Tesla

Freie Energie selber bauen

Ausgabe 2020

Mit Materialliste, Bilder und Zeichnungen

Tesla Spule - Tesla Generator - Tesla Transformator

und weitere Tesla Systeme

Tesla

Free Energy Knowledge

Build free energy yourself

including material list, tool list, drawings and pictures

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Introduction

Nikola Tesla - The real inventor of radio and the greatest genius of all time!

Dr. Nikola Tesla was once among the most famous people on the planet. Today, he has disappeared from our science textbooks and schoolbooks. What did he discover that caused him to fall so out of favor?

Tesla, - A person of whom few have ever heard. He is said to have discovered X-ray radiation a year before W.K. Roentgen, he built a tube amplifier a few years before Lee de Forest, he used neon light in his laboratory 40 years before industry invented it, he demonstrated the principles we use today for microwave ovens and radar decades before they became a part of our society. His inventions include alternating/rotating current, AC motor, Tesla coil, radio technology, remote controls, radio (energy transmitter, free energy receiver), high frequency lamp, disc turbine and more than 700 other patents.

Energy for anyone who puts a tuned receiver in the ground? Yes, Tesla planned to transmit both messages and energy wirelessly - the former we know today as radio.

Tesla also made hundreds of inventions in the field of energy and magnetism, most of which were patented. That is why Nikola Tesla is often called a great genius. It is known that Nikola Tesla worked not only with electric currents, but also with various free energies, which are still too abstract for us today.

"Before many generations pass, our machines will be powered by a force available anywhere in the universe.... There is energy in all space. - Nikola Tesla"

This book is also intended to give insight into free energy to people who have not yet studied free energy and Tesla's free energy devices very well.
Just discover for yourself with this book the world of free energy and the technology of the Teslas and his other inventions.

Later in this book will be much more into the topic: Tesla coil and transformer and build such devices. With material list, pictures, drawings, tool list, parts list, shopping list, patents and much more.

Free Energy Introduction

Free energy - what is it?

The keyword "free energy" is currently used to refer to inventions and developments that emit energy in some form or other without there being any scientifically sound explanatory models as to how this energy is generated or exactly where it comes from. By "energy" we usually understand electricity, thermal energy and mechanical forces.

Also the term fine-material energies has found in the last decades more and more entrance and is called energetics, or energetic energy. With energies one can do a lot, in the first place energies are transformed from one form into another.
"transformed". From electrical energy heat energy, as well as mechanical energy can be decoupled, likewise one can influence with it by application of the oscillation physics and the work with frequencies and information transfer fine-material, energetic energies. Heat energy from coal -, gas -, and nuclear power plants can be converted by means of different technical possibilities into electricity, or be transported or stored as thermal heat energy with the help of liquids.

Common physics uses a wide variety of materials and arrangements of the same to generate energy, transport it and make it usable for humans. Chemical processes also often play a major role here. Basically, the concept of
"industrial revolution" was founded by the implementation of knowledge that was allowed to emerge through the growing understanding of the laws of nature and the cosmos.

Nevertheless we are as "mankind" still in the middle of this process, still for a long time we have not reached the end of this understanding. The nature has still some secrets for us, and again and again tinkerers dive into the matrix of these cosmic secrets and experience effects with energy and energetics which seem to be inexplicable for the moment. This is due to the fact that the regularities, which cause these effects, are not yet generally available and therefore not recognized by the established science.

When man learned thousands of years ago to deal with fire (energy), he received power over those who could not control the fire. Power was and is the mainspring of man to stand out from the crowd, to be unique, and to experience affection, recognition, up to subjugation. Thus, all new inventions and

Knowledge always also abused, because power was present only as long as the tool of power was in the hands of individuals or a few. Today, for example, the possession of swords is no longer a symbol of power. However, shortly after the extraction and processing of iron was discovered, the possession of this technology decided the claims to power of entire peoples. Wars were started only through this, because only through this the probability of victory was given. This simple rule still applies today: he who has the knowledge has the power. This is also the reason why many new developments and discoveries have not yet found their way into society, because established power structures would lose their ability to manipulate entire peoples and use them for their own purposes.

Imagine there was a small box that could be taken anywhere. Without having to put anything into it, this box would supply enough electrical or thermal energy to power and heat a single-family home, provide unlimited drive energy to a vehicle without emissions, or power machinery.

What would the electricity suppliers say if everyone cut their power supply due to the easy availability of this box worldwide? What would the oil companies say if no one had to drive to a gas station anymore? But also other methods in the sector of the use of freely available plants and the use of energetic means, which maintain health, favor clear thinking, prevent deficiency symptoms and ensure a healthy diet, are not in the sense of the pharmaceutical and food industries and perhaps also not in the sense of political and economic interests, whose power depends on a people who live in constant worry and fear for their basic needs.

Thus, the technologies and means that bring freedom and health remain a myth for society; only a few people who are not officially taken seriously research them incessantly and advocate them. As long as these people do not have a voice that is heard by a large number of others, they are harmless to the established systems. If they actively go out to proclaim their message, the powerful easily find ways and means to silence them again.

As long as these people are lone wolves and have no lobby, the power-oriented systems will always strive to keep society dependent, regardless of the possibilities. Genius inventors like Muammer Yildiz, Nikola Tesla, Viktor Schauberger, Howard Johnson and many others, whose most exciting developments are still withheld from mankind today, are sad examples of how a few defend their power structures and thus slow down the evolution of all mankind.

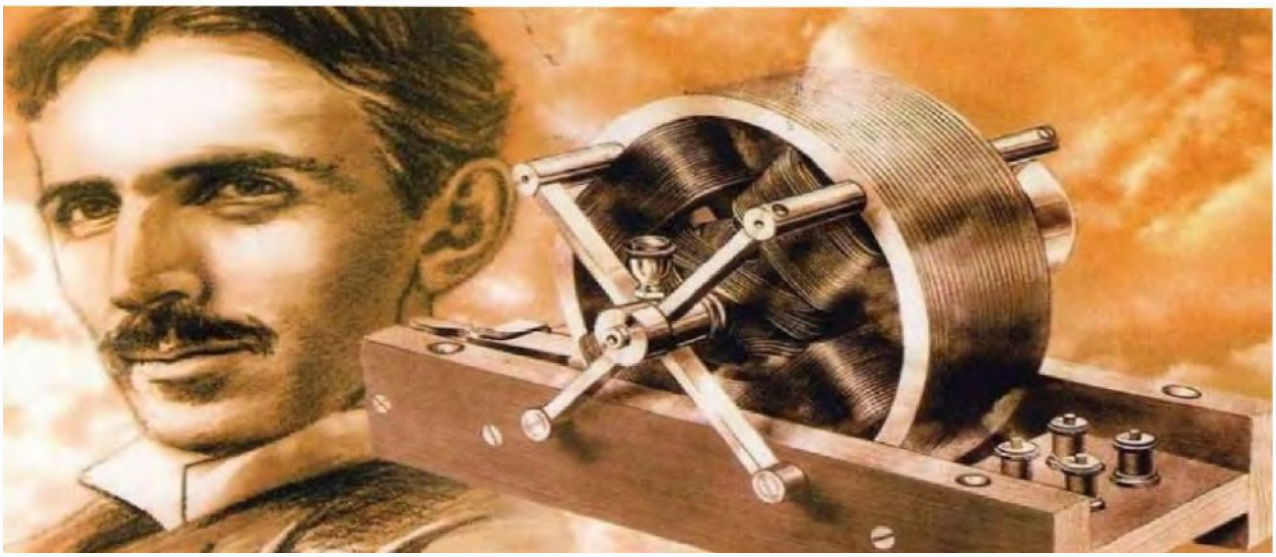
But the time is ripe for a change, as indicated by the spiritual awakening and the increased number of those who question the prevailing systems and overcome their fear and credulity.

discard. More and more communities are forming into interest groups that actively work on alternative possibilities for the positive technical and evolutionary further development of mankind. Once the power of the community is strong enough -even without the means of power- to itself introduce developments for the advancement of the personal freedom of the individual into society, even if this requires the circumvention of established systems and dogmatic structures, then a world-wide turnaround can no longer be stopped. The most important prerequisite for this is a change of consciousness, away from learned egoism, towards intuitive altruism, which is given to every human being from birth.

Creation makes no mistakes and knows that true evolution happens through the power of community and through the efforts of all involved to create the best for the good of all. Anyone who has learned to observe nature can see this for themselves every day. People who are free from dependencies are also free from time constraints, stress, existential fear, fear of illness and death, and fear of overreaching and crime. People who are free from dependencies are also free to give affection and appreciation, to give before they take, to pursue an occupation that matches their intentions and talents, and thereby define their status in the community.

Every creature living on this earth urgently needs this realization to stop the progress of the environmental destruction caused by the power-oriented structures in the last short decades. Now is the time to take the helm

to turn around, to look consciously, to take responsibility and, in the awareness that we are not alone, to tread new paths without fear. For us, the term "free energy" means, in a modification of the original definition, that it must be anchored as a fundamental right that every person has the same right to free access to energy, water, food and health.



We want Free Energy!

Imagine that they would no longer have to pay an electricity bill because a small device, such as the magnetic motor connected to the household power grid, would generate enough electricity to keep their lights on and to run all the electrical appliances they need. Imagine that your car would no longer run on gasoline, but on an energy source available everywhere, which would not cost you a penny and at the same time would be absolutely environmentally friendly. Very few people know that this technology exists and works. For example, there are machines that are able, in layman's terms, to generate pure energy from "the air" with an antenna. In former times one knew that the empty space must be filled with something, one could not prove it however practically. One spoke of the "ether" and "tachyons". Today we have another name for it: quanta! By quantum fluctuation in the space vacuum it is possible to produce energy. The discoverer was Nicola Tesla, by far the greatest genius of all times. You don't learn much about Tesla himself in school and also in libraries you can only find books about his basic inventions, without which nothing would be as it is today. No economy in this form, no computers, no radio, nothing would be as it is. But what is even worse, if Tesla's inventions regarding the production of free energy had been used instead of burning the natural deposits of oil and coal etc. for profit, we could live in a true paradise today.

But unfortunately, the world we live in is ruled by money. Neither Barack Obama are people who make any important decisions. These people are also just puppets of much more powerful individuals. But for now, back to Tesla's discovery. Tesla was firmly convinced that there was an energy field in and around the earth that could be tapped to produce electrical energy. He succeeded in providing experimental evidence for this. His experiments on modulation and extraction of the energy of the energy field belong to the breathtaking moments of physical research. Since Tesla was almost 100 years ahead of his time, the significance of his achievement can only be properly appreciated today. Unfortunately, discoveries like these have been erased from the history books so that it does **not become known that** the entire human race is being lied to in order to earn trillions of dollars with the supposedly necessary burning of fuels of all kinds, in combustion engines and through the extremely dangerous nuclear fission with its known and fatal consequences. But that thereby the poor become poorer and poorer and already millions of innocent humans had to die, bothers apparently nobody. How this all began, we summarize here. Around 1894, the banker John Pierpont Morgan began to invest considerable funds in Tesla's work. Of course, with the aim of making a thousandfold profit from Tesla's inventions again. Tesla's prestige was at a peak thanks to the successful Westinghouse technology. On a Morgan compound in Colorado Springs, Tesla quietly experimented, and by 1898 the technology of converting

Gravity-field energy, as we would call it today, had reached the threshold of technical feasibility. Tesla presented his plans to Morgan: Factories were powered, houses heated, locomotives and cars driven. A small converter was needed, and a short antenna sticking up in the air to capture the energy. When Morgan saw these plans (he knew how seriously to take them) he was horrified. "For heaven's sake. Then we'll just sell some boxes and antennas, and we can write off our lucrative heavy technology."

Just imagine that the government of an industrialized country could no longer levy a mineral oil tax when using free energy inventions and their further developments! That would be the end of the super rich and the beginning of a general prosperity.

Morgan ordered the facilities in Colorado Springs to be dismantled immediately. That was in 1899. It was not until 1931 that Tesla was able to realize the operation of an automobile by gravity field energy. In 1930, Tesla had his nephew Petar Savo, born in Yugoslavia in 1899, come to New York. Petar was thus 43 years younger than his uncle. Until then, he had lived in meager circumstances in Yugoslavia, Tesla's birthplace. In the summer of 1931, Tesla took his nephew to Buffalo to unveil and test what he said was a new car. Tesla had developed it with private funds. It was a Pierce-Arrow, a luxury model of the time. The engine had been removed, the clutch, transmission and axle transmission to the rear wheels remained unchanged.

The gasoline engine had been replaced by a round electric motor, closed on all sides, about lm long and 65 cm in diameter, with a cooling propeller at the front. It is said to have been a brushless motor. Tesla was not willing to disclose who had manufactured the motor. The "energy absorber" (gravity field energy converter) had been made by Tesla himself. The housing of this converter had about the dimension of 60 x 25 x 15 cm. This was mounted in front of the dashboard. Among other things, the converter contained 12 tubes, 3 of them of the type 70.L.7. A strong antenna of about 1.80 m length protruded from the housing of the converter. In addition, 2 thick rods protruded about 10 cm from the converter's housing. Tesla pushed these in and said: "Now we have energy". The motor then ran at a maximum speed of 1800 rpm. Tesla said it was running quite hot, so the wind fan was necessary. Incidentally, he said, the energy from the converter was strong enough that it could light up an entire house in addition to the automobile engine. The car was tried for over a week and easily reached a considerable speed of 90 miles per hour. Its performance data were at least equal to those of the comparable car with a gasoline engine.

At a traffic light, a passerby pointed out that there were no exhaust gases coming out of the exhaust. Petar replied: "We don't have an engine". The car was parked on a farm about 20 miles outside Buffalo, near Niagara Falls. A few months after this attempt, the Pierce-Arrow company in Buffalo had to stop production due to the economic crisis of the time. It is very likely that the electric motor was flanged to the transmission there. Tesla obviously knew that this construction was indigestible for the technical world of that time. So he avoided any discussion with engineers, teaching scientists or companies, with very few exceptions. An inventory of all available information was made only on September 16, 1967 by the aircraft engineer Derek Ahlers in New York. The experimental vehicle built by Tesla in 1931 already gives an idea of what a future car with advanced technology might look like. Minimal operating costs, unlimited range and absolutely no environmental impact in any form whatsoever would be the result. A dream. This technology could be used in all areas. And now look at our world. What the vultures who pull the strings make of it.

Millions of people could lead a life worth living where they now have to starve or freeze to death in agony. Every day it's all about money, wherever you look. The fewest people know the truth. No drop of gasoline would have to be bought for expensive money, no exhaust gases would pollute the planet. There are more and more diseases due to the poisoning and pollution caused by the exhaust fumes of this wrong technology. But not only by the use. What about the countless accidents with tankers on the sea. What horrible damage we do with it is nothing more than a top topic for the controlled media. What about nuclear power? The disposal of the fuel rods of a nuclear power plant is nothing else than an abnormal contamination of our planet. The radiation will only subside after more than ten thousand years (!!!).

