 250,000, as I have set forth in the patents; but I have also indicated that the will depend on what use the apparatus is to be put to. In the apparatus patent, I have stated that there were instrumentalities with which you can generate, if you like, e ic waves. It 11 give you a very high pressure and a very current. It is an ideal s for the production of these electromagnetic waves. If you want to transmit elect ic waves, use a of 500,000 if you choose; , if you want to transmit the way I , you will use a very low frequency so that the loss in these elect ic waves, which are thought to affect the receiver at a distance, but which have absolutely nothing to do with that receiver, and are only a delusion, should be minimized.

Counsel

Is this system a simplification of the same general principle of transmission as was illustrated by the coil in Colorado which you showed just a few minutes ago?

Tesla

Yes, this is the same apparatus. But, remember that in my patents I described a method, and I also described an apparatus for the carrying out of the method, which apparatus can be used for practicing any method of transmission. You see, those two things are distinct.

Counsel

Here [Fig. 65] you have shown an alternator connected into the primary of the circuit, and you say that this is the same apparatus you used in Colorado. I presume you are going to give a more full description of the Colorado apparatus?

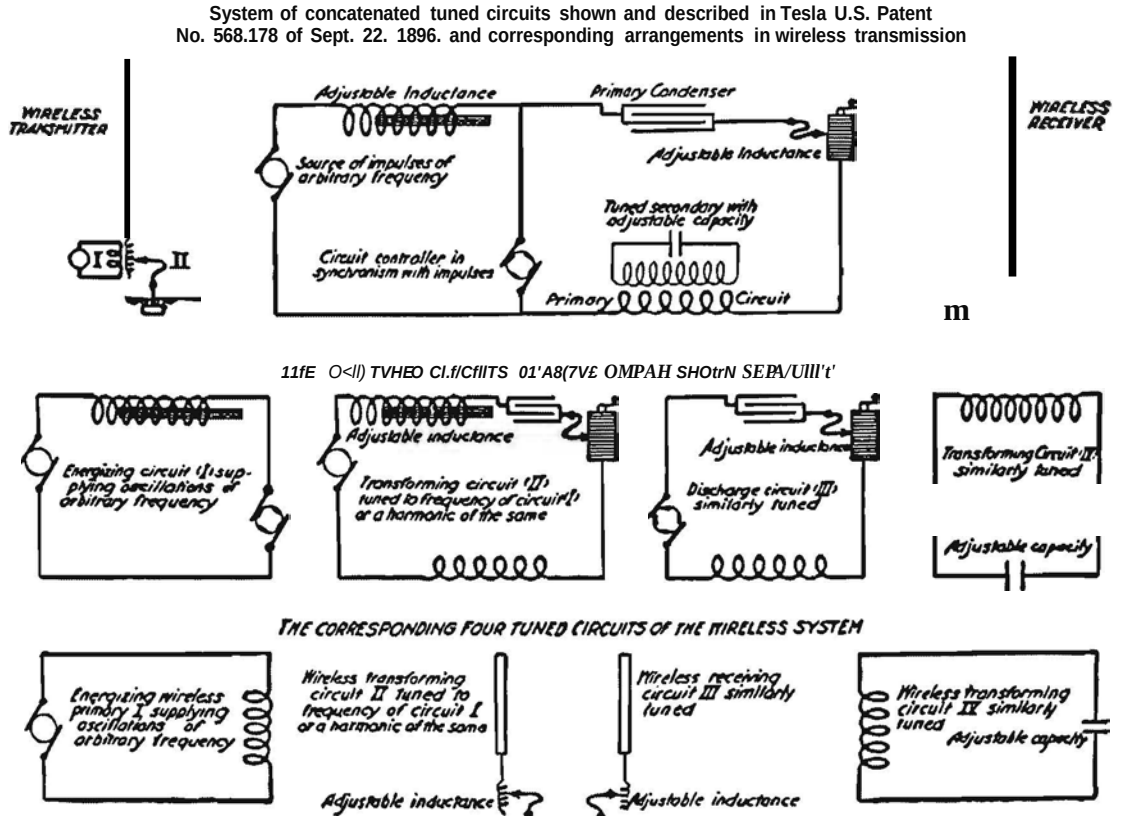


Figure 66.
Diagrams illustrating the system of four-tuned circuits as applied to wireless transmission. Described in U.S. Patent No. 568,178 of September 22, 1896. Application filed June 20, 1896.

la

I will dwell on that later.

Here [, which tr to illustrate a This diagram the system which I described in my patents of 1896, in which I showed four rcuits attunement, and I 11 endeavor to illustrate how these circuits are exact equivalent of less circuits.

You see, here on the I have " tern of concatenated tuned circuits shown and described in U.S. Patent No. 568,178 of 22, 1896, and corre arrangements in ss " The first ci t which have here is a controller, a source of ses of arbitrary , and an adjustable inductance. I have drawn that circuit and you see it here; that is my first circuit, "Energizing circuit (I)," supplying oscillations of arbi frequency.

The second one is the circuit including the source, the ustable inductance, this and this pr Ihave shown this circuit separately and marked it "Transforming r-cuit (II)" tuned to the frequency of circuit I, or a harmonic of the same.

The third ci is formed by the the self-inductance, and the controller, and it is shown as "Discharge circuit (III)" s tuned.

And then here is the fourth and last circuit an adjustable ty, shown as "Trans circuit (IV)• s tuned.

Now, if you look at wireless diagrams and bear in mind that Ihave, first all, established the equivalency between two-wire and one-wire transmission, that Ihave then gone a further and established the equivalency between the transmission through one wire and the transmission through the earth, which is wireless, then you will see that these wireless which are now, are merely an imi on of my s, are in fact, exactly the same. Here [left] is a wireless a primary circuit I, in which current impulses of arbitrary frequency are produced, corre to in this figure

Here is the tuned circuit to an antenna and to the including an ustable inductance, exactly as here; that is circuit II, which to this circuit (II) my arrangement

Then there is on the receiving side again the antenna ci with an ustable , ng to my circuit (III) with the adjustable inductance and this capacity

And then there is finally the fourth tuned circuit like my circuit (with adjustable condenser. All is therefore a perfect, exact equival ent of the a s I described ago.

This four-circuit arrangement has been claimed by others, but they overlook that Ihave that on September 22, 1896; and more than that, overlook the that my Belgian patent, the exact my American patent, was issued in 1898, to any suggestion Ferdinand Braun, or Marconi, or other men who have come subsequently. Therefore, if these are the facts, my statement of them cannot be inte as sl my fellow workers; Ipoint it out merely as facts, and if these men have c that this s it was merely due to ignorance on their part

Now, it is to you a clear of the differences between the apparatus Iproduced and the contemporary apparatus Ihave selected just these diagrams [Fig• 67) to give you, a few words, the exact fferences between the system Ihave deve and the illustrated below in this diagram, which is of the systems that had been used prior to my invention.

This upper diagram is taken from my patents, and this lower drawing from a of Marconi which appeared in 1901. Certainly, it is proper to compare his arrangements with mine because they were used at the time when I brought out these princ s.

As you see, here in this figure on the right, is my conductor connected to the and to the antenna, with abso- lutely no in it. This other [Marconi patent drawing] is a conductor connected to the antenna and the ground with a break in it. It cannot compare with mine because that break means resistance and diminution of the resonant rise. Furthermore, note the fference I have here -- the energy pass into a transformer, that these two s are tuned. There is no or a transformer in this Marconi It is a wasteful system to begin with.

At the receiving end, as you see, I have an antenna a sel in series with the no break. He a wire connected to the and to an antenna, a break or of , very resistance with which it is absolutely imposs to obtain any results.

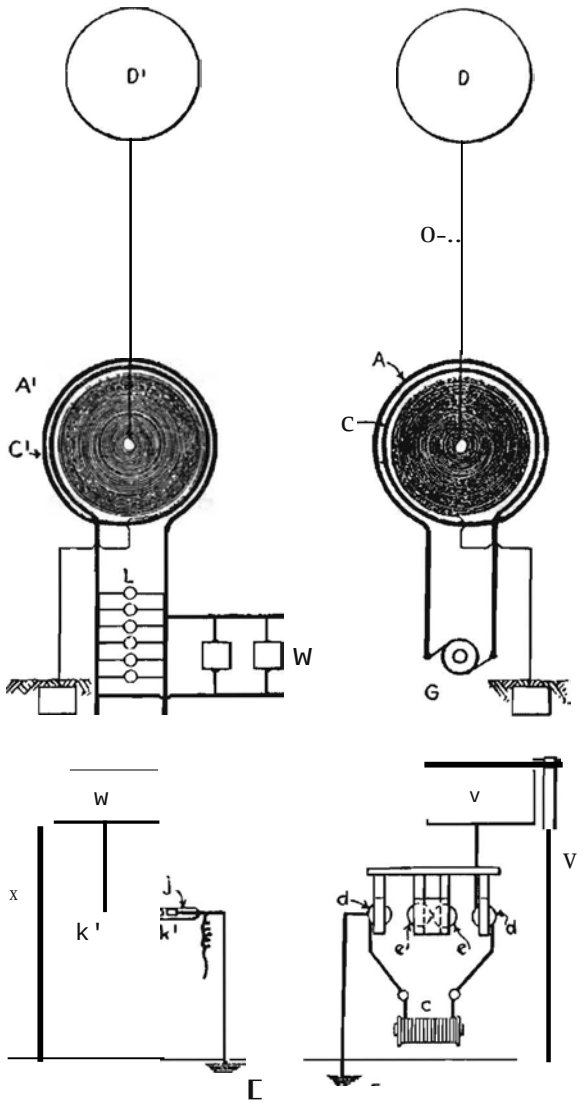


Figure 67.
Diagram showing the salient differences between the apparatus described in these patents and the typical Hertz wave arrangements of that period described in the Re-issue Patent of Guglielmo Marconi, No. 11,913 of June 4, 1901.

My system is a system which can be perfectly attuned, and it will transmit to this antenna, here [at left], hundreds of thousands of times, millions of times, the energy which his device can transmit to his receiver.

Furthermore, my system is a system which is exclusive, which can be tuned and rendered private; that of Marconi cannot be tuned. Moreover, his transmitter generates electromagnetic waves of very high frequency, which are absorbed in the

air and only a few miles, while mine produces current waves which pass to oppos of the with the greatest facility, and can affect instruments at any distance.

If you take these two s diagrams, and examine the subsequent developments, you will find that absolutely not a vestige, a vestige of that of Marconi remains, and all the present systems there is noth my four-tuned circuits. is us them.

In ng this to my system, there is where the great s in wireless has been made. But, as a matter of fact, this came When my s with the fying transmitter were ished in the Elect ical Review York, Mar. 29, 1899), there where the men recognized the necess or the of going to lower frequency. They started out with frequenc s, and you will hear it asserted that , say, to 1901, there were of 2 million used. There is no truth in that. Long before 1901 the radio men had followed my lead, and they had ly reduced their frequencies; and when in 1900 I published these results in the Century Magazine and showed that these were obtained with a frequency of 50,ODO, there was a for these frequencies. [T]hese s have been by all experts before 1901, so that there is no truth in the statement that very h frequencies had been used subsequent to that date. It was only in the very beginning that very high s were , but were ly abandoned, until in 1900 began to use low frequencies

Counsel

Was this system of yours used in anything but experimental work?

Tesla

Why, there is no other system that is [emphasis in original] used. Every ss message that has ever been transmitted to any stance has been tran s ; there is no other way. Mr. Marconi came here, when he announced that he had made a transmission across the Atlantic. I him. ▮ said to my secretary

> " cannot understand how Marconi could obtain these results. His s cannot do this; he must use my apparatus "

My secretary

> "How can Marconi use your s when here is his statement that he had tried it and it did not work?"

But, when you examine the publications of a year later, you will note Marconi comes out with the statement that he had used these four circuits, and the only excuse that he has put up is that he did not know that these four circuits had to be attuned. That was his excuse. And in the meantime, he had been using this apparatus. Every message that has ever been transmitted to any distance, by telegraph or telephone -- wireless, has been by the use of these instrumentalities and no others.

Counsel

Your experimental [work], as I understand, was on a considerable scale. Describe the size and use of those experiments.

Tesla

They were only experimental in the sense that they were preparatory steps to the construction of a big plant which I undertook to erect. You see, my apparatus of 1896, exhibited in my laboratory, was sufficient to flash a message across the Atlantic; but I was preparing for a very big undertaking, and as the things then looked I was capable of putting that undertaking financially through; I had excited the interest of a great man. But, when the radio business assumed the phase of stock jobbing, that great man said to me,

"I could not touch it with a 20-foot pole,"

and there I remained stuck with my project and unable to carry it through. But, I undertook the design and construction of a plant for telephony around the world, and just as certainly as you can hear my voice across this small space, you would hear my voice across the whole globe if I had completed that plant.

Counsel

You have spoken of these stations, elsewhere, as not commercial. I spoke of your experimental stations. In what way do you use the word "commercial"?

Tesla

Why, I mean commercial in the sense that you are transmitting messages for a charge.

Counsel

These stations that you constructed -- and let us refer to your Colorado station -- was the construction and operation on a scale adapted to commercial work?

Tesla

Yes, it was not only adapted, but better adapted than any plant that has s been built. I had in my Colorado plant a current of 1,000 amperes in the antenna. The biggest radio plants today ke 200 or 250 amperes in the antenna. Remember, also, that my current was under a great tension. My current was under a tension of 3 1/2 or 4 million s, others only 30,000 volts; so you can imagine the enormous difference between the energy of the vibrations ch ▮ produced and those in the present ants.

I had a of 500 or 600 centimeters [i.e. 550 or 660 picofarads], but this capacity was charged to 4 million volts; they have a capacity of, maybe, 18,000 or 20,000 cent [i.e., 0.020 or 0.022 microfarad 'whatever it is, but they charge it only to 30,000 s. You know the energy of a system depends on the square of the potential. If I used a , say, one-tenth of that and ▮ charged that capacity to a thousand times potential, I have an immeasurably greater energy in my system. [T]his is only possible, as I said, through the observance of the rules which Ihave already explained, which me to economize in the ion of electromagnetic waves, to suppress them as much as poss le, and to intensi current which can perform work at any point of the globe

Counsel

Going back for a moment, what was the longest tance over which there was actual o tran sion?

Tesla

Ihave al that the st distance that I ever transmitted was from Houston Street to West Point.

Counsel

Does that include Colorado also?

Tesla

Oh, at Colorado there was a fference. In Colorado ▮ demonstrated

Counsel

I do not want to get these things mixed up; are the same thing?

Tesla

No, not the same thing. This system of [Fig. 67, upper diagram] is the system I have described.

Counsel

Was that used out in Colorado?

Tesla

Oh, the Colorado apparatus was on the same principle, but looked different.

Counsel

Referring to this [Fig. 67, upper diagram], was this used only here in New York?

Tesla

Only here in New York.

Counsel

That is what I want to get clear in my mind.

Tesla

Only here in New York, and with this apparatus exactly as described in my patent I transmitted from my laboratory on Houston Street to West Point, and that was the biggest distance that I ever transmitted.

Counsel

In the Colorado apparatus, did you have a spark gap in the transmitting set?

Tesla

Oh, I sometimes had a spark gap, but not in the antenna. The antenna circuit was always grounded without any break.

Counsel

But your oscillator there was a spark oscillator?

Tesla

Oh, sometimes, yes. But, pardon me; in my patents I described both a dynamo and my transformer, and those two things are equivalent.

Counsel

I understand that, but I am speaking about what you actually used in Colorado.

Tesla

In Colorado I used the spark gap method because I could not get from any high frequency machine any such amount of energy. That is the point. But I used damped and undamped waves -- both.

Counsel

I have read in some of your writings that you went to Colorado to further experiment with certain apparatus which you had tested to your own satisfaction at sea level. What was the reason that you went to Colorado to continue those same experiments?

Tesla

I built the Colorado experimental station preliminarily to the installment of a large plant on Long Island, which I was designing at that time. I had some friends who were willing to back me up financially, but I did not care to take the responsibility. I told them that I could do it without any further experiment but, in order to satisfy myself of everything, I preferred to go to Colorado, spend $50,000 out of my own pocket, demonstrate the proposition, and then go to the financiers who were willing to trust me and say,

"I am now prepared to build."

Counsel

I was not asking for the personal reason as much as the scientific reasons. What I wanted to get at, was that demonstration undertaken in Colorado for the purpose of getting the higher altitude of the air?

Tesla

No, it was nothing of the kind. I simply went there because in Colorado my system of power transmission was introduced. All around the plants in the mountains, my three-phase system, and the induction motors were employed. All the mines surrounding Cripple Creek and Telluride were operated by them, and I had friends there who were only too delighted to give me all the power I wanted, and not charge anything for it. And furthermore, the climate was praised up very high. Of course, when I came to Colorado Springs I discovered that 30,000 consumptive were there, out of 35,000 inhabitants. And then I

made a remark, for which I was near chased out; I said that Colorado Springs was a nice ace but only two kinds of people ought to there -- those who have the ion and those go who get it. ıwas nearly chased out. want to

My experiments [on Houston Street] showed that at a he of 5 miles the was in conduction to the energy in this way, but my experiments in Colorado showed that at a he of 1 mile is pl raref to break down under the stress and conduct the current to the distant points.

I have to say here the ions of Septembe r 2, 1897, for the energy in which this method was dis it was al clear to me that I not need to have terminals at such high elevation, but I never have, above my s , announced that I did not prove first. That is the reason why no statement of mine was ever and I not think will be, because whenever I I go it first by experiment, then from experiment I calculate, and when I have the theory and ce meet I announce the results.

At that time I was absolute sure that I could put up a corrunercial if I do nothing else but what I had done in my on Houston Street; but I had already calculated and found that I did not need heights to apply this method. My says that I break down the atmosphere "at or near" the terminal. If my atmosphere is 2 or 3 miles above the ant, I consider this very near the terminal as compared to the distance of my receiving te , which may be across the f That is simply an expression. I saw that I would be able to power provided I d construct a n apparatus -- and I have, as I will show you later. I have constructed and a form of wh , with a moderate elevation of a few hundred feet, can break the r stratum down. You 11 then see s l an aurora borealis across the s and the energy will go to the distant place

That is very s An apparatus which permits displac- a certain quanti of electricity in the terminal -- we shall say so many units -- will potential at a stance of 5 mi , and the fall of electric potential per centimeter will be equal to the quantity of electricity divided by the square of the distance.

Now, I have satisfied myself that I can construct plants in which I may produce, per kilometer of the atmosphere, electric fferences of potential of some like 50,000 or 60,000 ts, and at 50,000 or 60,000 volts that atmo re must down and become conductive.

So that, when I had explained this principle to Lord Kelvin, he became absolutely convinced that I could do it; but Helmholtz was convinced from the very beginning that I could do it. It took argumentation, however, and demonstration by experiments, to convince Lord Kelvin.

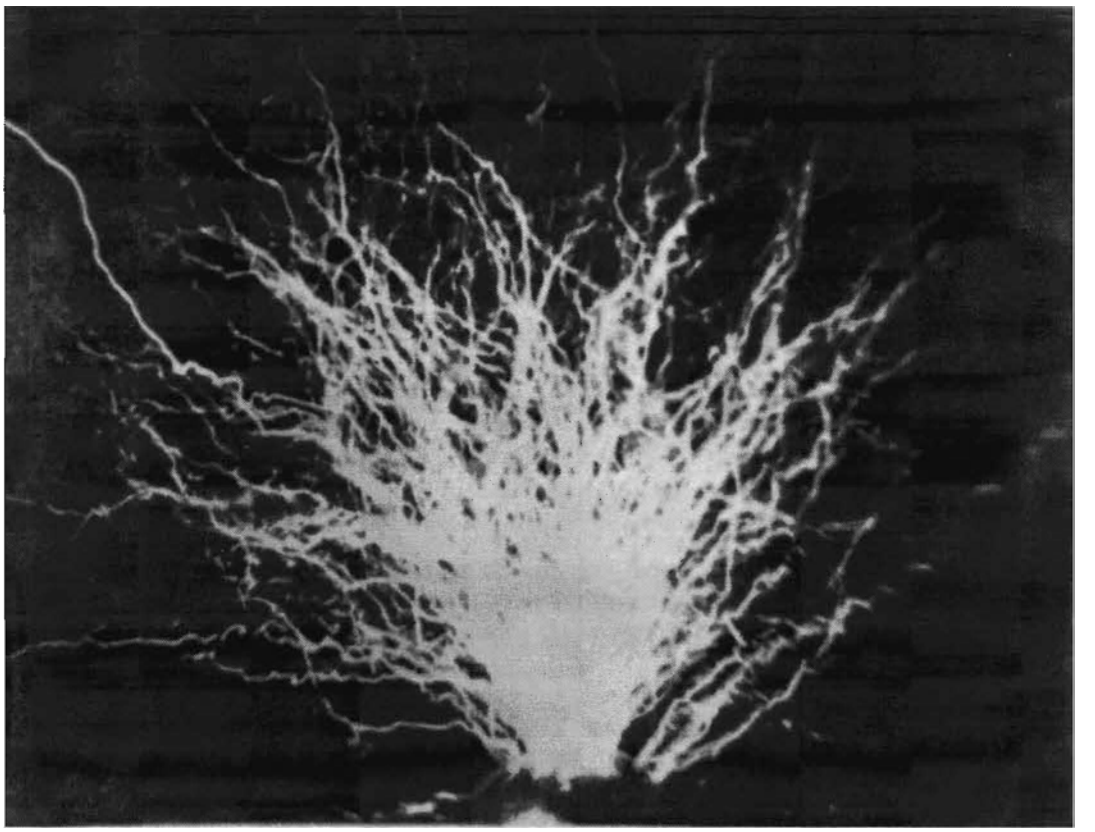


Figure 68.
Powerful discharge from a transmitter constructed in accordance with principles set forth in U.S. Patent No. 1,119,732 of December 1, 1914.

Here [Fig. 68] I have a photograph to just give you a striking illustration of some of these effects. This thing that you see here is a large ball [pointing to the bottom of the photograph], on top of a cylindrical conductor, lifted above the roof. The roof was removable made in two parts, which could be slid apart. The ball could be pushed up and down and lifted to a certain height as I needed it. The experiment shows just that kind of arrangement which I have illustrated in previous diagrams and with which I reached enormous potentials. So great was the pressure that the ball discharged into the air and I have been able to follow for a 100 feet some of these streams. That will give you an idea what a tremendous display it must have been. The current passing through this ball was about 1,000 amperes and the display, seen from a distance, was such that people might have thought the building afire, and many times they did think so.

Counsel

What was the voltage of it?

Tesla

In this experiment, the voltage might have been something like 7 or 8 million volts, but I want to tell you, though, that I am referring to the maximum potential. The moment you get these enormous streamers the potential drops. I mean that was the breaking potential.

Counsel

You had to store the energy in the condenser for a certain length of time and then let it out all at once?

Tesla

Yes, that is a natural process -- in a small interval of time.

Counsel

You could not have kept this display up merely from the energy of the alternator itself?

Tesla

No, sir, I could not have kept that energy up, but I will tell you the secret of all these wonderful displays. It is now perfectly well understood, but at the time when I did this work it was not understood. Consider a gun, for instance, a large gun which hurls a projectile of a ton a distance of 18 or 20 miles. There is a German gun now that fires at 28 miles. If you figure the horsepower at which guns deliver energy, you will find that it amounts to from 6 to 12 or 15 million horsepower. That is, the biggest gun may develop energy at the rate of something like 15 million horsepower, if my recollection of calculations I made is correct. With the methods I devised, with my transformer, it is not at all difficult to get rates of energy many times that, and I have, for instance, figured that in the plant on Long Island, which I put up, under certain conditions, if I wanted to operate, I could have just reached a rate of 1 billion horsepower.

That wonderful thing can be accomplished through a condenser. The condenser is the most wonderful electrical instrument, as I have stated before. You store less energy in the condenser than in the gun but, whereas a gun will discharge the projectile with a velocity of 2,000 feet per second, which means that the energy is delivered in, say, 1/50 of a second, a condenser can discharge the energy in 1 millionth

of this time. Thus, if you store in the condenser energy at the rate of 100 kilowatts, and then discharge it in oscillations of 250,000 per second, it means that you have to multiply these 100 kilowatts with 1 million; therefore, you have a 100 million kilowatt rate as the current discharges. So, all these effects which were produced, and which elicited, of course, great wonderment of the profession, were always produced by damped waves, because with the undamped waves it would not have been possible to attain any such activities.

In the plant in Colorado, my problem was to learn how to construct the apparatus and how to handle these enormous forces which it was necessary to control in a big industrial plant. In these effects, I took a scientific interest and these photographs were intended to show to the world that it was not a dream, what I was doing. That was the sole purpose, but I would not do that in a commercial plant. It was simply to show the marvelous power that could be developed with the apparatus I had perfected.

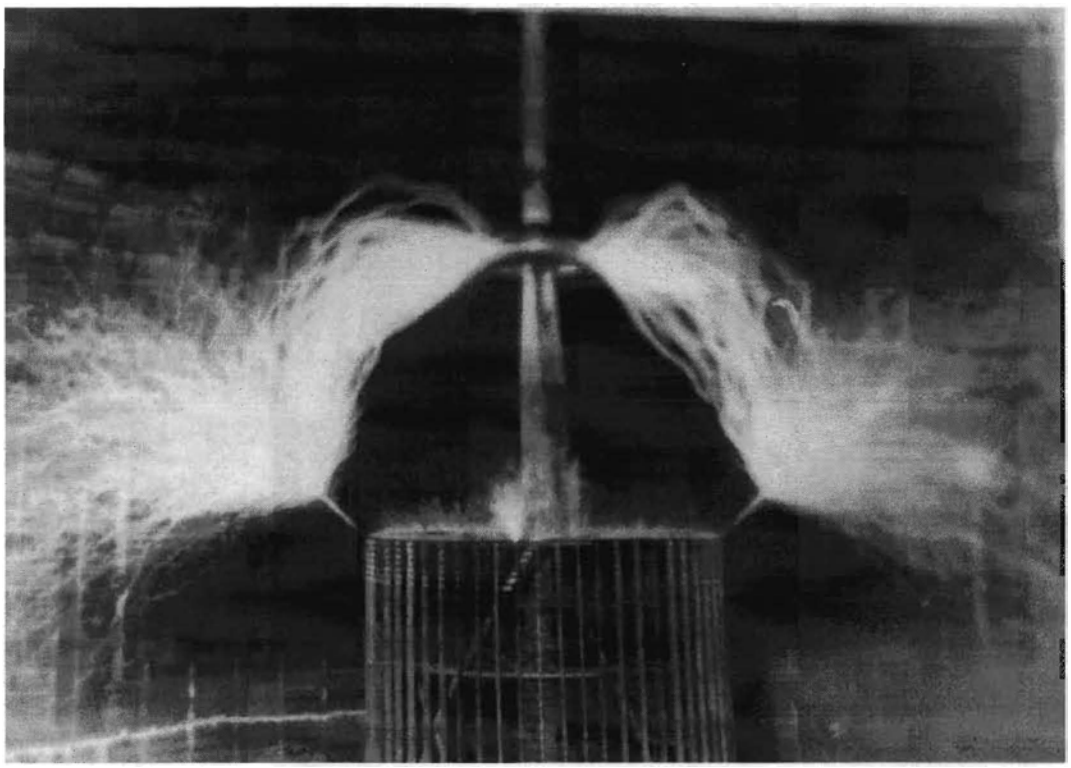


Figure 69.
Experiment bearing out the importance of the principles of design embodied in the transmitter described in U.S. **Patent No. 1,119,732 of December 1, 1914.**

I thought that with a few photographs of this kind [Fig. 69] I would throw light on the apparatus. Here, you see [top center], is a cylindrical antenna. This antenna was put up in 1899 and was a landmark for several years. Everybody has seen it. Therefore, when I am told that other people have used cylindrical antennae before, that cannot be true because I have done that in 1899 -- always in public and everybody has seen it.

As you see, this bit of curve behind, that is my self-induction in series with the antenna, which generates this alternating force, and there is another self-induction coil, and the whole circuit tuned to resonance. The antenna is not connected now. That is a perfectly insulated capacity, but the current passes into it, leaping through a great distance, something like 12 or 15 feet, with a tremendous display on both sides.

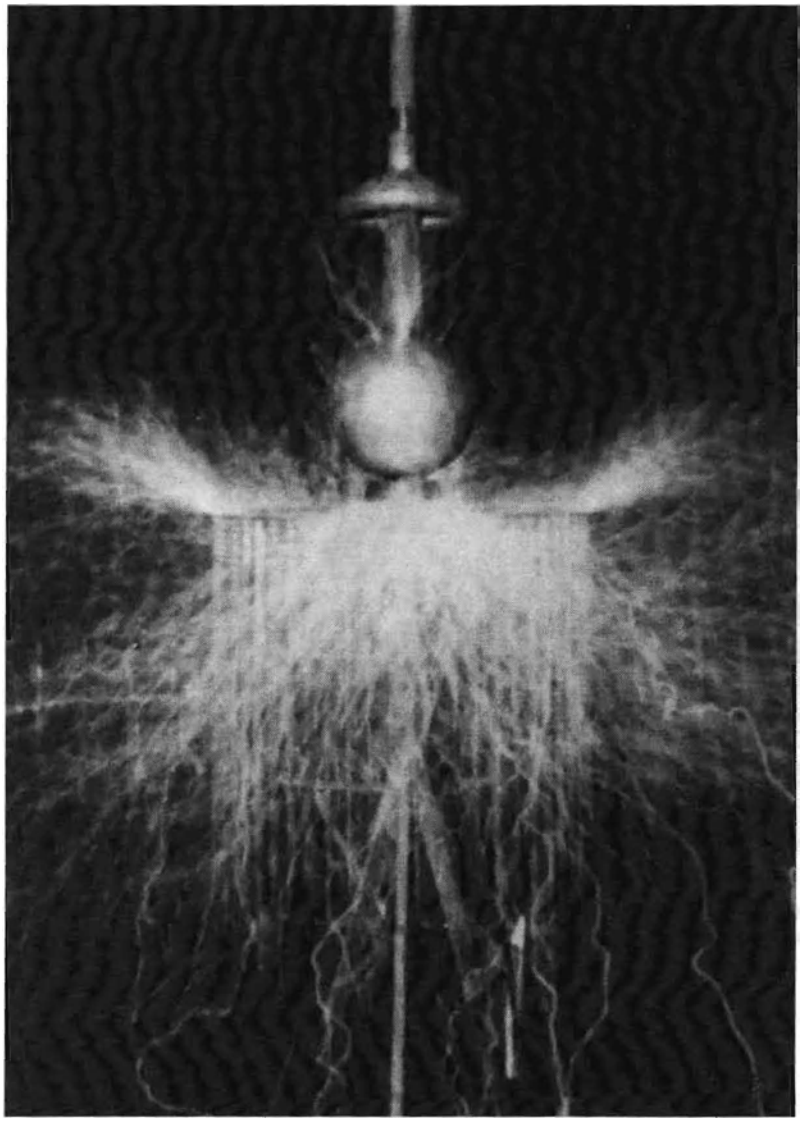


Figure 70. **Another experiment conveying an idea of the great quantity of electricity set in movement, as borne out by mechanical analogue.**

This [Fig. 70] was illustrated and explained in my article in the Century Magazine of June 1900, page 191. This is an experiment which is wonderful, and I want you to understand its meaning. Here I have a ball, a very large ball, connected to the circuit.

Counsel

That is made of what?