This alone shows that we do not think a bit about the consequences of our actions and not a bit about the coming generations. Chernobyl would never have been the place of one of the greatest catastrophes of mankind. In the months following the accident, so-called "liquidators" (soldiers, students and volunteers) came to Chernobyl, decontaminated the power plant, eliminated other sources of danger and finally rebuilt the sarcophagus that today encloses the exploded 4th block. Figures on the number of people deployed vary between 600,000 and 1.2 million people.

It is equally difficult to draw a (preliminary) casualty balance, since only very few liquidators succumbed to acute radiation sickness. Rather, most of the deaths are due to the late effects of radiation, for example, cancer, immunodeficiency diseases (so-called "Chernobyl Aids"), cardiovascular diseases and depression (suicide). Depending on the point of view of the observers, today the figures about all Chernobyl victims vary between 10,000 and over 250,000!

Exactly it will never be found out. Especially since throughout Europe, especially in the most affected areas in Belarus and Ukraine, "bystanders" are still dying today from the consequential damage of Chernobyl. Above all, cancer and child mortality rates are rising, even explosively in the heavily contaminated areas. The medical condition of children growing up on contaminated soil is frightening. And these consequences will not be limited to current generations. These are just a few of the avoidable **consequences that are** happening, and unfortunately will happen, **due to the suppression and secrecy attempts of Free Energy.** It is so sad how man is raping this beautiful planet, along with the creatures that inhabit it.

Instead of using clean and free energies to defeat hunger in the world, the representatives of the countries responsible for this pitiful state of affairs are meeting at the G8 summit to do again what they are the only ones who have ever done. Discuss and not act.

The list could go on for miles at this point, but surely the attentive reader will think of a few other things to connect with it at this point at the latest. Almost everything bad in this world is the result of unequal distribution and the greed for profit and power of the super-rich, who thus also control the governments.

The responsible persons, or however one should call these persons, are vigilant and pay attention to the fact that the technical state develops completely in their sense (whereby the word "develops" might be definitely wrong) and does not turn into the opposite. The real danger for the conspirators (no theory, but reality) is the beneficial development of the technology for the benefit of mankind, for which they were developed by geniuses like Tesla, Muammer Yildiz, Howard Johnson, or Schauberger, was and is difficult to banish.

Again and again there were developments and inventions that were not in the interest of the world conspirators, because they brought too great advantages to man. The human being should not have it too comfortable. The more he had to work for the preservation of his existence, the more dependent he became on the satanic power. Helpful for this are also examples like the introduction of the Euro, which led to the fact that one must pay now the double price for most products and does not earn a cent more. By more and more debts and worries there is no more time to think about the causes and about such important things and even more important - not to act. Tesla had recognized in time that the energy question meant not only an important factor for the advancement of the technology, but can be also a multiple means of extortion and exploitation for mankind.

That's exactly what it has been for over 100 years! That was also the reason why he made his

discoveries accessible to everyone. Everyone should benefit from his findings, which he had made possible a happy development of the technical age for the benefit of mankind. This is what he lived for. All his life he worked tirelessly, often for days without sleep. Was threatened and stopped again and again. At that time, he did not have the possibilities to take care of the dissemination of information as in today's age.

But now things are different. The name Tesla and its incredible achievements must never be forgotten. But clean and free energy for all people? That was not to be! The world conspirators immediately intervened. Free energy for every consumer, beneficial technical developments, they did not agree with that.

This would endanger their intentions of immeasurable material enrichment and the development of their power. Billions can be gathered only with a technology laboriously built under many difficulties. The attack on Tesla was aimed at a sore spot - his finances. Since he never regarded his inventions as a source of profit and did not even patent many of his inventions because he had long since come up with new visions, he was always dependent on large loans. These were abruptly cut off for him.

His laboratories, experimental stations and technical equipment were damaged or destroyed by saboteurs. Tesla was soon ruined, unable to work and defamed by the whole world. He died poor and broken in the Hotel New York on January 7, 1943. But Tesla was not the last who had such ideas. He was probably one or the first victim of the conspirators. Everybody can imagine now with some imagination, how our all life could look like. It is necessary that a rethinking takes place. Everyone has the power to change something and be it only by the spreading of this knowledge to friends, acquaintances or strangers.

Free energy for all!

Inventor Free Energy Devices

Nikola Tesla (1856 - 1943) "Father of free energy".

1899 First tests with wireless energy in the mountains of Colorado at the foot of Pikes Peak with the largest "Tesla coil" in the world. In 1900, Tesla was "stopped cold" by his backer, banker Morgan. He had his funding cut. 1902 Report in the New York Times about a man from the Canary Islands named Clemente Figueras who was said to have invented a generator that did not require primary power. One day later Tesla wrote to his friend Robert Johnson (editor of Century Magazine) that he had already invented such a device.

Howard Johnson (1919 - 2008)

Howard Robert Johnson is the researcher and inventor of an all-magnet motor, which made modern physics impossible. This device generates motion, - either rotational or linear motion as permanent magnets, in which rotor as well as stator, act against each other. In his inventions, a permanent magnet armature is magnetically driven along a guided path by interaction with the field within a flux zone (called a "permanent magnet motor"), which are bounded on each side of the path by an array of permanent stator magnets. Researcher Howard Johnson began the study of magnetism in 1942 as a doctor at Vanderbilt University. The permanent magnet motor was conceived by Howard Johnson some time after the 1940s.

Muammer Yildiz, born l.April 1965

Turkish inventor of another permanent magnet motor. After more than 30 years of research into electromagnetic fields, he presents mankind with a self-running magnet motor that, as you can see, does work. Even if it is currently "only" estimated 100 visible watts to run the fan. The big difference to all others is that his device / invention with - as he says - monopolar magnets just do not become even hand-warm and thus do not overheat, because from 80 degrees Celsius the magnets lose their magnetism.

John Bedini, born 1948

Years ago, John Bedini became known as a young engineer in California who had built a prototype "free-energy" engine that powered itself while doing useful work. Using a simple 12-volt battery, his motor ran

incessantly, but the battery did not discharge, as might have been expected. This was made possible by an innovative circuit that tapped into space energy and used the battery in such a way that the elusive energy from the vacuum was converted into usable electrical charge. John Bedini was not allowed to give the public a self-running machine that would power their homes, but despite the disappointment of being slowed down by energy policy, he continued to learn. He kept in touch with brilliant inventors of magnetic apparatus like Howard Johnson and built many toy-sized prototypes himself. Eventually, he was convinced, the time would come to bring clean energy to people in abundance. At a certain point in Bedini's unusual apparatus, the ethereal energy is converted into conventional, usable energy so that the whole system can run itself and still have mechanical energy available to do work. The magic conversion point from one form of energy to another occurs within the battery as it is charged by short pulses. **The Bedini 10-coil motor** can be a spinning wheel with a specific arrangement of magnets and coils, or a generator circuit with no moving parts, as exists in the "plug-in" battery chargers manufactured by Bedini and Friedrich.

Walter Rüssel (1871 - 1963) was able to capture space energy by means of a generator. He called this device "Optical Dynamo Generator". In 1961 this generator is said to have worked. Senior officers of NORAD (North American Air Defense Command) were present at this demonstration. However, no one seemed to care.

Thomas Henry Moray (1892 - 1974) followed Tesla's lead and invented a
"Radiant energy device" which converted space energy into usable energy. In 1939, he operated a self-built device with a usable output power of 50 KW. With this device, he succeeded in reliably pumping out space energy. He was repeatedly harassed in the years to come. Among other things, he and his wife were shot at. As a result, he had to buy a bulletproof car.

Victor Schauberger (1885 - 1958), Austrian forester who succeeded in discovering energy spirals in water through intensive observation of it. He created what he called "living machines". His motto was, "Get a hold of nature and copy it!" He was pressured by the German Nazis and forced to work for them. In 1958, he was invited by an American corporation to travel to America to demonstrate his invention. Well the consortium then promised him to use his invention to apply it. He was deceived. However, his implosion generator disappeared in the drawers of the consortium. Schauberger died of a broken heart 5 days after his return from the States. 100 million electrons tightly clustered together, where an electron is the part of an atom that orbits around the nucleus. Shoulders may have succeeded in producing conditions under which electrons break away from the nucleus and form remarkably stable, small

ring-shaped clusters together.
"It's the craziest electronic effect you could ever imagine," says Shoulders, who his creations as "little machines of immense complexity ", which are simply not "dead to the world". A patent was granted in 1991. It is entitled: "Energy conversion using high charge density".

Floyd "Sparky" Sweet is considered the pioneer of "solid state magnets". Sweet, who died in 1995, built the "Vacuum Triode Amplifier "(VTA) in which magnets served as a gate through which space energy could flow. This made it possible to use this energy as a power source. Shortly before his death, at the age of 83, he reported that the automobile industry was testing his energy device for use in cars. "They would have a device that would run for 5,000 hours". He said he was negotiating with representatives of General Motors. No one was able to confirm this claim. Other inventors are trying to continue his work today.

Bruce de Palma, the brother of "Scarface" director Brian de Palma, a universally respected faculty member of "MIT" (Massachusetts Institute of Technology) with an engineering degree. Trained in electrical engineering and a Harvard graduate in applied physics, he turned to meditation, among other things. One day he was thinking about what he had played with as a child. He had never understood why a spinning top, for example, behaved the way it did. His idea came suddenly out of the blue.... "Perhaps the rotation of a spinning top somehow aligned itself with space, around a rotating body, such as the Earth?" He experimented with ball bearings in the course of his experiments and found that it was likely that these ball bearings, which he spinningly catapulted aloft, were picking up space energy as they spun. In his "N-machine" he used strong magnets. With this machine, the space energy could also be used on earth to do work. Because he was blocked in the States, he moved to Australia, and from there to New Zealand.

Nikola Tesla's life

In the first part of this work the life story of the unique person Nikola Tesla is told. The aim is to show how Tesla came to his inventive genius, what successes he could record and what strange events accompanied his death. The reader should get a detailed insight into the most important events and get to know Tesla's characteristics. In the following section, I will go into more detail about Tesla's achievements, mainly in the field of electrical engineering. He is often praised to have been at least a century ahead of his time with his inventions! If he would live today, his apparatuses would still be so revolutionary that many scientists would not take him seriously. At the end of this work, the reader should be able to form his own opinion about Tesla's achievements and judge whether the claims that Tesla was a genius are justified.

Supplementary information, which one does not get in the commercial literature, is provided by an interesting interview by the founder of the Tesla Society Switzerland, Peter Stojanovic. Afterwards you can read where the numerous traces of Tesla can still be found today. You will be surprised where you can find Tesla's work everywhere.You can be amazed how current the topic of Tesla is. The amazing thing is that you rarely notice Tesla's effects. Only very few people know Nikola Tesla nowadays.

Tesla's childhood

At midnight, on July 10, 1856, Nikola Tesla was born in Smiljan, a small village in what is now Croatia. He was the second of five children.
His father was a Serbian Orthodox priest and a very learned man. His mother was a housewife. She came from a line of inventors and also had a very clever mind. Little Tesla had to constantly do exercises that sharpened his mind.

When Tesla was seven years old, his older brother had a tragic accident with a horse, as a result of which he died. The death of his brother weighed heavily on the boy and left its mark. No matter how hard he tried, he could never live up to his parents' expectations, which they now placed on Tesla instead of his brother. Mourning for the brother, who was also highly gifted, was always present. Therefore, Tesla grew up with low self-confidence. In addition, strange phenomena were peculiar to him. He often saw images accompanied by strong flashes of light. He could not distinguish whether these phenomena were real or imaginary. Reality and fiction were mixed. While the sufferer was very frightened and intimidated in the beginning, he learned in his

Youth to suppress and control suffering. In the future, the talent to manifest thoughts in the mind was to pay off as an important factor of his genius. Tesla could imagine and comprehend models, drawings or experiments down to the smallest detail. He later once said that if the devices worked in his mind, they would work in the real world exactly as he imagined the process. In his childhood, Tesla developed some almost pathological habits and phobias. For example, in his spare time he began solving mathematical problems and calculating the contents of objects, such as a coffee cup. He couldn't stand it when women wore earrings, especially if pearls were attached to them. Or he could never leave anything unfinished. This sometimes got him into trouble, as will be symbolized below. Young Tesla loved to read immensely and used to sneak into his father's library to read at night. Once he began to read a book by Voltaire. Afterwards, he learned that the entire work consisted of over a hundred books. However, he could not simply put the books aside, but laboriously struggled through night after night until he reached the last page, before which he could not have found peace. Tesla was an outstandingly clever student and was admired by everyone in the village for it. His inventive spirit was awakened when he was only 5 years old. At that time he had a vision of a turbine that worked much more effectively than the conventional ones without blades. 35 years later, he had actually built this invention. In another early invention, he wanted to exploit the forces of nature. He built a kind of rotor to which he attached "unpopular" cockchafers. These whirled in circles and actually produced a performance. But he was not to succeed in everything. Nikola's dream was to be able to fly, as he did in his imagination. With an umbrella he stood on the roof, breathed the fresh air deeply and jumped. The flight was gentle, but the landing was hard!

After attending elementary school for four years, he transferred to the high school in Gospic for five years. At 15, he attended the secondary school in Karlstadt. Tesla contracted a number of dangerous diseases during this time and was abandoned by doctors without hope. However, he was to survive.

In 1873, cholera swept through Croatia. Tesla was not spared, he also became infected. He was bedridden for nine months, and the doctors had already given up on him. One day, when his father was sitting at his bedside, Tesla talked to him about his career prospects. The father wanted to see his son follow in his footsteps, as a pastor. Nikola, however, did not want this. Therefore, he said he would not get well until the father agreed to study engineering. The father agreed, as he was happy if his son would get well again. Indeed, Tesla "rose from the dead like Lazarus." He then took a year off and hiked in the local mountains.

At the age of 19, he began his studies at the polytechnic in Graz. There he amazed his teachers with his exceptional talent. Among other things, he spoke six languages fluently. He needed only one for two years of his studies, achieving

even awards. Despite his above-average performance, the student was eventually expelled from school. The reason was that Tesla had fallen prey to a strong gambling addiction, in which he gambled away his already little money. The university also justified his expulsion by citing an irregular lifestyle. Tesla slept only 4 hours each night, slaving away the rest of the day. During this time, he smoked heavily and drank an extraordinary amount of coffee.

Tesla at the age of 23

Tesla, however, did not give in to his aspirations to become an engineer. He went to Prague and studied engineering there for two years without being enrolled at the technical college. His self-taught education was cut short by the death of his father. He then looked for work in Maribor, but could not find anything suitable. In the meantime, Tesla managed to curb his urges and desist from his addictions. His fickle character was strengthened as a result. His outward appearance was interesting. The thin man, barely 2 meters tall, made an impression on some people with his mystical charisma.

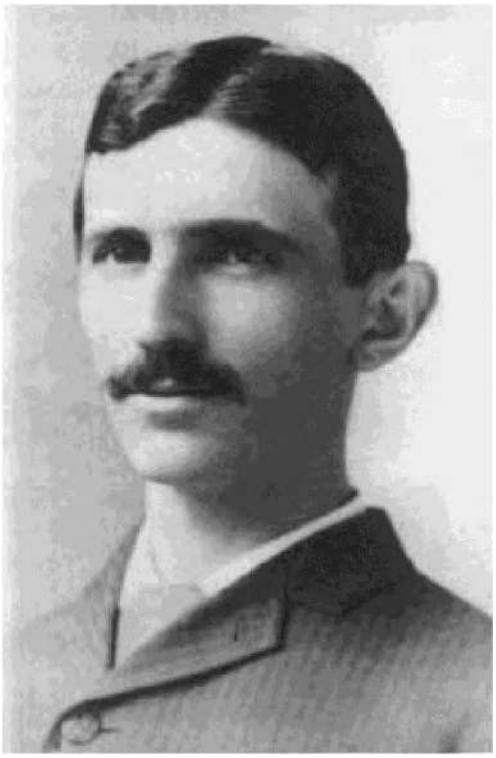
Tesla in adult age

At the beginning of the 1980s, the inventor Thomas Alva Edison conquered Europe with the telegraph. He established several branches, including one in Budapest. Tesla sought work at the Central Telegraph Office and was successful. Unfortunately, he obtained employment that did not suit him at all. He was hired as a draftsman and with low wages. Already during his studies in Graz seven years ago, his attention was drawn to alternating current by a Professor Poeschel. The student was convinced that a Gramme machine (=commutator; reverses the current) could be converted into an alternating current machine. Mr. Poeschel replied that this was impossible, "tantamount to converting a steady force of attraction like gravity into a rotational motion." One day, when Tesla was walking with a friend through the city park at sunset, he quoted Goethe's Faust. Here the solution to the problem came to him like a flash of inspiration. Nikola Tesla had discovered how the alternating current motor worked, which was to fundamentally change technology and the whole world.

He still worked unhappily as a draftsman, but was then able to obtain better employment through much diligence. This work gave him valuable experience for his future. The manager of the company gave up his business. However, he saw Tesla's talent and offered him work in France. In Paris, he was hired by Edison's telephone branch, where he was given some very difficult assignments. Tesla was able to master all of them with flying colors. He was promised a bonus. However, none of the superiors wanted to be responsible for this and so Tesla received no bonus. During one order, the inventor built a first rough model of his AC motor. This also worked, unfortunately he could not sell it, since nobody was interested in the alternating current, but all only in direct current.

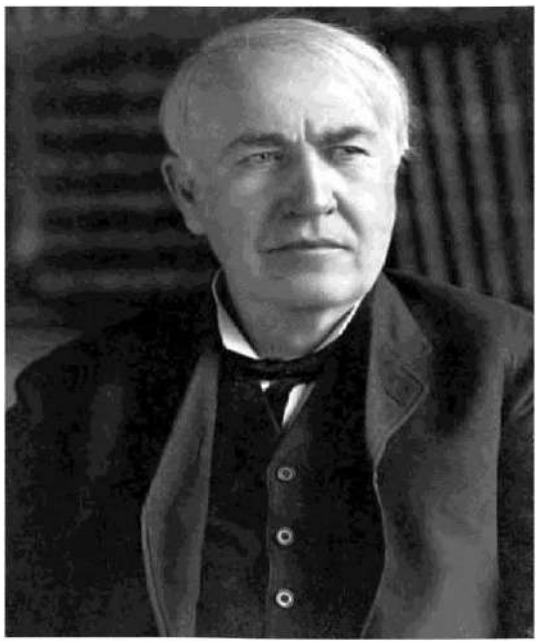
At the urging of a friend of Edison, Tesla was persuaded to emigrate to America and work there as an engineer. One reason was that he could not get capital for his inventions in Europe. He hoped to find support in America. Tesla was standing at the train station in Paris waiting for the train to the port from where he would then take the ship to America. But when he reached for his ticket, he was dismayed to find that the money and tickets were gone. With a lot of luck, he managed to pay for the train ride with small change and get on the ship with excuses. Tesla reached the shores of America in New York on June 6, 1884.

The 28-year-old was very disappointed in America. He described coming from "a land of dreams to reality." The city of New York seemed to him machine-like, rough and repulsive. This civilization, he said, was 100 years behind Europe. He maintained these views throughout his life. With no money in his pockets, but only a letter of recommendation, Tesla went to see Edison.



Tesla at the age of 28

Thomas Alva Edison



Thomas Alva Edison (b. Feb. 11, 1847; Oct. 118, 1931).

As a child, he received only a few months of schooling. An apprenticeship as a telegraph operator gave him the technical basics. But he did not possess great talent or intuition. As he himself said, "Genius is 1 percent inspiration and 99 percent perspiration." Nevertheless, he invented the electric voice counter, the phonograph, today's light bulb, and the phonograph record, among other things. He went down as one of the greatest

inventor in the annals. However, he always relied on direct current, which made him an opponent of Tesla and Westinghouse. Finally, he admitted that the biggest mistake in his life was not to rely on alternating current.

Edison hired Tesla on the letter of recommendation in his company, the "Edison Electric Company". The letter from Paris said, "I know two great men, and one of them is you Edison; the other is this young man Tesla." The two men were very different in nature. They had in common, however, that both were passionate inventors. Edison, however, invested all his resources in the research of direct current, while Tesla was convinced of his alternating current.

After Tesla completed the very difficult repair work of a lighting system on a ship, Edison was fascinated by this young genius. When Tesla once claimed that he could improve Edison's DC motors, Edison promised a bonus of 50,000 dollars. Tesla worked diligently day and night for months on the machines until he succeeded in improving them significantly. He then demanded his salary, but the manager refused to give him the money. Nikola did not understand his American sense of humor. As a result, Tesla's cooperation with Edison ended forever after only one year, an enmity developed. Tesla stood there, in a distant country, without a job and without money. Shortly after the termination, fortunately, a few investors asked him to found an arc light company with them. They wanted the inventor to invent only the arc lamp and nothing else. Tesla was ready. After developing the lamp, the company sent him away with some worthless shares.

As a result, the engineer was unable to find a job and had to earn a living as a construction worker. This job brought him to a company owner who was interested in the alternating current motor. In 1887, they founded the Tesla Electric Company. Tesla's wish became reality: he could develop his motors independently. This he did, almost continuously. Having already thought everything through in his mind, he built the multiphase alternating current system in just a few months and filed patents for the "electromagnetic motor" and the "distribution of electrical energy". At the age of 32, Tesla met George Westinghouse. Westinghouse was also an inventor and had his own company, the "Westinghouse Company". His field of employment was alternating current, making Edison his greatest adversary. Westinghouse was interested in the alternating current motor. An agreement was made between the two. It was agreed $2.50 for each horsepower of electricity sold, descended from Tesla's motors. At a later date, however, Tesla was to tear up the contract, as Westinghouse was suffering from a shortage of money and could not possibly pay out the millions of dollars he owed him in royalties. Tesla cared more about friendship than money, although he later had to deal with major money problems. An electricity war ensued between Tesla and Edison. The latter put

much to the fact that one used only the direct current, because otherwise he would lose very much. Edison launched agitation campaigns.

George Westinghouse

At public events he let Tesla's and Westinghouse's alternating current flow through animals, including an elephant, which died from the currents. It was not until four years later that alternating current definitively established itself. This was achieved by the World's Fair in Chicago. The alternating current motors ran the entire fairgrounds without any problems, while Edison's direct current had been too inefficient. Tesla demonstrated various electricity phenomena and was the big figure at the exposition. In the following years, Tesla worked in his new laboratory in New York. During this time, the industrious engineer filed many patents, including for high-frequency currents, the Tesla Coil, for the vacuum tube and for an electric oscillator. At the universities he often gave lectures with experiments. These were very popular with the students.

In 1892, Tesla interrupted his work because his mother was dying. Plagued by homesickness, the son wanted to see his mother one last time and went to Smiljan. She died only a few hours after his arrival. A few years later, Tesla invented an apparatus for transmitting information by means of radio waves.

Tesla was the first to invent the radio. In 1897, two years later, Guglielmo Marconi, an Italian inventor, claimed that he had invented the radio. To this day, all history books maintain this version. "Marconi's invention" was based on 17 patents of Tesla. It was a replica of Tesla's invention. The dispute over the radio was taken to court, where Tesla described exactly the construction of his radio. However, he lost the case. Only after his death was it officially confirmed by the United States that he was the true inventor of the radio.

In 1895, Tesla and Westinghouse reached another milestone in history. The Niagara power plant was opened. It will generate energy in huge

Tesla holds a wireless light bulb

quantities are extracted as the water cascades down the shafts and causes turbines to spin, which drive AC motors. This had always been a vision of Tesla's, to harness the power of nature. Now it had succeeded. The power plant at Niagara Falls was the first hydroelectric power plant in the world. Tesla was not only a very gifted inventor, but also a good philosopher and an intellectual. Nevertheless, the esotericists were deeply in his favor. The thinker Tesla put forward many theories that were philosophically inclined. For example, in his article "The Problem of Increasing Human Energy," he ponders how to further the development of human civilization. In the meantime, the Croatian Serb became very rich and therefore came into contact with the high society of New York. Thus he became an American citizen, which pleased him very much. He loved to live in splendor and was not afraid to spend his money to the fullest. But Tesla was bad with money, which was to become a problem at his age.

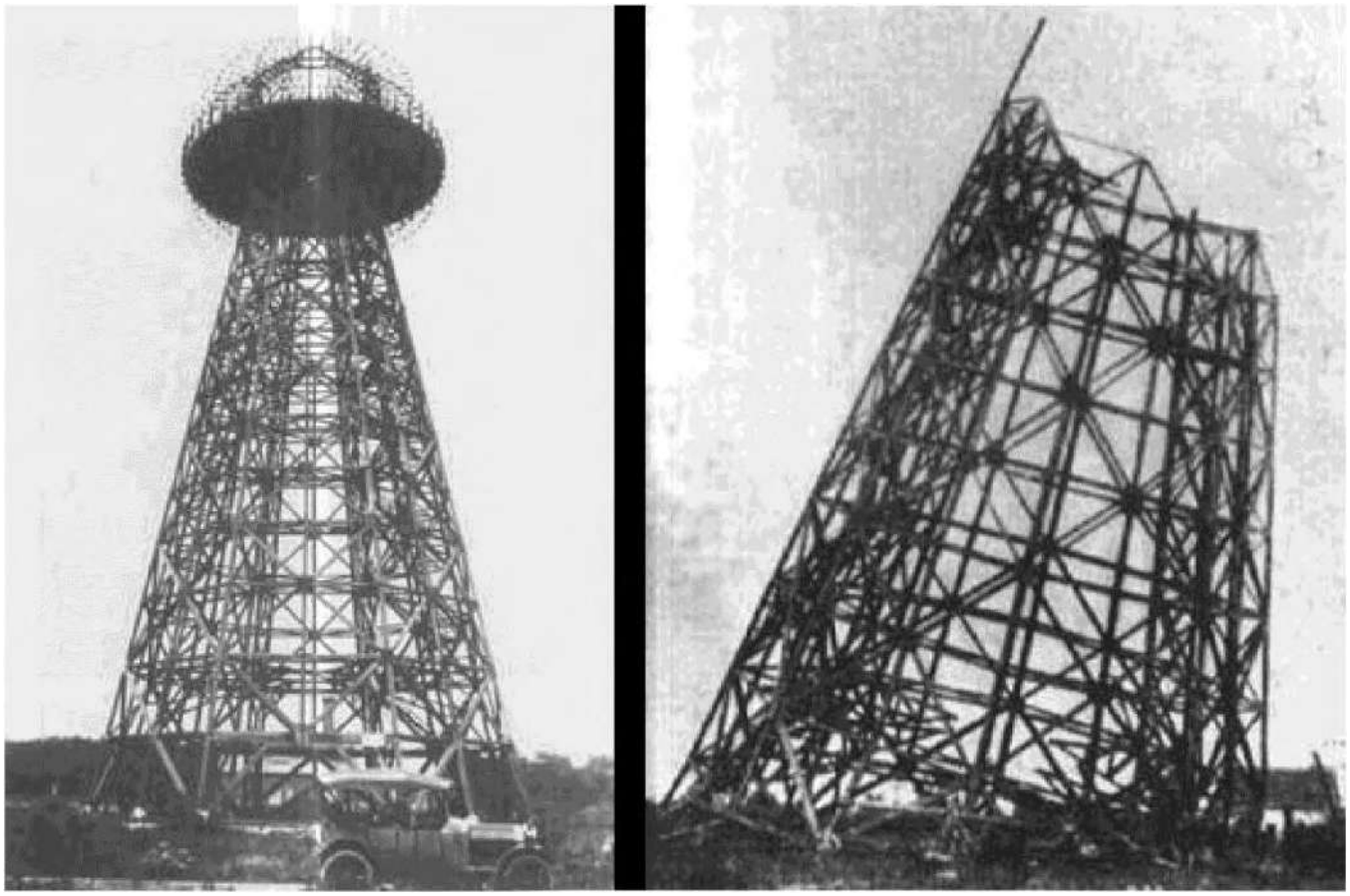
At the age of 43, driven by a constant urge to invent, Tesla went to Colorado Springs in the desert, where he had enough space to test his inventions. For a year, he conducted research primarily with high-frequency currents. With the help of a 50 meter high pole, which was equipped with a copper ball at the top, he was able to produce strong lightnings. They became up to 40 meters long. In a village 25 km away, the consequences of his experiments should still have been incredible.

Experimental station in Colorado Springs

Residents of the nearby village reported, "...sparks flying between their feet and flames blazing from the taps..."