Tesla

This ball is of wood, covered with metal, because the electricity does not go into it, and it does not get hot, so it is perfectly safe to employ wood. Around here is a bent 2-inch pipe -- a bare pipe. I put it there because if I did not do so my insulation would immediately catch fire; therefore, I had to protect it. In this experiment there is a distance of about 60 feet from here to there [*], and through this pipe electricity escapes into the air.

To explain this phenomenon, imagine, presently, that you had a big water main, say a main that supplies the city, and on that main a gate valve, and before that valve a reservoir which could stand a great pressure. Suppose that you turn the pressure on this main and that the water cannot flow out; then there will be full pressure on that reservoir, but if you open the valve wide, the moment it is opened the pressure will go down to nothing if the main is large. Therefore, in the reservoir before the valve, there will be no pressure. Here is the electrical main. This pipe [Fig. 70], out of which the electricity escapes in a powerful stream, is the open water main -- a large main through which the water can freely flow out. This ball here is the reservoir on the end of the pipe, a reservoir which can stand a tremendous pressure, and notwithstanding that this main is open, and that all the electricity, probably 800 amperes, can flow out readily, nevertheless the pressure on the open main is so great that this reservoir bursts under the stress and you see streams coming out of the ball. That is a wonderful thing. It shows the volume of the discharge.

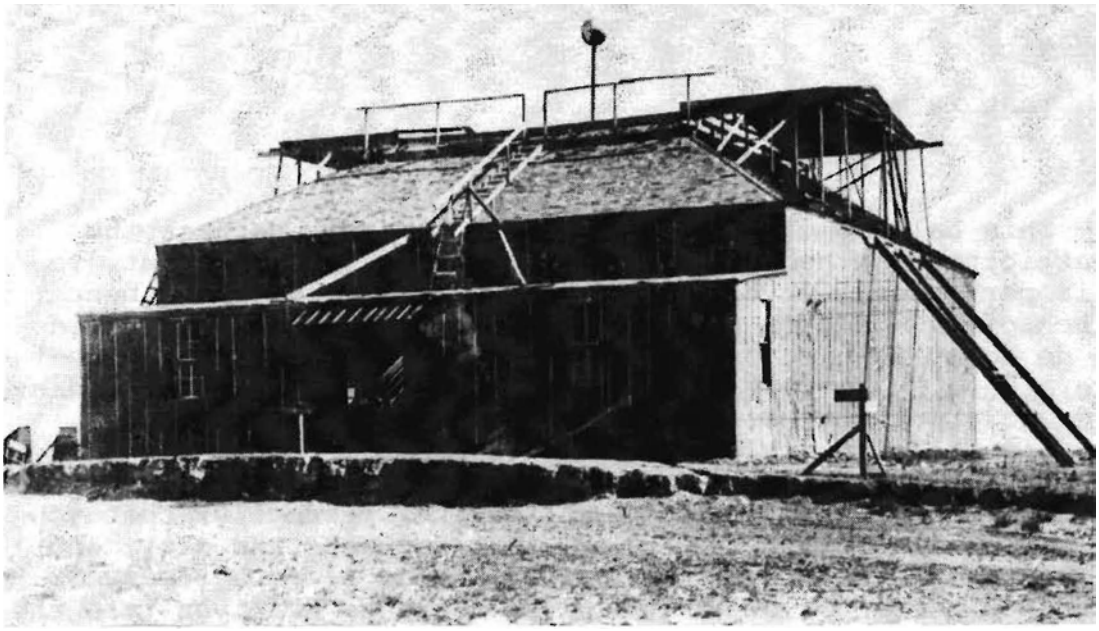
Counsel

Has that any relation to the aurora borealis effect that you referred to awhile back [at p. 110]?

Tesla

No, sir; not at all. This is simply a scientific experiment.

* Editorial note: Points referred to not known.



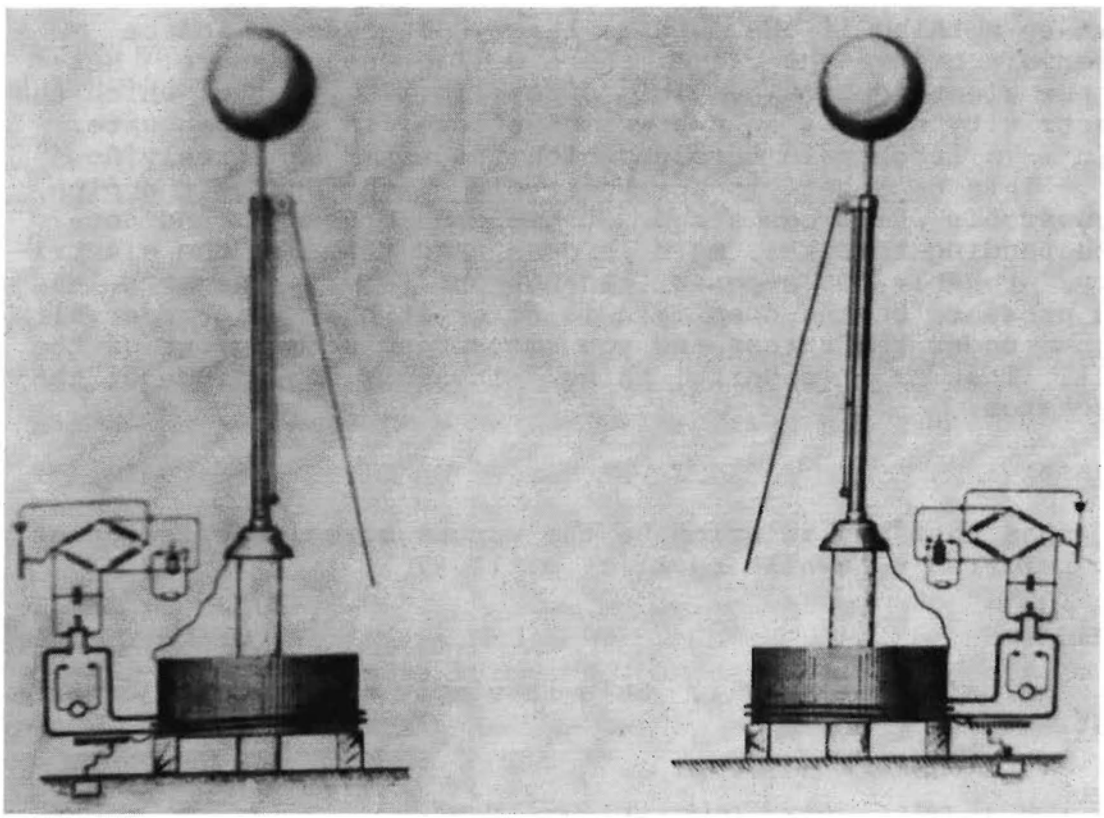


Figure 71 (verso, top).
Distant view of experimental wireless station at Colorado where these experiments were performed. The terminal protruding above the roof is adjustable.

Figure 72 (verso, bottom).
Diagram showing the general arrangement of transmitting and receiving circuits with adjustable capacities as used prior to 1900 and subsequently.

There [Fig. 71] is a view from a distance of my plant at Colorado Springs. You see here the removable roof, through which I could pull this capacity up and down. There is a pipe of 8 inches in diameter, and on top of it is a ball. That was my capacity. That is the capacity from which you have seen the streamers come out in one of the previous photographs [Fig. 68].

This [Fig. 72] is simply intended to show how I operated these adjustable capacities. Here is a pipe, and a ball on top of it, an arrangement of a transmitter and receiver. These capacities lifted up and adjusted. This is a drawing of 1897 or 1896, possibly.

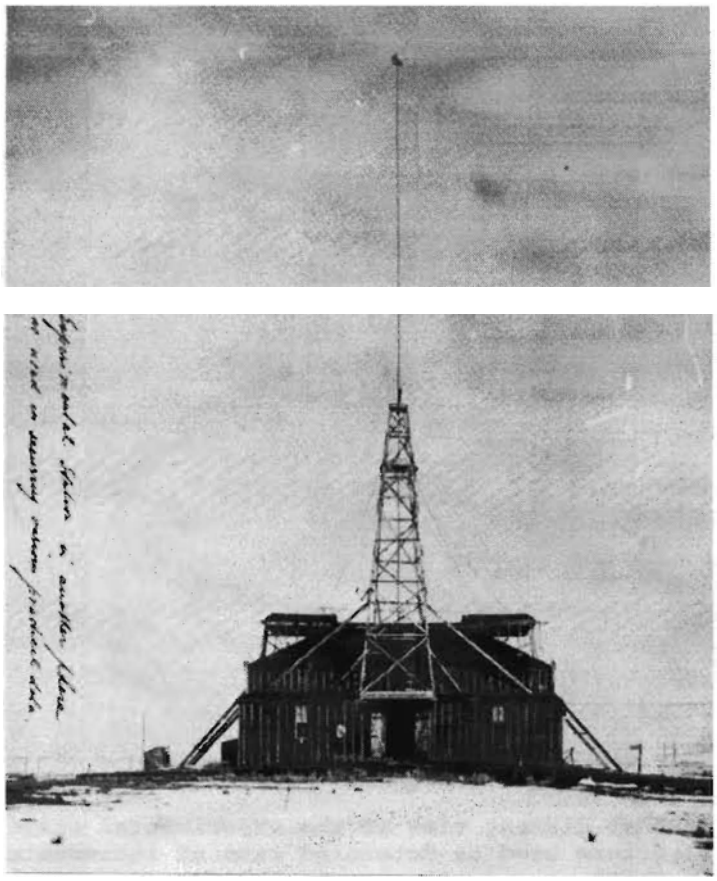


Figure 73.
A distant view of the experimental station at Colorado in a phase of development showing the cylindrical antenna, 168 feet in height.

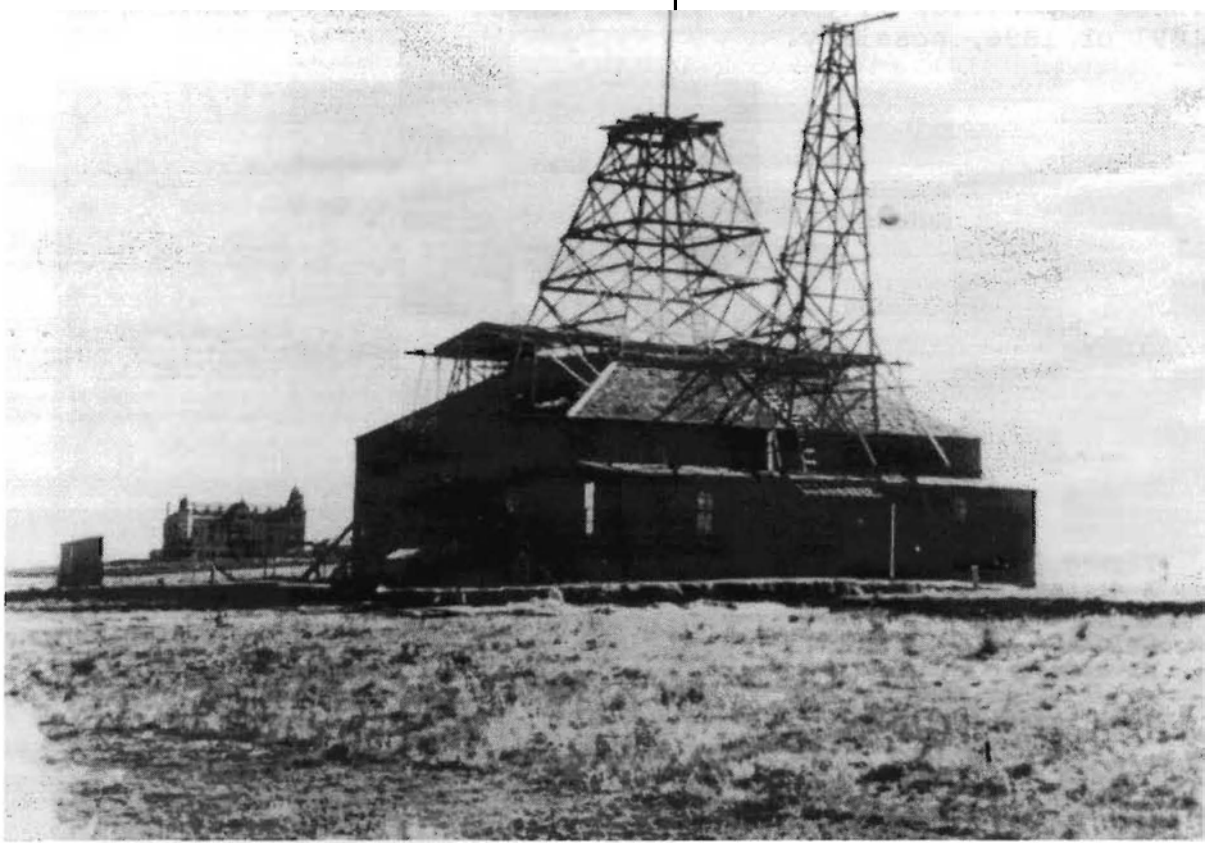


Figure 74.
Another distant view of the experimental station at Colorado showing the structure used to dete.rmine rate of incremental capacity with reference to earth.

Here [Fig. 73] is another view from a distance. This is the cylindrical antenna ng a height of 168 feet.

▮ take of ing to this little structure on the side shorter mast at r]. [Note] this ball su That is just an Iwas making in the measurement of capacity, determining the rate of increment of the with reference to the earth.

sel

When was that up in that form? Does that repre sent some over the earlier photograph?

Tesla

No, it does not represent change. It represents simply various s in my experiments. As ▮ in my inves ti , I was ly sing the antenna and studying the effects I was gett , but I always true to the principle to arrange my conductors on a of large curva- ture so as to to work up very ls with low surface densi for / you will find il lustrated in structures of wires. I know of an illustration a cal antenna made up of wires, but when I the density of di I find that it was an ozonator; it was not an antenna such as my own. It generated ozone. The t s on this thing were enormous, even with low ials. I have my cur- vatures, my large surface, so that nowhere would I get an cessive density. Nevertheless at night, this antenna, when turned on the full current, was illuminated all over and it was a marvelous sight.

Counsel

When you used the higher potent ials?

Tesla

Yes.

Counsel

This was a column you say 168 feet high?

Tesla

Yes.

sel

And the diamete r of that column was what?

Te la

ıthink the first pipe was 10 or 11 inches, and then it lly diminished a few sections.

sel

And the size of the ball on ?

la

The ball on the top [was], I think, 32 inches [in diameter].

Counsel

What was the column itself made of?

Te

Ordinary iron pipes

Counsel

Wrought iron pipes?

Tesla

Wrought iron s, yes.

Counsel

What was the ball made of?

Tesla

The ball was of wood covered with metal.

Counsel

And the column was insulated with what from the ground?

sla

That was supported on a special tree of fir. I went to the lumber men and various woods and could not find anything until I a of a certain of fir. I took , tested and found were very highly ulat I tested the fiber and was prodigiously strong a sufficient to antenna. As a matter of fact, it carried it for 4 years.

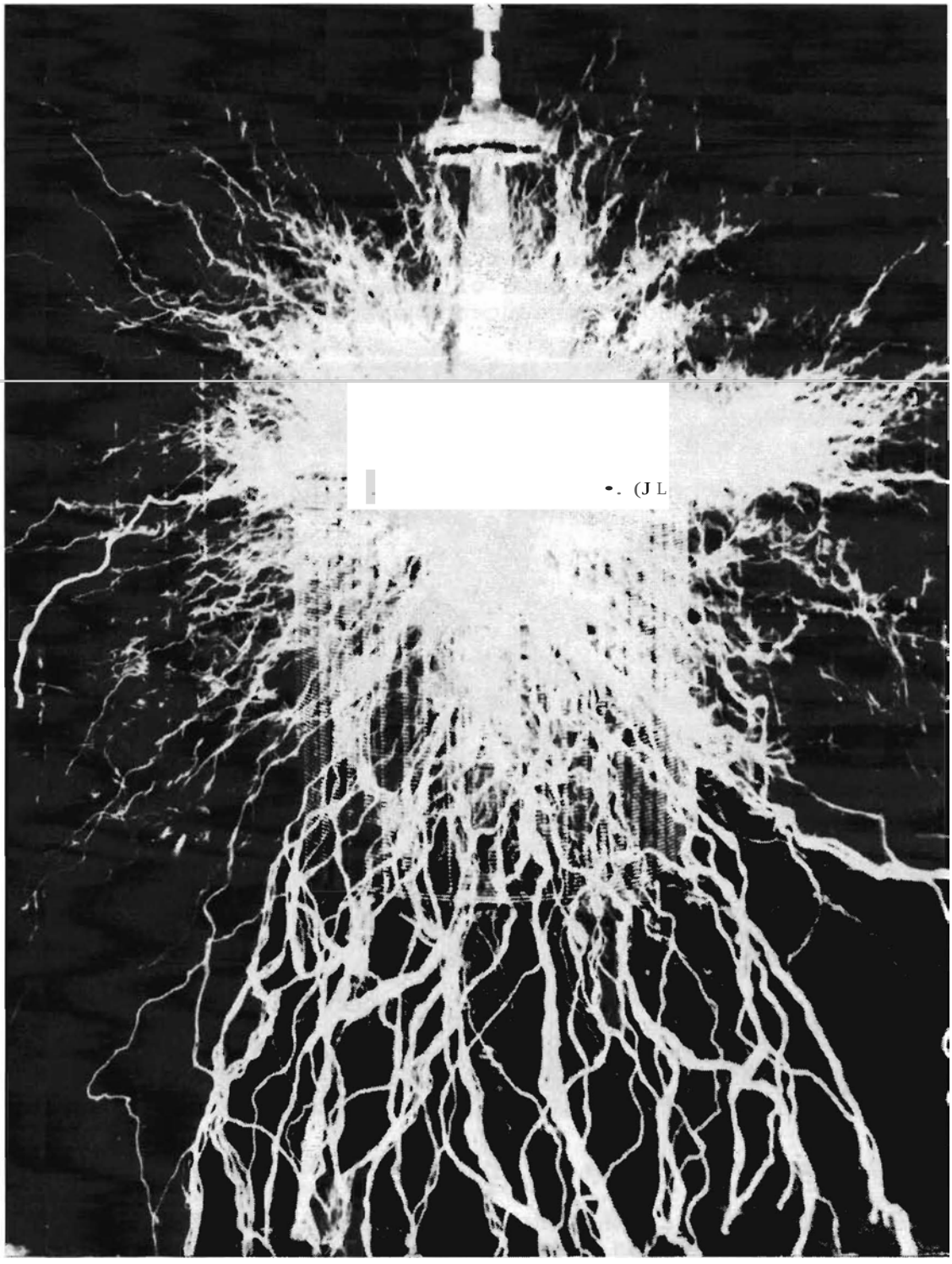


Figure 75.
Discharge of a powerful transmitter under a pressure of 12 million volts, 70 feet from end to end. (Article, "The Problem of Increasing Human Energy," Century Magazine, June 1900, Fig. 10, p. 192.)

Counsel

When was it completed in this case?

Tesla

In November -- probably late November, 1899.

That photograph [Fig. 75] is illustrated in my article in the Century Magazine of June 1900, and it shows a remarkable display. When I sent these photographs to such men as Lord Kelvin, Sir William Crookes, Sir James Dewar, Roentgen, Lenard, Slaby, and others, some of them cabled me expressing their wonderment at how I produced these effects.

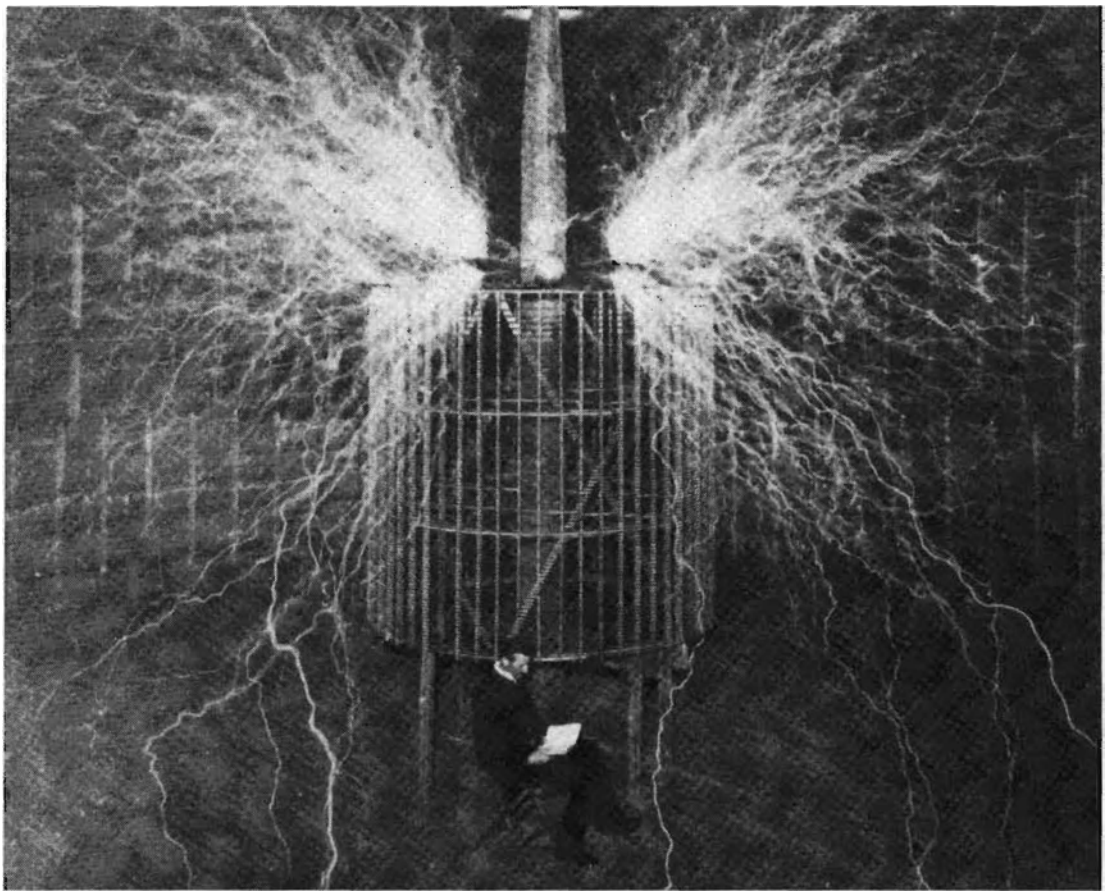


Figure 76.
Another discharge remarkable for symmetry at Colorado plant.

Here [Fig. 76] is another one. There is the fir tree which I obtained, and on top of it is the antenna peculiarly supported; namely, as it is explained in one of my patents. It is imperative to support a system of that kind on places of low electrical density. If I do not support it on places of low electrical density, then the first thing that will happen

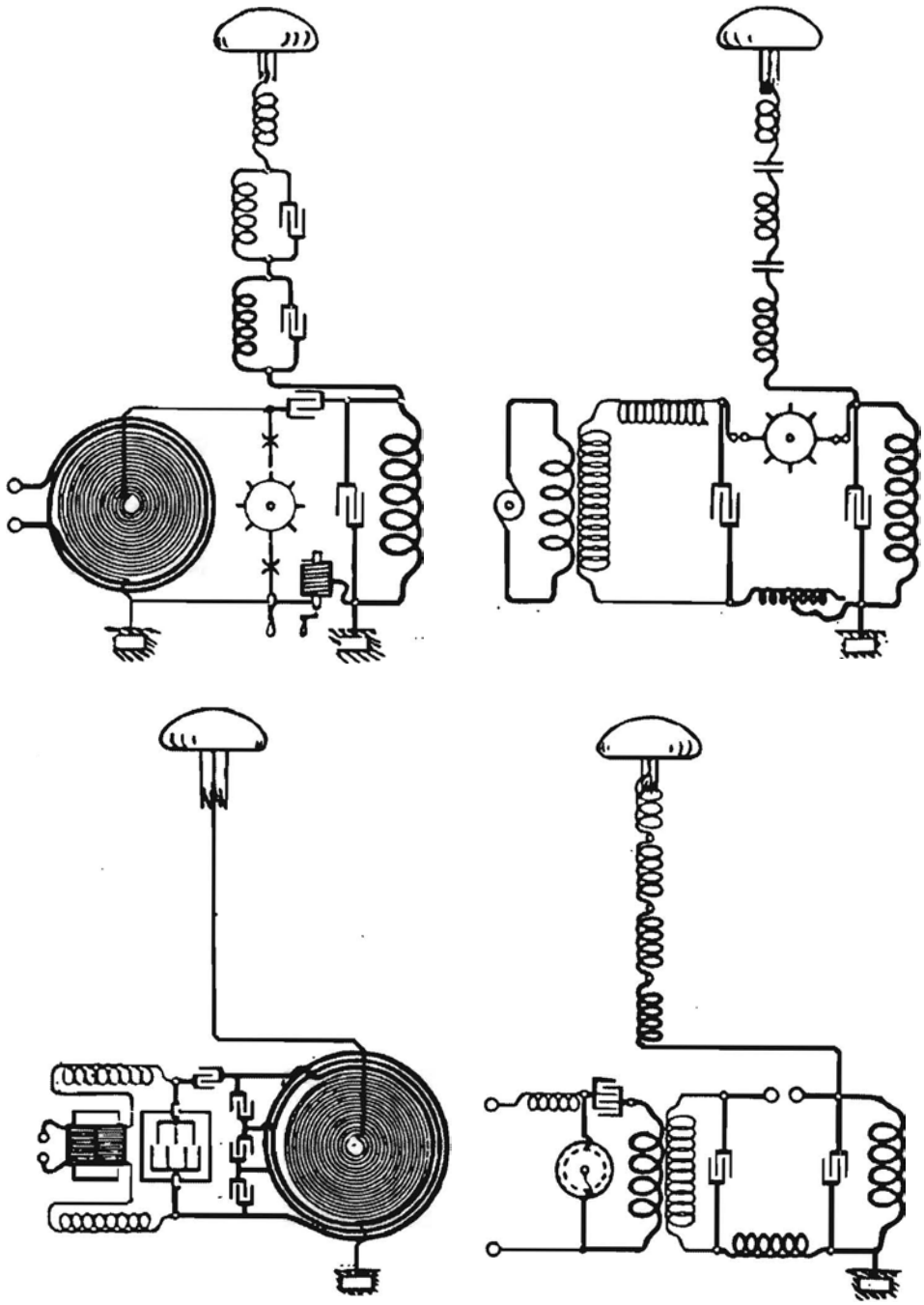


Figure 77.
Diagram illustrating use of sectional circuits. Suggested in St. Louis lecture. Employed in Houston Street laboratory and in Colorado.

will be surface conduction enabling the current to flow to earth, and before one knows the antenna will be grounded and everything destroyed. But, by providing a sort of roof, I get on the under side a support on which the electrical density is nothing, and then the support is absolutely safe, even in rain, because it keeps dry, and it is always in contact with a conducting surface of low electric density.

There [Fig. 77] is another improvement which I carried out in the laboraories on South Fifth Avenue and Houston Street, and which I also employed in Colorado. That is, the employment of sectional circuits. I had sometimes as many as 20 of these sections. There are specific results which can be obtained with these sectional circuits, but the technical literature is full of illustrations which are erroneous, showing apparatus that clearly could not work. That is a special subject on which I have spent a great deal of time, and in this short account of this work I can do no more than just say that these various sections are tuned either to the same or to different frequencies. I sometimes tuned them to compound frequencies and then worked with the fundamental tone, corresponding to the Fourier harmonic. Professor Stone has also done a great deal of work in that direction. I do not know who of us would be prior in records.

VII. Theory and Technique of Energy Transmission

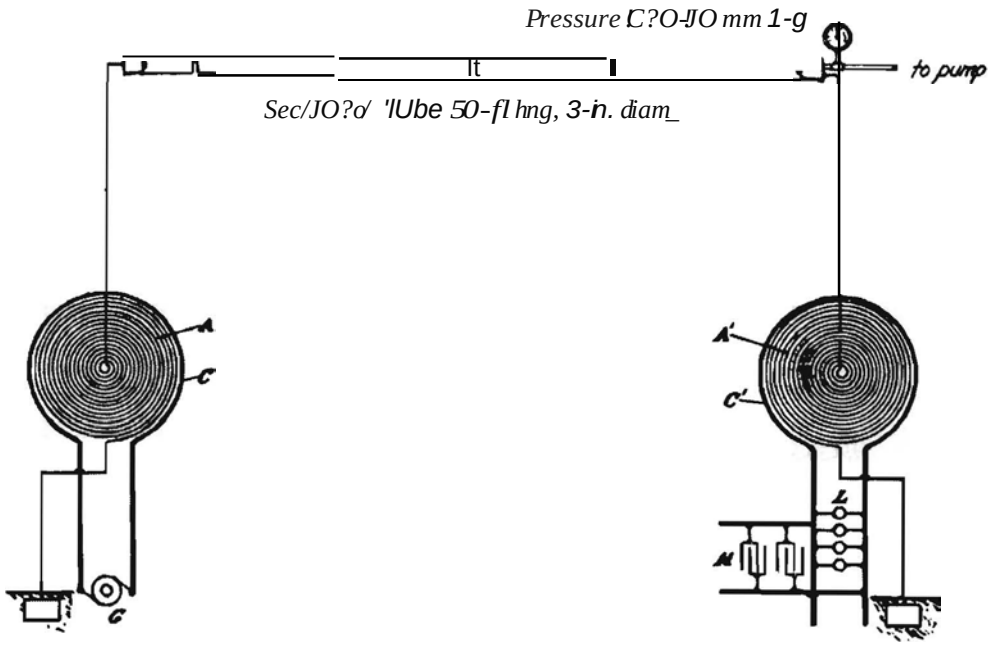


Figure 78.
Experimental demonstration in the Houston Street laboratory, before G.D. Seeley, Examiner in Chief, U.S. Patent Office, January 23, 1898, of the practicability of transmission of electrical energy in industrial amounts by the method and apparatus described in U.S. Patents No. 645,576 and No. 649,621. Applications filed September 2, 1897.

Tesla

This [Fig. 78] is a diagram representing the arrangement of apparatus as in a practical experiment which I performed before G.D. Seeley, Examiner in Chief, U.S. Patent Office, on the 23rd of January, 1898. This experiment illustrates a great departure I had made a little prior to that date. Up to the end of 1896, I had been developing the wireless system along the lines set forth in my lecture which is in the Martin book, particularly in the chapter on Electrical Resonance, pages 340-349. As I stated then, if that plan of mine was practicable, distance meant absolutely nothing; distance merely came into consideration when you flashed rays, electro-magnetic or Hertzian waves, or some agency of that kind. By the plan I had conceived, if it was realizable, it was just as easy to telegraph or telephone across the entire globe as it is across this room.

Developing along these lines, my effort was first to have the biggest possible capacity because I had shown that, theoretically, the effect would be dependent upon the quantity of electricity displaced. The quantity of electricity displaced is proportionate to the capacity. Therefore, in order to realize my scheme, it seemed necessary to employ the biggest possible capacities that could be practically constructed; that was my idea at the beginning.

But I knew also that even with a big capacity, if I connected it to the ground, through a generator, there still would be a frequency high enough to cause a considerable loss of energy in the production of the Hertz or electromagnetic waves; consequently, I had to employ also a very large inductance. Thus, my system was based on the proposition that I employ a very large inductance and a very large capacity and, furthermore, that I raise the potential of the source so high, by resonance, as to displace a quantity of electricity big enough to affect sensibly not only the near portions of the globe, a distance of 100 miles or so, but the whole globe.