Tesla also worked on the transmission of energy without wires and the transmission of information. He could send a signal 1000 kilometers and claimed he could send signals to Mars with this apparatus. In addition, he wrote an article saying that he could electrify the sky to make it a sea of flames. Based on years of thinking, he wanted to build a station for a world broadcasting system. The idea was to supply the whole earth with radio channels of every wavelength from a single place. It would not need many small transmitters, but only one big one. The Wall Street magnate J. P. Morgan was interested in this project and supported Tesla financially. He did this for selfish reasons: he hoped to have a radio monopoly at the end and thus to cash in. Construction began in 1901 and the project was called Wardenclyffe. It consisted of a laboratory and a tower 60 meters high, reaching 30 meters into the ground, with a huge copper dome at the top. After five years, however, the construction work, which was almost finished, was abandoned due to lack of money. J. P. Morgan learned the tower's true purpose, to send free energy anywhere in the world, and withdrew. Tesla could not pay the remaining mortgages as it was. In the year

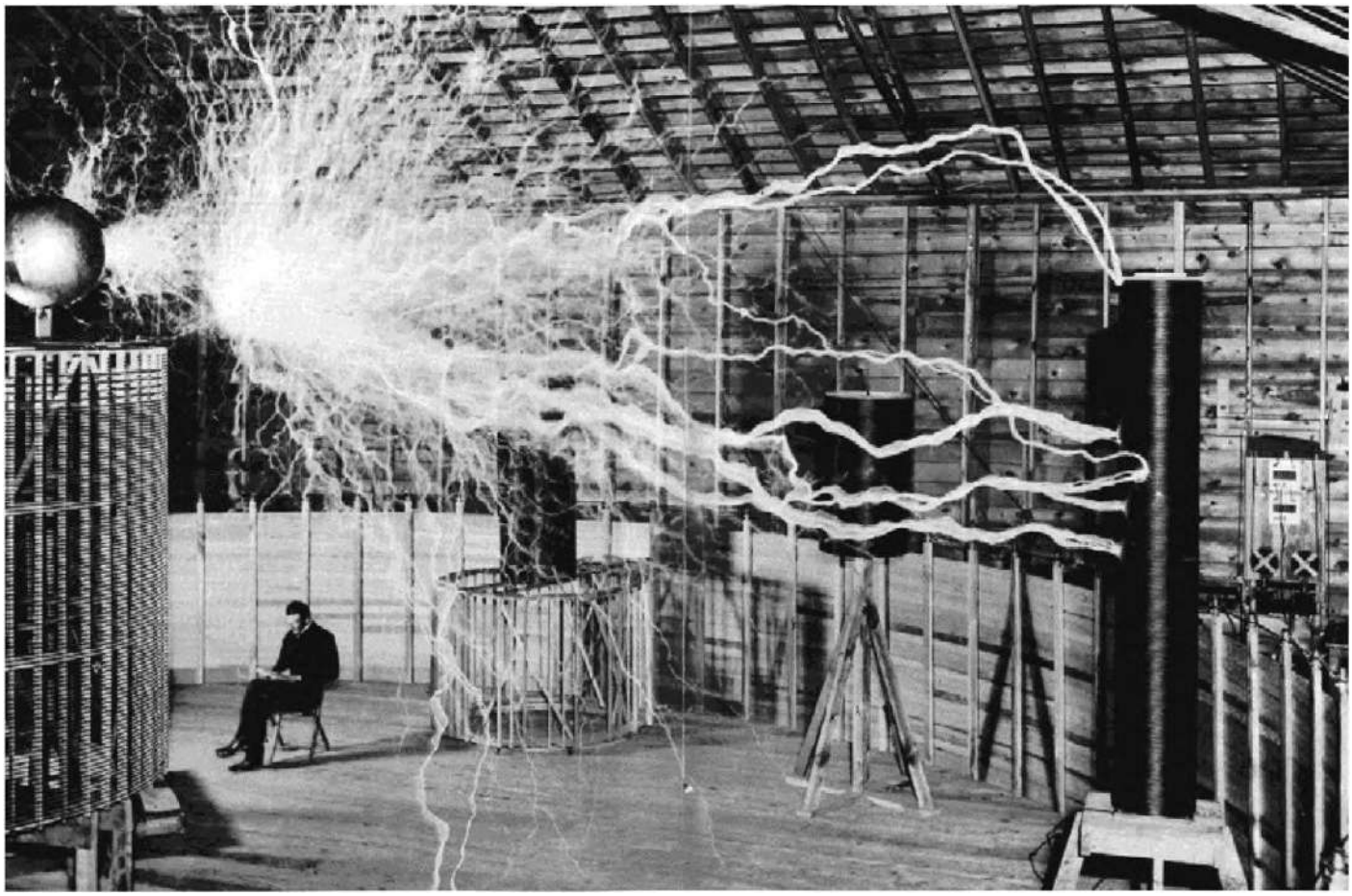
In 1917, the Wardenclyffe tower was finally demolished so that some of the debt could be paid off from the scrap. The payoff was a few dollars.



Wardenclyffe Tower

Tesla filed most of the patents before the 1920s. After that, only a few followed. He had to give up his laboratory in 1922, at the age of 66. But this did not mean that he enjoyed life idly thereafter. Now he concentrated his energies on constructing inventions that were absolutely novel and out of the ordinary. Nowadays, many see him as a fantasist during this time and they claim that his statements cannot be taken seriously because he was crazy. In fact, Tesla was a crazy personality, but as they say, "Genius and madness are close together." In his own words, "My enemies were very successful in making me out to be a poet and a visionary." He loved to go to the park every day to feed the pigeons. He fed thousands. As he told it, a single one stood out from the crowd. She was special, he said. He took her to his room and fed her every day for months. A relationship developed. If the pigeon was sick, he stayed with her until she recovered. Tesla had never been interested in women, and perhaps he had satisfied his need for love with the pigeon. If the old man had not renounced his patent rights in the past and lived with so much ostentation, he would have been one of the richest people in the world

become. The income from the royalties for his AC motors and other patents would have been huge. The sum would have amounted to 12 million dollars, which today would be a fortune equivalent to a billion dollars. But Tesla had to spend his twilight years in poverty, on the edge of existence. He lived in a hotel room that he had long been unable to pay for. In addition, his best friends were increasingly dying, including Mark Twain and the Johnson couple.

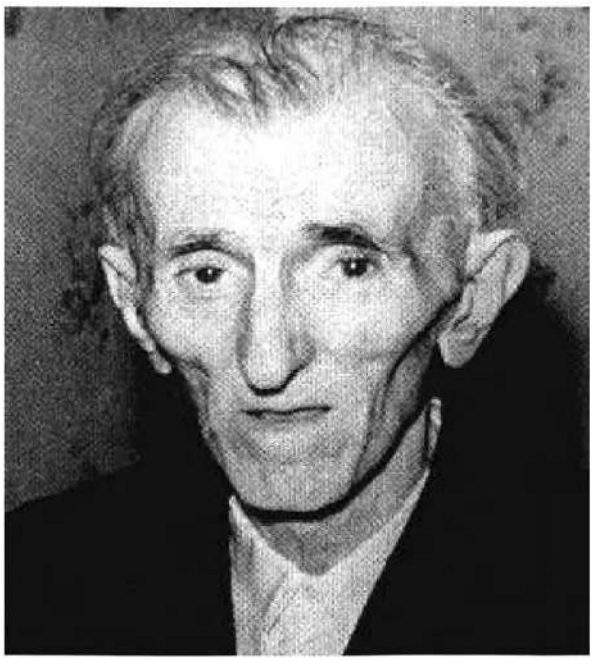


Discharge of several million volts. (This is a photomontage, Tesla was inserted into the picture afterwards).

Tesla received many awards during his life, which made him very proud. He was awarded honorary doctorates in several universities. He was also offered the Nobel Prize. But Tesla refused, because he would have had to share it with Edison. Later, he was not offered this chance again. Tesla died without a Nobel Prize. Despite all the fame of earlier days, he fell into oblivion during his lifetime. The press no longer wrote about the great inventor. One crazy invention he told about at the age of 78 was the death rays. Tesla claimed he could use them to knock swarms of 10,000 planes 400 km away out of the sky. Other ideas included a rocket that would fly 300 miles per second, a machine to send energy into space, a mechanical oscillator to recycle air, a mind reader, and an antigravity machine. Although he was old and many portrayed him as a madman, he still had a sharp

mind. Thus, he refuted a part of Albert Einstein's theory of relativity, namely the cosmological constant. Einstein himself later said that he was wrong about his theory, that it was his "greatest hoax". Some sources claim that Tesla was involved in the so-called Philadelphia experiment. This was the predecessor of the better known Montauk project. This enterprise was awakened in the 2nd World War by the NSA, the National Security Agency, in co-operation with the Navy. Various famous physicists, including Thomas T. Brown and Albert Einstein, were said to have been involved in this. One observer claimed that it was possible to make a Navy ship invisible and even to dematerialize it, i.e. to beam it from one place to another. However, all the ship's personnel were supposed to have perished in the process, and Tesla resigned for moral reasons. Any evidence is missing until today.

In the first days of 1943, Tesla summoned a messenger boy. He gave him a letter to deliver to Samuel Clemens. Tesla was too ill and weak to go himself. However, the commissioner could not locate the person. After Tesla explained to him that it was Mark Twain, whose real name was Samuel Clemens, he was told that he had been dead for 25 years. Tesla did not believe this, as he had spoken to him only the previous day. He sent the assistant away and told him not to come back until he delivered the letter. There was $100 in the letter. Shortly after that Tesla did not want to be disturbed in his room and retired. On January 07, 1943 the life of Nikola Tesla ended. He became 86 years old. The death occurred in his sleep. The official cause of death was thrombosis. The mayor of New York, La Guardia, made a speech on the radio on the occasion of Tesla's death. Among other things, he said: "Nikola Tesla is dead. He died poor, but he was one of the most useful people who ever lived. What he created is great, and the more time passes, the greater it becomes."

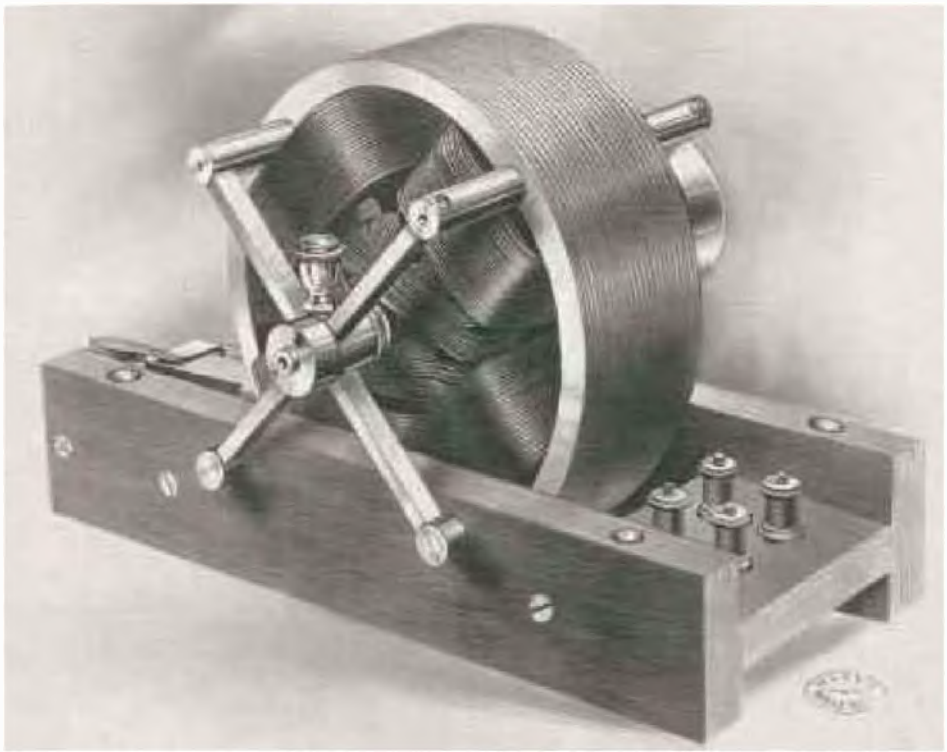


Tesla at the age of 85.

After Tesla's death, the big question was what to do with his legacy. The dead man had not left a will. His closest relatives were five nieces and nephews. One of them, Sava Kosanovic, was Yugoslav ambassador to America. But there were also countless private parties interested in the documents. Even the American state interfered. The OAP (Office of Foreign Assets) took over the case. Everyone wanted Tesla's secret records. However, Tesla kept many of his ingenious inventions to himself. With his photographic memory, he stored his ideas in his mind. It's probably for the best, who knows what would have happened if his powerful inventions had been given to the wrong people! The OAP sealed all the property after his death and stored it in Tesla's final resting place, the Hotel New Yorker in Manhattan. After that, everything was moved to a storage facility at Kosanovic's request. There, however, government officials came several times and photographed the records with microfilm. Those interested were defense research emissaries, a Navy official, and two Navy boatmen. This supports the rumors about the Philadelphia experiment. During these visits, additional documents are said to have disappeared without a trace, including the personal notebook with several hundred pages of Tesla's knowledge. After Kosanovic took responsibility for the inheritance, the FBI wanted to put him behind bars. The reason is probably clear, they wanted the documents from his uncle. Finally, Kosanovic shipped the incomplete legacy to the Tesla Museum in Belgrade, where it still is today. It is also interesting to note that two days before his death, Tesla informed the War Department about a matter concerning his death rays. Are death rays, death, heritage and intelligence related? We may never know. The Tesla file from the FBI on Nikola Tesla was closed in 1943. It contained copies of his documents. However, the file was reopened. The reason given was a circulating false information about Tesla, which they wanted to verify. The organization then announced that no action was required and the file was closed again. A second and final time, the file was opened at the request of the U.S. Army Air Force General. The original requested documents were loaned in their entirety to the Aviation Technical Service Command. However, the latter had not returned it and claimed that it had never received anything.

Tesla's inventions at a glance

The AC motor

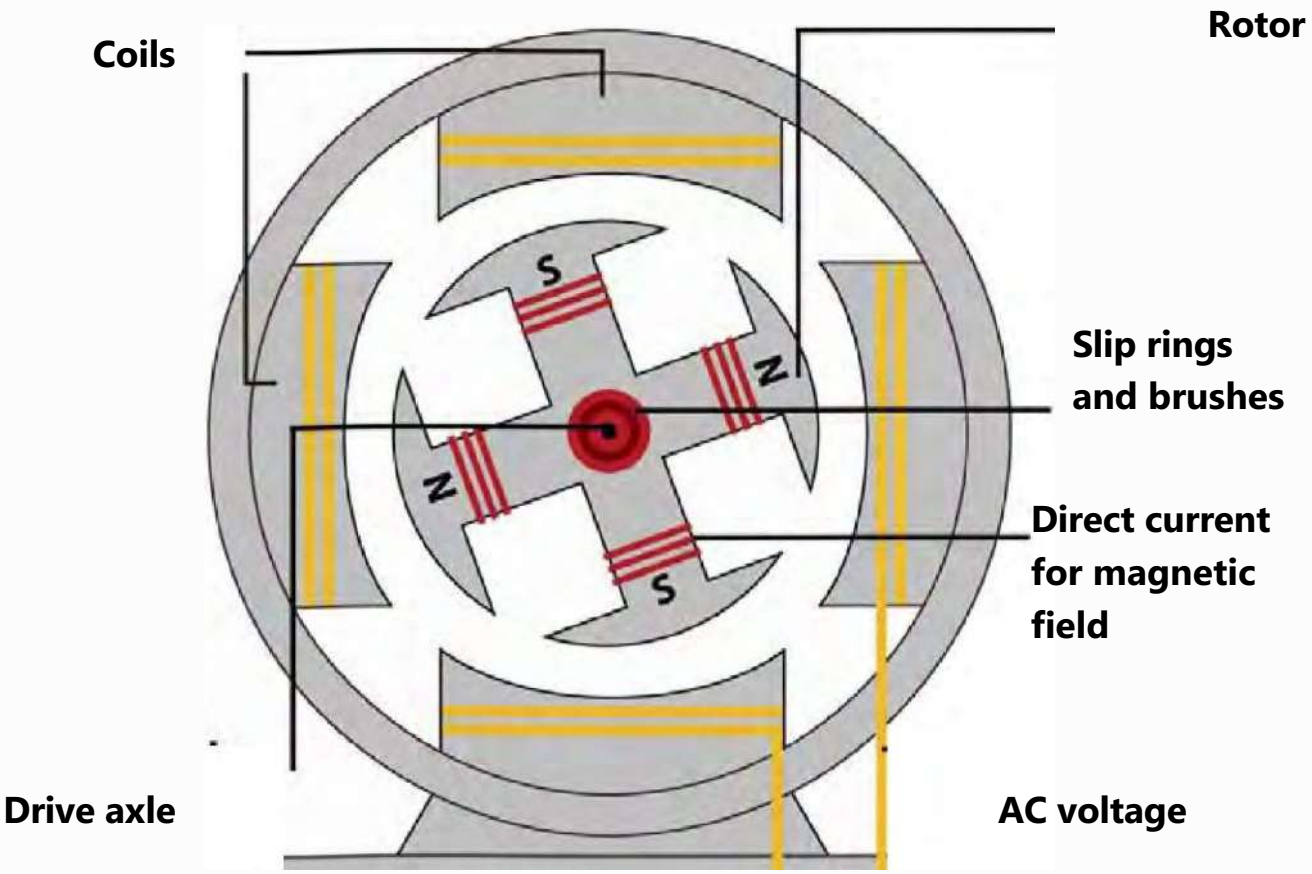


The AC motor.

This is Tesla's most famous invention. The idea of the alternating current motor came to him at the age of 26 when he quoted Goethe: "She advances and retreats, the day has survived, there she hurries and promotes new life, oh, that no wing lifts me from the ground. After her and always after to die. A beautiful dream while she escapes, even to the spirit's wings no physical wing will join so easily!" It came to him like a flash of inspiration, the machine should consist of a rotating element. However, the introduction of his engine did not go as he wished. He encountered a lot of resistance. Until now, all devices worked with direct current and it meant ruin for the lobbyists behind it, would alternating current be introduced by Tesla. Tesla found his greatest opponent in the person of Thomas Alva Edison. After a bitter electricity war, Tesla triumphed over direct current with the help of Westinghouse. Tesla's achievement was not to have rediscovered alternating current. Before him, alternating current had already been used and there were also machines that were fed with it. For example, Elihu Thomson had already produced electric light with alternating current and Werner Siemens had also built alternating current motors. However, all the previous motors were very inefficient. They could not keep up with DC motors. Tesla's great achievement was that through his discovery of the rotating field, alternating current could be used efficiently. The

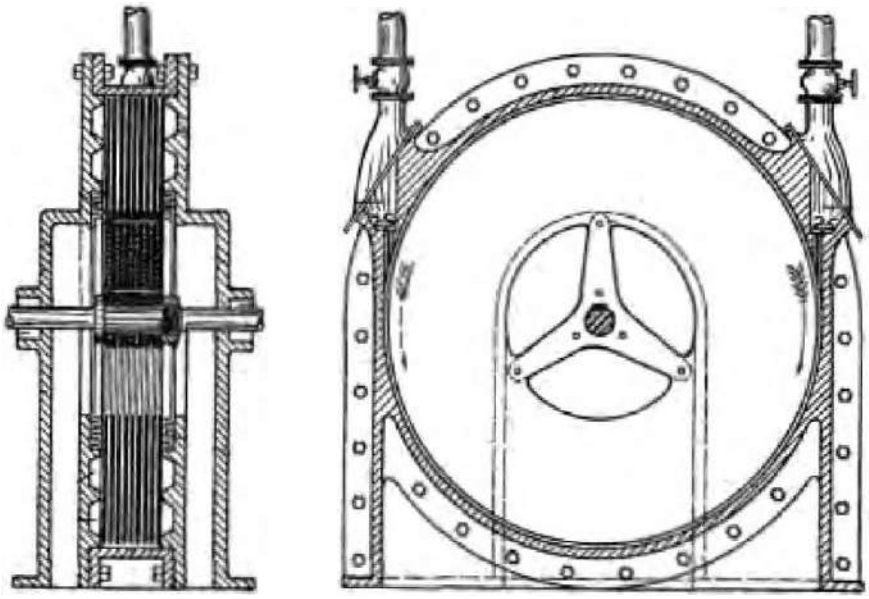
Alternating current could be well up-transformed and transported. During his lifetime, he had developed several motors based on this rotating field. The alternating current system is still used today as Tesla had invented it. The three-phase induction motor can be traced back to him and the multiphase induction motor was patented by him in 1882. **Tesla's patent: 381,968; 1888**

Induction or three-phase motor



electr. energy

Tesla turbine (disc turbine)



Tesla's patent of the disc turbine.

What does a turbine need to work?

Blades and a medium, you will probably have thought of first. Nowadays, this is also true for all conventional turbines. The flowing medium is also absolutely correct, without it nothing turns. However, a turbine can also work without blades. Tesla had invented such an apparatus. In the following it will be shown how it is possible that a turbine rotates completely without blades. Tesla had the patent
1,061,206 for its disc turbine in 1882. The structure of the invention is astonishingly simple, and at first glance it is impossible to see how this turbine is supposed to move.

The core is formed by several smooth discs, which are arranged parallel to each other. When the fluid is injected through a nozzle, it gets between the thin discs and runs in circles until it finally flows out in the center.

But how does a rotation occur? The medium flows in a spiral in a circle. In order for the raceways to become smaller and smaller in the direction of the center, the water or gas must be diverted from its current path to a shorter one. The adhesion between the water and the disks sets the rotor in motion.

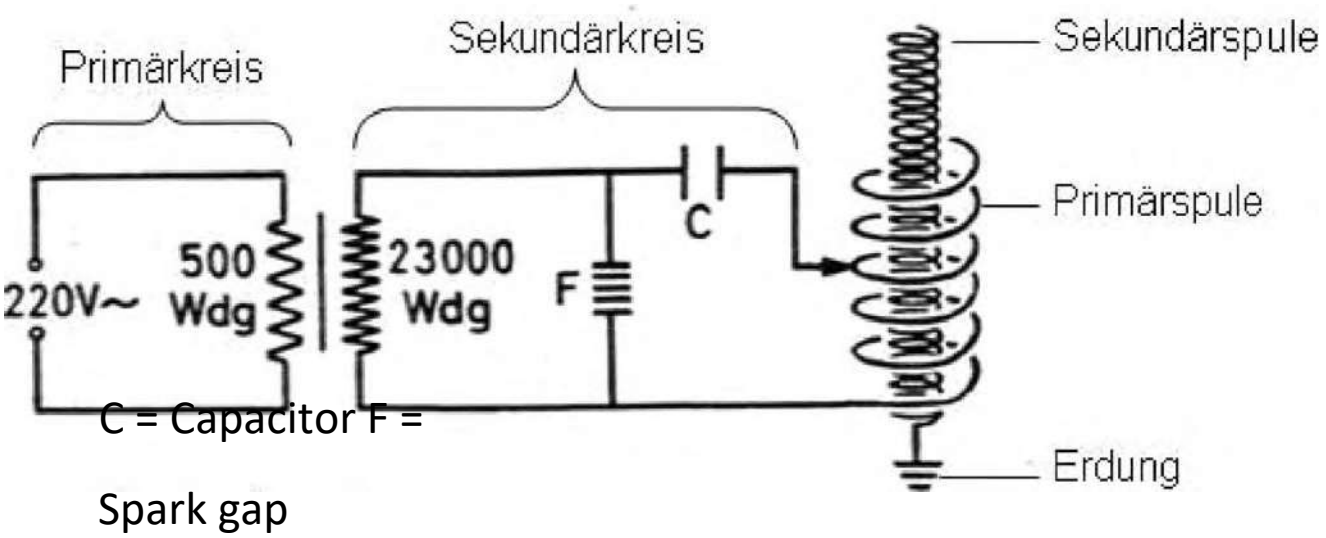
The discs reach extreme speeds and have an efficiency of 95% 95%. The question that now arises is why this turbine is not manufactured.

Their efficiency is high and the structure is simple. The reason is that the rotational speed is exceptionally high and the turbine can no longer be controlled. **Tesla's patent: 1,329,559; 1916 and patent: 1,061,206; 1913**

Tesla transformer (Tesla coil)

This invention has only been made possible by the alternating current. This is an apparatus which, to put it simply, consists of two transformers attached to each other. The core is a multi-wound coil, the so-called Tesla coil. With the help of the first two coils, a low input voltage (e.g. 220 volts) is transformed to a high output voltage (approx. 10,000 V).

The induced voltage charges the capacitor. If the voltage is then high enough, a spark is generated at the spark gap and the capacitor discharges. This produces high-frequency, damped oscillations. Because of the large ratio of turns between the primary and secondary coils, very high voltages are induced in the latter at high frequency. Tesla succeeded in generating voltages up to several million volts and in increasing the frequency almost immeasurably. He had even claimed that with the necessary means it was possible to generate currents with arbitrarily high voltage.



Circuit diagram of the Tesla transformer.

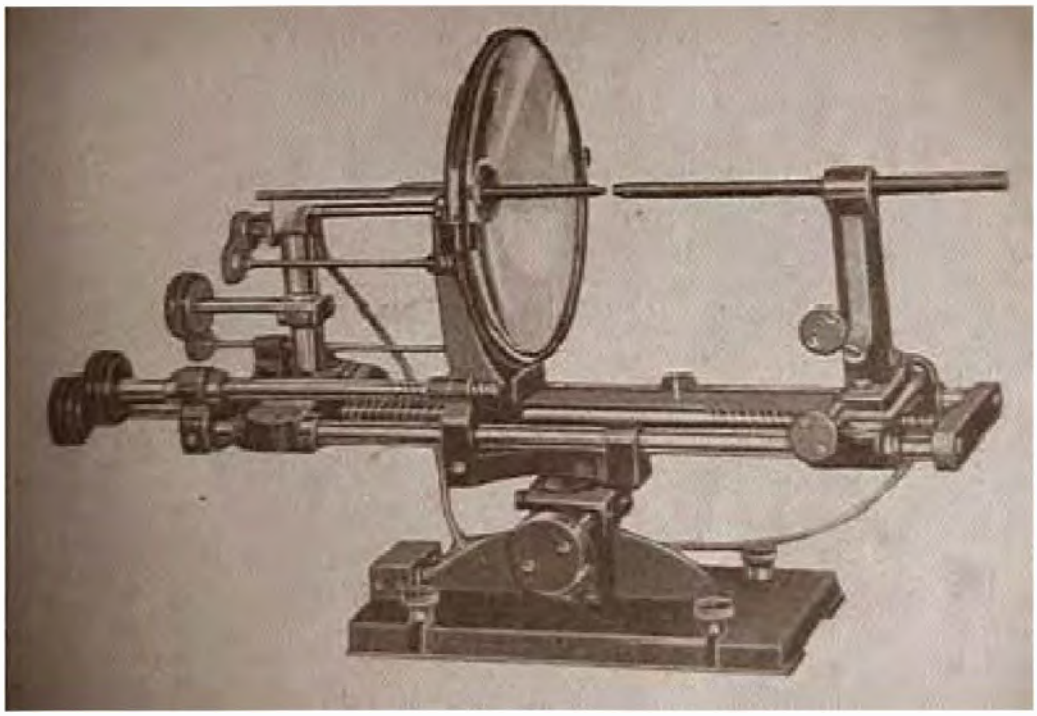
Tesla experimented a lot with high-frequency currents. In this field, he achieved results previously thought impossible. He could produce wonderful discharges. These became several meters long and were very energetic, and the variety of phenomena was huge. A light bulb began to glow near a coil. At one presentation, Tesla had himself placed under a current of several million volts. This caused a bright mantle of fire to surround him, with flames shooting out of his body everywhere. Nothing happened to him, however. One journalist described how he was able to watch Tesla create a fireball in his hand with a mere snap of his fingers. This did not burn his skin, however.
At the Colorado Springs experimental station, Tesla devoted several years of his

Life of the research of high-frequency currents. Here, his experiments had an impact as far as the village several kilometers away. About what he had discovered during this time can only be speculated. In any case, it was spectacular and new.

The high-frequency currents generated by the Tesla coil can be used to heal people, which is what Tesla always wanted to achieve with his inventions. In 1890, he announced that currents can also be used to treat diseases such as arthritis or cancer. If the current is directed to the diseased area, heat is generated, which destroys the cells. This medical branch used to be called diathermy and nowadays it is called hyperthermia. **Tesla's patent: 454.622; 1891**

The invention of the arc lamp

There were light bulbs. One could light up a room without any problems. But incandescent bulbs were not enough for all needs. If you wanted a very bright light, you had no alternatives. That's why Tesla was commissioned in 1885 to improve the already existing arc lamps. After only a short research, he filed the patent. The arc lamp was then the most powerful light source at that time. It could be used as a spotlight and especially in research (microscopy). The most important part of the arc lamp is two carbon rods. Between them there is a voltage. If they are now approached and removed again, then a gas discharge occurs between the rods, the so-called arc.



Drawing of an arc lamp.