In [my] Houston Street laboratory, I had already satisfied myself that it could be done. But in experimenting with these high potential discharges which I was always producing, I discovered a wonderful thing. I found, namely, that the air, which had been behaving before like an insulator, suddenly became like a conductor; that is, when subjected to these great electrical stresses, it broke down and I obtained discharges which were not accountable for by the theory that the air was an insulator. When I calculated the effects, I concluded that this must be due to the potential gradient at a distance from the electrified body, and subsequently I came to the conviction that it would be ultimately possible, without any elevated antenna -- with very small elevation -- to break down the upper stratum of the air and transmit the current by conduction.

Having discovered that, I established conditions under which I might operate in putting up a practical commercial plant. When the matter came up in the patents before the Examiner, I arranged this experiment [shown in Fig. 78) for him in my Houston Street laboratory.

I took a tube 50 feet long, in which I established conditions such as would exist in the atmosphere at a height of about 4 1/2 miles, a height which could be reached in a commercial enterprise, because we have mountains that are 5 miles high; and, furthermore, in the mountainous regions we have often great water power, so that the project of transmitting it, if the plan was rational, would be practicable.

Then, on the basis of the results I had already obtained, I established those conditions, practically, in my laboratory.

I used that coil which is shown in my appli of September 2, 1897 (Patent No. 645,576 of March 20, 1900), the primary as , the rece circuit, and lamps in the secondary transforming rcuit, as illustrated there. And when I turned on the current, I showed that a stratum of at a pressure of 135 11 rs, when my four circuits were tuned, several were li ghted

Counsel

What did you use as the source of energy in your primary transmitting circuit, at the time you demonstrated this apparatus to Examiner Seeley?

Tesla

I used a break, a mechanically rotating break, which was charging a condenser 5,000 times a as I described in my patent Number 645,576 of March 20, 1900.

Counsel

What was the voltage that was generated?

Tesla

The voltage was about 4 mill volts.

Counsel

You say you used a break, which I understand to be a rotary spark gap. What was the original source of power?

Tesl

The original source of power was an alternator which I employed regularly there, from which I could about 30 horsepower in ordin ry experimentation It was a machine of a frequency of about 60 cycles.

Counsel

And that was connected in circuit with the condenser and a gap in the well known way of your oscillators?

Tesla

Yes.

Counsel

Then you got from that, by means of a rotary gap, about 5,000 ?

Tesla

Yes, 5,000 per and I transferred [these] to a frequency of 200,000 to 250,000 per second. Pardon me for saying, ıhad arranged for the to make this demonstration with a alternator; but just as the work was press it and could not the necessary tension with it, se ıwould have used the alternator. But in s other way, I could the 4 llion volts I needed; that is the reason why the was made with this kind of apparatus

Counsel

And you had a wave frequency of what?

Tesla

Between 200,000 and 250,000. That was s wave frequency; that did not mean anythi ng here because ıwas transmitting a conductor. ıwas not energy into space.

Counsel

Was that a s tube?

la

Yes, 2 or 3 inches in r, and joined with rubber. Then there was a pipe that led to the pump, and ıhad a manometer to show accurately the pressure in the tube. I calculated it so that it to a definite he of about 5 miles. Because I had ment in my 5 miles, I did not want to retract that statement. It was s y to show that this was icable.

We shall come immediately to something ch will this in a fferent light. put all

Here rring to Fig. 79] the earth. Radio engineers do not realize this truth, when they do they will immediately get a fferent view of the whole radio transmission and will des their apparatus accordingly. [I]n fact, will do exactly what ıdid. It was a revelation to me.

The earth is 4,00C les ing atmosphere. The earth is a the atmosphere is a conductor, only there is a e stratum the conducting re and the conducting earth is insulating Now, on the basis of my in laboratory on Houston Street, the insulat layer of r, separates the conducting layer of air from the conduct-

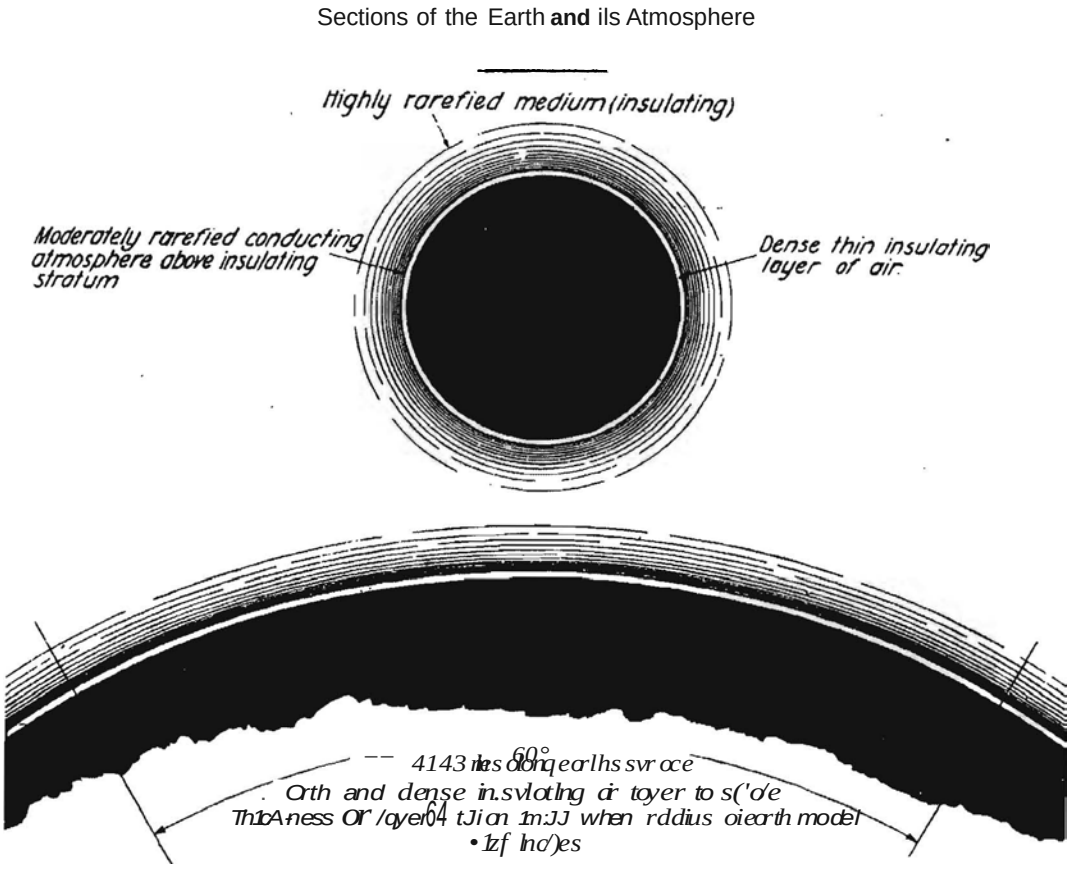


Figure 79.
Diagram explanatory of the transmission of electrical energy by the method described. First put before Lord Kelvin in the Houston Street laboratory, September 1897.

ing surface of the earth, is shown to scale as you see it here. Those [radii lines] are 60° of the circumference of the earth, and you may notice that faint white line, a little bit of a crack, that extends between those two conductors. Now, you realize right away that if you set up differences of potential at one point, say, you will create in the media corresponding fluctuations of potential. But, since the distance from the earth's surface to the conducting atmosphere is minute, as compared with the distance of the receiver at 4,000 miles, say, you can readily see that the energy cannot travel along this curve and get there, but will be immediately transformed into conduction currents, and these currents will travel like currents over a wire with a return. The energy will be recovered in the circuit, not by a beam that passes along this curve and is reflected and absorbed, because such a thing

is impossible, but it will travel by conduction and will be recovered in this [emphasis in original] way. Had I drawn this white line to scale on the basis of my Colorado experiments, it would be so thin that you would have to use a magnifying glass to see it.

Counsel

Will you pardon me for interrupting again. You spoke some time ago about getting all of the energy from your transmitting into your receiving station by this method of yours. I do not understand how you can get all of it.

Tesla

Oh, that is hardly true; I am speaking as a matter of principle. You never can get all the energy, because there is no such thing as perfect apparatus.

Counsel

I did not mean it in that sense. I understand that there is, of course, always some loss, but my conception was that when you created the disturbance in the electrical condition of the earth at your transmitting station, that that extended out in all radial directions.

Tesla

Yes, it did.

Counsel

And therefore how, at any given station, can you get more than a very small fraction of that energy?

Tesla

Pardon me, you are mistaken.

Counsel

That is what I want you to explain. I must be mistaken, because my conception does not fit in with your statements.

Tesla

All right, I will explain that.

In my first efforts, of course I simply contemplated to disturb effectively the earth, sufficiently to operate instruments. Well, you know you must first learn how to walk before you can fly. As I perfected my apparatus, I saw clearly that

I can recover, of that energy which goes in all directions, a large amount, for the simple reason that in the system have devi once that current got into the earth it had no chance of e , because my frequency was low; hence, the electromagnetic radiation was low. The , e c potential, is l temperature. We as well call potential electric rature. The earth is a va: body. The potent ial fferences in the earth are , radiation is very small. Therefore, if I pass my current into the earth, the energy of the current is stored there as electromagnetic momentum of the ions and is not consumed until I put a rece at a distance, when it will to draw the energy and it will go to that and nowhere else.

Counsel

Why is that, on your theory?

Te a

I will ain it an analogue

Suppo se that the earth were an elastic filled with water. t is equivalent to a pump. I put it on a point of the globe, and work my little ston so as to create sturbance of that water. If the piston moves sl so the t is long for the disturbance to spread over the , then what will be the result of my working this pump? The result will be that the bag will expand and contract rhythmically with motions of the piston, you see. So that, at any of that , there will be a rhythmical movement due to sations of the pump.

That is , however, when the period is long. If I were to work this pump very rapidly, then I would create impulses, and the spread in ci rcles over surface of the will no longer and contract in will be ect to these outgoing rippl ing waves.

Remember, now, that the water is incompressible, that the bag is perfectly elastic, there are no hysteretic losses in the due to these expans s and contractions; and re member also, that there is a vacuum, in space, so that the energy cannot be lost waves of sound. Then, if I put at a stant point another little pump, and tune to the rhythmi cal ses of the pump at the central , I will excite strong ions and will recover power from them, sufficient to a rece But, if I have no pump there to receive these oscil , if there is nowhere a place where this ela energy is transferred into frictional energy {we a use in our devices l energy -- everything is lost through friction), then there is no loss,

and if I have a plant of 1,000 horsepower and I operate it to full capacity, that plant does not ta power, it runs exactly as the plant at Niagara If I do not put any motors or any lamps on the circuit, the plant runs idle. There is a 5,000 horsepower turbine going, but no power is to the turbine except such power as is necessary to overcome the frictional losses.

Now the vast dif scheme of radio engineers and my scheme is s. electromagnetic waves with a plant of 1,000 r, you are using 1,000 horsepower right along whether there is any receiving being done or not. You to y this 1,000 horsepower, exactly as you have to coal to your stove , or e se no heat goes out. That the vast difference. In my case, conserve the energy; other case, the energy is all lost.

Counsel

Mr. Tesla, does that not presuppose fluid must be incompressible?

Tesla

I should say so, and electri , whatever it is, certainly it is incompressible because all our experiments show that.

Counsel

if you were giving that a name, what principle would you say was involved by which radiation loss, where there is no rece , becomes a or a conservation where there is a receiver?

Tesla

There is no radiation in s case. You see, the apparatus I devised was an s enabl one to produce tremendous differences of l and currents in an antenna circuit. These requirements must be fulfi led, whether you transmit by currents of conduction, or whether you transmit by electromagnetic waves. You want al currents, you want a great amount of vibratory energy; you can graduate this vibratory energy. By proper des and choice of wave lengths, you can arrange it so that you , for instance, 5 percent in these e and 95 percent in the current that goes through is I am doing. Or, you can get, as these radio men, 95 percent in the energy of el waves and only 5 in the energy of current. Then you are wonde why you do not get good

results. I know why I do not good results in that way. The apparatus is suitable for one or the other method. I am not producing radiation in my system; I am suppressing electromagnetic waves. But, on the other hand, my apparatus can be used effectively with el waves. The apparatus has to do with this new method except it is the only means to ice it. So that in my system, you should free yourself of the idea that there is ation, that energy is radiated. It is not ; it is conserved.

Counsel

Right in that , and to illustrate your theory, I would like to know whether you consider that the radiation from any wireless stat is was or conserved, or whether the effect by any of them is due to this conductive action, so far as it is effective

Tesla

Absol -- the effect at a distance is due to the current energy that flows through surface layers of the earth. That has already been mathematically shown, real by Sommerfeld. [See edi note p. 75.) He agrees on this theory; but as far as Iam that is positively demonstrated For instance, take the lle antenna. Professor Zenneck took me out and gave me the iculars. I went over the culations and found that at 36 kilowatts they were radi 9 kilowatts in ic wave energy. They therefore, only 25 of the whole energy these waves, and I told Professor Zenneck that this energy is of no effect -- that , by the current, fferences of potent in the earth, and these differences of felt Germany and affect the ; but the a little beyond Long Island and are lost.

I have an [you] will best cture of the process in of tran ssion if you will imagine that the earth , say, of fluid under pressure that is the energy -- and at my a distant tuned ci t, I must open a valve and enable that energy to flow in. It is that way. The energy is all conserved, whether it is ng or y ial. Whatever the tter does in the receiver, the effect is s to open a valve, as it were, and t energy to flow in.

of course, the hardest thing to understand, if one is not a al in that line and has not years, as I have, in exper s and in that rection, is how can a like be economically when we know that there are mountain peaks everywhere? Those are

antennae; are likewise charged. Well, it took me a long time to that out. To you an idea, let us take a big, enormous mountain like the peak of fe. That is a mountain that ses out of the sea and goes up to 17,000 or 18,000 feet. Naturally, that is a tremendous antenna, everybody will th k. passing through the ence Ihave gone through, you will say that alone will take more than all the antennae you can put up all over the world. That s not so.

The peak of Tenerife has no more than something like 100 centimeters [110 picofarads], and it will be charged to a very low potential, whereas my antenna could be charged to a very high potential. Ican show that the mountain would not absorb much energy, not 0.0001 of my antenna would. Icould my antenna to the , and it will take 10,000 times more energy.

You must simply realize that the earth is, so far as it is mechan looked upon, like a rough ball; but when you look at it e ly, it is a shed ball. Lord Kelvin has already, in his papers on of which he kindly sent me two at sending me one -- grasped that; he considered the distribution of electricity on the globe, and came to the conclusion that the capacity of definite terrestrial areas does not increase sensibly with elevation.

You see, the e surface dens on the highest peaks is not any more than just a fraction of l percent greater than on the sea. So that the whole , to my mind, appears as a ly , and we can by this means realize thi so marvelous that one would be almost afraid to talk about them; and the apparatus I do not say that I am inventor the is practical the of Aladdin.

Counsel

Is it because the earth is this ine c mass of electricity that it is the basis for your statement that distance is of no consequence? That is the way I visualize that it is, that if the earth is an inelastic mass or body of electricity, and you set that mass at any one , that vibration will extend s as well as it will to a distance of Is that what you had mind?

Tesla

I must rst clear away You must first understand certain r, for instance, the term "resistance." When you think of resistance you imagine

naturally, that you a long, thin conductor; but remember that while resistance is directly proportionate to , it is inversely to the section. It is a quali depends on a o. If you take a small sphere of the same size of a pea, and compare its length with its se on, you would find a ce resistance. to Now you extend this pea the ze of the , and what is go to ?

While the length increases, say a thousand times or a million times, the section increases with the square of linear dimensions, so that the bigger s thing is the less resistance it has. Indeed, if the earth were as big as the sun we would still be better off than we are; we could readily te from one end of the sun to the other by the system, and the larger the planet the better it would be.

Counsel

Then do I your idea correctly, that distance is of no rtance because of the low re stance to the sec- on of the earth?

la

No, pardon me.

Counsel

I cannot te get that. is it that with your system distance cuts no figure?

Tesla

Distance cuts no for the reason that there is no fall of potential. Now imagine s: e that earth, in reality, were a b main, a main of copper, say, all the copper of the earth would be fused a big main, and then you will see it would not make any difference where you that energy, whether you do it or whether you miles further, because the resistance of is The resistance of the earth does not come in in but in another way.

These ques The resistance is only at the point where earth with your current. The rest is Those will be very ff lt to ain without a lot of theoretical stuff, which would be unprofitable, when it is here the object to give a clear idea of the princ and nothing else.

This [80] illustrates one of fallacies which the questioning has already brought out. Here is, for instance an attempt to produce a large capacity, an antenna of very

No. 676,332. Patented June II, 1901.

6. MARCONI.

APPARATUS FOR WIR HES> TELEGRAPHY.

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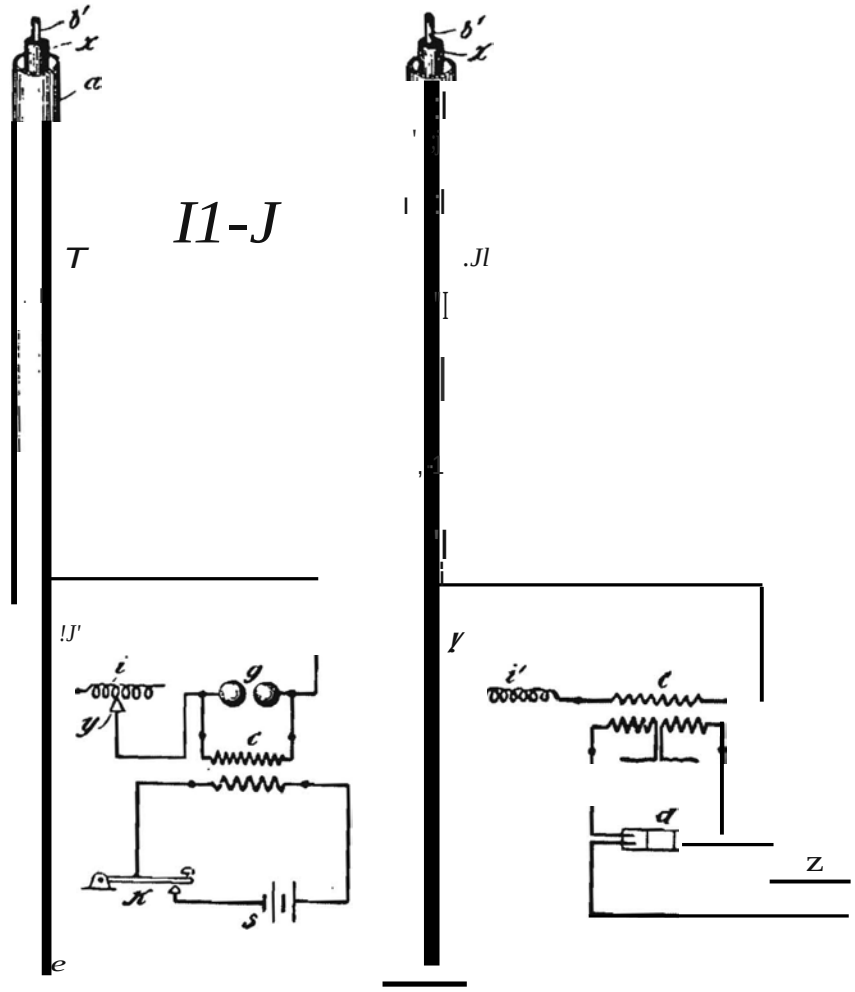


WITNESSES:

INVENTOR

Gu._§l\elmo MaTCon\.,

BY

AfTORt-;EYS.

Figure 80.
Diagram illustrating one of the many wireless fallacies, taken from a U.S. Patent of Guglielmo Marconi, No. 676,332, June 11, 1901.

large capacity, by using two concentric cylinders. I have already elucidated this error, but in a different phase. The capacity between those two conductors has absolutely nothing to do with the capacity which enters into the transmission of the energy to a distance. That is purely and entirely a local flux, simply a means of wasting energy. Such errors as this you will find throughout all the technical literature, but this has already been explained in another way.

[Summarizing,] I have already explained the various steps I have set forth in the introduction to this long talk. I have explained how I produced the apparatus giving the requisite oscillations; the second step how I transformed those oscillations into vibratory energy capable of going to a distance; and, furthermore, how I solved another problem, namely, that of the right wavelengths which are effective in the conduction of energy to a distance.

Before I went to Colorado, the one thing which I needed to find out was, how does the current flow through the earth? In my experiments from Houston Street and around New York, I had already learned that the effect is proportionate to the quantity of electricity displaced, and I was in the position to accurately calculate a plant for transmission, for instance, across the Pacific or Atlantic. Those were simple problems; but I could not yet tell how the current passes through the earth, and until I could do that I could not undertake the design of a plant in all these particulars so that it could be a piece of engineering.

I spent 30 years of my work in the design of machinery of all kinds, and have never yet designed a machine which did not do as I expected, and I cannot imagine why it should not because when one calculates the things out on the basis of experimental data, the machine has to work as intended. This is engineering.

Therefore, when my friends offered to back me up for a plant under my patents, I though it was best to devote some time to an investigation, to find out what I needed, in order to have all my data accurately and guarantee that the plant would work.

The law which I discovered in Colorado is wonderful, and it shows that results undreamed of before and of incalculable moment will be obtained as soon as a plant, embodying these principles, is established on a large scale.

To give you an idea, I have prepared a diagram [Fig. 81] illustrating an analogue which will clearly show how the current passes through the globe. You know that in a solar eclipse the moon comes between the sun and the earth, and that its shadow is projected upon the earth's surface. Evidently,

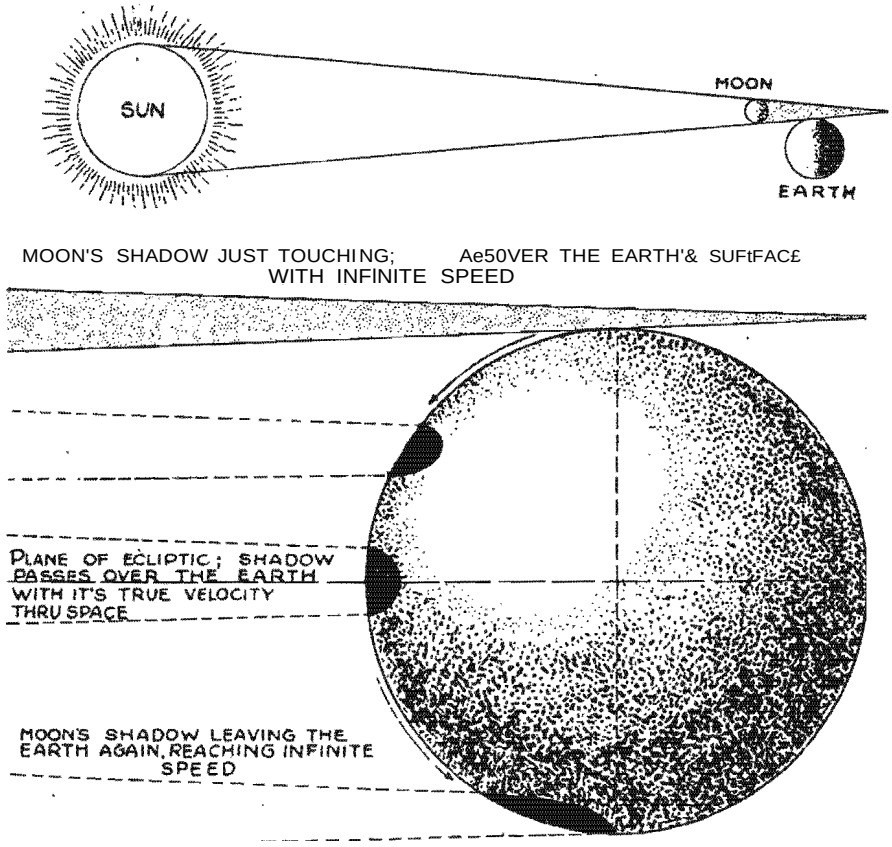


Figure 81.
Diagram illustrating the mode of propagation of the current from the transmitter over the earth's surface.

in a given moment, shadow will just touch at a mathemati cal point, the earth, as it to be a sphere.

Let us imagine that my transmitter is located at this point, and that the current by now passes through the earth. It does not pass the earth in the ordinary acceptanc of the term, it only to a certain depth according to the frequency Most of it goes on the surface, but with frequencies such as I employ, will dive a few miles below. It can be mathematically shown that it is immaterial how it passes; the effect of these currents is as if the whole current passes from the tran tter, which I call the e, to the opposite point, which I call the antipode

Assume, then, that here is the transmitter, and imagine that s the surface of the sea, and that now comes the shadow of the moon and touches, on a mathematical point, the

calm ocean. You can readily see that as the surface of the water, owing to the enormous of the earth, is nearly a plane, that point where the shadow falls will immediately, on the sl motion of the shadow downward, the circle at a terrific rate, and it can be shown mathematically that this rate is inf In other words, this half-circle on s side will over the globe as the shadow goes down; will first start at infinite ve to enlarge, and then slower and slower and slower, and as the moon's shadow goes further and further and further, it will get slower and slower until, finally, when the three bodies are on the of the eel ic, in line one the other in the same plane then that shadow will pass over the with its true veloc in space. Exact that same thing in the ap- pl ion of my sys and I will show s next.

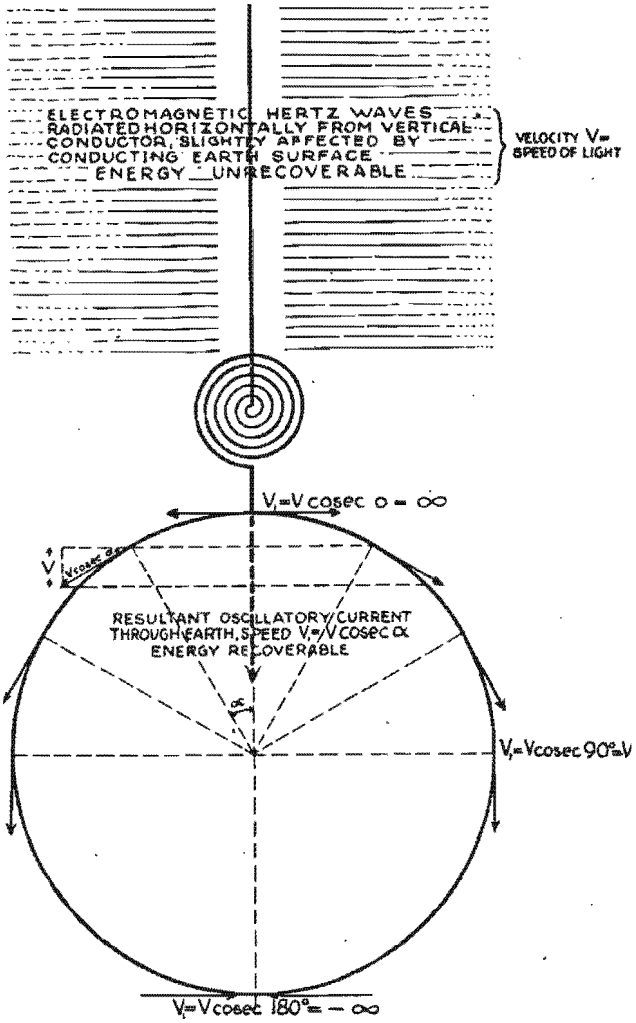


Figure 82. Diagram the law governing the passage of the current from the transmitter through the earth, first announced in U.S. Patent No. 787,412 of April 18, 1905. Application filed 16, 1900. See also J. Erskine-Murray, A Handbook of Wireless **Telegraphy**, Chapt. 17, **pp. 312-330 '1913 edition**, published Crosby Lockwood and Son, London, and Appleton & Company, New York.

This [. 82] illustrates, on a larger scale, the earth. Here is my transmitter or anybody's transmitter -- because my system is the of the day. only difference is in the way I it. They, the radio , want to apply my system one way; I want to it in another way.

This is the circuit antenna. As the vibratory energy flows, two There is electromagnetic energy radiated and a current passes into the earth. The first goes out in the form of rays, which have definite properties. These rays with the velocity of light, 0,000 kilometers per second. This energy is a hot stove. If you will that the inder antenna is hot -- and indeed it is the current - it would radiate out energy of exactly the same as it does now. If the system is applied in the sense I want to y it, this energy is absolutely lost, in all cases most of it is lost. While this e ic energy throbs, a current passes the globe.

Now, there is a vast between these two, electromagnetic and current That energy which goes out in the form of rays, is, as I have here [on the diagram of Fig. 82], unrecoverable, lessly lost. You can operate a little by catching a billionth of but, except this, all goes out into space never to return. s other energy, , of the current in the globe, stored and tely cal not much effort to in electrical vibration. I have, in , worked out a plant of 10,000 horsepower would operate with no loss than l percent of the whole power ; that , with the ion of the frictional energy that is consumed in the rotation of the en- gines and the of the conductors, I would not lose more than 1 In other , if I have a 10,000 horsepower plant, it would take only 100 to the earth vibrat so as there is no energy taken out at any other place.

There is another fference. The elect energy travels with the of l see how the current flows. At the rst moment, s current propagates exactly like the shadow of the moon at the earth's surface. It starts with infinite velocity from that point, but its speed rapidly diminishes; it flows and slower until it reaches the equator, 6,000 miles from the At that , the current flows with the of - that is, 300,000 kilometers per second. But, if you cons the resultant current through the globe the axis of of propagation, the current flows continuously with the same veloc of light.

Whether this current pass through the center of the earth to thesidereal, or whether it is merely an effect of these surface currents, makes abs dif- ference. To understand the , one must that the current from the flows straight to the opposite point of the globe.

There is where I answer the attacks which have been made on me. For instance, Dr. n has culed the Tesla sys- tem. He says,

"The energy goes only in directions "

It does not. It goes in one direction. He is deceived the size and shape of the earth. Looking at the horizon, he imagines how the currents flow in all directions, but if he would only for a moment think that this earth is like a copper wire and the t tter on the top of the same, he would im- mediately realize that the current flows along the axis of the propagation

The mode of propagation can be expressed very simple mathematical law, which is, current at any flows with a veloc proportionate to the cosecant of angle which a radius from that includes with the s of sym- metry of wave tran , the cosecant is infinite; therefore, the is in At a s- tance of 6,000 miles, the cosecant is unity; therefore, the velocity is equal to that of 1 This law I have expressed in a patent by the statement that the of all zones on the axis of are of the same length, which means, in other words, as is from rules of trigonometry, that the areas of all the zones must also be equal. It says that although the waves travel different velocities from point to point, nevertheless each half wave always includes the same area. This is a s law, not unlike the one which has expressed by with reference to the areas swept over the radii vectors.

I hope that I have been clear in this exposition in b your attention that what I show here is the system of the day, and is my system -- only the radio use my apparatus to too much of this electromagnetic energy here, instead of concentrat all their attention on designing an will ss a current upon the earth and not waste the ant an uneconomical process.

Counsel

You say radio engineers put too much energy into the radiating part. What, as a matter of fact, to your conception, is the of the energy in the

receivers in the present system?

Tesla

That has been invest Very valuable experiments have been made by Dr. Austin [*], who has measured the effects at a distance. He has evolved a formula agreement with the Hertz wave theory, and the energy collected is an absolutely vanishing quantity It is just to operate a very delicate receiver. If it were not for such devices as are in use, the audion, for instance, nothing could be done. But with the audion, they magnify so that infinitesimal energy they get is sufficient to the receiver. With my system, I can convey to a distant millions of times the energy transmit

Counse

To illustrate my question, take for instance the energy used at lle and the reception of that at Nauen. I want to know whether it is your idea the reception there is due to the earth currents that you have describec or to the radiated energy.

Tesla

It is far more due to the earth currents than to the radiated energy. I believe, indeed, that the energy alone could not possibly the effect across the Atlantic. It is simply because they are incidentally sending a current through the globe which they think is their current -- that the r is affected. The current s variations of at the earth's surface in Germany; these fluctuations of potential energize the it, and resonance they increase the potential there and the receiver. But I do mean that it is absolutely ssible to use my with electromagnetic waves across the Atlantic or I only say that according to calculations, for instance, which I have made of the Sayville plant, the radiated energy is very small and cannot be operative. I have also calculated the distr of the charge on the antenna. I am told that the antenna is without abrupt changes of It is impossible. There are changes even in a indrical antenna; but icularly in that lle -- there are very s.

* Editorial note: Lewis W. Austin, Chief U.S. Naval Radio Telegraphic Laboratory (located at the National Bureau of Standards), 1908-1923. Austin's papers discus radio transmission-reception are: "some ve experiments in long-dis quantitative tance radiate of the Bureau of Standards, Vol. 7 (1911), No. 31 , Quantitative experiments in radiotelegraphic transmission," Bulletin of the Bureau (1914), No. 1, pp. 69-87.

Counsel

What would an engineer have to do to the wireless systems of today in order to produce very little radiation of electromagnetic waves and produce a large amount of these earth currents? What changes would he have to make in the system?

Te

He would have to construct and operate the apparatus described in my s and in my lectures.

Counsel

He would have to get very much more inductance in the system than he has today, relatively?

Te

It is just like this: In an ente se of this kind, you have to start with fundamental itions. If you are to build a comrnerc plant, the stion comes up how money is it to cost. Now, you go to speci before your talists the various s of the ant, and you will find that your machinery and the aerial structure will cost so much. If your ists are willing to go deep into their pockets, you can up a tremendous antenna because, as you know, as I out in 1893, that the effects will be proportionate to the invested in that ; but you will find limits there.

I designed a [Wardencl to Fig. 83] years ago with a large ty and it before certain architects. f that the antenna would cost $450,000 and I had to modi ans. As you see, you are limited cost as to the size the antenna; that is, you are limited as to the capaci and, furthermore, you have selected the frequency. In order to lower the so that there would be no wasteful radiation of you have to employ a large inductance You have to as as permissible, and you must use a in order that you may reach the low which is economical.

Counsel

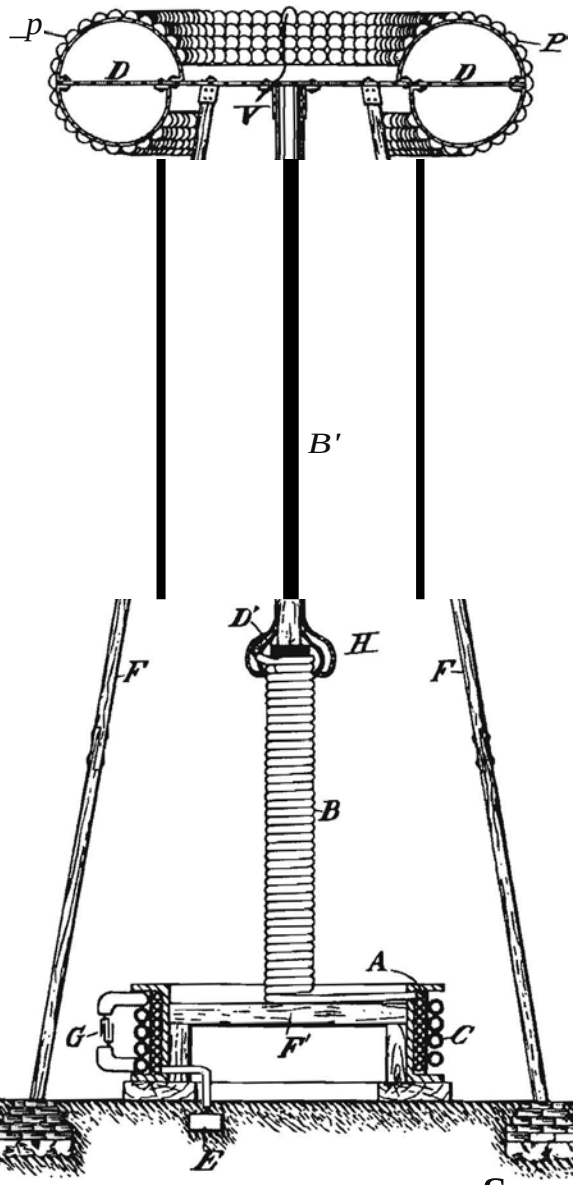
What low frequency is it that is economical?

Tesla

In a patent ch appeared in il 1905, the on of which was filed on May 15, 1900, I have enunciated the law of propagation, which I have explained, and have stated that the frequencies should not be more than 30,000 or 35,000

N. TESLA.
APPARATUS FOR TRANSlllTTilil O, ELEOTBIOAL EBEBGY.
.IPPLIO.ITIOI fiLED 1.lll.18, 1901. IEIEWED •AT 4, 1807.

1,119,782. Patented Dec. 1, 1914.



WITNESSES:
H. Lawson Dyer
Benjamin Miller.

INVENTOR,
BY K <21'-
ATTORNEYS.

Figure 83.
Improved transmitter described in U.S. Patent No. 1,119,732 of December 1, 1914. Application filed January 18, 1902.

cycles at most, in order to operate economically.

Counsel

And would it also be necessary to provide for the potentials of t order of which you have named in order to insure maximum rect currents and minimum electromagne c wave radiation?

Te la

No sir. The currents are proportionate to the s which are devel under otherwise equal ions. If you have an antenna of a certain capacity charged to 100,000 volts, you 11 a certain current; charged to 200,000 volts, the current. When I spoke of these enormous potent i s, I was described an industrial plant on a large scale because that was the most important application of these pr s, but I have out in my patents that the same principles can be telegraphy and other purposes. That is y a question of how much power you want to transmit.

Counsel

In Coloradc which you use?

Tes

■ used the so-called Tes transformer. I did not have the high frequency machine with which I could develop as for the experiments, but much energy energy I needed. transforme r I could get any amount of That is why I used transformer. the

Counsel

Tell me what D P stands for [in Fig. 83]?

Tesla

is a curved The plate has a large radius of curvature. You see, it is to be borne in mind that, in a general way, e ci will accumulate in the same way as the curvature of the surface has a smaller This is an old truth has been zed 200 years ago. The des contemplates an arrangement whereby nowhere is electricity accumulated in excess. I am at a substantial y uniform distribution of electricity in this structure, in the structure, but along the whole circuit where there is a high potential s, of course, is s to illustrate the principles. If you des a machine like that [referring to Fig. 83], it will be very much or to those now in existence,

but I have since that introduced refinements and can produce very much better results than would be poss with just that construction.

Counsel

You of the fact that you could use either the alternator or the transformer, and you have illustrated in this . 83] a condenser at G?

Tesla

Yes.

Counsel

And stating, I bel , that that represents to your mind any method of ing continuous waves. I think you said, previou you actually used of these methods at Colorado and still had ion.

Tesla

Yes.

Counsel

Was the method you used there [in Colorado], a spark? an arc? - or what was the method where you continuous generation?

Tesla

The method was this: I had a 550-volt current with which I charged the condensers. These condensers I discharged through a in an arc, sometimes I also introduced in this arc a break of several thousand per second. And I obtained a pe continuous train of waves as has been described in my s. The reason why I show the condenser here [Fig. 83] is that is synonymous with undamped waves. If I had shown the whole s as arranged there, then I s 11 have damped waves; but whether I use an alternator or some other way of energy to that condenser, the condenser is usually there. For instance, if I use an alternator, I shunt s s a condenser in order to fy the current in the primary. I then tune this circuit to the alternator, and magnify the current in primary in of the inductance to the resistance. Therefore, this condenser here stands for either method, and means that in this as is obvious from the description in the , the waves are undamped because high rises of ial would not be obtained otherwise. Whenever I wanted to obtain a potential, I had to

observe these rules in order to force the potential up to that value.

VIII. Long Island Plant

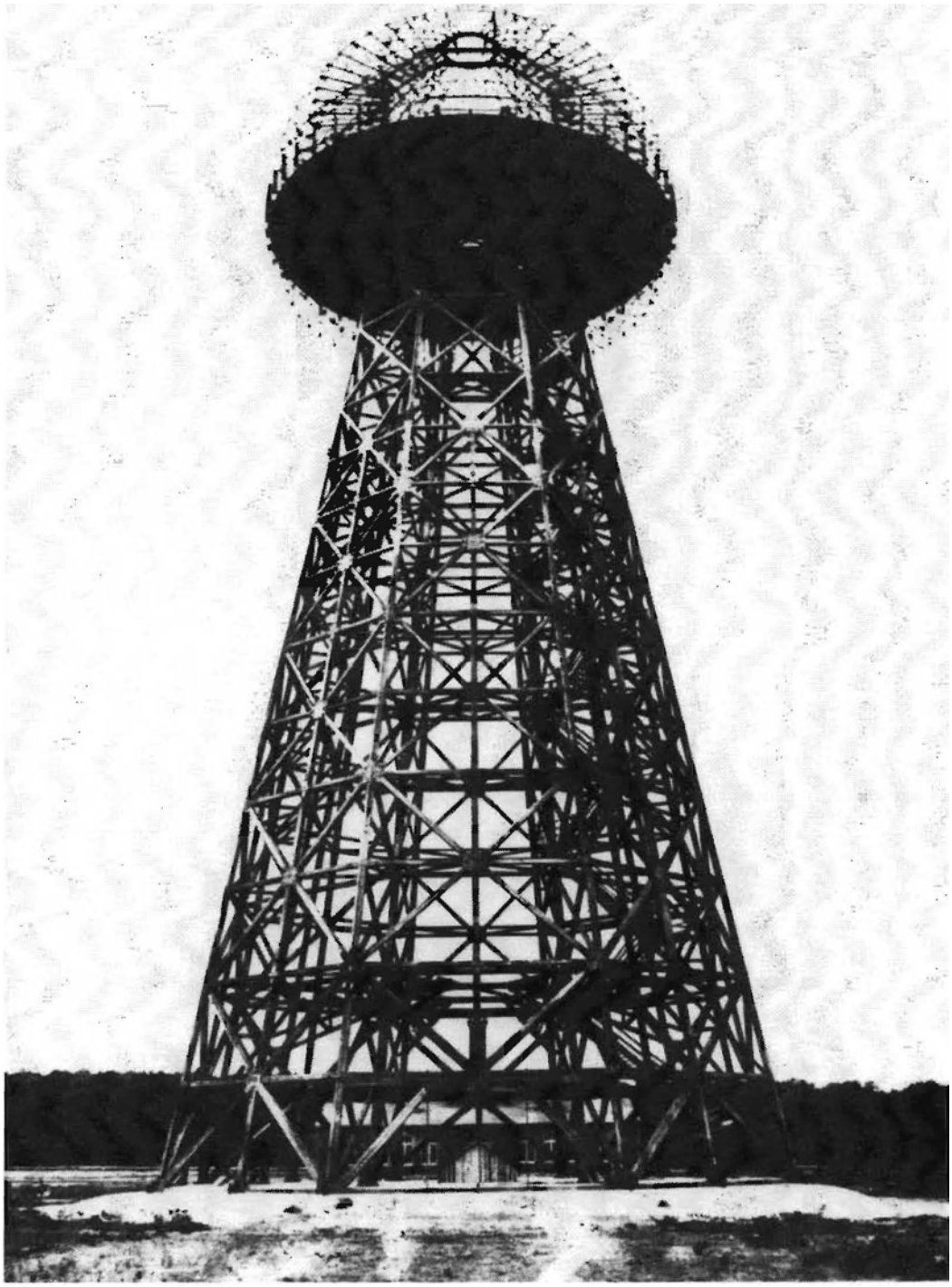


Figure 84.
Transmitter at Wardenclyffe, erected in 1901 for purposes of "world telegraphy." (Long Island Plant)

Counsel

How high was that [referring to Fig. 84]?

Tesla

That was 187 feet high.

Figure 85.
View of the plant. (Long Island Plant.)

This [referring to Fig. 85] was started in 1901 and finished in 1902. [*]

Counsel

When were the designs prepared for it?

* Editorial note: For comments on the Long Island plant appearing in earlier sections, see pp. 60, 64, 81, 109, and 112; in later sections, see pp. 159, 170, 172, 173, and 179. Also refer to Appendix II for Tesla's description of the Long Island plant and inventory of the installation as reported in 1922 foreclosure appeal proceedings.

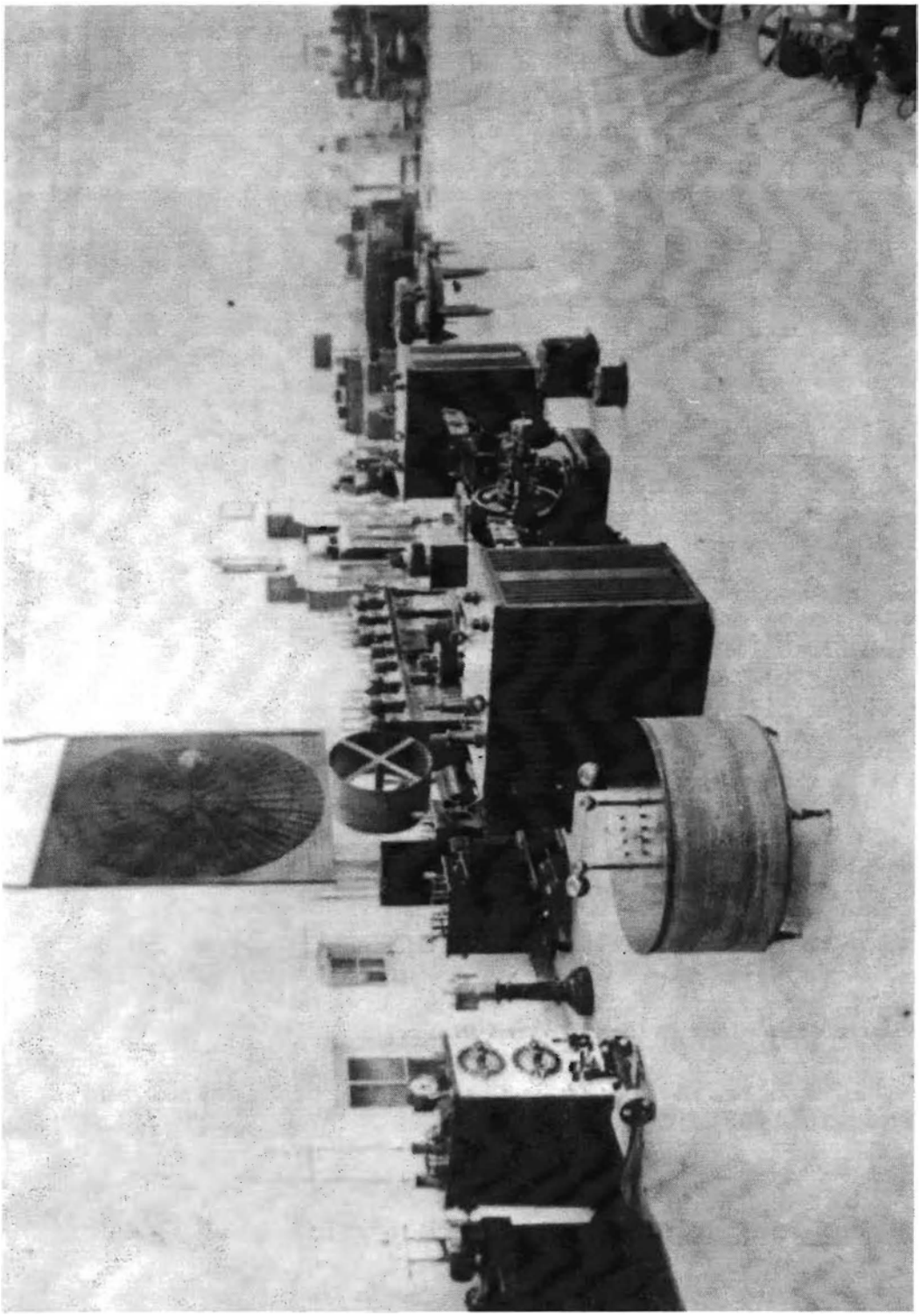


Figure 86.
A view of some of the apparatus in the electrical part of the plant.
(Long Island Plant)

Tesla

In 1900. [Fig. 85] shows the power plant and there is the antenna behind. The distance [of the tower] from the building is 350 feet. That is the smallest distance practicable because I calculated that the spark might jump from the antenna to the chimney, and it was necessary to take a precaution. The distance was indispensable on account of the potential which I was to develop.

This plant was built for wireless telephony. There [Fig. 86] is a view of some apparatus in the plant which you will presently recognize, which I have described. That [at top] is the spiral coil which you have seen previously and which has been illustrated in my patents. This is the instrument which I had before the New York Academy of Sciences and which I have shown previously. And there is the coil, you see, which was moved all around and which I used as a tuning table, and then there are other things.

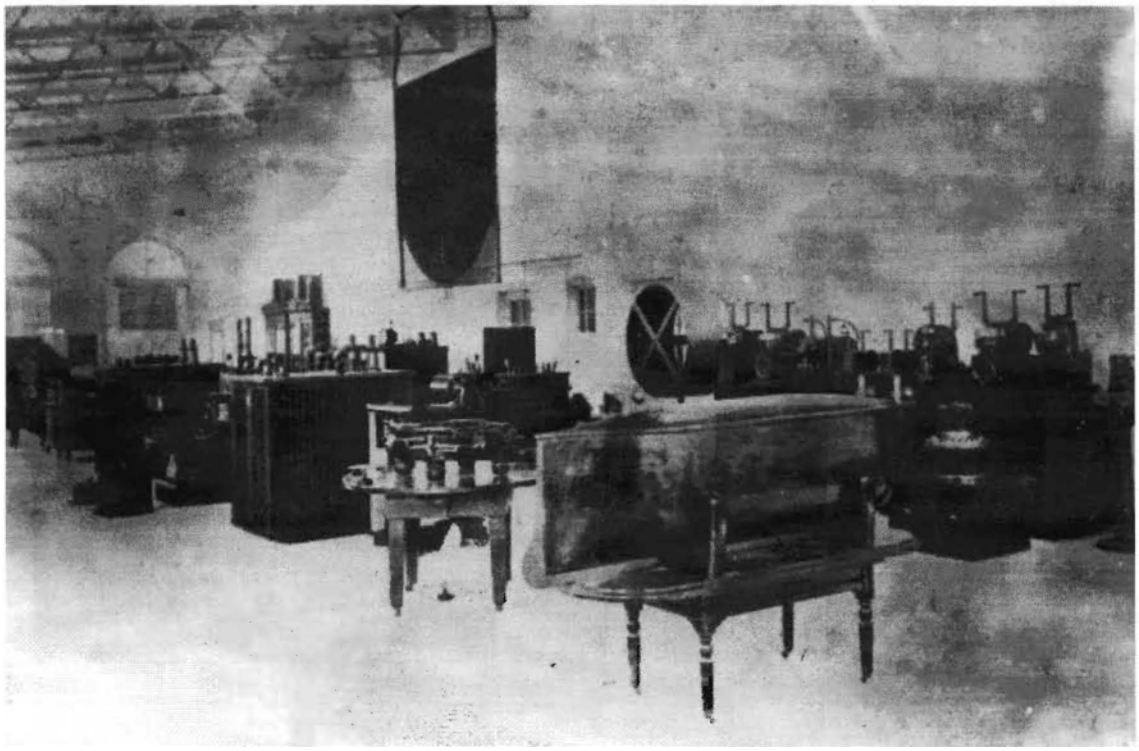


Figure 87.
A view from a different direction. (Long Island Plant.)

There [Fig. 87] you see the same apparatus again. The spiral coil very plainly seen, suspended from above. Here is a telautomaton. These are mercury interrupters, you see how many there are all around here. Here is the mercury interrupter of high frequency in which I had 25 rotating arms and 24 streams to break. That was much used in high frequency work. Here, you see, is the variable inductance and the condenser tanks; these are resistances which I used for reducing the currents to any value desired.

Counsel

When were these photographs taken?

Tesla

These were taken sometime in the summer of 1902. We had just whitewashed these walls and it occurred to me to take a snap of the shop as it was and that is the reason why they were taken. No particular purpose, but they come in here in this connection because they show apparatus which I have described previously and which was constructed from 1896 to 1898, or in that period.

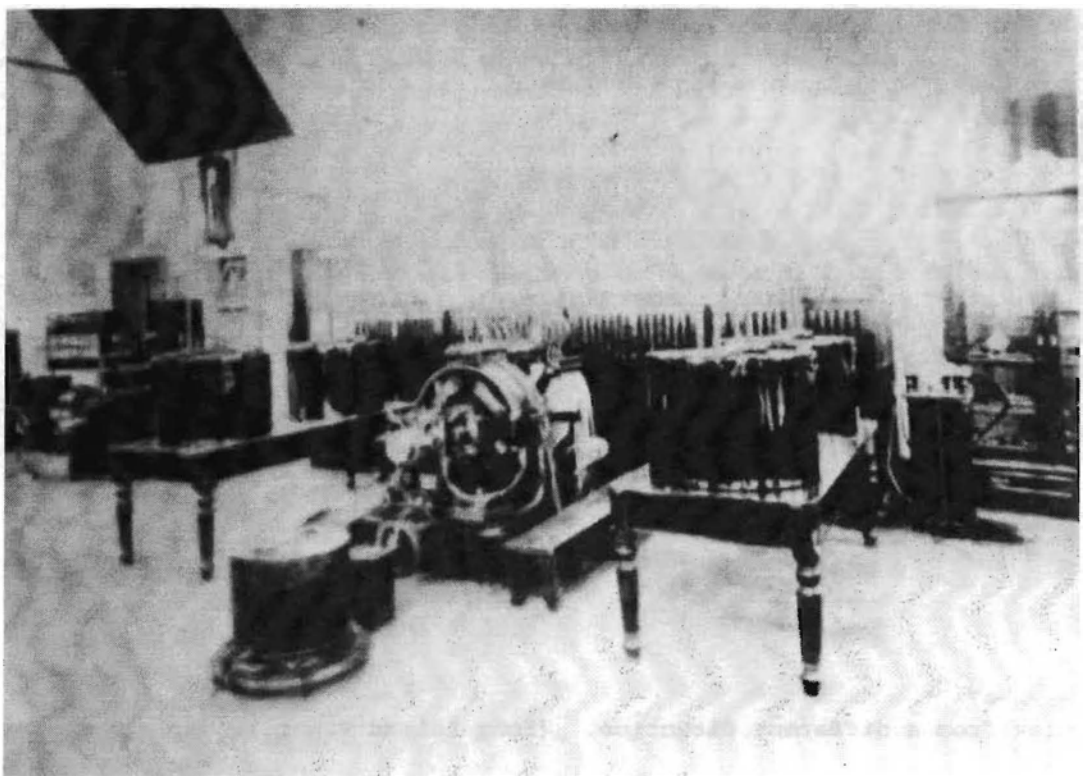


Figure 88.
Another view. (Long Island Plant.)

This is the machine [Fig. 88, center] which transforms the alternating into direct currents of high tension. These are the aluminum plates, wires, and connections. That is the commutator which commutates the alternating current of 11,000 volts, joined in series so that I get 44,000 volts of direct pressure to charge the condensers.

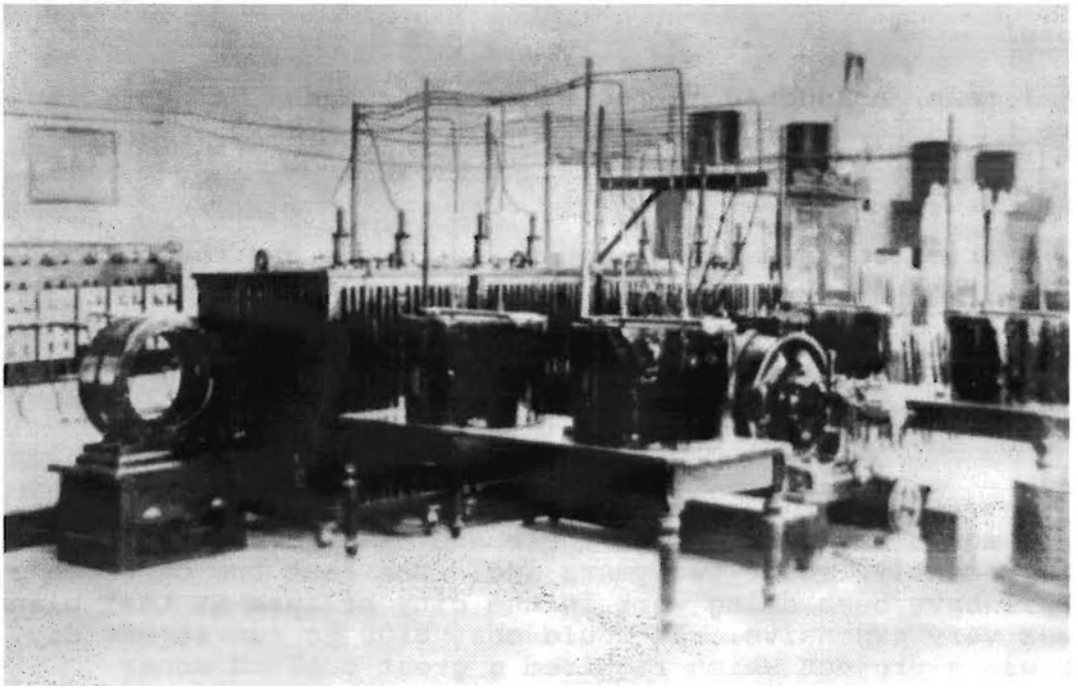


Figure 89.
Another view showing some of the apparatus which has been described. (Long Island Plant.)

Here is [referring to Fig. 89] that high frequency transformer, you see; and here, the apparatus for transforming which I have already shown. There are the four phases, or four transformers, of this apparatus which furnish continuous pressure of 44,000 volts. The condensers from which I obtained undamped waves are, however, not shown here.

Counsel

This Wardenclyffe station was what -- experimental?

Tesla

No, it was a commercial undertaking, but it required so much money that I found impossible to realize it.

Counsel

When was it abandoned?

Tesla

It is not abandoned today. I always hope. It is practically abandoned, yes.

Counsel

I mean, abandoned in the sense of no human beings being there.

Tesla

I tried to keep some human beings there but the bill nearly broke me up.

Counsel

When did this work stop?

Tesla

I would occasionally go there and make some measurements, until recently, about two years ago. The last two or three years I have been doing work in the city because at that plant it was very expensive. It would cost $100 to run it one day. That was a project which required a great deal of money.

It is too bad that some wireless men did not have the technical ability and experience to enable them to make a success from the start as I would have made. They tried and tried. You take for instance, Marconi -- four times in succession he built a plant.

Counsel

I understand the situation. Was the power ever turned into this antenna at Wardenclyffe? Did you use it in that sense?

Tesla

Oh yes. I used the antenna. I used it right along up to 1907. I made my measurements and experiments, and I transmitted for the purpose of tests, energy and all that, but it never went further than is shown in the picture [Fig. 85]. Several times I spent $1,000 to paint the thing up, and that paint in a little while was off again.

Counsel

And these times, when you turned the power into the antenna for s, what did you use?

Tesla

I could operate from very low s, from 1,000 cycles on -- to 100,000, 150,000, or 200,000. I had facility every highest. to operate with the lowest ies up to the

sel

How did you those frequencie s?

Tesla

The low frequencies I usually from an alternator, and then with this other apparatus the higher ies.

Counsel

At what frequencies you actually operate?

Tesla

I operated according to the nature of the experiment, as I say, from very low frequencies up to 100,000, but most general I operated with the frequencies which I ained in my , say up to 30,000, which I have found to be most economical.

Counsel

What was the nature of those experiments you were making there?

Tesla

The were te , telegraphic demonstrations, measurements of energy, and all that.

sel

Was there any receiver station built in connection with this Wardenclyffe ?

Tesla

No, that I used transportable apparatus with which I made my measurements and received.

Counse 1

I here a small book led th Alternate Currents of Potential and " containing a lecture delivered you before the Institution of Electrical s, London, 1892, th an Appendix on the "Transmission of Electric Without Wires," shed McGraw-Hill Book , New York, 1904. You are, of course, familiar with it.

Tesla

I have been told this book existed. I cannot remember that ever had it in my hand. I know it was ished, and without my permission, so far as I recollect. As the Appendix beginning at page 149, that is really my article that appeared in the Electrical World and Engineer, March 5, 1904, pp. 429-431.

IX. Arrangements for Receiving.

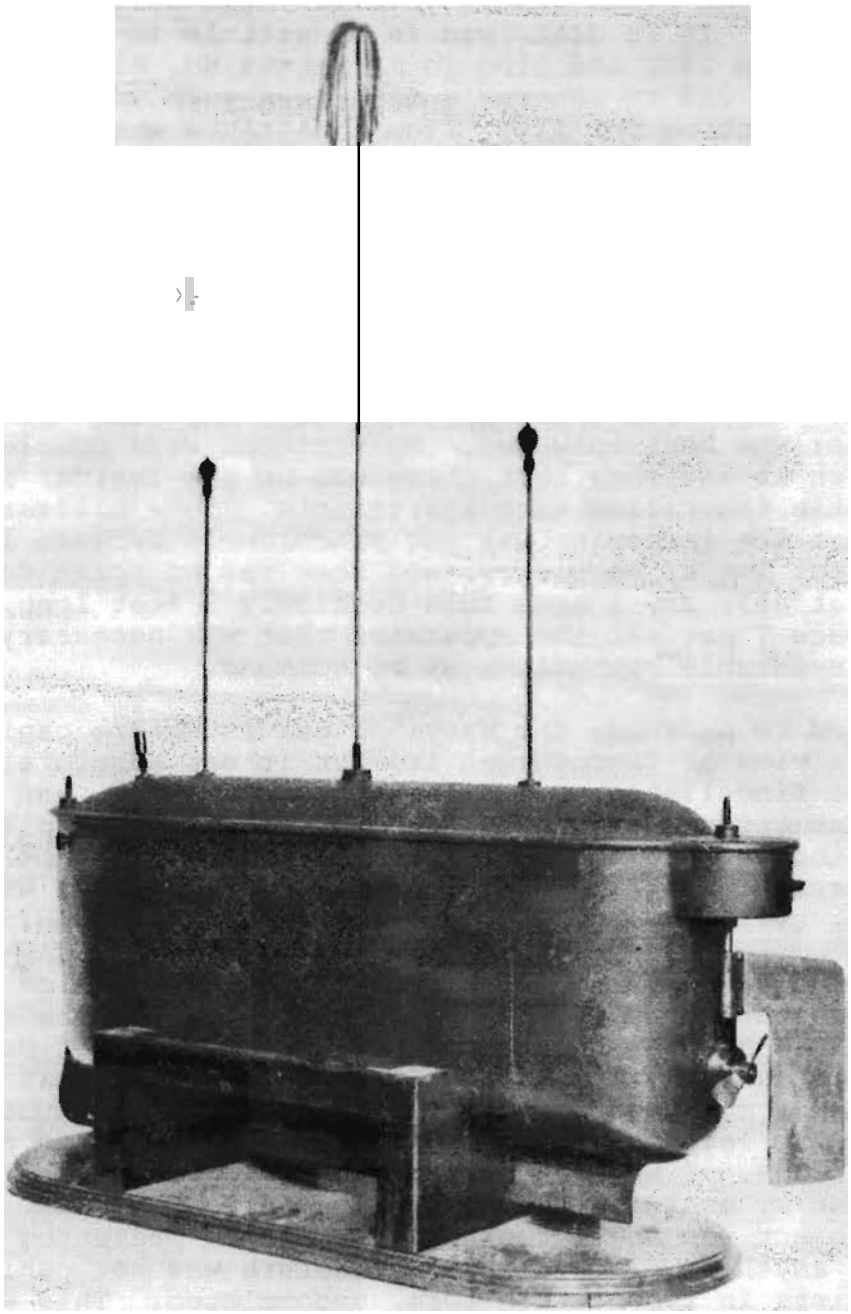


Figure 90.
The first practical telautomaton built on principles described in U.S. Patent No. 613,809 of November 8, 1898. Application filed July 1, 1898. (Article, "The Problem of Increasing Human Energy," Century Magazine, June 1900, Fig. 2, p. 185.)