Tesla's patent: 335,786; 1886

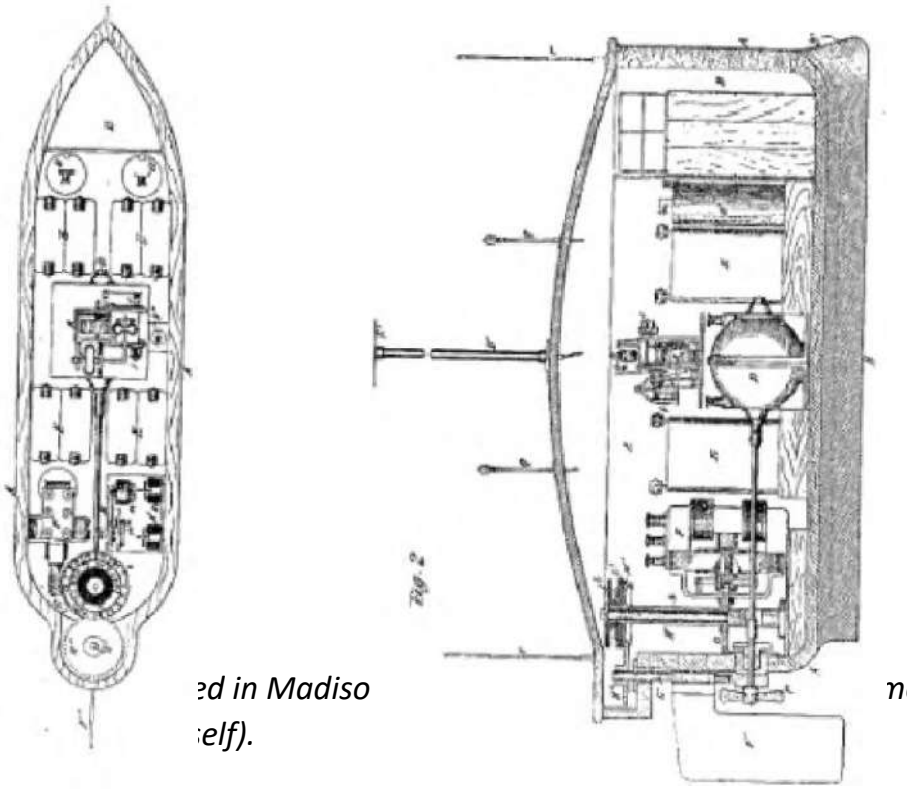
The invention of radio remote control, radar technology

In 1892, Tesla built the first devices that he could control with a radio. When he publicly proclaimed the following year that he had made an invention that he could control without being connected to it, no one believed him, of course. This was unimaginable at the time and was almost considered magic. But Tesla's remote-controlled submarine moved along as if by magic during the presentation. Its operation was limited to steering left and right. An electrical impulse was sent out by a remote control and hit a receiver on the boat. There, the signal delivered electrical energy from a battery, which caused a change in direction.

fr

Submarine.

Tesla had the idea of radar many years before the first radars were built. He laid the foundation in 1917, when he described the exact functioning of a radar device during a lecture. The apparatus emits very high-frequency pulses. These propagate continuously in space until they finally hit an object. At this object they are reflected and some of them move on again in the opposite direction until they reach the receiver again. This principle was adopted by the military and used in World War II. Tesla, who wanted only the best with his inventions, was not aware that radar could be used for war. It was unthinkable at that time that it could be used to detect enemy submarines.

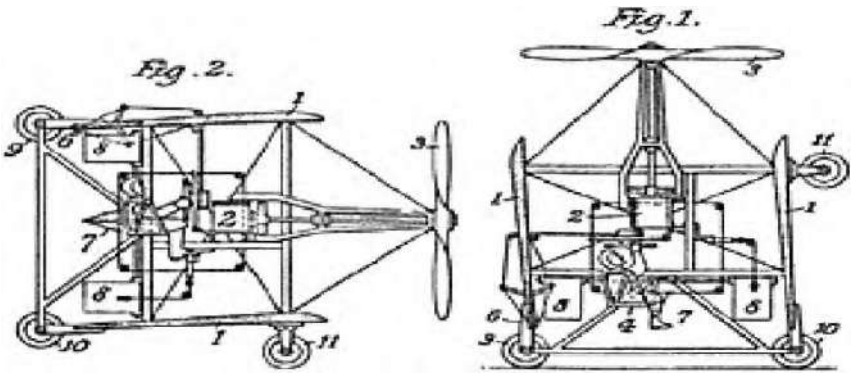


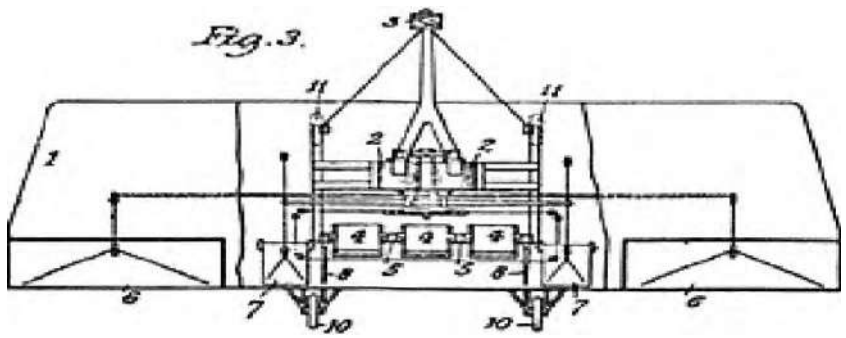
Patent of a boc ed in Madiso mote control and robotics (b elf).

Tesla's patent: 613,809; 1898

Other inventions

This was a selection of Tesla's most famous and fundamental inventions. Most of the patents he filed were in the field of electrical engineering. Among them were patents for an electric generator, electric light bulbs, an ammeter or electromagnetic motors. He also developed a machine for producing ozone or a system for illuminating the sky at night. But he also developed other things that did not fit into his typical field of research at all. In 1928, he patented the VTOL (vertical take-off and landing) aircraft. This was a kind of helicopter, which could fly vertically and horizontally. Unfortunately, the record of Tesla's inventions ended with this patent. After that, he did not care about patenting his ideas.





In New York, he had houses shaken with an oscillator that could artificially generate earthquakes. This even brought him into conflict with the police. But they could not harm him and went away. Nowadays the oscillator has an important part in seismology. Tesla is the real founder of robot technology. He built the first robot before anyone else. One of his boats (see Fig. 19) was also a robot. It steered itself. As mentioned at a previous time, Tesla is the actual inventor of the radio. Marconi had stolen the invention from Tesla and is unfairly praised as the first builder of the radio.

Tesla's other ideas and inventions

The Wireless Power Transmission

Tesla sacrificed his whole life to make possible the transmission of energy without wires. All the time he had the desire to supply every point on the earth with electricity, from a single place. The recipient would not have to pay anything for the energy. Unfortunately, he was not able to complete his project. Today, the landscapes of industrialized countries are covered with high-voltage power lines. These would never have had to be erected had Tesla's scheme succeeded. But with wireless power transmission, some companies would not have been able to make money selling lines. So they did everything t h e y c o u l d t o m a k e sure that Tesla would never get to build his inventions.

Tesla defined three conditions that had to be met in order to send energy across the world:

1. Develop a powerful transmitter to send out the energy.

2. Machine for individualization and isolation of the transmitted energy.

3. Exploring the propagation of currents through the earth and atmosphere.

Tesla wanted to accomplish his plan with the Wardenclyffe Tower. It was to have been used as a huge transmission tower. Its power should have been 10 million horsepower had it been completed. But shortly before completion, a problem arose. Tesla needed more money to complete it. He sought out his investor, J. P. Morgan, and asked him for additional financial support. After the latter refused to pay, Tesla explained to him the true purpose of the construction. Morgan would not have been able to make a profit from the plant himself and pulled out of the affair. Construction was suspended and never resumed. A few years later, the tower was demolished for a few dollars to pay Tesla's outstanding debt. Wireless power transmission could not be realized. Tesla saw it as part of his life's work, which unfortunately he was unable to accomplish. Whether his idea would have worked in the end is a matter of speculation. Critics say that Tesla's principle would have worked on a small scale, but on the scale he envisioned, over the whole world, it would not have been possible. It is impossible to build such a strong transmitter. And which effects this has on nature is also still unclear. Defense machine would have razed all attacking fleets to the ground

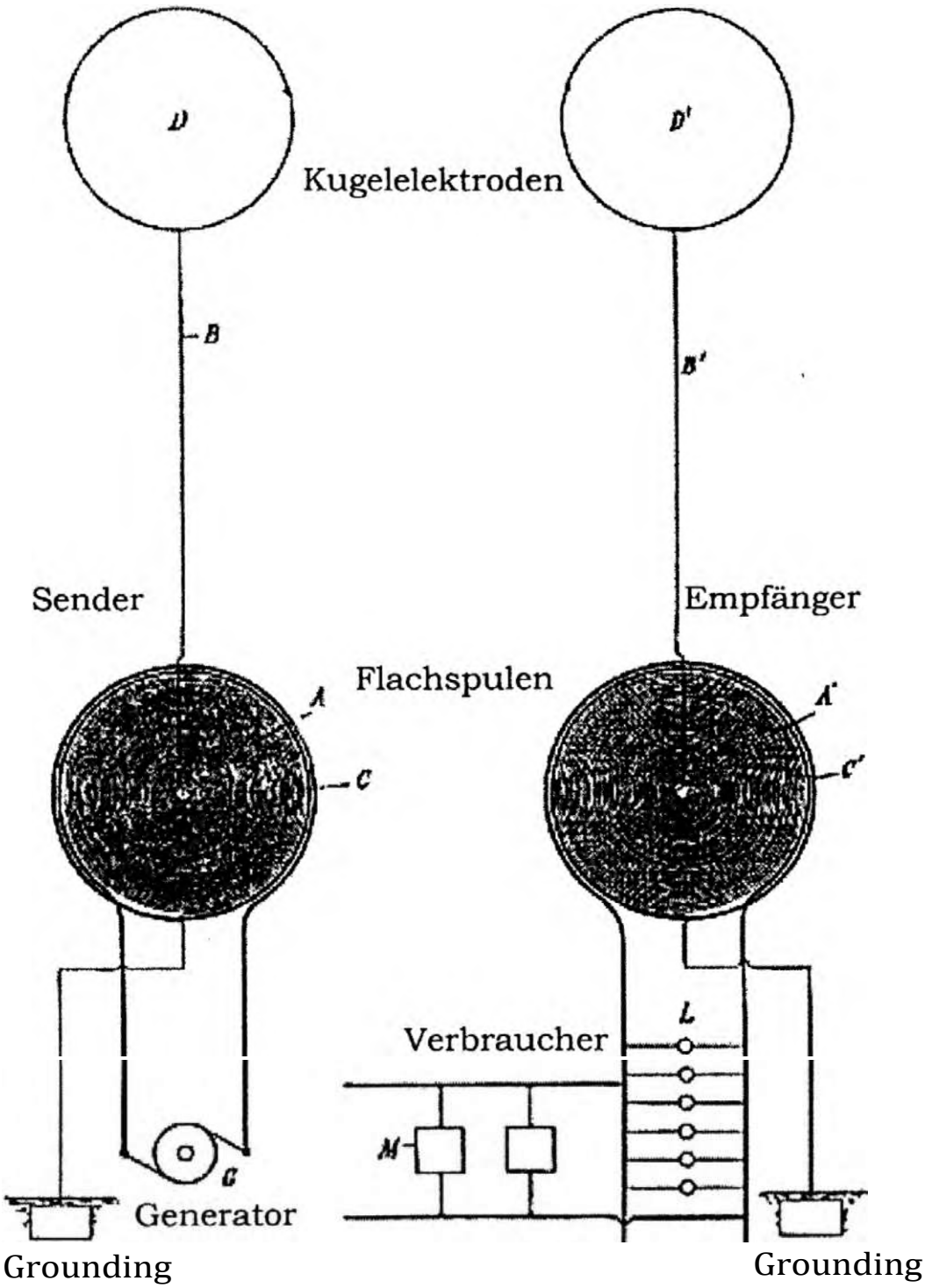


Fig. 33: Wireless power transmission, Tesla's patent No. 645,576 (1900).

Tesla Patent: 645,576; 1900 and Patent: 787,412; 1905

The death rays

Tesla first publicly reported the death rays in 1934 in the New York Times. The headline read: "Tesla Unveils New Death Ray at 78. Invention powerful enough to destroy 10,000 planes at a distance of 400 km. DEFENSIVE WEAPON ONLY. Scientist tells interview of device that can kill without leaving a trace."

The THEL system.

With this invention, Tesla wanted to bring peace to the earth. His idea was that there would be no more wars once the machine was built. The defense machine could have razed all attacking fleets to the ground without leaving a trace. However, Tesla saw the danger that the death ray could also be used as an offensive weapon, as it would have put a lot of power in the hands of the owner. It would have been the ultimate weapon, with a power that is unimaginable and a range that seems incredible. According to the documentary Master of Lightning, the British were the first to experiment with the death rays and the bundled light based on Tesla's invention

is supposed to be based on. The THEL system is a laser that can destroy approaching shells and missiles using only energy. Passenger aircraft are to have this missile defense system installed for protection.

Theories exist worldwide that the meteorite impact of Tunguska has a connection with the death rays. Tesla wanted to demonstrate the power of his invention. Its destructive power was to be unleashed in the Shoreham area on Long Island. Since the amount of energy was very difficult to control, the electric wave missed its target. Tunguska and Shoreham are on the same latitude. In addition, no impact crater was found in Tunguska. The trees were down and the bang was still heard at a distance of 1,000 kilometers. The official theory is that the destruction came from a hydrogen meteorite that vaporized just before it hit the Earth, leaving behind a huge sound wave. In any case, the explosion had a tremendous force, that of 10 to 15 megatons of TNT.

Information on other inventions

There are many rumors and flawed documents that try to explain what else Tesla is supposed to have invented that is out of the ordinary. It is difficult to say at the present state of affairs how much truth there is behind it. So Tesla should have invented a machine which could produce energy freely. It could have drawn from the aether, which invisibly encompasses everything The key words here are space energy, radiation energy and zero-point energy. You should be able to put this small apparatus in your garden and the whole house would be continuously supplied with electricity. Numerous replicas, based on the patent 685.957, were unsuccessful. Furthermore, he was supposed to have invented a light bulb, but not a normal one. The difference is that it started to glow as soon as someone touched it. Small currents are constantly flowing through people. These are then converted into electric light by this light bulb. Tesla had demonstrated this light bulb several times. An essential component should be a strongly evacuated vacuum. However, a replica never succeeded. Although the X-rays got their name from Wilhelm Conrad Röntgen, their discoverer, he should not have been the first to experiment with them. Tesla should have already known about these rays and also told about them at lectures. Röntgen had discovered them only years later.

Questions and answers about Tesla

Tesla was a unique and above-average person. What fascinates the many people about Nikola Tesla?

- Tesla was not a material man. He renounced all his wealth by refusing the royalties on his patents, because at that time there was an industrial crisis and Westinghouse would have gone bankrupt with his company. He reneged on the contract. Today, he would otherwise be one of the richest people in the world.

- Furthermore, he had promised energy to the whole mankind. This he also kept. The idea was free electricity. However, this was prevented by individual industrialists for reasons of power.

- **For many, what is Nikola Tesla's greatest invention?**

- In any case, the alternating current system, which is also still used worldwide. If you look at the earth from space at night, you can see all the lights in the big cities. That is Tesla's achievement.