Tesla

Now I come to the arrangements for receiving. This invention [Fig. 90, overleaf] is one in which I applied certain principles for the first time. This has been called since the "telautomaton." It is described in my article in the Century Magazine of June 1900 and also in my patent No. 613,809 of 1898. The idea was to control a mechanism such as a boat, an airship, or anything you like, from a distance without wires, and in this and in other machines I constructed I applied a certain principle that has been since designated as the prin- ciple of individualization. I had it embodied in this boat.

That boat was shown publicly in New York and it was at one time the wonder of the city. I usually would let any person ask some questions, a mathematical operation, or anything else. For instance, somebody would ask, "What is the cube root of 64?" The boat would answer, "4." Anything that I could answer the boat answered. My visitors were puzzled. I would open it and show that there was no one inside; it was just a little box filled with instruments. Some military men told me that the invention was not practicable because I would have an awful lot of machinery, and they had no space for such machinery at all; so, I made this boat only 3 feet long, and in this space I put all the apparatus that was necessary to perform innumerable operations at my command.

I tried to persuade the Navy. I put it before capitalists with a view of introducing it, but it was absolutely impossible to find listeners until my patent expired, and now Congress has appropriated $750,000! My patent has expired -- I get nothing, and a much smarter radio man [*], but of much lesser experience than my own, is to get $750,000. I wish him luck. But, still, I ought to have had something, I believe.

The photograph [Fig. 91] shows an instrument which I have used, and which I proposed to use in a practical industrial plant. It was brought before the New York Academy of Sciences; that is, a description of it was given before that scientific body at a meeting in 1897, to which I have previously referred. The lecture was not published because I had to do a lot of things. I had undertaken an extensive program, and I found that my energies were not adequate to the task. Later on, the subject was neglected; other business prevented me from doing anything else, and so my lecture was not published. It only exists in typewritten form, uncompleted. This was not the only lecture of mine that has met with this fate.

* Editorial note: Reference is to John Hays Hammond, Jr.

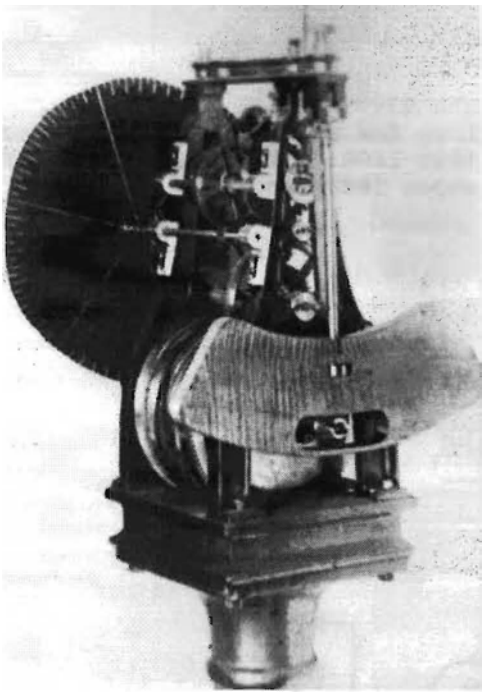


Figure 91 (left).
Special clock constructed for purpose of measurements, especially useful in receiving. Described in lecture before The New York Academy of Sciences, 1897.

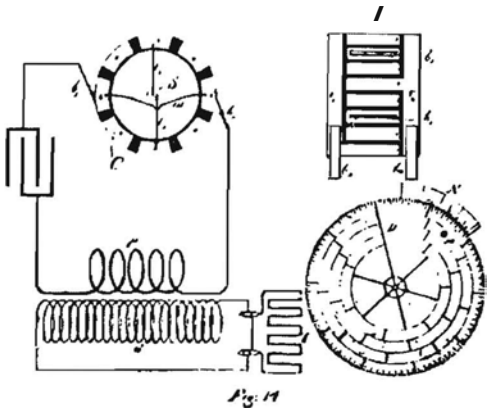


Figure 92 (above).
Illustrating some of the attachments and mode of using same. Houston Street Laboratory, 1898-1900.

The construction [of the instrument] was intended to produce an absolutely constant rotation so that certain intervals of time could be definitely fixed, and in relation to these intervals of time I could analyze the waves. This I used in many of my experiments. Later, I brought it to the Long Island plant, and you have seen it in a picture among other apparatus I had there. This apparatus was employed by me from 1896 or 1897, right up to 1904 or 1905.

These [referring to Fig. 92] are some of the tikkers -- or what do you call them now? I have been capable of inventing these things, but I am incapable of giving them a name. I mean the tone wheel, tikker, and all such devices. You see, I had a shaft which was rotated at a perfectly uniform speed; I could attach to it any kind of device and depend on the synchronism, and in this way indeed I have obtained very fine results in determining quantities of moment in the installment of the commercial plant [on Long Island] which I had undertaken to construct. The bottom of the diagram shows vacuum tubes designed for very minute currents. They were excited by the secondary of the transformer and illuminated the dial. If I used, for instance, two vibrations of different wavelength, then there was a beat, and I would notice, as this disc rotated, the marked lines travel one way or the other. When perfect synchronism was obtained, these lines appeared stationary. I exhibited this instrument during the lecture I delivered before the New York Academy of Sciences.

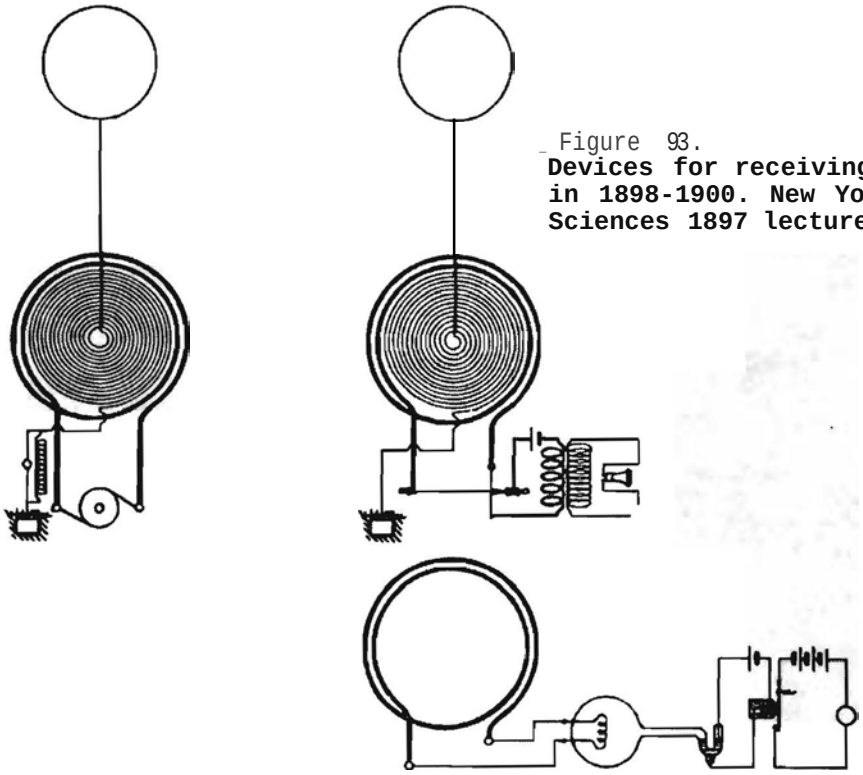


Figure 93.
Devices for receiving as practiced in 1898-1900. New York Academy of Sciences 1897 lecture.

I am now showing [Fig. 93, top] a [drawing of a] device for telephonic and telegraphic signals I have used in my laboratory on Houston Street and also on Long Island. That [left] is a transmitter arranged in the usual way, and this is an inductance which is bridged by a device such that by speaking into it, or actuating it by hand or otherwise, variations in the intensity of the waves are produced.

On the receiver side [right] I have my antenna and self-inductance coil connected to the ground, and in the secondary I have a wire which is under a tension. Another wire, likewise under tension, controls two microphonic contacts or carbons. The tension of this wire is adjustable, and as I will show in another drawing, I can regulate the pressure of the contacts so that a certain current from a battery, here, will flow through this primary coil.

When the transmitted oscillations are controlled and produce corresponding variations in the intensity of the received effects, then the current generated in [the secondary of the receiver] heats that wire more or less and the alternate heating and cooling of the latter results in periodic expansions and contractions vary[ing] the microphonic pressure of the contacts in obedience to the changes produced in the transmitter. In the secondary [of a transformer], I have a telephone

[receiver] special ly wound to reproduce the speech. This is a very device; I have used it with success my laboratory on Houston Street very frequently. It was [a] very good ce. It repeated telephonic speech very nicely.

Counsel

When was that published, and where?

Tesla

That ished, but that is a drawing of 1899 or 1900. [It] a drawing for a patent which was not ied for on account of pressing business. I have hundreds of inventions which I could not take the patent on, on account of my misfortunes. I have described his invention only in its s_ . . . form. It was sometimes more complex.

I had numerous for attunement and magnification in this ; this [Fig. 93, just illustrated the broad princ heating a wire, ng the pressure of a microphonic contact thereby, and in a telephone [rece] s corresponding to those the transmitter produced by the human voice, or in any way.

Counsel

When you used that s in your laboratory on Houston Street, where were your transmitter and receiver located?

Tesla

My transmitter was on Houston Street and I would take the re with me. For instance, I take a few toy balloons, go on the roof, and then put my box there with the struments and listen to the signals.

This [Fig. 93, bottom] another drawing of a] device which I also used with success, not telephonic. It operbut ated on the e of the Reis r thermometer. This is a bulb, you see, and in the bulb is a resistance wire which is heated and cooled, owing to the fluctuations of the received currents. The attendant expansions and contractions of the operate a little mercury column, pushing it back and forth. Curiously , for receiving telegraphic s s, this crude instrument was certainly good, but of course it was not suited for tel ic reception.

That [Fig. 94, overleaf, top] illustrates a device which has al been discussed [i.e., the instrument shown in Fig. 13]. I have used it very ly. This is also a drawing of the od of 1898 to 1900 and illustrates a way of producing audible notes reaction of the received impulses

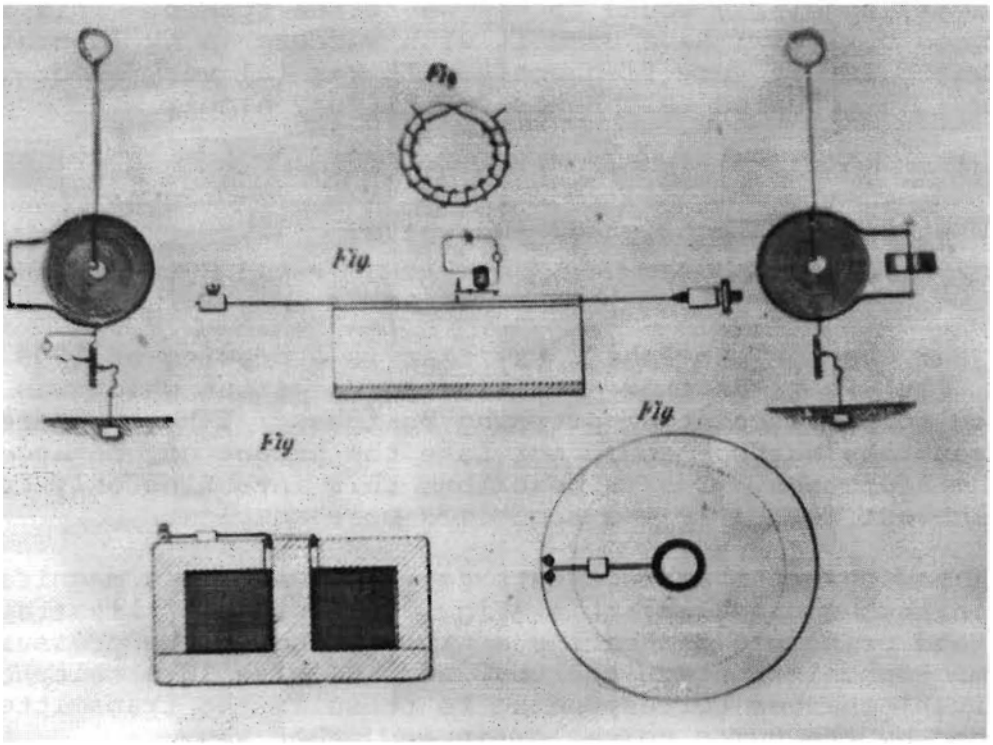


Figure 94.
Other ways of receiving practiced in 1898-1900. New York Academy of Sciences 1897 lecture.

upon a magnetic field. Here [left] is a transmitter, diagrammatically represented, with an arrangement for varying the intensity of the waves emitted, and on the receiver side I have, as you see, a grounded antenna. [The] secondary [has a conductor under tension in] a very powerful magnetic field, and [the reaction of] this conductor, traversed by the received currents in the field, causes the conductor to emit audible notes.

I had several magnets of various forms, like this, and employed a cord in the field, which, when the current traversed it, vibrated and established a contact. Or, I used a small coil like this one here [Fig. 94, top] through which the current was passed, and which by its vibrations produced the signal, an audible note, or anything else I desired.

Counsel

Where was that patent drawing published?

Tesla

That drawing was not published. It is exactly the same thing as the other, but in my writings, which I have before commented upon, I had already shown the reaction of the high

frequency and low frequency currents on magnetic fields, and had specified the frequencies within which one has to keep in order to receive efficiently audible notes.

Counsel

This drawing, however, was actually made about when?

Tesla

From 1899 to 1900. The date of these drawings we can easily locate from the bills I have received.

Counsel

And the devices shown here, were they ever used by you?

Tesla

I used them, of course, frequently. That is, in fact, one of the best forms, but as far as the principle of the employment of the magnet is concerned, it is not novel. The only novel thing was that I used my own discovery, which I had made known in my writings before. I was the first to use high frequency currents reacting on a magnetic field and producing audible notes through the reaction. I employed here only what I described in my lectures. It was a logical application of the principles which I then set forth.

Counsel

Is it one of the forms of receiving instrument which you employed in noting the effect of the signals or waves sent out from Houston Street and in Colorado?

Tesla

Yes. although in Colorado I had some devices a little different. I had a great many of them.

Counsel

Is that drawing [Fig. 94] a part of the patent application or intended for an application?

Tesla

Yes, but it was never filed.

I have a few more photographs here [Figs. 95-100]. The drawings from which they were made have been exhibited on the wall at that Academy of Sciences lecture in 1897. Here I show a great variety of bulbs I used.

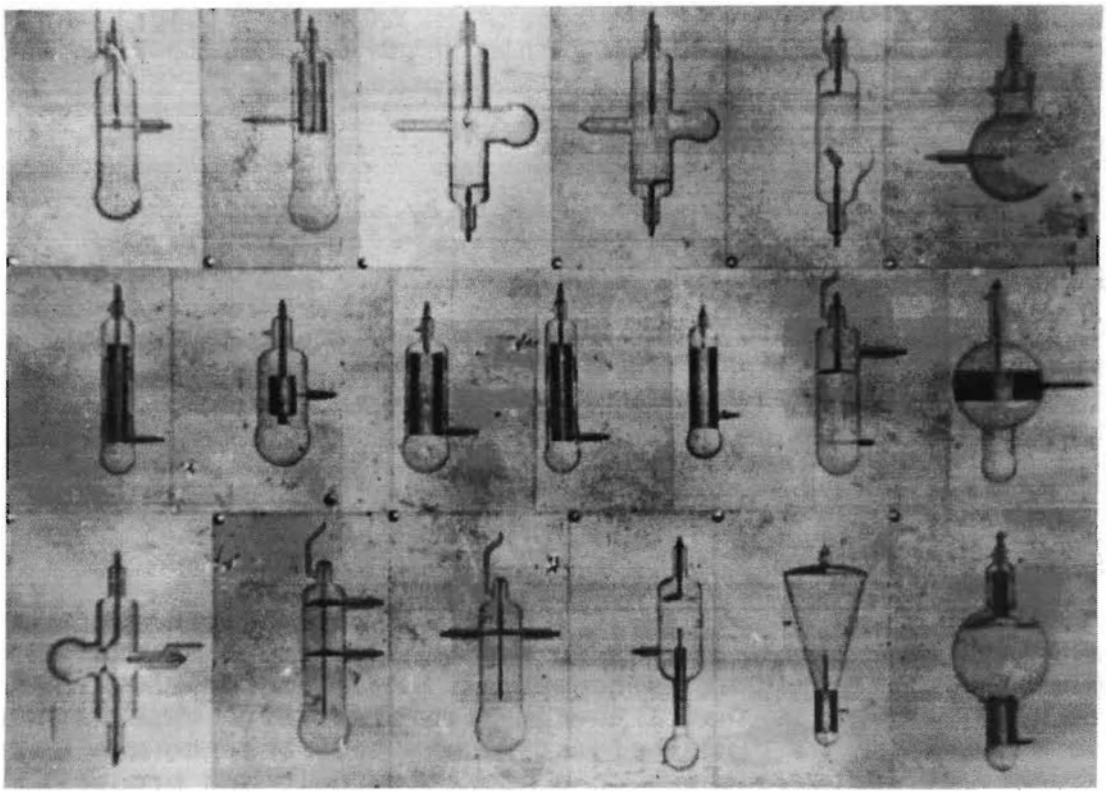


Figure 95.

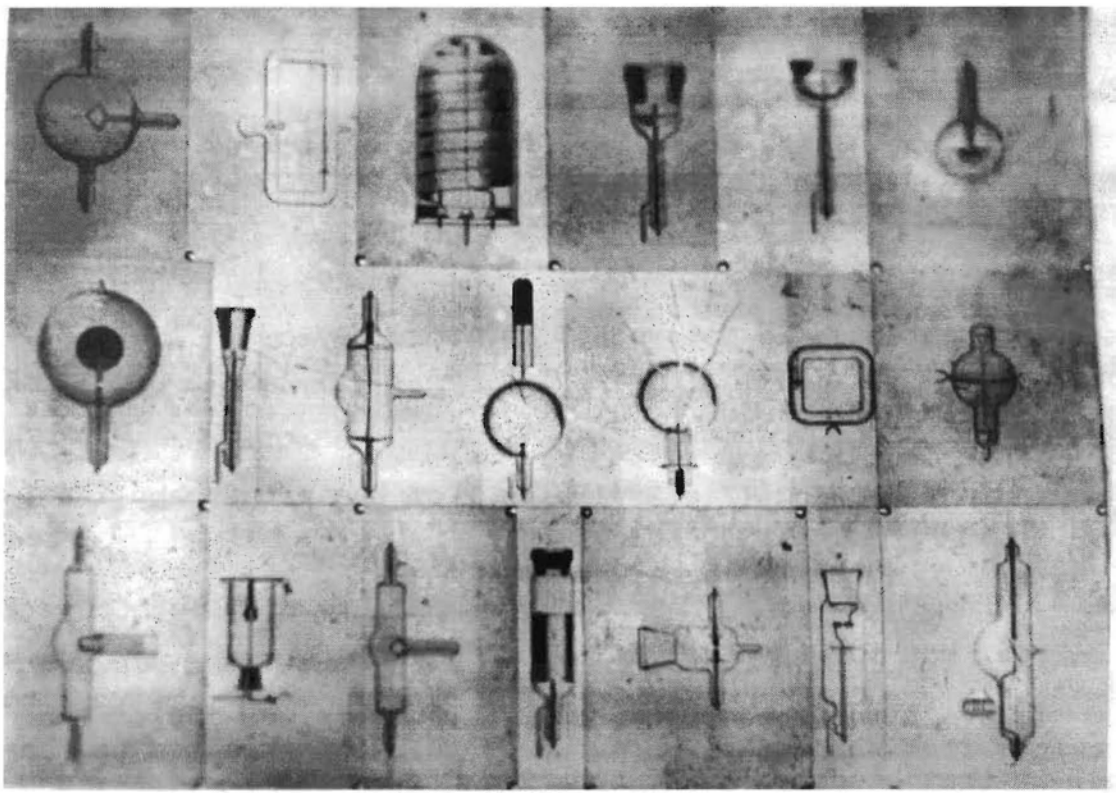


Figure 96.

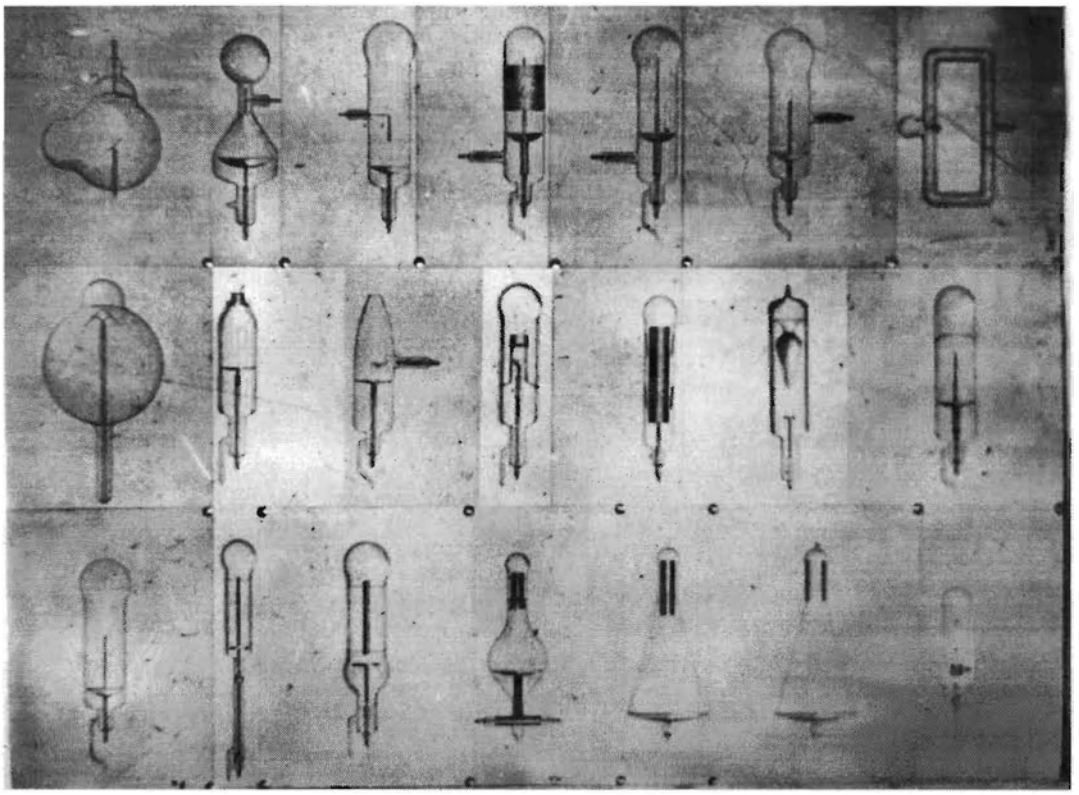


Figure 97.

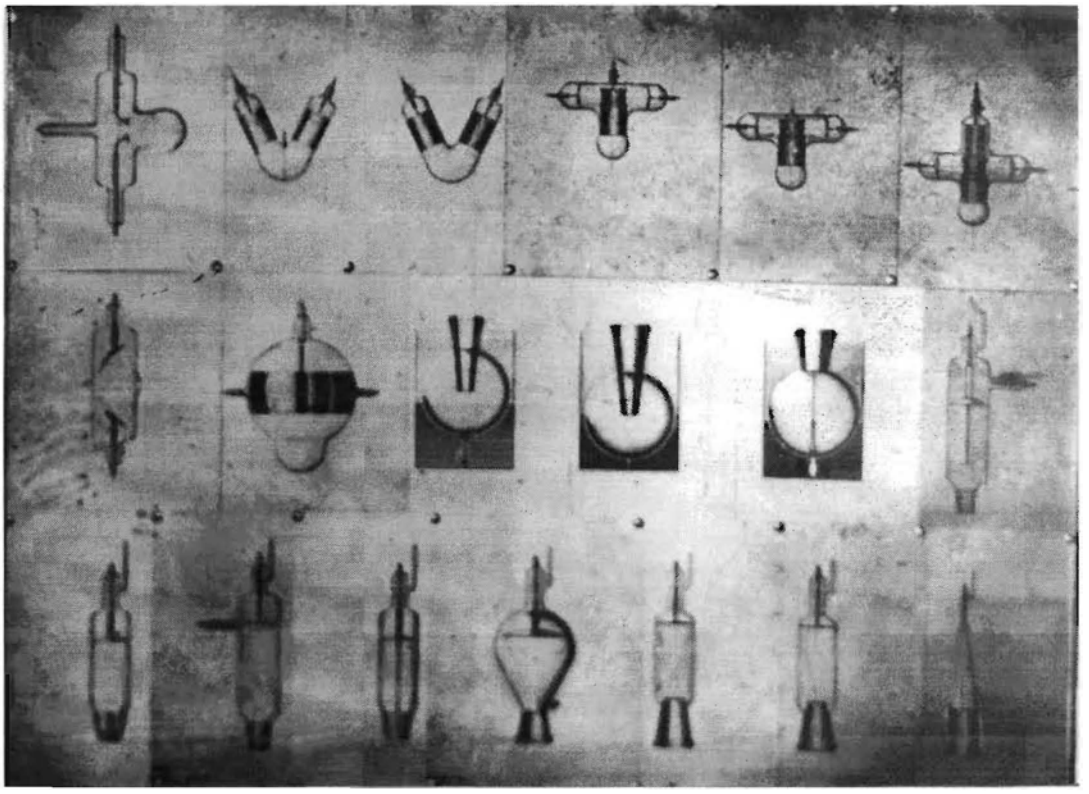


Figure 98.

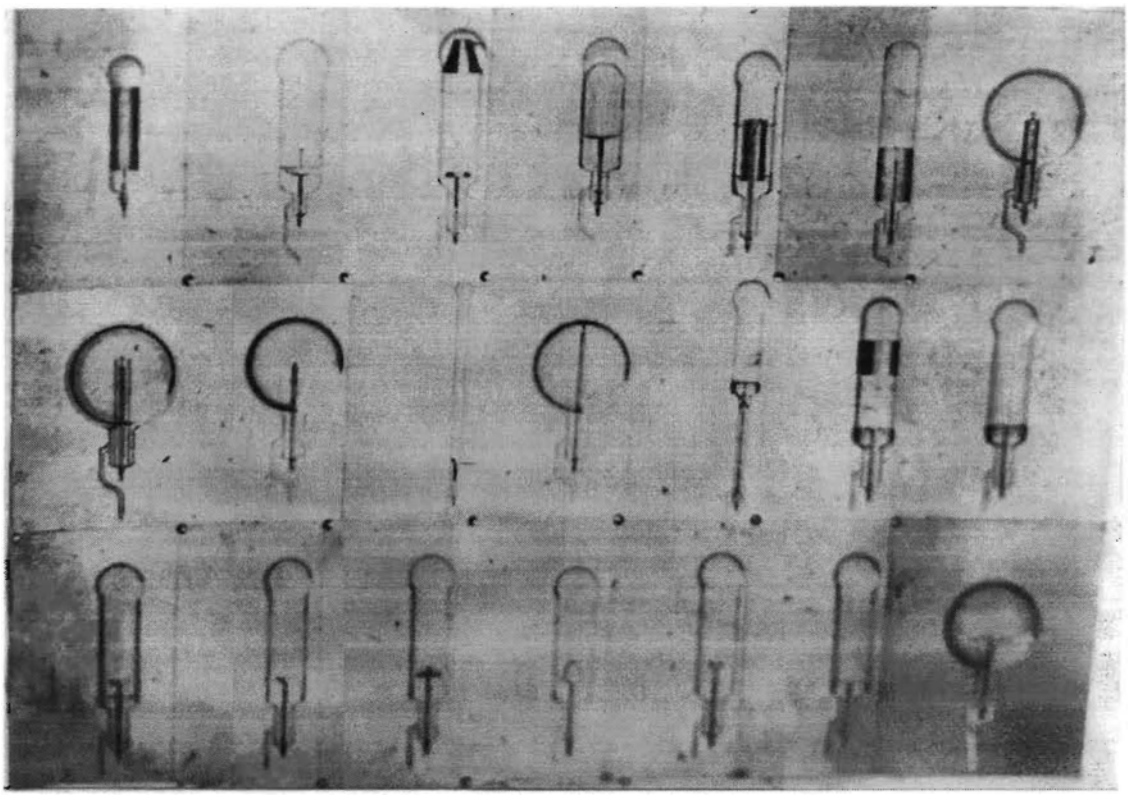


Figure 99.

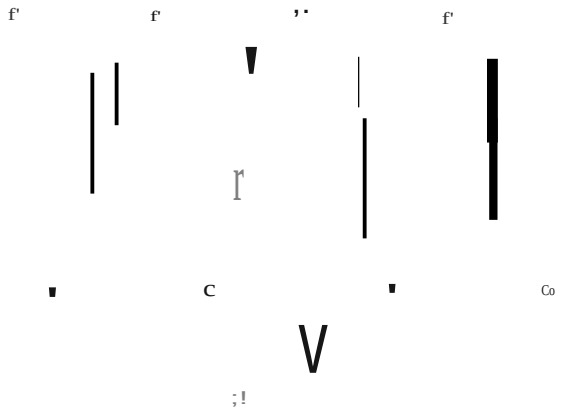


Figure 100.

Figures 95-100 (pp. 164-166).
Illustrating bulbs made prior to 1900, many of which were used in receiving and exhibited in a lecture before The New York Academy of Sciences in 1897.

Every one that you see was built, not in one, but in several forms; they have been experimented with and records have been obtained with them. Among these bulbs I have a great number of receiving devices, and some of them come remarkably close to those which others have used since.

Counsel

In what form has the principle of these bulbs been used by others, as you stated?

Tesla

Well, in some of these bulbs I have shown, for instance, that a heated conductor emits a stream of ions, or, as I said at that time, charged particles, and a few of these bulbs I have been using exactly in the same manner as the audion is used today.

This instrument [Fig. 101] was built [at] a recent date, but the principle involved in its operation I have employed in Colorado. It is what I call a static preventer. A great trouble, when I came to Colorado, was that I could not operate at all. You know that the static interference is today the great bane of the wireless transmission. The reason for that is defective construction of the plants, but with this invention I am enabled to even make these defective plants operate satisfactorily.

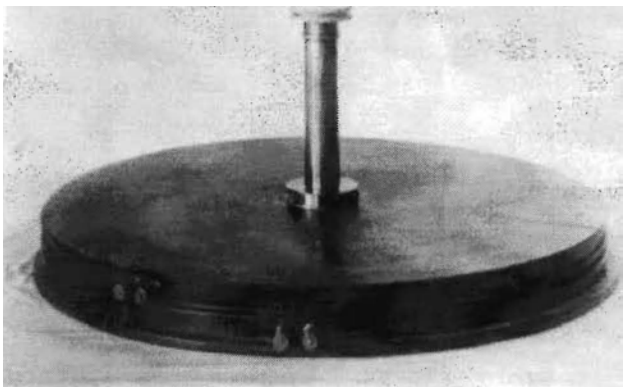


Figure 101.
Static preventer.
(Colorado station.)

The principle involves the employment of a plurality of tuned circuits in series as shown [in Fig. 77]. However, any interaction of the circuits, arising from mutual induction, produces results which are exceedingly complex. The emitted note will not be pure because of the beats produced. Radio engineers are not fully appreciative of this. The instrument shown [Fig. 101] consists of coils suitably arranged in demonstration of the principle to overcome the detrimental effects.

X. Rediscussion/Clarification of Selected Remarks.

Counsel

Suppose a telegraphy a source of low su electrical oscillat , delivering its current to an antenna of large capac , tuned to the frequency of the current delivered to it, and a or switch delivering such current of such antenna at will for signaling. Did you ever construct a installat lving these conditions?

Tesla

Why, in almost any of the experiments of sending installments I made, those were the normal conditions. I have already shown that, in order to operate efficiently, I had to employ a low frequency and sustained oscillations. Furthermore, as regards the capacity, I have also pointed out that I made s capacity as large as was possible under the circumstances.

These oscill ons were obtained in the various ways either from a high frequency alternator or by my methods of energy transformation of ordinary currents sustained waves of high frequency, or higher frequency than normal.

Counsel

Will you name two or three installations which embody those conditions?

Tesla

I may name r tances in which those installations were made, operated in exactly the manner described. I oper from my l at 35 South Fifth Avenue, where I would usually run one of my gh s, connected either directly or a secondary, to the antenna on the roof, and as a receiver station I would have a tuned circu some devices, usually telephonic, for receiving the s nals. The s _ _ either in a order, by an automatically rotated switch, or I asked an assistant to operate the switch according to my instructions

The receiver plants were usually on some other bui s the city; most generally, as I stated, I operated between 35 South Fifth Avenue and 28th Street at the Gerlach Hotel, where I was s ng.

In my laboratory on Houston Street, I had a similar installment, using an antenna on the roof and either a

frequency alternator or my transformer as a source of undamped waves or s o lations, and I similarly tuned receiver circuits at other distant , among others, West Point, which was the farthest distance I ever used the transmitter, [and] results enabling me to calculate the performance of a ant, which I was then planning

In Colorado I erected a for the practical purpose of at accurate data for the canst a large plant which I have termed a universal relay, or some such words. The in Colorado was merely designed in the same sense as a naval constructor designs first a small model to ascertain all the s before he embarks on the construction of a vessel. I had al planned most of the detai ls of the comme plant, subsequently put up at Long Island, except that at that time the locat was not settled upon. The Colorado plant I have used dete ing the con struction of the various parts, and the which were carried on there were for the purpose of enabling me to design the transmitters and receivers which I was to employ in ly erected.

In Colorado it was my practice to operate ther perfectly sustained with a wave d my methods, which I have already described, from a 550-volt current I attained from the street railway mains, or else I used sustained waves produced other ways, which I have already described.

Now, these impulses of the tter were controlled either a controller or by an assistant, and the s were received by me in portable instruments which I took out occas and with which I made measurements and observations.

Then, on Long Island, dur the construction of plant, and when the antenna was aced in tion, I used the antenna in similar s and demonstrations while the work was on. I had, however, other provisional antennae in the meantime which I used before the big one was erected.

Counsel

Earlier you spoke of i sm in the frequencies of the alternators or sources. How did that lack of isochronism compare with alternators of present that are used for se ce of s kind?

Tesla

All the alternators ever designed failed to isochronous impulses, but the alternators of high frequency which were des later years by my followers were very much

worse in this re than mine reason that
they were built for much higher the the
frequency, the are the isochronism.
You see, certain definite will have a
greater effect on the isochronous character of the scilla-
tions if the are shorter; therefore, the the
frequency of the the less i sm there is. The
dynamo of Alexanderson, designed for 200,000 cycles, cannot
fail to show a very departure from isochronism much
greater than in my s of 1891 and 1892.

sel

Would your answers be the same if the source of current were a high or ?

Te

If the source of current is an alternator of very frequency, then the drawback comes in; that is, a wasteful action is introduced. Therefore, as I have stated, unless s dynamo is of reasonably low cy, the effects will be undoubtedly fi and would be not so good as when the frequencies which I have fied are employed

Counsel

But, so far as concerns the involved, and the strumental is there any real difference?

Te la

Absolutely no difference.

Counse

And that would be true even though you used some form of a transformer between the dynamo and the antenna?

Tesla

Exactly true.

Counsel

Referring to the fferent trumental s described as be used you for supplying su electrical 1 lations to an antenna of high capacity and tuned to the frequency of the current ssed, for the transmission of energy without s, what, if any, fference in princ was involved in the transmitting of such energy to a distant telephone, for tance, or for signal , as compared with

such tran ssion to any other form of translating device such for instance, as a lamp?

Tesla

There is no difference whatever that I can see in the principle

Counsel

Was there any fference in the equipment employed for e two purposes?

Tesla

Absolutely none that I can see.

Counsel

Would there be any difference in the or in the instrumentalities used if such work is carried on with a single-wi re it?

Tes

Not to my knowledge

Counsel

Can you give some idea about the amount of expenditure involved these various tests and that you have described?

Tesla

Oh, the mere thought of those tures makes me ill. Why, I have in the wireless work, before I ever saw Colorado -- I think my knows that -- I have expended certainly not less than $750,000. And then I have spent in Colorado over $60,000; yes, more than that $70,000; and I have about $500,000 on the Island plant. If my results had been onate to those expenditures, I would be a great man in Wall Street.

Counsel

What was the distance of the receiver from the sending station in the Colorado test?

Tesla

Well, these distances were small, for the reason that they were to me quantitative data.

Counsel

Could you the number of miles, approximately?

Tesla

Oh, 10 miles or so.

Counsel

And what form of receiver did you use in this instance?

Tesla

All kinds of forms. Some of them have been described and ished; others I have not yet publi and the finest ones of them are not yet.

Counsel

In the Long Island test, what was the greatest distance that you transmitted there?

Tesla

Similarly, in the Long Island plant, I was too much absorbed in the construction and the was not yet quite ready. The experiments which I made there were simply preparatory

Counsel

Was the receiver substantially the same as that used in Colorado?

sla

Yes -- substantially the same.

Counsel

when you came to this greater stance of 30 miles to West Point, what receiver did you use in that instance?

Tesla

I used several rece rs. I made several trips to West Point. In one of these experiments I used what I have termed a 1 mass resistance, something on principle of Bolometer. The rece oscillations passed through a conductor of extremely small mass, which I have to produce thereby the produced di s of potential

which could then be detected in the telephone through the use of a battery.

Counsel

Could you tell, just in a few words, the mechanism actually used by you in Colorado for getting the continuous waves?

Tesla

I produced these continuous waves in several ways; but before I answer that question, let me define what a continuous or undamped wave means. That is so elastic a term, and there is such confusion in this respect, that unless I elucidate that a part of my remarks will not be understood.

I have pointed to this already, and I have given a mechanical analogue by a bell. If you put a bell in mercury a dense, heavy medium, and you attempt to make this bell vibrate, you will find that, unless the blows of the hammer with which you try to keep the bell swinging are delivered in a very rapid succession, the vibrations of the bell will die out between the successive blows. But, if you take a bell and put it in a vacuum, with no resistance, with nothing to take up energy, then you can tap the bell once in every half hour and still it will ring with practically the same note, the same intensity. Therefore, before we talk of these continuous or undamped waves, we must realize what conditions there existed to keep up waves of this character. It makes a vast difference. In one apparatus the waves will die out quickly; in another one, they will not. Even when I operated as in some instances with a few of these hammer blows, even then, owing to the design of my circuit, the waves were practically continuous; but I have had several ways of obtaining absolutely undamped waves, irrespective of the manner in which the energy was taken out from them.

Counsel

That is, at the Colorado station, you mean?

Tesla

Yes. One of these devices comprised two choking coils, which I connected to the mains of a 550-volt circuit. These choking coils were connected to a condenser, and in series with this condenser was a primary. I would establish across that a spark gap or arc, and directly I did this a continuous oscillation of any period what I desired was produced, and I would adjust it by altering the capacity of my condenser or by varying the turns of that self-inductance coil which you have

seen there [i.e., self-inductance coil with wooden crank handle shown Fig. 57], ch I usual these experiments That method was desc me ago. It was described in my patents and practiced by many electricians. There was nothing novel in it, except that in 1896 I introduced these coils for raising the tension from 550 volts to a much so that I could [a] smaller condenser and [obtain] a more s vibration. That was a well known way.

Counsel

What was the effect on the frequency o this rais of the voltage at the same time?

Tesla

Well, the frequency remained any frequency I wanted. There was no effect on the frequency, except that the energy of the lation was greater and the frequency could be pushed if I wanted it.

Be s s, I had another way of producing continuous oscillations. driving a That was by mechanically operated is I break, such as I have shown. would rotate at a certain speed, such a number of breaks as to the number of half-waves of the oscillat antenna circuit, which of course was to the primary.

To show you how I did this, I , for in Colorado, with s from 5,000 in fact, lower than ,000, up to any , say 00,000. I had 5,000 os llations per second in the antenna, and I rotated my break in such a way that it gave me 10,000 makes and breaks; then my make-and-break was in ism with the waves in the antenna I produced a train of ly undamped waves.

Furthermore, I have also operated with an break, as I showed one of those earl [f], and I have relied on the energy accumulated in the antenna to br over the gaps of the successive di I have had my circuit so constructed that even if I used only the frequency of the , say 300 ions per second, I sti l could dge over the gap between these interrupt ions with the waves in the antenna.

Counse 1

And this s that you have been just describ is what you actually used at Colorado?

Tesla

I actually used in all these three forms, almost every all these devices; and furthermore, I had other methods ch are not and se are corking methods.

Counsel

That was, as understood, spark gap transmission?

Tesla

It was impossible to s tremendous which energy I needed in my expe s with the machine. frequency with That is the reason why I relied on that method, because that method I could get any energy I wanted from the circuit. With the high frequency alternator, I could not. The waves are absolutely identical; you can them either one way or the other. They are of the same character -- s o

Counsel

Do you use "sparkn and "arcn as simply equivalent terms, or whether they mean especially different?

Te

Yes, they are I never make any distinction between them. If stream is continuous and fat, it is nothing but an arc. I never have of this distinct between an arc and a ; there is no distinction.

Counsel

The question is, whether the waves are damped or not. Perhaps in this case the ustments were such that y were undamped -- is that it?

Tesla

As I say, with the transmitters I have designed, and way operate, you cannot get anything but undamped waves, unless you want. In those striking effects which I produced for a certain purpose, I did use damped waves in order to magni my effects.

Counsel

Earlier [p. 85], you referred to certain experiments that had been made by Mr. Pickard and which you criticized as having been improperly made. Do you know in what connection Mr. Pickard made those experiments?

Tesla

I understood from Mr. Pickard that in a certain of which ido really know nothing, the question came up as to whether the described in my patents, which have been f y quoted, of March and May, 1900 [referring to U.S. Patent Nos. 645,576 and 649, 1] -- whether an apparatus constructed exactly as described in those patents would be capa- of ing commercial messages, and Mr. Pickard told me that he made up exactly the same transmitter, true to dimens , and that they transmitted messages 200 or 300 miles with the st facili

On that occasion he told me he had a certain antenna. Then I cal his to the fact that if he had calculated the antenna so as to adapt it to an oscillating ci of energy, he could have transmitted the message to any distance he 1 pe across the Atlantic, but Pickard did not do that. He just used a condenser capacit y of 0.04 mi I believe as I des [in] patent, instead that of up a capaci there, ng more energy in the oscillator, slowing down the oscillations and a more efficient system of energy. He could have then transmitted messages to great distances without the sl di He that he knew it, but that there was no purpose in t ng to stance, that the ect was to show that the apparatus was designed on rational lines

I would like to correct an erroneous impression. I did not mean to criticize the work of Mr. Pickard. I simply say that he d have an experiment under those conditions.

Counsel

ite outs of the question of the di that you had, from a commercial of view in some of these ideas that you with and still agree were any of the var s that you have referred to having to do with the transmi end used commercially; that is to say, installed connection with some system that took messages for pay or the , or some other ther or ic body?

Tesla

Yes -- the owners of my in the first gave a license to an engineer who was installments for the ; and, as a matter of fact, on the vessels of the the system was installed under my my transmit ter, my receiver, with four tuned circuits.

Counsel

was that?

Te

This was Mr. tz Lowenstein, who began the introductior about five years ago, to Navy, continuously, from my patents Yes, he started about five years ago, and since that time he been cont ly introducing it. As a matter of fact, the naval officials have acknowledged that it was the best apparatus on the market

Counse

What do you mean apparatus? Will you g me a definite reference?

Tesla

I mean the transmitter and in my fundamental patents of March and May, 1900, which have frequently been referred to; relating to various ways of produc- oscillations of which there are a number. of the patents gave a l se to Lowenste , under eight patents, which have been di on the nameplates.

Counsel

These matters are presumably public, involving an expenditure by the of approximately how many dollars?

Tesla

Iknow spent probably $40,000 or $50,000.

Counsel

My que is not conf to the Navy. I am seeking to ascertain what commercial use, if any, your have been put to. We have already established what is understood as commercial use, which would include Tuckerton, lle, the -- any place where the be actual used, or have been used for pur- poses, and for ther yoursel f or others as to or, in other words, where the used under circumstances where real for the use of the patents. Have not at the Tuckerton station [*],

* Editorial note: For an interesting dissertation on this topic, see Nunn, Roy M., The Goldschmidt Wireless of Tuckerton, New Jersey, submitted to the History Department of Albright College, May 1967, in partial fulfillment of the requirements for BA (46 pp.).

as well as the Telefunken at the lle station, for some years been ing as a licensee under the Tesla princ s?

Tesla

Yes.

Counsel

During what years was Mr. Fritz Lowenstein connected with you or your company?

Tesla

Mr. Fritz n came to me 1899, recommended by the consular of Germany, and he stayed me about three weeks while I was at 46 East Houston Street. When I needed an assistant in Colorado, he came for a short while to Colorado Spr and left me n in or about the middle of , 1899, before my was really completed Then , while I was carrying on the first construction on Long Island, during the first process of construction, while the plant [was] not far advanced, he was there again for a certain He was with me for a short period, and was not empl my company in any way. It was a matter of having an for a short until he would get oyment somewhere else.

Counsel

When did he last work for you?

Tesla

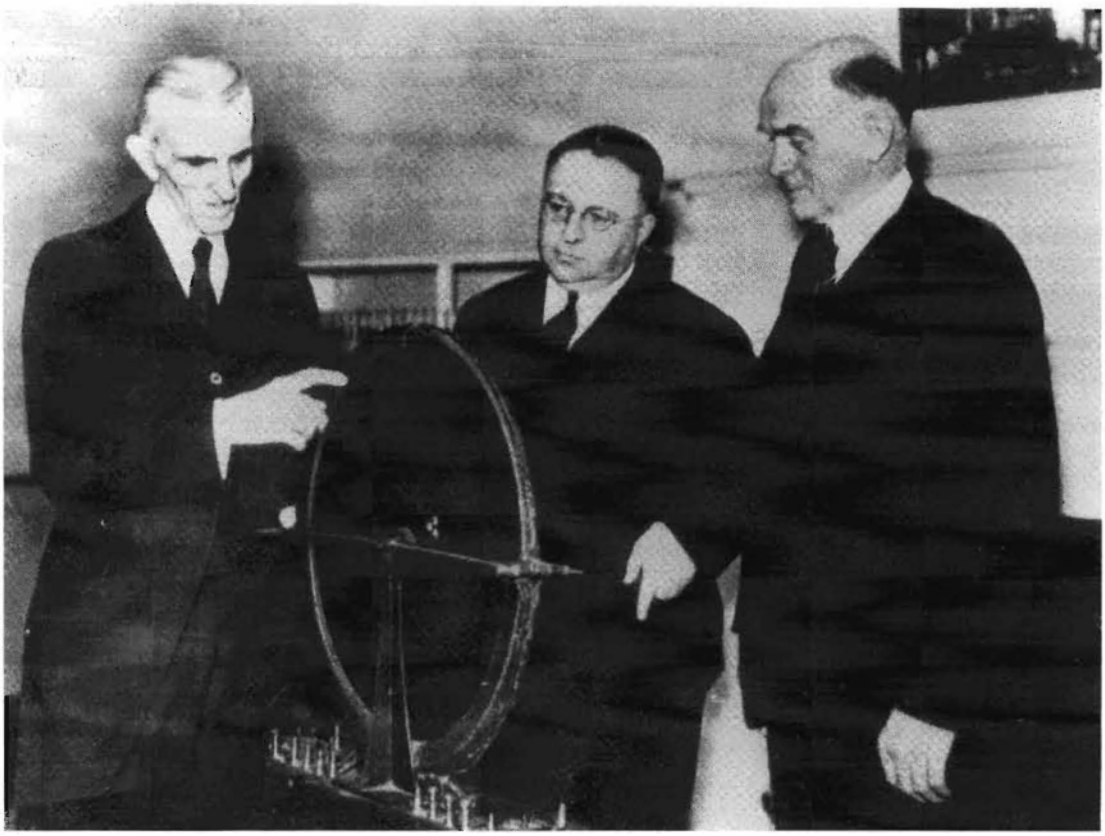
He did not work for me since 1902.

Counsel

Thank you, Mr. Tesla, for your presentat which took the form of a lecture some I think we were all deeply sted, as an intellectual exercise, and attracted by the unusual of the subject.

- END -

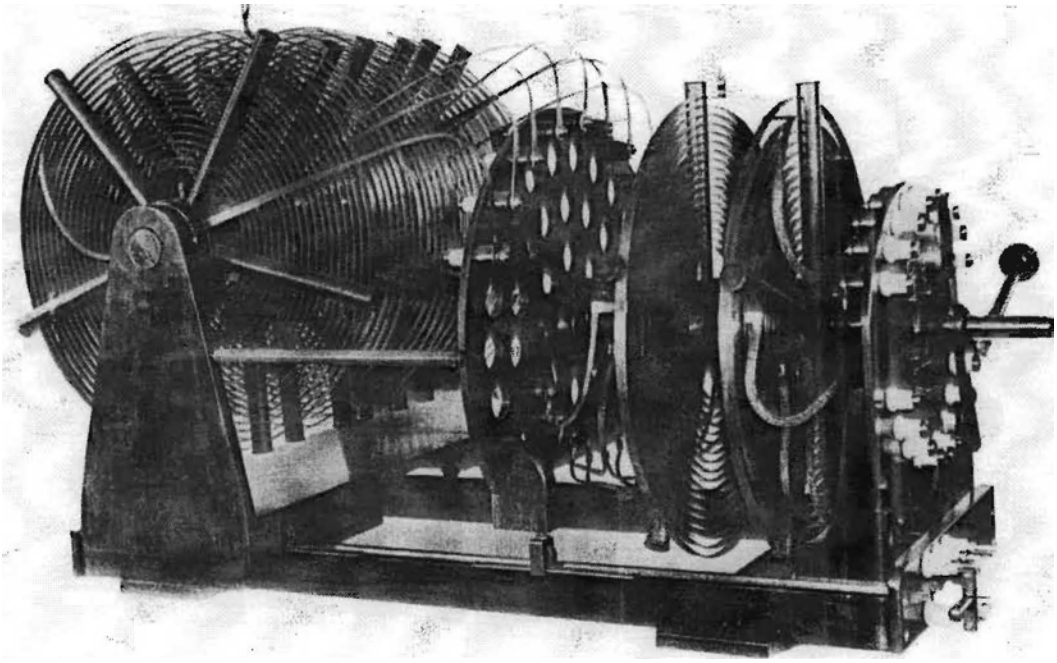
Appendix I



Westinghouse

Figure Al-1 (reference from p. 17).
In the spring of 1938, the Societe pour la Foundation le 'Institute Nikola Tesla of Belgrade, Yugoslavia, conununicated with the Westinghouse Electric & Manufacturing Company concerning its endeavor to collect information about Tesla's early work. Victor S. Beam, patent counsel for the Westinghouse Company, had earlier uncovered an alternator in company storage identified as belonging to Tesla, and an invitation was extended to Tesla to be photographed with the alternator in Mr. Beam's office, 150 Broadway, New York City. An appointment was scheduled for May 10, 1938. When Tesla arrived, he recognized the alternator as one that had escaped destruction in his laboratory fire March 13, 1895. The Westinghouse Company had borrowed the alternator, but the fire disaster so absorbed Tesla's efforts in re-establishing his laboratory that the machine was forgotten.

Five photographs were taken on the occasion of Tesla's visit. In this photograph are shown, from the left, Tesla, Victor Beam, and John T. Morris, Secretary to Mr. Beam.



George Scherff

Figure Al-2 (reference from p. 85).
Shipboard quenched-spark transmitter, produced by the Lowenstein Radio Company and licensed under Nikola Tesla Company patents, installed on naval vessels prior to WWI. Shown is a 5-kilowatt transmitter having a range up to 1,500 miles. Note that this apparatus adopts the flat-spiral type of antenna-circuit coils shown in the Tesla sister patents No. 645,576 and 649,621 of May 1900. Secretary of Navy Josephus Daniels remarked that this apparatus was "superior to any other" at that time.

Appendix II

Wardenclyffe Foreclosure Appeal Proceedings

In the spring of 1899, before establishing his experimental station at Colorado Springs, Tesla took up residence at the old Waldorf-Astoria, a rococo style, red-stone hotel located at Fifth Avenue between 33rd and 34th streets, now the site of the Empire State Building. When the Wardenclyffe project ran into financial difficulties, Tesla mortgaged the property in 1904 to George C. Bold of the Waldorf-Astoria for expenses of residence and entertainment furnished him. In 1908, Tesla again mortgaged the property to the Waldorf-Astoria for the same necessity.

The anticipated income of the Wardenclyffe project from transmission of messages across the Atlantic was unrealized. Tesla was unable to repay the mortgages. Action was taken by the mortgagees in 1915 to foreclose the property, and a bill of sale offered to Lester S. Holmes. The tower was destroyed in order that the property could be commercially developed. Tesla appealed the foreclosure judgment, and the case was heard by the Supreme Court of the State of New York, Suffolk County. Tesla lost the case on appeal. Following the judgment on April 20, 1922, Tesla vacated his suite at the Waldorf-Astoria and took up residence at the Hotel St. Regis.

The transcript of the case substantially revolves on matters concerning the merit of the legal instruments involved in the mortgaging and foreclosure actions. However, in the course of the testimony given by Tesla, important information about the Wardenclyffe installation is provided. A portion of the testimony by Ezra C. Bingham, chief engineer for the Waldorf-Astoria, is also of interest with respect to the condition of the premises and its vandalization. In addition, a complete inventory of the plant is given as Exhibit B. These extracts from the transcript of the case are reproduced in the pages that follow.

The pagination of the original transcript appears top center of each reproduced page. The pagination of this work is shifted to bottom center on the numbered pages of the transcript. The extracted transcript sections are:

	transcript pages 163-
Nikola Tesla for Defendant-Direct	181
Ezra C. Bingham for Plaintiff-Direct	235-247
Nikola Tesla for Defendant-Direct	269-275
Defendant's Exhibit B [inventory of plant)	309-312

Supreme Court,

APPEU.ATE Dt\"lSlON-sBC(\'fn DBPA.ITMEMT.

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TOU OP ,... LuT WtU. AJQ) Taft'AXDT OP Oaoao• C. hM',
DECEASED,

Plaintiffs-Respondents,

against

NIKOLA TESLA,

Defendant-Appellant,

THOMAS O. SHEARMAN,

Defendant-Respondent,

et al.,

Case on Appeal.

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*•)oA

A. Of course I had signed and the transaction 487
waB completed.

Q. And those papers were then in Mr. Hutchins' possession?

A. Yes those were almost his parting words.

Q. I think you said that conversation took place early in 1917 or late in 1916?

A. I think early in 1917, if I remember rightly, but my memory is a little-on account of the con· centration--

Mr. Hawkins: I do not reeall the date of that deed.

:Mr. Fordham: Vhy don't you let your wit- 488
ness complete his answer about bis memory?

Mr. Hawkins: I Msumed he had.

By .Mr. Fordham:

Q. What were you saying?

A. I answered all the questions to the best of my ability.

Q. No, counsel interrupted you intentionally in the middle of a sentencP... —

Mr. Hawkins: That is not true, that I in· terrupted him intentionally.

Mr. Fordham: \Vell, strike out the word in- 489
tentionally. You interrupted him in the mid· dle of the sentence. He can say what he started to say about his memory in connection with this transaction. The witness evidently thinks he does not need to pay any attention to what I say. Will your Honor kindly instruct. the witness to complete his answer.

R:\· the Referee:

Q. Had you completed your answer?

A. Yes, those were the parting words of)fr. Hurehins.

490 By Mr. Hawkins:

Q. As Mr. Fordham seems anxious to have you comple what you said, I heard what you said–

Mr. Fordham: He says he has completed.

A. Yes, in regard to the memory of the exact date, I say that I cannot exactly remember the dates on account of concentration on some other work that I am doing now, but I can easily a.scertain all the dates from doeuments.

Q. Now at the time that you delivered that docu· ment to l\Ir. Hutehins, I refer now to the deed, will you please describe to the Court what there waR
491 upon the property?

A. Upon the property?

Q. Yes, described in the·deed, which property is situated at Rocky Point

Ilr. Fordham: That is objected to on the ground it is incompetent, immaterial and ir· relevant at this point what there wa.s on the property.

The Referee: I will take it.

Mr. Fordham: We except.

The Referee: You mean structures, I sup· pose?

4!l2 Ilr. Hawkins: Yes, absolutely. Improve-- ments, I bad in mind, if there were any build· ings there or structures.

Q. TeJI the C-0urt what there was there.

A. There was a brick building in which was located the power plant--

Q. PlP"ase ilescribe the size of the brick building.

A. The hu i1d ing fo1·ms a square about one bun· drell hy om• h nrnhflrl feet wide an<l it is one floor, i·at h l' high. ,\·ith a 1oof cov(•red with gravel, as they usnally make them. This bui1<ling was divided in·

side in four compartments, two of which were very large, one being the machine 403

Q. How large was that?

A. That was one hundred feet by about thirty-five feet, I should say.

Q. Now ten how big the other compartments were.

A. The other one was about one hundred by thirty-five and then these other two smaller ones where the engines were located on one side and the boilers on the other were about thirty by forty, thirty one way and forty the other.

Q. I think you said the building was one story high?

A. Yes.

Q. It had one floor, did it?

A. One floor, yes.

Q. Further describe the building, if there is any further description, and tell the Court whether there were any brick chimnes, outside chimneys?

Oh yes, right in the center of the building rose the chimney.

Q. How big was the chimney?

A. The chimney was four by four feet; it was calculated to the proper speed to the products of combustion under the boilers. 4.-95

Q. Of what was the chimney composed?

A. Brick.

Q. How high was the building?

A. The building might have been. I think the extent of the wans on one side, the lowest part of the roof might have been something like twenty-eight feet, I would say.

Q. Twenty-eight feet at the corners of the building?

A. Yes.

496 Q. And did it have a gable roof or a lantern roof?

A. Yes, as you call it in English-how is thi1 roof caHed?

Q. I think t is a gable roof.

A. Gable roof. The buildi ng was resting on cemen t foundations and t here were the usual modern conveniences ———

Q. Ten what you mean by t he usual modern conveniences?

A. I mean the channels f or leading off the waste, t.he rain drips and all that, and then at-
497 tached to it was, of course, the water pum p that pl.imped th e water for the building.

1\Ir. Ford ham : I do not wish to interrupt counsel but what possible use can there be in a detailed descri ption of the building on this property?

The Referee: I do not. know at th is time.

Mr. Fordham : Neither do It does not seem to me that we should burden the record indefinitely with these descriptive details.

The Referee : I will let· him dese1ibe them.

l\Ir. Hawkins: It a material pa1t of the de-
498 fense here.

The R eferee : Go ahead. I will take it.

The \Vit ness: I suppose what belongs to the build ings is the boiler plant, wit h two 300-horse power boilers on one ———

Q. That was two 300-horse power?

A. Two 300-horse power boUers, yes, and the pu mps, inject.ors and other accessories, · and then t here weie big water ta n ks that w<>re placed around the chimney so as to u t il ize some of th e waste heat. These tanks had a capacity of abou t 16,000 gallons, if Iam correct.

Q. Of what were the ta.nke composed? 499

A. Of quarter inch thick sheet steel, galvanized.

Q. Those were aU in one compartment, were they?

A. They were around the chimney under the roof, for this purpose the room had an extension upward there. This couJd be shown on a photograph if his Honor wishes to see the photograph.

Q. Just a moment please. Now describe the other three compa11ments of the building.

A. Well, I have described the boiler plant. Now right opposite to the boiler plant lengthwise was a corresponding compartment and therein were located the engines. Of these engines there was one 500
400-horse power Westinghouse reciprocating engine, driving a directly connected dynamo which was speeiaHy made f01· my purposes. Then there was a 35-kilowatt "estinghouse outfit also driving the dynamo, which was for the purpose of lighting and other work, a permanent to the building to furnish an conveniences. There was tben a high pressure comp101" which also formed au essential part of the equipment. And then there was a low pressure compressor or blower. Then there was a high pressure pump and a reciprocating Jow pressure pump. That was all— 501

Q. "rater pumps?

A. Vater pumps, yes. Those were al1 in that compartment, and of course this compa1tment also contained the switches and the switchhoar<l and an that which with the equipment of the plant. Then there was a gaHery on the top on which certain parts were pJaeed and arranged that were needed claily in the operation.

Q. Those were parts of what?

A. Well they were the tools, you know, that were needed in the plant.

502 Q. Please describe another compartment.

A. The compartment that was towards the railroad, that was the machine shop.

Q. \Vhich part of the building was that, the north, south, east or west?

A. I cannot locate it—

The Referee: The north side.

The \Vitness: Towards the road, facing the road. That compartment was one hundred by thirty-five feet with a door in the middle and it contained I think eight lathes.

The Referee: You are speaking now, when
503 you said facing the road, that is on the south side, the travel road or—

The \Vitness: Facing the railroad. It is just close on the railroad track, your Honor, this building. That contained I think eight lathes ranging in swing from eight inches to thirty-two, I believe. Then there was a milling machine and there was a planer, and shaper, n spliner, a vertical machine for splining. Then there were three drills, one very large, another medium and a third quite small one. Then there were four motors which operated the machinery. Also a grinder and an ordinary grind·
504 stone, a forge'---

Q. Blacksmith's forge?

.A. Yes, a blacksmith's forge. Then a special high temperature stove and the blower for the forge. Of course the shop was full of counter shafting and ther were a few special tools which suited certain purposes which I contemplated there. I cannot at preseut recall them exactly, but there were five or six of them.

Q. \Yere those stationary tools or hand tools?

A. No, .some of them were attachments to the

ordinary lathes or milling machines, suitable fm· 505
certain work and others were of course portable.

Q. Now have you described the four compartments of the building?

Xo. Now the compartment opposite, that i facing further a·vay from the railroad, which also was one hundred feet, the whole length of the building, by about thirty-five, there is where the real cxpe11Rhe apparatus was located. That contained also the desks un<l the office accessories. Shall 1 describe now this one?