Can you really say that he was a genius?

- In any case, he was unique. There is only one inventor, Edison, who also applied for over 1100 patents. 700 of the 1100 applied for, were granted to Tesla. He was the greatest inventor of modern times, because he had worked out all the patents himself, in contrast to Edison, who registered the inventions of his employees.

- He is also the only physicist to whom a sect church is dedicated. He is revered by the members in Santa-Barbara, USA.

And was Tesla a fantasist?

- He loved to be loved by everyone.

He had always had strange preferences and phobias, for example he was afraid of bacteria and never had a steady partner. Was Tesla socially incompetent?

- You can't say it like that. He sacrificed himself for mankind, for whom he wanted to let his machines play. He wanted only the best for people. He did not reach his goal of living to be 150 years old because he was hit by a cab in 1937. He was never able to recover properly and died a few years later.

Tesla and women?

- He had had many admirers. Especially Katharine Johnson, daughter of an influential publisher. Tesla was afraid of losing his mind to women, because he could not concentrate 100% on his science. He sacrificed himself completely for the world.

All his life, images appeared before his mind, accompanied by flashes of light. Were these visions?

- Madness and genius are close to each other. What this phenomenon really was, is not yet researched today. This is still written in the stars.

Couldn't this be the origin of Tesla's inventiveness?

- That was put into the cradle of the man. Everyone has a talent. Tesla's talent was, among other things, his inventiveness. It came down from above, something oversized. It's impossible to say exactly what it was.

Tesla claimed to be in contact with extraterrestrials. What can you say about this subject?

- This began in 1899, when he had done research in Colorado Springs. There he had various experimental stations with which he sent signals, or wireless energy. The signals did not stop at the atmosphere and went on to Mars. Likewise signals arrived at the transmitting or receiving station, which came after Tesla from Mars.

At his age, he claimed to have invented many fancy things, such as death rays. Was he just trying to attract attention or was he speaking the truth?

- Today, the Americans have special laser weapons, the bundled light. Tesla experimented with the death rays and said he could bring the world wars to an end overnight. A few years ago there was a program about it on TV, where a rocket flew off and after that a big spotlight, just the bundled light (THEL system), appeared. The rocket was destroyed.

Is the Tunguska event related to Tesla and his death rays?

- This has never been properly researched. Many tend that it has a connection. However, there are no official documents on this.

Tesla's greatest enemies were the lobbyists. He said himself, "My enemies were good at portraying me as a visionary and a poet." Was that so?

- When money and power come into play, the one who is stronger wins. Tesla was not a businessman or a politician. His religion was his science. He lived for his ideas and would even have died for them.

After his death, numerous documents and machines disappeared. Who was interested in them?

- Sava Kosanovic, the then ambassador of the Kingdom of Serbia, had a conflict with the FBI. He complained why all the documentation had been stolen. Mr. Hoower from the FBI replied that they had nothing to do with it. Eventually it came out that the FBI had had a hand in it. In Margaret Cheney's book, man out of time, it was mentioned that several countries have the secret documentation of Tesla. Among them are the Canadian and American governments, Russia and Great Britain.

Many of his inventions, often patented, are not credited to him or are kept quiet, such as the Tesla turbine. Why?

- At that time, there were not many patent offices, only in England and the USA, the rest of Europe did not have any. When Tesla applied for so many patents, the officials hardly kept up with the processing of his inventions. This has its effects until today.

Is Tesla the true inventor of the radio?

-1895 Tesla proved for the first time that he was using radio signals. He transmitted signals from one laboratory to another in New York. Guglielmo Marconi attended Tesla's lectures. Whether Edison was in on it is a matter of speculation. In any case, Marconi used 17 of Tesla's patents to build his radio. In 1901 Marconi sent the first signals from Europe to America. Tesla was incensed, even pissed off. When a journalist asked him:
"What do they say about Marconi?" To which Tesla replied, "Marconi is a good man, let him continue to use my 17 patents." Later, there was a court case in New York City, where Tesla was rebuffed in the first instance in 1917. After Tesla's death, in 1943, the Supreme Court had granted that the entire invention of the radio was due to Tesla. Nevertheless, the Nobel Prize had been awarded to Marconi, and this cannot be revoked overnight.

Why does Tesla rarely appear in history books, even though he had accomplished so much?

- In America, the history books are full of Tesla, in Europe less so. The information never really made the leap across the Atlantic, as there was little documentation. The Tesla Society is now pooling the information, with cooperation from America and individual Balkan countries, and has published it online. We also have the most activity with the many exhibitions about Tesla, even more than the Tesla Museum in Belgrade. In our 13 exhibitions in the last 24 months we had over 180,000 visitors.

How should free energy work according to Tesla?

- Up to now no official machine exists which can tap energy from the zero point out of the ether. However, evidence does exist. A major piece of evidence can be found in Hamburg, Germany, where the then director of the German Inventor's House, Heinz Jebens, visited Edison and made a side trip to Tesla twice, in 1930 and 1931. He examined the Tesla Car, the so-called Pierce Arrow, which is a converted luxury car. The car worked with a converter, the operation of which, unfortunately, cannot be understood today, and drove about 130 km/h. It worked without gasoline, Tesla only had to push two iron rods into the engine and after that it ran. Hitler was also interested in it. I don't think the industrialists would be interested in such a car.

- If we had such cars, the world would become much faster. From one day to the next, there would be 20,000 cars in a village instead of 10,000. How would that turn out? We would become quite wasteful and everything would go too fast for us. The question is, are we willing to pay the price if we could get the energy for free? I think it would get out of control.

And what benefits would free energy have for the world?

- There are definitely many advantages. But it is difficult to judge whether there are more advantages or disadvantages. You would just have to sit behind it and see what the pros and cons are.

His inventions would have a lot of power, would be nowadays all fully researched and work. With a seismological device, he should have been able to destroy entire cities. Would his legacy be a blessing and peace or destruction for humankind?

- Tesla wanted all people to be happy and without suffering. He renounced wealth and women for his ideals. I don't think he wanted to use any death rays. Tesla knew that people always want more and more. So he also knew about the atoms, but always said this does not exist. He pleaded that the atoms can be very harmful and was concerned to erase the attention in it away.

Interest in Tesla has risen again recently. What do you think is the reason for this growing interest?

- The decisive factor was definitely the 150th anniversary. We did a lot for it with our exhibition. We made many visits to the governments.

What efforts are being made worldwide to revive Tesla's inventions?
- Wireless energy transmission is the dream of the future. At the moment, research is being carried out diligently in the Black Forest and at MIT (Massachusetts Institute of Technology). So far, they have succeeded in transmitting energy with a strength of 40-50 watts. Who comes out on top will be decided by the money. Whoever gets the big grants will be the winner. Tesla also already failed because of the money. The investor, J. P. Morgan did not want to give him any more money when Tesla revealed his energy to him. He wanted to give away the power for free to everyone. Morgan could not have made a profit from it and forbade his support. Two examples of the use of wireless energy are that electric cars would no longer need to be refueled because they get power from below, and that cell phones would no longer need to be charged by cable.

Tesla in today's world

Tesla is, so to speak, in the process of resurgence. After it was quiet around him for many years, he has been much more present again for a few years. On the Internet you can find numerous sites and forums that write about the inventor. Tesla companies are looking for appearances in public. Tesla's left behind documents are researched in the research centers and the machines are rebuilt. However, much remains unclear and unsubstantiated. All of Tesla's patents were published a few years ago. They are freely available to all and are being used. Some have been able to gain great fame by working on individual patents. But Tesla's degree of fame is still low in Europe. In school, one learns little or nothing about him. If one were to ask for Nikola Tesla on the street, accordingly few people would know this inventor. As seen in the previous chapter, we owe Tesla that many things in the world work the way they do today. I am thinking especially of alternating current, which is used to power the vast majority of technical devices. Each and every one of us is heir to Nikola Tesla. Stamps with Tesla printed on them appeared in various countries. They appeared in Croatia, Ghana and Palau, among others.

As of 1994, Serbian banknotes feature Tesla's likeness. He used to be on three different notes, but today he still fascinates on the 100 dinar note. A theme park about Nikola Tesla was recently built in his hometown of Smiljan. The mad professors in the comics, who want to destroy the world, are mostly based on the person Nikola Tesla. They often have a laser weapon, which is a reference to death rays, with which they want to destroy the world. For example, he had a guest appearance in the Superman comics. In the video game "Command & Conquer: Red Alert", one of the strongest defensive weapons was a Tesla coil, which would hit the enemy with an electric shock.

eliminated. The Hollywood movie "The Prestige" is essentially about a Tesla invention that can duplicate objects. Tesla is embodied by the actor David Bowie. A few years after his death, in 1960, the physical unit TESLA was introduced. Only a total of fourteen physicists came to the honor of having a unit named after them. TESLA describes the magnetic flux density. An American pop-metal band set out to bring Tesla his due fame worldwide. They called themselves Tesla and sing about him and his deeds in their songs. Tesla Motors is a company that produces electrically powered cars. These run on alternating current and no gasoline at all. Overnight you plug the car into the wall socket and in the morning it is ready to drive. The performance is comparatively great. Since Tesla focused on new technologies and the alternating current, the company took Tesla as its namesake.

Car from Tesla Motors.

Now, with this chapter, you could already take a deep look into Tesla's life and inventions. For us, Tesla is the greatest inventor of all times and was ahead of his time, technically as well as morally, by many decades. Even today, his greatness has not been understood, many of his inventions would still be very relevant. His legacy is in any case a huge enrichment for all mankind. It is a pity that his enemies had such great success in making Tesla small. Good always attracts a lot of evil. Good was Nikola Tesla undoubtedly, how many people would have renounced their royalties for the alternating current or would have wanted energy for free for every inhabitant of the earth.

Nikola Tesla patents in German

In this chapter you will learn a few patents of Nikola Tesla translated into German.

Here is a translation of the original patent specification from 1901 written by Nikola Tesla:

I, Nikola Tesla, citizen of the United States of America, residing in Manhattan, State of New York, have invented certain new and useful improvements in the use of radiant energy - the following is a specification of which the drawings are a part. It is well known that certain radiations (ultraviolet, cathode, X-ray, or the like) have the property of either charging or discharging conductors, the discharge being particularly noticeable when the conductor which the radiations strike is *negatively charged. These radiations are usually considered to be vibrations of extremely small wavelength. Some explain this phenomenon by the fact that these vibrations ionize or make conductive the atmosphere through which they pass.*

However, my own observations and experiments lead me to believe that the sources of this energy emit tiny, highly electrically charged particles of matter at great velocity which are capable of charging an electrical conductor - or, if this does not occur, are nevertheless capable of discharging a charged conductor of electricity, either by "physically carrying" the charge - or in some other way. My present application is based on a discovery I made when rays or radiation fall on an insulated conducting body connected to one of the terminals of a capacitor, while the other terminal can independently either receive or deliver current. As long as the insulated body is exposed to radiation, current flows into the capacitor, which can accumulate an infinite amount of energy under the following specifications. During a period of time when the rays can act, a powerful discharge can occur, which can be used to operate or control electrical equipment or otherwise.

In the application of my discovery, I prefer to use a capacitor of considerable electrostatic capacity and connect one terminal to an insulated metal plate or other conductor which I expose to the radiation of matter.
Since electrical energy is absorbed very slowly by the capacitor, it is important to build it with great care. I use the best quality mica as the dielectric (Wikipedia: A ***dielectric*** *(plural: dielectrics) is any electrically weak or non-conductive, non-metallic substance whose charge carriers are generally not freely mobile. A dielectric can be a gas, a liquid, or a solid. Dielectrics are usually referred to when they are*

materials are subjected to electric or electromagnetic fields. Dielectrics are typically non-magnetic). I insulate the fittings with great care so that the device will withstand great electrical pressure without leakage, and also not cause noticeable electrification if a sudden discharge occurs. In practice, I have had the best experience with capacitors under patent 577 671, which was granted to me on Feb. 23, 1897. The above precautions should be more carefully observed the slower the charging takes place and the shorter the time in which the charge accumulates.

The insulated plate, etc., should be as large as practical for the matter irradiation. I have ensured that the amount of energy to be absorbed per unit time is nearly proportional to the area exposed to radiation under identical conditions. The surface should be clean and finely polished or coated. The second fitting or terminal of the capacitor can be connected to a battery or other electrical apparatus that can conduct electricity. An easy way to supply positive or negative electricity is to connect it to an insulated conductor at some height in the atmosphere (positive) or to a grounded conductor (negative).

Since matter radiation normally brings positive charge to the first capacitor terminal, I connect the second to ground because that brings negative electricity most easily. To use the accumulated energy in the capacitor, I also connect it to a circuit that includes an instrument to operate it, and a switch that can open or close the circuit. The latter can be operated either by the stored energy or otherwise. The radiation or rays can have a natural source (sun) or artificial (x-ray). My discovery will hopefully be more understandable by the following detailed description and drawings. Figure 1 is a diagram showing the typical elements when the device is operated by the stored energy only. Figure 2 is a modified arrangement where the switch is operated independently. In Fig. 1, C is the capacitor, P is the insulated plate exposed to radiation, P' is an additional plate or capacitor, all connected in series.

The terminals T and T' of the capacitor are also connected to a circuit which includes the receiver R and a switch d. This consists in this case of 2 very thin conductive plates t and t', which are very close to each other and very mobile, the latter either because they are very flexible or by the way they are fixed. To ensure good operation, they should be in a vacuum container. The receiver R consists of an electromagnet M, a movable armature a, a retractable spring b and a switching wheel w, which has a spring lock that is rotatably mounted to the armature a. The spring lock w is a spring lock. In such an arrangement, the incident radiation on Peine will cause storage of electrical energy in capacitor C.

This phenomenon can best be explained like this:
The sun or other sources send tiny positively charged particles of matter which, when they hit P, charge P up. Since the second terminal of the capacitor is grounded, which can be understood as an infinite reservoir of negatively poled electricity, a weak current flows incessantly into the capacitor. Since the matter particles are very small and therefore very strongly charged, the charging of the capacitor can continue practically indefinitely*, even to the destruction of the dielectric. Therefore, the switch should break the circuit when the capacitor reaches the designed charge. Therefore, Fig. 1 shows that plates t and t' close the circuit between terminals T and T' when the intended charge is reached. This allows a current flow that charges the solenoid M and therefore pulls down the armature a and gives a partial rotation to the switch wheel w.*

When the current flow stops, the armature is retracted by the spring b, but without moving the switching wheel w. At the same time the plates t and t' are separated and the circuit is back in its original state. A modified arrangement is shown in Fig. 2, in which the source S is a special X-ray tube invented by me, having only one port k (made of aluminum) - semi-spherical, with polished surface at the front, from where the radiation emanates. This may be excited by connection to any generator with sufficient electromotive force.