Q. Yes, descl'ibe any stationary fixtures there were in this other compartment.

506

A. \Vell, machinery a stationary fixture?

Q. Yes we call that a stationary fixture.

A. Right along the back wall that separated this compartment from the of the building there were two special glass cases in which I kept the historical apparatus which was exhibited and de· sr1ibed in my let.tures and scientific articles. Therr were probably at least a thousand bulbs and tubes each of which represented a certain phase of scien· tific development. 'rhen close, beginning with theSl" two gla8s cases, there were five large tanks. Four· of those contained special transformers according to my design, made by the "estinghouse Electri<· 507
Manufacturing Company. These were to transform the energy for the plant. They were about, I should say, seven feet high and about five by five feet each, and were fiHed with special oil which we can transformer oil, to stand an electric tension of 60,000 volts. £hen besides these four tanks there [illegible] her similar tank, [illegible] purpm;es, containing a transformer. Then there were two doors, one door that led to the other com· partment and the other one led the closets, and between those two doors there was a space on which

508 wns placed my electric generating This apparatus I used in my laboratory demonstrations in two laboratories before, and I had also used it in the Colorado experiments where I erected a wire· Jess plant in 1889. That apparatus was precious because 1.t couhl flash a message the Atlantic, and yet it was built in 1894 or 1895. That is n complicated and very expenshre apparatus.

Then beyond the uoor there were again four tan ks, big tanks almost the same as those I described. These four ta n ks were to contain the condensers, what we caH electric condensers, which store the energy and then discharge and make it
509 go around the world. These condensers, some of them, were in an advanced state of construction, two, I think, and the others were not. They were according to a principle of <1isco,ery. Then there was a very e:xpensh-e piece of apparatus that the \Yestinghou8e Company furnished rue ; only two of this kind of apparatus were marle by the \Vesting· house Company, one for me and one themseheR.

was de,eloped together by myself and their neers. That was a steel tank which contained a very elaborate assemblage of coils, an elaborate regulating apparatus, it was intended to give
510 eYery iruaginab]e that I wanted in measuremenb and control of energy. Then on the last side, where I had described the first four tanks there was a special 100-horse· power mot01 and this motor was pped with elaborate cl· vices for rectifying the alternating currents and then sending them into the condensers. On th.I apparatus alone I spent thousands dollars. 100-horse power motor was specially constructed for me \Yestinghouse Company, bnt the othe1 parts were an made by m_\self that took a considerable portion of space there and it was a

wonderful piece of apparatus. I have photographs 511
of these which will make this description very clear.

Then along the center of the room, I had a very precious piece of apparatus. That was a boat which was illustrative of my discovery of teletaumatics; that is a boat which was controlled without wire, which would do anything you wanted, but there was no connection. This boat was exhibited by me on many occasions.

Q. The boat was not stationary, was it?

A It was stationary, yes, on the supports. It was stationary on the supports but as I say that boat was my wireless boat ; that a boat that you rommanded it and it would perform as many evolutions as you wanted, by just commanding it.

Q. Was that about an there was, generally speaking?

A. Oh, no, nowhere near. Then there were on each side long specially made, how do you call them, not desks or shelves, but closets, I might say, which were specially made to contain the apparatus, because I had accumulated for years hundreds of different kinds of appliances which stand for a certain principle, and this apparatus was stored there, and on top these I had again an full of apparatus, each representing a different phase. And then on one side there were the desks and then on the other side there were the drawing implements and tools. And then in the corner, when you looked at the railroad side, on the right side in the corner there was my testing room and that contained-there were two precious instruments among these that Lord Kelvin made especially for me. He was a great friend of mine. A device for measurement invented by him; it is called a breach; and another a voltmeter of his. Both of these things were given to me and prepared for me by his

514 special instructions. There were a lot of other in· strumen ts, voltmeters, wattmetel's, ampere meters; in that small space thflre was a fortune in there.

Mr. Fordham : The last, that there was a f vrtu ne in there, calls f or a concluaion as to the salable value of the stuff and Ithink it should go out.

The Referee : Yes, strike it out.

Q. Ithink you said this building was constructed of brick, did you not?'

A. Yes.

Q. How tl)ick were the walls of it?

515 A. That I cannot tell now exactly, but I should say about twelve inches.

Q. It was more thP.n one brick thick, at any rate?

A. Oh, I should say so. I paid something-

Q. Ipresume thi building had windows in it?

A. Oh yes there were large windows which were dhded into panels.

Q. And what were the window sash made of, metal or wood?

A. "\Vood sashes.

Q. Ishow you a docu ment, Def endant's Exhibit C, and call your attention to the signature on that

516 docu men t, and ask you if that is your signature?

A. Yes sir, that is my signature.

Q. l>o you recognize the instr umen t?

A. Yes sir, that 'as one of the--

Q. That is the deed which you delivered, is it not?

A. Yes.

Q. I call your atten tion to the date of the deed, M arch 30, 1915.

A. 1915?

Q. Yes.

A. \\.en that wms-1915? 517

Q. Yes.

A. I was under the impression it was a little later.

Q. Yell that is the only deed which you delivered in the transnction)fr. Holmes, it not?

A. Hutchins?

Q. Hutchim'.I, yes.

A. So far as I know.

Q. Then would you like to change your testi· mony when you said it was in 1917? 'I'he date of this in March 30, 1915.

A. I have stated that I was not sure about the dates, but I could ascertain it exactly looking at the documents. 51

Q. '\Yell there is the document.

.A. \\'.!'ell it must be so beeause it is there.

Q. It is then instead of 1917?

.A. Yes, but my impression was thRt U1is was an· other att01ney who had it first. nn<l it was made to Mr. Hutchins later.

Q. I do not know what yon mean by sa·ing it was made to Mr. utchins. grantee in the deed is IAt>Rter S. Holmes.

.A. Yes, Lester S. Holmes.

51\t

Ry the Referee:

Q. The transaction you had was with :\Ir. Hut.chins?

A. Yes that is all.

The Referee: I do not think there is an\" dispute a.bout that.

l\Ir. Fordham: There was only one, I understand. The witness does not claim there were two, one in 1915 and another in 1917.

TheYitnes: Xo.

520 By Mr. Hawkins:

Q. No there was only one and Mr. Holmes was the grantee in the deed which you gave to Mr. Hutchins, was he not?

A. Yes, and I reeaH the t.ransaction with M:r. HutLhins.

Q. \Vere there any other structures upon the property aside from the building?

By the Referee:

Q. Did you read that paper at the time you executed it?

521 A. Yes at the request of :\fr. Hutchins.

By Mr. Hawkins:

Q. \Yere there any other structures upon the premises other than that brick factory or laboratory which you have just described?

A. Yes sir, there was the structure which in a certain sense was the most important structure, because the power plant was only an accessory to it That was the tower.

Q. Please describe the tower as to dimensionR and -material and method of construction and kina of construction?

522 :\Ir. Fordham: \Ye renev. our objection, if the Court. please. This is entirely immaterial, irrelevant and incompetent until after they have succeeded in estaulishing thtir contention that the deed is a mortgage.

The Referee: I win take it.

Mr. Fordham: Exception.

A. The tower was 187 feet high from the base to the top. It was built. of special timber and it was built in such a way that ever\' stick could be

taken out at any time and replaced if it was nces· 523
sary. The design of the tower was a mutter of considerable difficulty. It was made in the shape of an octagon and pyramidal form for strength was what I termed my scientific articles d t:erminal.

By the Referee: 2 0 1

Q. There was so1t of a globe at the top?

Yes. That, you1·Honor, was only the carrying out of a discovery I made that amount of tricity within reason could be provided you make it of a certain shape. Electricians even to- day do not app1eciate that yet. But that. construc- tion enahled me to prodnee with this small plant many times the effect that could be produce<l by an ordinary plant a hundred the size. Antl this globe, the framework, was specially shaped, that is the girders had to be bent ln shape and it weighed about fifty-five kms.

By Mr. Hawkins:

Q. Of what was i't constructed?

. A. Of steel, all the girders special1y bent into shape.

Q. '\\l'as the tower that supporte<l it entirely con· structed of wood 01·partly steel·?

A. That part alone on top was of steel. tower was all and course the timberi;; were held together b)·special1y shaped stee] plates.

The Referee: Braces?

The '"itness: Yes, steel plates. I hnd to construct this way for technical reasons.

The Referee; '"'e are not interested in that.

Q. '"'as the tower enclosed or open·!

.A. The tower, at the time of the execu tion of this

524

525

526 deed, was open, but I have photographs to show how it looked exactly and how it would have looked finished.

Q. After you delivered the deed was the tower ever enclosed?

A. No, it was just open.

Q. Now the doe or the terminal at the top, was that enclosed?

A. No sir.

Q. Never enclosed?

A. Never enclosed, no.

Q. Had that structure ever been completed?

A. The structure so far, if I understand the terms right, yes, the structure was all completed but the accessories were not placed on it yet. For instance that globe there was to be covered with specially pressed plates. These plates —

Q. That had not been done, hall it?

A. That had not been done, although I had it all prepared. I had prepared everything, I had designed and prepared everythig, but it was not done.

Q. Was the structure of the tower in any manner connected with the brick building or power plant?

A. The tower was separate.

527 Q. I understand, but was there ans connection between them?

A. There were of course two channels. One was for communicating, for bringing into the tower compressed air and water and such things as I might have needed for operations, and the other one was to bring in the electric mains.

By the Referee:

Q. In order to do that there was, as a matter of fact, was there not, a well-like shaft going down right in the middle of the tower in to the ground some dfty or sixty feet?

A. Yes. You see the underground work is one of 529
the most expensive parts of the tower. In this sys· tern that I have invented it is necessary for the machine to get a grip of the earth, otherwise it cannot Rhake the enrth. It has to have a grip on the eal'th so that the whole of this globe can quivr, and to do that it necessary to carry out a very expensive construction. I had in fact invented special machines. But I want to say this underground work belongs to the tower.

By Mr. Hawkins :

Q. ·Anything that was there, ten us about.

A. There was, as your Honor states, a big shaf t about ten by twelYe feet goes down about one bun· dred and twenty feet und this was first covered with timber and the inside with steel and in the center of this there was a winding stairs going down and in the center of the stairiot there was a big shaf t again througb which the current was to pass, and this haf t wm.i so figured in order to ten exactly where the nodal point is, so that Icould calculate p\ery point of distance. For instance I CQuld cn late exactly the size of the earth or the diameter ()f the ent·th and memm rf it exactly within four feet with that machine.

Q. And that was a necessary appurtenance to 531
your tower.?

A. Absol u te]\' necesNaJ'\: A nd then the real expensive work wm.:; to to1rnect that central part with the earth, and there I had special machi nes rigged up which would push the iron pipeH, one Jen th afte1' another, and I pushed these iron pipE>. Ithink i.;ixteen of them, three hundred feet, and th<n ttie current through these pipes takes hoM of th earth. Xow that was a very experisive part of the work, but it <loes not show on the tower, hut it belongs to the towe1-.

532 By Ir. Fordham :

Q. "a the hole really one hundred and twenty feet deep. <lid you say?

.A. Ye, you see the ground water on that place is about one hundred and twenty feet. We are above the ground water ahout one hundred and twenty feet. In the welJ we struck water at about eighty feet.

lly the Referee :

Q. "nnt yon cn1l the main water table?

..\. Yes the mnin well we struck at eighty feet,
5:33 l.rnt there \\'(hatl to go deeper.

B, l\lr. Haw.kins:

.Q. Tell the Court general1y not in detail, the purpoe of that tow()r and the equipment which you have <lPcrihed conneeted with it?

)Ir. Fordham : How is that material?
The Referee : I will take it.
)Ir. For<lham : "..e except.

..-\. „.<>11. thP pr·irnar· pnrpoe of the tower, your Honor. wai-: to tt.>lephone. to sencl the human voice nnd likene around the globe.

lly the Referee :

Q. Through the iu t1·1unentality of the earth.

.A. Tjll·ough the in trnmentaJity of the earth. That wa my cliicovery that I announred in 1893, anll now all the wireless plants are doing that.. · There is no other system bei ng nsed. .And the idea was to reproduce this apparatus ah<l then connect it jnst with a eentral station and telephone office, so that nm m:1y pkk np your telephone and if you wanted to taJk to a telephone subscriber "in Aus-

tralia you would t->imply call up that plant and the plant would connect immediately with that subscribe1; no matter where ir1 the world, and you could talk to him. And I had contemplated to have pre8 1nessag(•l'\, 8toc:k (p10tations, pictures for the pret;is and thei-;e 1cp1otluctions of signatures, checks nnd evm·ytbing trammiitted from there throughout the world, but— 535

By Mr. Hawkins:

Q. 1lw purpo:-:t- tht>n h1ieH„· was for wireless communication 'to va1-ious parts of the world?

A. Yes ·and the t0we1· was so designed that I could apply to it any amount of power and I WB> plan ning to give a demonstra tion in the transmission of power which I have so perf ected that. power can be transmitted clear across the globe with a loss of not more t.han five per cent, and that plant was to serve as a practical denwnstration. .An<I then I was going to interest people in a lrugpr 1>rojeet and t.he :Xiaga.ra people had given rue 1O,OOO horse power--

Q. \Vhat do.you mean by power. energy·!

A. Yes, power i any amount.

Q. Yere the:re ·an· other structures upon th premises?

A. No, just these two big structures.

Q. I caH you1·attention. lh:. Tesla. to I>efenclanb Exhibit which I characterize as a biH of i.:ale ancl ask you to not.ice the signat.lne there.

A. That i my signature. sir.

Q. Now t.he <late of this d<X!ument i!': the 30th day of liarch, 1915?

A. Yes r.;ir.

Q. that the bilJ of sale that was deHver<-'d the same time t.he deed wa <lelivered '!

A. Yes.

538 Q. I do not wish to repeat this, hut when you stated that that was also on or about the,,early part of 1917 JOU had in mind this document which you deliye:red in March, 1915?

A. Yes, but what stands out in my mind strongest is the construction of the tower, and that is the reason I have that in mind, the construction of the towe:r.

Q. l>o ·ou reca l1 the testimony of Mr. Hutchins, that the \\aJdorf entered possession the property?

.A. Of Hutchins'?

Q. Do ·ou recall the testimony of lir. Hutchins?

539 A. I recall something of that which be t)tated.

Q. And when was that tlone, in 1917, lJefore or subsequent to the destruction of the tower?

A. It was done some time before the actual cle· trut•t.ion of the tower.

Q. Do you recaH when the tower was destroyed'!

A. It was about. in 1917, as near as I can reeall, hut I can ascert.ain--

Q. \Yheu \\as the tower erected?

A. The tower was erecte<l fiom 1901 to 190.

Q. ''hat had you done to it to preserve it?

540 A. I spent considerable money on it. by painting all t.he metal parts over three times, I think, each time a.t a cost of about a thousand dollars.

Q. \Yas there anything done to prese1ve the wooden pmtion of the structure?

A. Oh we ca:refully watchell everything, and—

Q. I know, but. did you apply anything to it?

A. Xo not to _the wood.

Q. Did not paint it?

A. No. not the wood.

Q. Had the wood ht'en treateil in an.Y manner prior ro being pnt in the construct.ion, to presene it? 541

Mr. Fordham: How is this material, your Honor? All this detail of preliminary·work?

The Referee: I want to give counsel much latitude, but I 1rngget to be just a hrief as you can about it.

.Mr. Hawkins: Yes.)J·idea is this, if the wood had been creosoted or treat] in any way to presene it that was part of its value.

·)fr. Fordham: Xot unl<.>ss it <'Olllld haYe bPen so1<1 for morp m01w·. It is ahsolutPl ·imma· terial. 542

The UefPrt•e: I wi11 lN him stah• if it had been treated.

A. o. but it was the fint=st timhe1·.

Q. '"hat was tlw timher?

A. Pine.

Q. \Y'1at kin<l of i>itw?

A. I rannot te11 on. th<'l'P m·P so man·kinds of pine in ..-\.merira.

ThP Refe1pe: I think it was n>llow pine.

The \\"itncss: I could asce1tain exactly.

The Refr1•(•p: Timhet of that sort. generally are. 543

Q. Xow 1wior to the time wlu-·n the tower was taken down <licl on have a conversation with)Jr. Hutehins concerning that"?

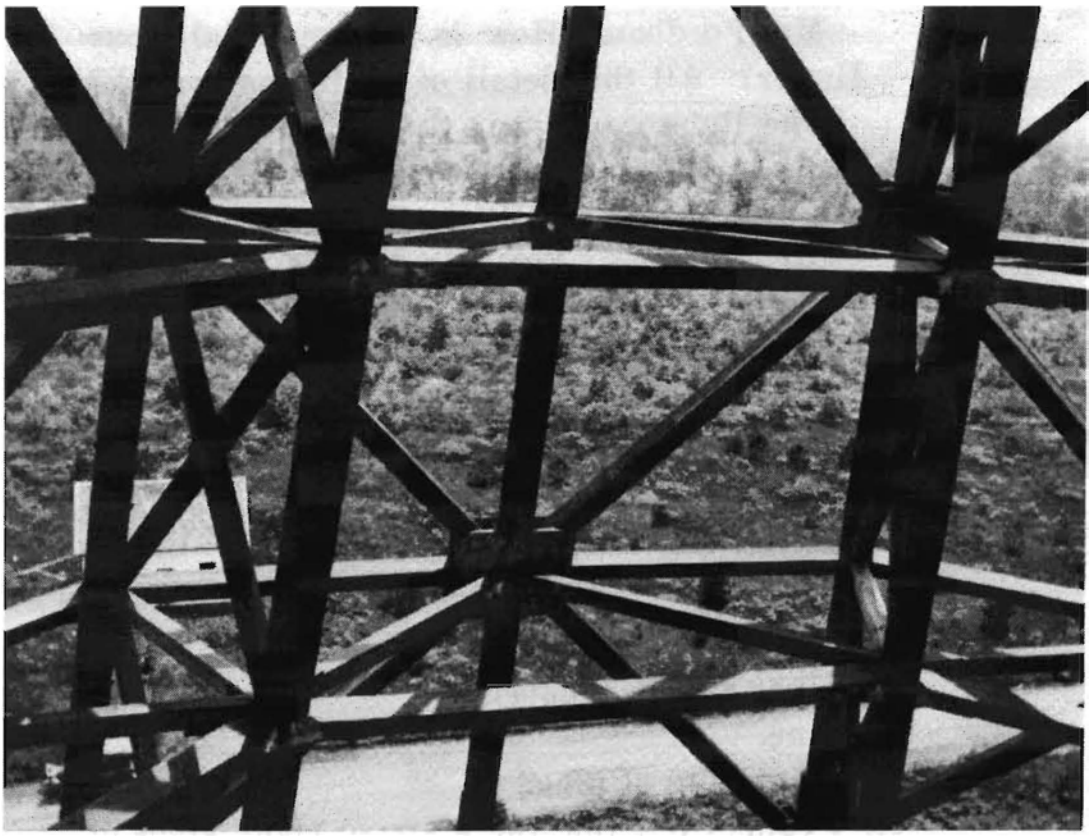
A. Concerning the tower?

Q. f'oncPrniug th <lestrm•tion of the tower'!

A. Conrel'ning the dcst1·nrtion of the tower?

,Q. Yes.

'.-\; Xo, t·t-rta i11l · not. IIP aYP me a friendly as· sura nee that not hi11;,! wonl1l ht.) tlone in an nn· frit)ndly way.



Lillian Mcchesney

Figure A2-l
Construction detail of Wardenclyffe plant tower.

Note : This photograph was not an exhibit for the case.

The Referee: OverrnJed.

l\lr. Hawkim•: Exrflption.

.Mr. *Fe*.dham: Yon may proeed, ll:r. Bingham.

A. \\'hat is thf.l queHtion nf,?nin, pJease?

Th.:• 1. 1wstion wa reiul aR follows: Have you had an· experitinc• •Iid if so what. in the purchase and :-:ale of machinery·!

.A. \\'ell. I hnn not had any in a great many yf•ar 110, r. eitht>r direct pnrrha!'ie or selling.

<2. \\'e11. han" on bad any experience so that you art' tprn litit•d to s1wnk afii to the ,aine of machiner·!

A. Only purtinlly, I think. -;o

<i. I cuH _rour attention to the testimony of the cltifrnclatnt TP!otlu. whi<'h appears on pageR 88 to lfil of the reeord here in«:Jmdve, at the hearing on Jan- unry 19:?2. and ask you if yon have read that ttiNtimony?

A. YeR, sir, I reatl that whole paragr£\ph th:rongh.

(J. arquainted with the refel'red to in the l'omplnh•t in this action and the deed wh ieh in e\idence uf the prPmises of the defen<lant Tetdu"!

lfr. HawkinR: That is objected to as immn· tt>rial. h·reh\ant antl incompetent. ';o5

The Heft>ree. Ove1·rnled.

lh·. Hawkh :Jx('eption.

.:\• \'t'N,)'.

Q. \\•}wn did on fil'Nt \'iSit those pn.aTie.ises?

1:. Hnwkins: nme objection.

The Heferee: umc-- ruling.

lh-. HawkinN: Ex('t•ption.

.-\. \\'t>ll. it h• ha1d ftfr me to statP jnst when I first——

706 Q. (lnt(lrrupting.) \\'ell, as near as you re:aH'!
A. I wou1<l say about 19l:J.
Q. \\'bat was the oc<'aRion '>f your visit then?

lfr. Hawkins: ame objet·tion.
The .kferte: ame rnHng.
Mr. Hawkini;: Exception.

Mr. Boltlt held a mortgage on thiR propert)· nml he Rent 1.1e down there to eheek up and go ov1· the (•ondition of it and see what condition it was in.
Q. Yes; and how many times were you ther<.?

Mr. Huwkins: 8ame ohjPr tion.
The Referee: me ruJing.
707 Mr. Hawkins: Exception.

A. Oh, up ·1nti1 the time that I received that notice frm11 llr. Hukhins, I presume twenty time8.
Q. The notice to whkh '·ou l'efer i:-; the lettr of J uJy :!O. 1915, of whi t·h I how you a copy!

llr. Hawkin: mue objection.
The Reff:'ree: anw ruling.
.llr. Huwkim;: Exe•..ption.

" .;'t.. .?es, sn-.
\. You ha\en't the original letter in your possession, haYe you?
708 A. :Xo, sir; I have not.
Q. This is a corrert copy?
A. Yes, sir.

The Referee: I see that, :Ir. Fordham? I do not just bear it in mind.

Ir. Fordham: Yes. I offer this letter in t>vi<lence.

lll·. Ha w k i n : Ohjt><:tPd t o as incom peten t h·rt•Jpra n t •UHl i m n m t <>l'in J and t'u r1he1· on the· gl'o n n d that it is n s(•lf-er,·i n g <lt>C'huat ion : and I f u rtlwr objt•et to ht•c·u n P it is not t he 01·igin al <locmnen t.

The Referee: I will take it. 709

Mr. Hawkins: Exception.

I Let marked Plaintiffs' E"\hibit o. 8.-1

..l. 1\11:. Bingham, between the lime you first went t to the properfy in 1913 and July 20, UH:>. i- 0 fat· u1-1 on recaH, how many ,h:its did ou mak<·f O the JH'Opl l'ty '!

l\Ir. Hawkim:: am.- ohjedion.

The Ueferee: 8ame ruling.

.M1·. Hawkins: Exleption.

. I eonl<l not Ha\'. I used to go there on au arN·a e of onct> or twke a month.

(l. that pcrio<l '!

.\. Hmi that perio<l.

(l. 'rill you pJt>u e tell the Coul't what you found on t jwo1>e1t.·thH'ing those ,isits?

:\Ir.' Hawkin : Objedetl to as incompeten t. immatt>rinl mu1 h-re]eYa n t an<l certainly can huve no bearing upon the question as to whether these instruments were deliyered as ab:-;oJ u tt- (•on,eyance:-: or as securit,:.

Tl!e Referee: Overruled.

llr. HuwkinH: Exeeption.

A. The first time I went down there I fouml thP 711 windows—well, I should say there was half a <lozen of them tha.t were '\\ide open. and in the big room such as was used for experimenting and thingH of that kind there wus probably a dozt•n or fifteen desks in there and a great many wa.rtlrobes, that is closets aml thing of that. kind, and among \\as you wou1d call a mode] submarine. \YPIJ. this phwe hall practica lly been wrecked.

Hawkins: I mk that be stricken out

Ihe Ueferee: Yes. strike out the "practically l;een wrt"Cked. • Just describe its condition.

712 A. There had been a desk that the drn.wers had been opened pulled out and thrown .on the floor and a11 t.he tops of the <leHks-they wel't. roll-tops deks-tht>:' hod Leen rippeel otf nntl thrown 011 tilfl Jloor, the dooni were ripped off t.h<> closet und the hooks and .- utl' that wn.s in there, I would a)·thPre wuH four trurk Jouds of t.hat thrown nJI oYer thi hig room, and I came back and macle a report to)Ir. Boldt. of the condition we found things.

)fr. HawkinR : lask that he stricken out.

The Ref(•ree: No, the fact t.hnt he made *a* I'<"" port., Jet it stand.

;1a Ir. Hn.wkinR: Exception.

.\. (<'outittniug.) And in t.wo or th da,n1 I took n couple of carpenters and we went. 'lown there mul . nailed up th':windows.

:\Ir. Hawkins: I ask that be Htrieken out..

Q. (Interru pting.) \Ycn. Mr. Bingha m, bea r i u min<l the question I was nkini,? ou; thp tiri-;t. t.inw on went there in 1913 ou did not. go 'lowu and nail up wirnlows, 'lid you?

A. I did in two or three dayR.

Ir. Hawkins: IR t.},e Inst pal't. of that. nnswt·r· stricken out on IDJ motion "!

The Referee: Yes.

..:\. (<"ontinninJ?.) .-\nd put. in om<• lii:ht piel"8 of boa rd, sueh as "Com po" bouJ'd \\ h<•r(• tht> lass wus J.?OlH out., so ns to kind of protect. tlie plnce, ai-; at hiis sugi,?estjou h<> thought I better {lo t.hat.

:\(1-. Hawkins: I uk that ht• stri('ken out.

The R feree: trike ont the· 1nNt. part.

:\Ir. Hawkins: \nd alo that. tht·- naikd up IJoar<ls.

· The Referee: :o. I will Jet that :-;taml.

lfr. Hawkins: Exception.

Q. Proceed. \Yhat did ·on then dbicover? 715

A. .About two \\'(ks JalPr Iwent down again aml I fouml t.he t.hinJ?i-; a.B rip]x•d 01wn a nin nnd Uw doors opt>n. r: nd I came hack and locke«l t.ht>m up the lJtl'Ht I couhl aucl went mpr to sPe the f.ltntion agent. n ncl the,\·<li d n't k11ow an ·thing about what ha<l happend or an ·thing of that. kin«l.

:Mr. Hawkins: I aHk that. he t.rlcken out

Tht" Referee: Oranted.

A. (<'onfinuinA'.) .An<l in tlw nwantime tht:>J't• had ht"\•r some of these dPsks that wa.1.1 in thPre that was com.'h't(l>l :smafih(:l(l up an<l takPn awa-. I should !':fl" thPre wa."l nhont. half of Uwm A'One. jJ ti

Mr. Hawkins: I ask that be ·dril'li:en out.

The Referee: Denied.

lrr. Hawkins: Except.ion.

(ConUnuinA'.) And I went down, I would not su.y just. how soon aga in, but proba bl· wi thin n mon th beea use I had to f?O therP that. of ten, lh. Bo1'lr insish'd on my goiu:,r (lown th<"•tc nn(l ketlpinJ,? a cheek on it..

?tfr. Hawkins; I :l'lk t.hat. be stricken out

1he Referee: Strike that out.

Q. You may Kft)' what on cli<l? 717

„\. I continnaH)·kept oing down thel'e up until the time I rt>eeinc1 this notire from 1\Ir. Hutchins. rp until that

The Rrferep 1interrupting): Tliat the ex· hihit that has just h"t>u offf:'1'<•cl

Ir. Fordham: Ye, Exhibit 8, dateu July 20,]91

Q. P1{}(«"f..lf1.

.A. rp until that time the· had practka11,y trippe<l the pJat'e of PYer·thing: the,\·had stolen ott' all the ruilings antl everything that might per·

718 tain to brass of any description, even the boiler feed pumps the.v had taken the tops otf ad taken the valn•s and valve 8eats out; all the toiletM, thy bad taken otf the toiletR nnd taken aII the lead pipe back of the ti>ilet and everything that ronld he po iuly sol<l that could be drawn in any kind of a wagon Jrnd been taken awa)·; I suppose for juuk, thut is the only thing tht.·y <.oul<l possibly use it fol'.

\Ir. Hawkin : I uk that he stricken out.

The Referee: The supposition strike out.

A. (ContinninJ!.) 1he lJoilen; were thel'e, simply the ht:>aders and tubes; ever,vthing that pe1taiued to
7W them wert.) •"one' tht.•\·hml sto1en an<l dra•rc"e<.l awa\', the tlynamos were isti1J the1c, the main part.

lL-. Hawkins: I a8k the patt of the unswe1· in effect had been stolen be stricken out.

TileRefereP: Yes, the charadel'izutiou 8toJen we will strike out. The fact that they were uot there we will Jet stand.

Q. Proceed.

.A. \\'<-•JI, that had been tuken away.

The Referee :·\Yel1, the)· were gone'!

The "itness: Tht.. ·were not taken for 01·11a· ments; the·were gone.

7'20 The Referee: Yes.

1he "ituei-;N : The tniue the muin part of the rn iues were theJ'(\ that is the foundation uul the th·wheeh.;. hl't.·nnse thev could not take them away; and some of the hi part of the maehiut.>ry. the tlitfe1t.>nt 1nthe nncl milJing mu·hinrs and tht• main dd11-prc ; ull smaJl JatJu..:-; ;tncl motor and en•1;vthinJ! ot' that kirnl w 1e 1!OIH'. '"hat hall hec'<ymc of them I coul<l not a·.hut I wouM a.Y the)·were stolen. .Ant.1 when I ot thi notfre from Ir. Hutchins I

went clown then o.nd got the notice the same as today I made the signM up and went down to· morrow and put UJ> the sigm, and in about a or dayR from then Itook a couple of tlucks a down there and brought the nut.chi ner· away 721

l1 Just what di<l you hring away'!

A. I brought awa·a large drill-pre:.;, milHng machine, J>1aner and two lathes.

you know the value of thos.;e articles which \'ou brought away?

.\. I do not know exadh· the value of those things. I have everything yet at the Valdorf. with the exception of the milling machine.

Q. \\'ell, wa,.; the value a few hunclretl dollars or wns ;t a great many thons'\nd?

llr. ins: That is objected to on the ground the witneMs is uot qualified.

The Referee: Objection sustained.

Mt·. Fo1<1ham: \\e except.

Q. Yon have the thingl'i now. with the exception of the miHing machine?

I havt\ „ith tht> exception of the miHing machine, yes. sir.

Q. Do you know what became of that?

llr. Hawkins: That is objected to as immaterial.

The Referee: O\erruled.

.h·. Hawkins: ExcPption.

'l'hat waN Rold; I don t know now who it WUl!t

Q. Yon don't know?

hut I €Ouh1 find out. I conJd look the book n p mul thul out who did huy it, but I don•t remem ber.

724 Q. Do you know what was received for it?

A. No, I do not.

Q. I show you Defendants' Exhibit A, a rrtain hill nf saJe, and J your attention to the schedules ';etting forth t.he „alious items purporting to havt> been t·o n·eetl hy that bill of sale, and aHk you to 1ook on•1·those and to tell the Court what, if any of t were on the property on July 20. I:>?

llr. Ha\\·kint;:'fhat is objected to as incom· pt•H•ut, irrelevant antl immaterial.

The :Overruled.

l\Jr. Hawkins: Exception.

725

A. You want me to start at the top of it?

(l. Yes, and right through it. if you please?

.A. :Xo. 1 \\"estinghouse Compound Engine wa there.

Q. \\'hat was i condition? Deseribe its con dition.

lr. Hawkins: That objected to as imma· teriaL

The Referee: I will take it.

lll'. :Exception.

A. The compound engine was there without any 72H tdmming, as I haYe stated before, everything wa,.. 8trippetl.

Q. Yes, bu --—

A. Unterrupting.) There wasn't anything left .on it.

Q. Yei;;, uut re11eat your statement as it appUett: to eath of those items?

A. Both numbers, 1, the \\'estinghouse ..Alterna· ting an<l the \Ye1dingbouse Compound lngine were there. that is the hod of the engine; and the d ht-rt <·on neett-cl douhle currt>nt generator waf'I there, the 25 .; the horRepower motor, and

Xo. 1 item here. 1623, was not there ; the tram· 727
forme were not tht.are ; the tank was not there ; the t11wk was not there; Fairbanks Scale was not thl'J'I' ; Laic11aw-Dunn-Om·don Pump wa there, but the ·.1 MP was out of it ; \Vtistinghonse Electric)rotm· was uot thet·e ; milJing machine was not tht>1e ; lathe Xo. 1 was not there, there was no tools of auy clt· ('ript ion lef t thf'rP ; th work benchei;; wt.·1e still the1e, hut nothing on them ; \'ises wert• gone ; \\'eHtinghoui-;e Type C 2-horsepower motor was gone ; \\'e$tinghouse T·pe C inducting moto1· was gone; \\'estinghoue Tpe C 5-ho1"8epower motor was gone; \\'estjnhouf!:e btor about one- 72 .
'luarter horsepower was gone ; the t.h lat.hes that he mentiom; here, only two co1l<l have n there at most at that. time, the two that Iha ve ; I<lon't know the names of them.

Mr. Hawkinis : I ak that IJe stricken out. 011J,r two cou1cl have l>t'en there.

'l'hP Referee : \Veil, ·ou onl.Y got two, is that what JOU mean "!

Th<• \\'itness : Yeli, sh.

tl. How m:u1y we1e there?

A. I clon't know how many there was, quite a oo<l manJ tlw tht time I Jooked in there, but I 7W know at the time wt' took posession from the timP I went th<11e, the·we1e alJ <'arte<l away, some tru<'k <·ame in the1<1 fol' ome plaee al'ound the1e one <la· ancl la ke(l the agP.nt there, and he said Ir. Tes1n to1c1 thil-1 fplJow-ht-> 1i1111 a garage O\'t'l' there- that he t'OnJd han• tht•m and he took a lot of stuff' of that class.

Q. \\'h<'n was that?

\. I think that was along nhont u ."ear before J ot that notice.

(. Pl'0t·et1. pleaHt>, with tJw other items.

730 .A. Planer ma<le by the Headley people, I eee no planer there; planer made by Pedrick, no planers at all ; no drill-press; that was gone; one large drill-presR that I have ; 36 lockers, they were an ripped to piece8 ; one testing fan motor-

...r. Hawkins (interrupting) : I ask that be Htrieken out.

The Referee: Denied.

•h: Hawkins: Exeeption.

..\. (Continuing.) That was gone; telephone and be1J "ire gone; cp1antit.·of Jead cable gone; 4 radi·atorR. t.hey were gone; drilJs, bits, reamers, taps and aH tools for miUing machines and lathes at p1-esen t U me in storeroom 1oeated inside workshop, that wa an gone; oil tanks, the· were ripped n p and they viden tly had torn t.hem apart. because they wanU:ou to get something inside of them, Pi t.her 1ead or coppt'r, I <1on't know which.

lh: Hawkins : That objected *to.*

The Referee : trike it out.

Q. ..eave ont ·om·conclusions about why they tlid it; what was the condition of them?

.A. J u t. Pipped to pieces; all the meters and sta1-ting hoxeR and switches had all been stripped off, onJ„· the bare slates left there; 2 Babcock & \\'ikox Boilel's, everything hut the shell and tt1bes were gone, antl feed pumps. just the houRing was Jeft; one hand——

The Ueferee (interrnpU) : "hat tlo you mean b„v that?

The "it.ness :Yell, it is mnrle out of cast iron. an rl the insides a:re brass, t.hat is t.he valve seats a.nil vnht•s, the· are aJwayH brasl'. 1hey had been taken on t. One hand black-smith's f0ge WM gone ; toilets. urinals. wash basins, an ripped to pieces ; 7 rheostats, desks,

sales, 3 meters, all th06e things were gone; one 733
set of st.orage batteries. tanks, submarine boat, \Vestinghouse Motor 28292, \Yestinghouse Iotor Type C 5-horsepower Xo. 62320, "estinghouse llotor ype 5-horst>power o. 22070; 4 high-t:ension transformers in tanks and switchboardf-1, wi ring drums drafting boards and tools all gone.. Chairs. there was two or three old chairs left there, was an; clocks, no clocks; ra<liators no ra<liators at. all.

Q. \\'hat did on find the condition of the tower to be?

. Hawkins: I a. k that the eutire testimony of this witness concerning the items mentioned in the Defendant.:;;' Exhibit .A, I think it. was, he sbicken from t.he record as incompetent, irrelevant and immaterial. e8pecial1· because that testimony bears no weight. upon the question as to whet.he1· that bill of sale was delh-erd as a security or as an aboJnte conveyance.

The Referee: Denied:

lfr. Hawkins: Exception.

M1l"ordham: Read the last. t]uestion.

The queRtion was read the stenographer.

llr. Hawkins: That is objected to as incom· petent, irreleYant. and immaterial. 735

The Referee: I will]et him describe what he fonnll. Overruled.

\Jr. H;:1wldm: F.xrPption.

A. The towei·was badl·rotted, the main supports g-oing up where the stai the grat big" timbers were rot.ted out., the·were half gone and it i!'i a wonder they could Rtand up.

llr. Hawkins: I move to strike t.hat out

The Referee: Yes, the wonder they ever stood, strike that out.

736 Mr. Hawkins: Yes.

Th \Vit.ness: The stairs leading up to the top of thP haH were half rotted away so that we cou1•1 not get. np to the hall. I wanted to !.'lee what the hall was made out of an<l I took a man ilow n t ht-1{•, a riggt"r, and he went up about two-thirtls of thf' wa·. (·Umhing up ov(:lr it, and he was so afrai<l he c·amP haek.

.lfr. Hawkins: I ask that ht> s:trfrkt-n out.

'Iht- R f Pl'Pt' : That ht> wal'4 afraid and c•ame hack. ·es. I wil1 lt-t tlw *fa.<'t* sta ml t11at he d id not go on up.

:\fr. Hawk ins: I a!-!k tlw oth(•1· ht• strirken out. that the ri gtir was Rent up thC'l't".

The Referee: Denied.

lb. Hawkins: Exception. .\ n d I als:> 1110\ e that it he strirkPn out 011 tlw grou rnl that it ht in no sense n-huttaL

The Referee:)lotion denit'"l.

:\Ir. HawkinM: ExcepUon.

Q. Yon ma·tPJl what the ril?ger «lid?

A. Th is hig ba ll on top of t he tower, yon could tivt tell .w h at it was ma•Je out of. wht>t h er it was brass or stet-1, as tlw muts· of t.l1e w h·t>s w here it had been g-1ounrle<1_ha<1 1·uste-d ont. and b1own away, and there was a thousa nd and one little wires stick- i ng out in enry fJi rect ion, so you rou1d not see what. it was made up of.

ThP Referer•: You ronld not up·!

The \Yit m· : You coul<l not get. np. You f'ouM get np so 'on <'<>nld RP<1 t he tihrf>S of every. thin n p there.)On conl•l S<"e H plain «>nongh. hnt the towt·1· waR 1·ottefl in no end of pla<"es it had nen)r lwen ta ken <·are of, not hi ng ha'1 Mer hetin done tot:

lfr. Hawkins: J IUlk that. that. he stricken out.

The Referee: Yes. granh'd as to tht' last part. 739

:l[r. Forflham: '"hat is grantecl'!

The Referf>e: He said nothin ha<l heen done to it.

l1r. Hawkins: .\ncl I ask also that it be stricken out t.hat. the tower ha<lnot been taken care of.

The. Ht-fere(): Oranted. l>t-srrihe its condition.

Q. Yei;i, '.on ma·tell thP <'OJHlition of the tower, .Mr. Bin ham. '"as tht> <·mulition seeure or in·se('u re?

..\. Insc<·nre. Tht>J·c·wa none of the woodwork that hail ·Yet· hn painh•cl. all that held it together ;40 was the big steel plate on thP sidei;; of it.

Q. .As Innderstornl, yon sa':·tlw wo:)(lwork was ha1lly rotted out?

.\. Rotted awa-, es, sir.

Q. So that the tower in that condition wa a menace> to anyhOfl·pa ing nf'ar it, in Yiew of its inseru l'ity?

)fr. Hawkimc Tllat is ohjt-'{'ted to as ca11ing for a ront'iusion nn<l a spen1lation.

ThP Refel'ee: I think so.

)fr. Fordham: Not a specnlation. The man is nn t)xpp1·t in his own line.

ThP Rt'ferec>: Ohjt><·t-ion sustained.

)[r. Hawkins: I ask that it h strfrken out.

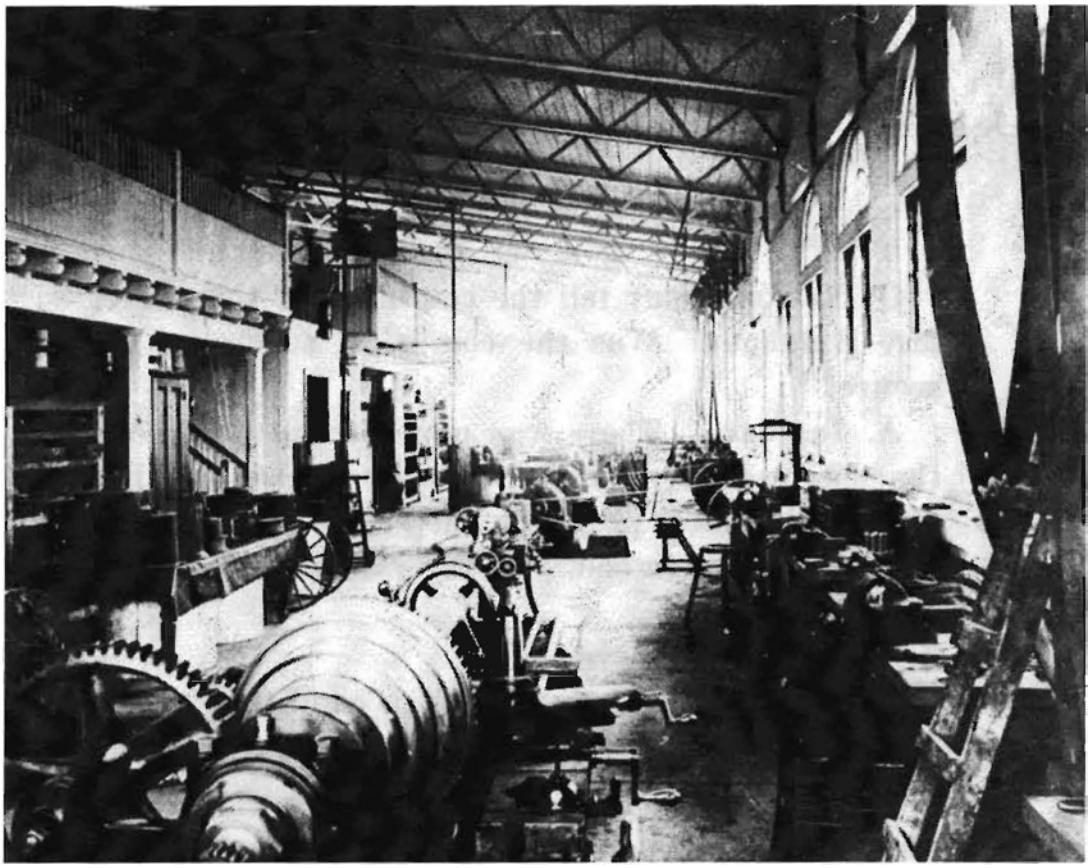
Tht> RefereP: trickt>n out.

Q. Ttll the rom1 from :our own knowlerlge of trnctnl'al materials, as an <>ngin<>Pr, wh thp1·the towe1· was safe or un&ifP, as ·on fouml it at that time?

)Ir. Hawkins: That is ol>jeeted to.

.\. Ahsolutely unsafe.

The Refert:ie: Ha\P ·ou suffir·iently qualified him in that. rf>rn1;l to tPstif_v at tllis time?



William Kolb

Figure A2-2
Workshop on north side of Wardenclyffe plant building.

Note: This photograph was not an exhibit for the case.

Q. (lnt.erl"Upting.). Yes or no. 805

Mr. Fordha m : Just a momen t. If the Ciourt please, I object *to* this on the ground that no foundation hft.8 been laid *to* qualif y this witness.

The Referee : I wiH Jet him answer that question. Overruled.

Mr. Fordham : Exception.

A. Yes.

Q. At that time, t:o what use could the pn>perty be put?

Mr. Fordham : That is objected to, if the Court ples.se, on the ground that it calls for the conclusion of an expert and that there has no foundation been laid to qualify llr. Tesla as an expert on real property ndue. 806

llr. Hawkins : :So, I have not. aske1l him the valne in that respect.

· The Referee : I wiH take it..

Mr. Fordham : \Ve except..

(The question wa111 read.)

A. The property was expressly built. for thP t.ranRmission of wireleMs impulseR.

'fhe Referee : I clo not think on umlerstand the •1uestion. do yon, Jloc.-to1? The question WiiH to what u8e it waf« fitted,H that right? 07

lh:. Hawkim.;:

llr. Fmdham : I mov to :-4tl'ikt" out this answei".

ThP Referee : Ye1.-1. stl'ike it out.

llr. Hawkins : I wiH formally ex<'ept.

The RPfflret> : I thought he mbmnrlerstood it.

..\. 1he nmii it waR built-

(l. 1 lntt>1·1upti ng. t :Xo. Te11 to whnt use it c·ould lit' put at the th1w that dPed Wft.8 made?

808 A. At time that deed was it could have been used as a receiving wireless station.

The Referee: Yes.

The Witness: Putting me for atlting, it could uhm hare hl·n nuue use of aH a tiansmitting gtatiou, hut not to extt:nt that it could in the fuHy <leveloped pJant.

Q. But aHbouh it . waM not fully developed or J>t"l'nuu1eu t1.v e•1nippec1, it could at that time have l>efln nsed &R a tran!ilmitting station"!

..\.. Yes, sir.

Q. And us a ren4ving station r

809 .A. As a receh-ing .itation.

Q. Ami thereM now a large Htation of a similar khul ,ery near)'<hn premitwH at Hrn·ky Point, tht>1-e not?

lh·. l•ordham: That i ohje<'ted to, if the (,01nt pleastA, aR immaterial and irrelevant.

The Refe : Overiuletl.

Mr. Pordhum: ·J.xception.

•\. YeN, Mh\ there h, hnt it iN of incomparably HU UtlIt'l·j)OWfll" than mint-.

Q. Are you familiar with the uipment an..I sfrm·tm<Pt!I for the purpose of the receiving and
810 ham.m1ission of wireleMI!' Dlt'HHagf:ls?

A. Yes, I am.

(. '"hut haM het-n 'om· experit-tu·e in that line, Dm·tor?

.A. I u-m-ked for J"t\' \'PIll'N on tht> art and Junp given aJJ of the fnndttUH'ntal JWilldJ>les to it; uiul f1u ri ng a t lea t twPn ty Yal'K I have been making appauatuM of tha t kin<l and f'X perimenting with it.

Q. Huvt> nn1 been making aparntnl'l of that kin'l fm·sale?

..\. Ye1o1 and no. l did attemJlt to start mantt·

faC'turing sevttral times, but could not ftnd wtflcient encou ragement, because at the time that I started the art was not sufficiently developed for the gen· era) 1mblic to hale faith in it. I was ahead of the time, and that waR the onJ · reason why it was im· prartknbJe to start manufacturing. 811

Q. Have you invented aml put on the market ele••·tri,al ap1>aratus for nee in ronnf'f'tion with "irP.· leRRopeiations?

..\. Yes, sir.

Q. *At* the time the clef'd \\'a'" gh·eu, what was the vnlne of tht> premises at Rork·Point in their eon· tlition at that time for the pnrpoe wireless re· ceh'ing rnul trammitting uses? 812

lh·. l•'ordham : I objet·t to that, if the Court l>Jea8e, on b?tou nd there is no proper foun- dation Iaitl to qualif ·this witness to speak of the commercial or financial Yalue of the prop· at that time or at nuy other time. As to the st·ientific \•aJue or possihiHties of it, he already been inte1·10J.u1ted. And it objected to, if that is the point of the question that obje('kd to on the grotuul it is net>iHess 1epeti· tion.

Mr. HawkinH : I 8Uhmit. if ,vour Honor please, the witne8.i; iw (1nalitied to answer this 2'peeifir c1uestion, and hns i-ihown it by hhi thnon;r hel'e.

The RPfPret' : I 4lon•t mulrNtand. lh·. Haw· kin . .Are you m<1king him to h.-i-dify as to tht> va1ue of the land?

lfJ·. Hawkins : :Xo, ; I am mking him to te1dify as to the \"ulue of the f:lntire prPmiseN, iudu11ing the land ancl tht-i hniJ«linA'R, hut pa1· tknJarJy the .buildings.

!\Jr. Pordham : '"eH, comme1•t•iaH:r and

81-i financially what is their value? And he knows nothing about it.

The Referee: I will overrule your objection and take it.

Mr. J4'ord ham: "ell, we except, if the Court please. I particularly caJI your Honor's attention to the fact that the testimony shows that the witness could not have known, because he had not been there for months before.

The Referee: IwilJ take it for what it is worth.

Mr. Fordham: Ye except.

· H5 The Refel'ee: .Ans\\•er the <1uestion. Mr. Tesla, if you can.

A. At the time the tleetl waM given a fair estimate of the value of the propett would have been something like '350,000, becauHe the incomR-- —

Q. Never mind all that, yon have answered my question.

The Referee: You mean by that, t.aking in the land and your scientific development on it?

The Witness: No estimate it on the basis of earning power as a transmitting and receiving plant for the purpose for which it was made.

The Referee: Had it ever earned anything at that time!

The Witness: Yes, but becauselwas carrying on the pJan which would ultimately have yielded t25,000 a day income, hut at that time- –

Q. (Interrupting.) Never mintl, don't go on with that.

l\Ir. Ford ham I move to strike out the answer on the ground that the witness' explanation hows he is not qualified to make an

estimate, and that hie estimate as made is not based on any sound financial or legal or other ground. 817

The Referee: I am inclined to agree with you, but-I don't see, Mr. Hawkins, that that is admissible.

Mr. Hawkins: I submit that that ls admis· sible. The man shows he has worked in that line of business for many years and knows the value of that equipment for that purpose.

The Referee: If you want it to stand, J will let it stand.

Mr. Hawkins: Yes, sir I do.

Mr. Fordham: We except. 818

The Referee: The objection is overruled.

Mr. Fordham: Our motion is denied to strike out?

The Referee: Yes, motion denied.

Mr. Fordham: We except.

Q. Did that condition which you have just described, and those values, obtain at the time the bill of sale was given?

A. Oh, at the time the bill of sale was given the property was very much more v81uable, it was worth-it could have earned at least five times as much as the Tuckerton plant on Long Island, and they had an income of something like forty thousand or fifty thousand dollars a year. 819

The Referee: Vell, it could have earned if it had been completed. Now, was it in that position to earn?

The Witness: I must explain it. If it had been completed, it could have earned f25.000 a day, but in that time in the state it was, if it had not been for my pushing the plant to completion, it could have earned something like

820 one hundred thousand or one hundred and twenty-five thousand dollars a year.

The Referee: What was it earning at that time!

Th \Vitness: It wat1 earning nothing.

Mr. Fordham: If the Court please, I move to shike out this last answer on the ground that it is contradictorv to former testimony, because it appears that the deed and bill of sale were both given the same day, and it is im· possible there could have been a wide differ· ence in value between the few minutes when the deed was given and the bill of sale was

821 given.

The Referee: I will let it stand.

The itness: Maylexplain?

Q. Yes, explain.

A. Pardon me then, I did not understand the question. Vhen I \\"as asked when the deed was given, I bud in mind when I first placed the property with Mr. Boldt, that was the valuation at that time.

Q. That was the first mortgage, wasn't it?

A. Oh, at the time the deed was given, now I understand better. Yes, that was 1915, the pr6p·

822 ertv was worth verv much more because the art had been developed, the power stations had multiplied, the receivers had multiplied and where I would have had a hundred customers, then I would have thousands.

Q. Doctor, when you speak of the v&J.ur; at the time the bill of sale was given, do you mean the value at the time you first made a mortgage to Mr. Boldt?

A. :.So. sir. I mean at the time that the deed

was given, the property was worth more than '350,000. 823

Q. Yes, but what did you have in mind as the value when you spoke of the value as of the time the bill of sale was given?

A. I had in mind the value at the time I gave the mortgage to Mr. Boldt.

Q. Yes, the first mortgage?

A. Yes, the first mortgage.

Q. Upon the property to Mr. .Holdt?

A. Yes, sir.

Q. Doctor, the property was developed for the purpose and use of a commercial wireless station, was it not? 82-1

A. Yes, sir.

Q. And so far as you know, it had no particlar value for any other purpose, did it?

.A. Yee1, it might have been used for an electrical pcwe1-plant for dishibu tion.

Q. Yes.

A. In fact, the proposition was made to me at one time for that purpose.

Q. But looking at the situation from the local real estate market, it had no particular market ,aJue for any other purpose than that of wireless telegraphy, did it? 825

.\. It might have as a fac-tory building.

Q. llnt yon are predicating your statement of ,a1ues upon its uses for the purposes of wireless telegraphy, are you not?

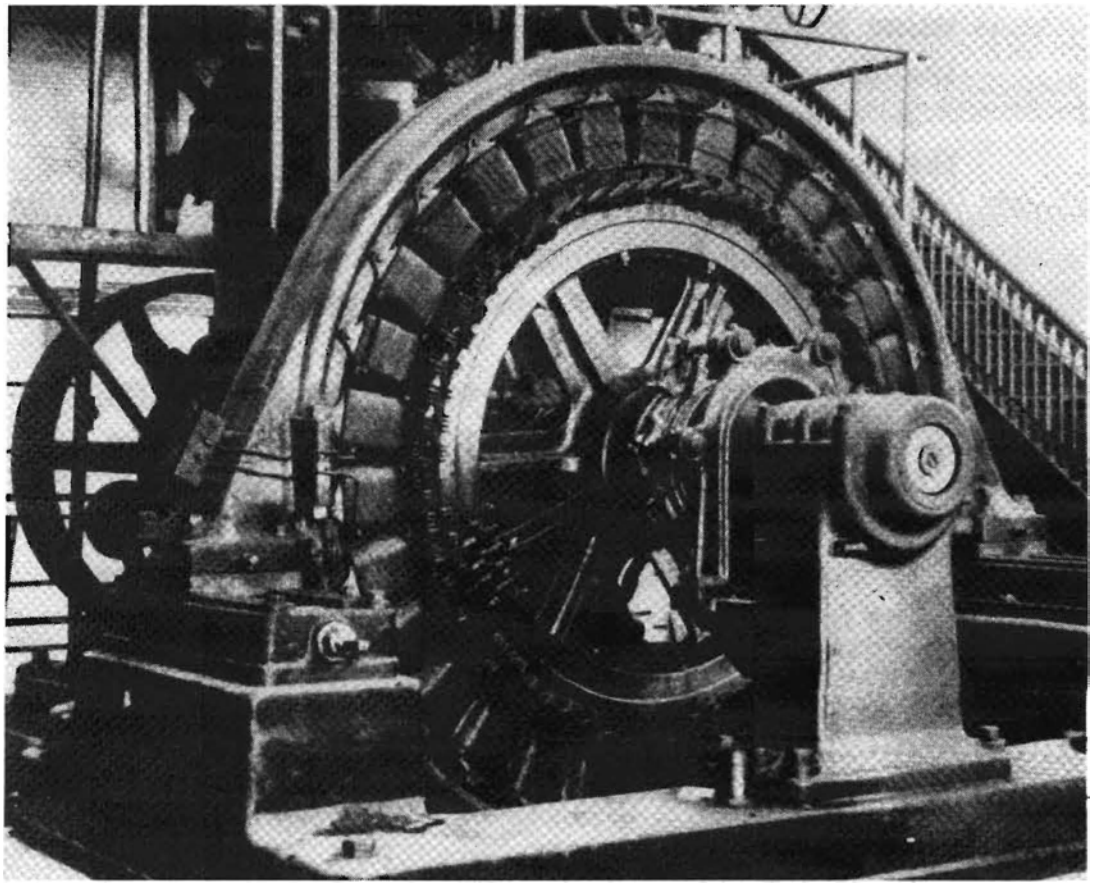
.A. For the purposes of the wireless art, yes.

Q. TI"ireless art?

A. Yes, in an its numerous applications.

. Q. Do you remember Ir. Bingham saying that he went down to the property?

A. Yes, sir, J remember.



Bruce Kelley

Figure A2-3
Generating room of Wardenclyffe plant building.

Note: This photograph was not an exhibit for the case.

Defendants' Exhibit B.

925

K.Now MEN THESE PRESENTS, That I, VILLIAII N. HAI.,LOCK, of the City, Coun ty and State of New York, party of the first part, for and in consideration of the sum of One Hundred and more dollars, lawf ul money of the United States, to me in hand paid, at or bef ore the ensealing and delivery of these presen ts, byValdorf -Astoria Hotel Company, par ty of the second part, the receipt w hereof is hereuy ack nowledged, have bargained and sold, and by t hese presents do gran t and convey, u n to the said party of the second part, ih; succe8sor8 a nd assigns, all and severa l the chattels located in the brick f actory building near 926
Skeleton Tower on prem ises owned or heretofore owned by Nikola Tesla, im mediately adjoini ng on the southerly side the rail road tracks of the Long Island Railroad at boreham Station, Long Island, in the Town of . Brookhaven,· Suffolk Cou n ty, New York, incl uding bu t not U mited to the chattels sped ficnl1y set out on the Sched u le hereto annexed.

To H A VE A XD TO HOLD t he same un to the said party of the second pal't, its succsors a nd assigns f orever. A nd I do f or my heirs, executors and ad· ministra tm·s, covena n t and agree to and with the said party of the seconrl pa rt, to warran t and de· 927
fend the sale of the Raid chattels hereby sold u nto the said par ty of the 8econd pa rt, successors and assigns against aH and every person and persons whomsoever.

IN WITESS WHEREOI<", I have hereunto set my ha nd and sea! t he eighth day of .April in the year one thousand nine h undred and fif teen.

WILLIA M :S. HALLOCK.

[L. S.]

Defendants' Exhibit B.

928 SCHEDVLE OF FOREGOING BILL OF SALE.

IN THE GENERATING ROOM.

1 \Vestinghouse auto compound No. 1497, size 16 by 27 by 16,
1 direct connecting Westinghouse alternating current generator . 200 Kw., Serial No. 155407, complete with lubricator, gauge, Rheostadt, switchboard and switches,
1 \Vestinghouse engine :So. 4750, *si1* 81:! by 8, with direct connected double current generator, 25 kw., Serial No. 168362, complete with lubricator, gauge, Rheostats-, switchboard and
9::!9 . switches,
.-1 15 H. P. \Vestinghouse motor, No. 162315,
4 Westinghouse transformers, 15 kw. type 0. D.,
1 tank manufactured by Stoutenborough,
1 truck,
1 Fairbank's scale
1 Laidlaw Dunn-Gordon pump, No. 16473.

IN THE VORKSHOP.

1 Westinghouse electric motor, used for power tO drive machine shop, type C, induction motor, 6 H. P., No. 162319,
930 1 Milling machine with tools complete, made by Brown & Sharp :\lnnufacturing Company,
1 Jathe made by Pond Machine Tool Company, No. P-3040, with tools, belting and shafting,
11 work benches,
4 vises,
1 \Vestinghouse, type .C, 2 H. P. induction motor, No. 162278,
1 Westinghouse, type C, induction motor, 2 H. P. Serial No. 162272
1 "\Yestinghouse type C, induction motor, 5 H. P., No. L-74487

Defendants' Exhibit B.

1 \\estinghomse motor, about 14 H. P., No. 22190 931
a lathes made by F. E. Reed of Vorcester, Mass. with shafting, belting and tools,
1 plainer made by Hendey Machine Co., with shafting, belting and tools.
1 plainer made by Pedrick & Ayr, with shafting, belting and tools.
1 F. E. Reed, hand drill press, shafting, belting and tools,
1 large drill presN by Prentice Brothers, with shafting, belting and tools
36 lockers containing miscellaneous supply of valves, joints, lubricators, fittings, scales, switches, single and double pole, socket, wrenches, fuses and plugs, 932
1 testing fun motor,
A quantity of telephone and bell wire,
A quantity of lead cable material,
4 radiators,
A quantity of drills, rose bits, reamers, taps, and all tools for milling machine and lathes, at present time in store room located in said workshop,
2 oil tanks.
1 testing motion b· Crocker Wheeler, ½ H.P. with Rheosta, No. 1000, 933
1 submarine boat,
1 clock
All of the aforeaid motors with starting boxes and switches.

BOILER ROOM.

2 Babcock & Wilcox boilers with steam gauges and water columns and with Metropolitan injector and \Vorthington feed pump,

Defendants' Exhibit B.

934: 1 other feed pump
1 hand blacksmith und forge
toilets,
1 nrinnJ, . all ndjoining boiler room.
6 wash hnsrns,

TESTIXG OR LABORATORY ROOM.

Rhemtat,
4 desks,
safes,
3 motors,
1 set of storage batteries and tanks
1 submarine boat,

935 1 "restinghouse motor, Xo. *28292*
1 "t>stin house motor, t·1w C, 5 H.P. Xo. 62320
Ye8tinghouse motor. t ·pe (\ 5 H.P. o. :?20i0,
4: hig11-tension 'transformers in tanks; and switch· boards
"iring drums
Draf ting boards and tools,
24 chairs
2 clocks
14 ra<liators

STATE 01' XEW YonK.1
('ountr of .Xew York ss

93n On this eight day of .April in the year of our Lord one thousand nine hundred and fifteen be· fore me the undersigned personally came nnd appeared Vn.I.J.A)f . HALLOCK to me known and known to me to be the indivh1ual described in and who executed the foregoing instrument, and he acknowJer1ged to me tat he executed the same.

ISÍDOR W. MUI,LER
Notary Public No. 45, Bronx County
Certificate filed New York County No. 85
Register's No. 6216
Commission expires\larch 30th, 1916

[:\OTARIAL SEAL]

l'i<i!>t
Court Pre. N. Y. • .

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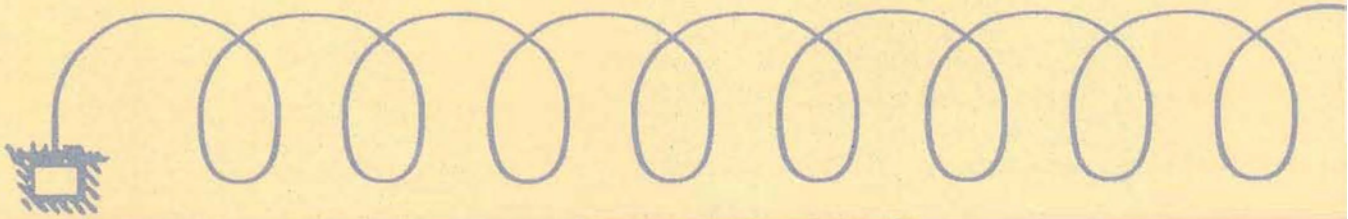

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