In any case, it is important that the tube is discharged as completely as possible, because otherwise there may be no effect at all. The discharging mechanism, which is connected to the terminals T and T'of the capacitor, consists here of the primary coil p of a transformer and a switch, which has a fixed terminal or brush (t), and a movable terminal in the form of a wheel with insulated and conducting sections. This can be moved at any speed. In inductive connection with the primary coil p is a secondary coil s with many more windings, to the end of which the receiver R is connected. When the tube now emits radiation, this causes a positive charge on the plate P and the capacitor terminal T, while the terminal T' constantly receives negative electricity from the plate P'.

This, as already explained, stores electrical energy in the capacitor. This happens as long as the circuit with the primary coil k is interrupted. Then, when the circuit is closed by the rotation of the terminal t', the stored energy is discharged by the primary coil k, causing an increase of induced energy in the secondary coil s, which operates the receiver R. According to what has been said before, it is clear that the terminal T', should it be connected to a plate that supplies positive electricity instead of negative, the radiation should supply the plate P with negative energy. The source S can be an X-ray or Lenard tube. But to be most effective, the electrical pulses which excite it should be exclusively, or at least largely, of the same valence. If normal symmetrical alternating current is used, precautions should be taken to hit P only when this is true (electrical pulses of the same

valence). If now the radiation of the source is terminated or its intensity is changed, e.g. by periodically interrupting or rhythmically varying the current supplying the source, this has an effect on what happens in the receiver R. Thus, one can transmit different signals, etc. In addition, it is clear that a switch which operates when there is a certain amount of energy in the capacitor can be used instead of the design described in Fig. 1. Also, the arrangement of the individual parts of the apparatus can be varied to a large extent.

Original patents from 1901 with witnesses signature

nu. aou.aoö. Patentöd Nev. 5, 1901.

N. TESLA.

METHOD 0F UTILI2ING RADIANT ENERGY.

(ApptluUoo Äl "d lUr. 31. 1901.1

(No Model.)

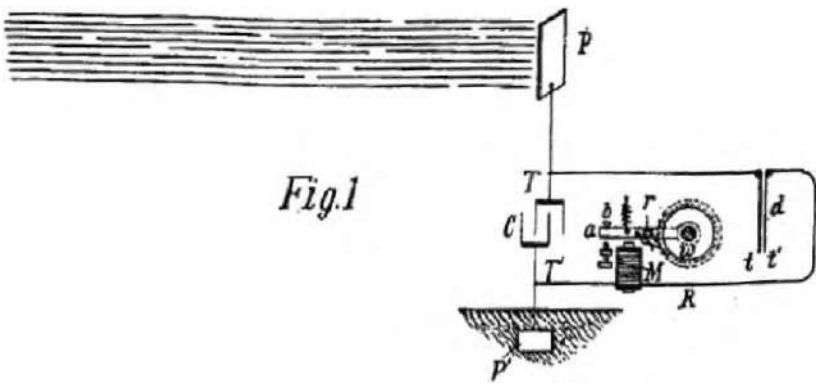


Fig.1

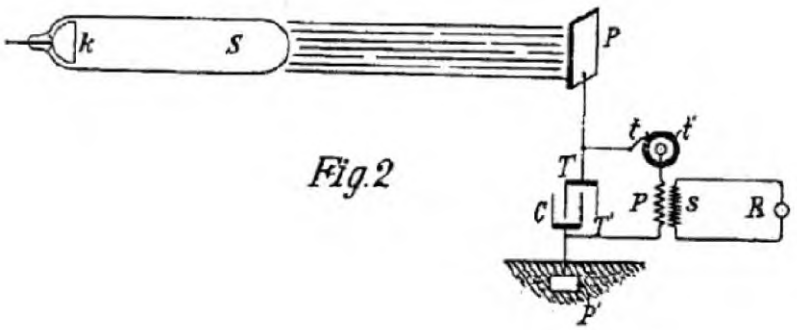


Fig.2

'Witnesses:

Raphael Netter
M. Lawson Dyer

Nikola Tesla

by Kerr, Page & Cooper
Attys

And here the original patents in English

UNITED STATES PATENT OFFICE.

NIKOLA TESLA, OF NEW YORK, N. Y.

METHOD OF UTILIZINQ RADIANT ENERGY,

SPECIFICÄTION forming part of Leiters Patent No. 385,958, dated November 5, 1901.

Application £led March 21,1801. settel Bo. 62,154. tBomoie!.)

To all ichom it may concern:

Be it known that I, NIKOLA TESLA, aother Citizen of Ilie United States, residingat the boroughdenser, Manhattan, in tbe city, connty, and Statestatio of New York, have invented certain new andminals to an insulated meta! plate or other nseful Improvements in Methods of Utilizingeonducting body exposed to the rays or Radiant Energy, of which the following is astreams of radiant matter. It is very itnporspecifIcation.refcrencebeing hadtotheoraw-tant,particnlarly in view of the fact thatelec- 60 lings accompanying and forming apart of thetrical energy is generally suppliod at a very io satne.

It is well known that certain radiations-same as those of ultra-violet light, cathodie, rays, ortbelike-possess the prop-essing charging and diseharging eonductorsthe armatures, so that the Instrument may 15 of eleetricity, the discharge being particu-withstaud great eleetrical pressures withom larly noticeable when the condnctor uponleaking and may leave no perceptible electri- which the rays impinge is negatively electri-fication when diseharging instantaneously. fied. These radiations are generally consid-In practice I have found that the best results 70 ered to be ether vibrations of extremely smallare obtained with condensers treated in the 20 wave lengtbs, and in explanation of thephe-men described in a patent granted torne nomena noted it bas been assnmed by someFebruary23,1897,No. 577,671. Obviouslythe authorities that they ionize or render con-above precautions should be the tnore rigor- ducting tbe atmospbere throngh which theyously observed the slower the rate of charg- 75 are propagated. My own experiments anding and the smalier the time interval during 25 observations, however, lead me to conclu-which the energy is allowed to accumulate in sions raore in accord with the theory hereto-tbe condenser. The insulated plate or cou- fore advanced by me that sources of suchdneting body should present as large a snr- radiant energy throw ofi with great velocityface as practicable to the rays or streams of 80 minute particles of matter which are stronglymatter, I havingascertained that the amount 30 electrified, and therefore capable of chargingof energy conveyed to it per unit of time is an electrical condnctor, oreven if not so mayunder otherwise identical conditions propor-. at any rate discharge an electrified conduc-tionale to the area exposed,or nearly so. Fcireither by carrying often bodily its charge orthermore, the surface should be clean and 85 Otherwise,

35 My present application Is based upon a dis- The second terminal or armature of the con- eovery which I have made that when rays or denser may be connected to one of the poles radiations of the above kind are permittedfrom a battery or other source of eleetricity or to fall upon an insulated eonducting bodytoany conducting body or object whatever of 90 connected to one of the terminals of a con-such properties or so conditioned that by its 40 denser, while the other terminal of the samemeans eleetricity of the requiredsign will be made by independent means to receive orsupplied to the terminal. A simple way of to carry away eleetricity, a current flows intosupplying positive or negative eleetricity to the condenser as long as the insulated bodythe terminal is to connect the same either to 95 is exposed to the rays, and other the condi-an insulated condnctor, supported at some 45 tions horeinafter specified au indefinite ac-height in the atmospbere, or to a grounded cumulation of eleetrical energy in tbe cou-condnctor, the former, as is well known, fur- denser takes place. Tbis energy after a suit-nishing positive and the latter negative elec- able time i nte rval, du ring which the rays aretricity. As the rays or supposed streams of 10c allowed to act, may manifest itself in apow-matter generally convey a positive charge to 50 erful discharge, which may be utilized forthe first condenser terminal, which is connect- theOperation orcontrol of mechanicalor elec-

ed to the plate or condnctor above mentioned,opposite terminal of the condenser beingcon- I nsually connect the second terminal of thenected to the ground, which may be consid- c.ondenser to the grouud, this being the mostered as a vast res ervoir of negative electricity. convenientwayofobtaining negative electric-a feeble current flows continuously into the ity, dispensing with the necessity of provid- condenser, and inasmuch as these supposedly ing an artificial source. In order to utilizeparticles are of an incouceivably small radius for any useful purpose the energj' accumu-or eurvatnroj and consequently charged to a lated in the condenser, I f nrthermore connectrelatively very high potential, this charging to the terminals of the same a circnit inclnd-of the condenser tnay continue^ as I have ro ingan Instrument orapparatus which itisde-found in practice, almost indefinitely, even to sired to operate and another Instrument orthe point of ruptnring the dielectric. Obvi- device for alternately elosiug and opening theously more volatile circuit - controller be em- circuit. This latter may be any form of cir-ployed it should operate to close the circnit cuit-controller, with fixed or movable partsin which it is included when the potential in or electrodes, which may be actuated eitherthe condenser has reached thedesired magni-by th e st 0 re d e n e rgy o r by i n d e.pe nde n t mtude. Thus in Fig. 2 when the electrical pres-eans. sure at the terminals T T' rises to a certain value The rays or radiations which are to be used-predetermined the plates *f.1',* attract- ized for the operation of the apparatus aboveing each other, close the circnit connected to described in general terms may be derivedthe terminals. This permitsa flow of current so from a natural source, as the sun, or may bewhich energizes the magnet M, causing it to be artificially produced by such means, for ex-dra w down the armature *a* and impart a par- ample, as an arc-lamp, a Roentgen tube, andtial rotation to the ratchet-wheel. As the the like, and they may be employed for acurrent ceases the armature is retracted by great variety of useful purposes. the spring *b* without, however, moving the Mydiscovery will be more fullyunderstoodwheel *w.* With the stoppage of the current from the following detailed description and the plates *1t'* cease to be attracted and sepa- annexed drawings, towhich reference is nowrate, thus restoring the circnit toits original inade, and in which- condition.

Figure 1 is a diagram sho wing typical forms Nany useful applicatioos of this method of of the devices or elements as arrauged andutiliziug the radiations emanating from the connected in applyltig the method for the op-sun or other source and many ways of earry- eration of a mechauical contri vance or instruct- ing out the same will at once suggest them- ment solely by the energy stored; and Fig. 2selves from the above deseription. By way is a diagrammatic representation of a modi-Of Illustration a modified arrangement is fied arrangement suitable for special pur-shown in Fig. 2, in which the sourceS of ra-poses, with a circuit-controller actuated bydiant energy is a special form of Roentgen independent means. tube devised by me having but one terminal

Referring to Fig. 1, C is the condenser, Pfr, generally of aluminiuin, in the form of the insulated plateorconductingbody ,whichhalf a sphere with a plain polished surface is exposed to the rays, and P' another plate oron the front side, from which the streams are conductor, all being joined inseries.as shown.thrown off. It may be excited by attaching The terminals T T of the condenser are also connected to one of the terminals of any generatorof connected toa circuit includinga receiver R,sufficiently-high electromotive force; but which is to be operated, and a circniUcontrol-whatever apparatus be used it is important ling dev-ice *d,* which in this case is eomposedthat the tube be exhausted to a high degree, of two very thin cond ucting-plates *11',* placedas otherwise it mightprove entirely iueffect-. in close proximity and very mobile, either byive. The working or discharge circuit con- reason of extreme flexibllity or owing to thenected to the terminals T T' of the condenser oharater of their support. To improve theirincludes in this case the primaryjp of a trans- action, they should be inclosed in a receptacleformer and a circuit-controller comprislng a from which the air may be exhausted. Thefixed terminal or brush *t* and a movable ter-receiver K is shown as consisting of an elec-minal *t!* in theshapeof a wheel with conduct- tromagnet M, a movable armature *a,* a re-ing and iusulating segments which may be tractile spring b, and a ratchet-wheel u>, pro-rotated at an arbltrary speed by any suitable vided with a spring-pawl r, which is pivotedmeans. In inductive relation to the primary armature *a,* as illustrated. The apparatuswire or coilp is a secondary s, usnally of a being arranged as shown, it will be found thatmuch greater numberof turns, to theendsof when the radiations of the snu or of any otherwhich is connected a receiver R. The ter- source capable of producing the effects beforeminals of the condenser being connected as described fall upon the plate P an accumula-indicat-ed, one to an insulated plate P and tion of electrical energy in the condenser Cthe other to a grounded plate P', when the will resnlt-. This phenomenon, I believe, is tube S is excited rays or streams of matter best explained asfollows: The sun as wellasare emitted from the same, which convey another sources of radiant energy throwing off mi-positive charge to the plate P and condenser- nute particles of matter posittvely electrified,whlle terminal T is continuously which, impinging upon the plate P, eommu-reeeivitig negative electricity from the plate nicate an electrical charge to the same. The

P'. This, as explained before, resulte in a accumulation of eleetrical energy in the eondenser, which goes ou as long as the circuit the including the primary *p* is interrupted. Whenever the circuit is closed, due to the able rotation of the terminal *t',* the stored energy is discharged through the primaryp, this ger- in the secondary s to indnced cur- rente which operate the receiver R.

It is clear from whathasbeenstatedabove that if the terminal T' is connected to a plate supplying positive instead of negative elec- tricity the rays should convey negative elec- tricity to plate P. The source S may be any form of Roentgen or Lenard tube; but it is preponderatingly of one sign. If ordinary so symmetrical alternating carrents are em- ployed, provision should be made for allow- ing the rays to fall upon the plate P only the other by independent means, varying the dtiring those periods when they are produc- intensity of the said rays or radiations to a dpe- tive of the desired resnlt. Evidently if the riodioally disoharging the eondenserthrough sj radiations of the source bo stopped or inter- cepted or their intensity varied in any män- ner, as by periodically interrnpting or ryth- mically varying the current exoiting the conductor, connected to oue of the armatures source, there will be corresponding changes of a eondenser, rays or radiations capable of 30 in the action upon the receiver R, and thus positively eleetrifyiug the same, carrying often 75 Signals may be transmitted and many other electricity from the other armature bj' con- usefuleffects prodneeded. Furthermore.it will necting the same with the ground, and dis- be understood that any form of eircuit-closer chargiog the accumulated energy through a which will respond to or be set in operation suitable receiver, as set forth.

35 when a predetertnined amotint of energy is6 . The method of utilizi ng radiant energy, So stored in the eondenser may be used in lieu which consists in charging one of the arma- of the device specificaliy described with ref- tures of an eondenser by rays or radiations,and erence to Fig. 1, and also that the special the other by independent means, and effect- details of constrimtion and arrangement of ing by the automatic discharge of the aceu m u- 40 the sevcral parts of the apparatus may be lated to the operation or control of a 85 very greatly varied withont departure from suitable receiver, as set forth. the Invention.

Having described my invention, what I Claim is-

451 The method of utilizing radiant energy, which consists in charging one of the arma- tures of a eondenser by rays or radiations, and other armature by independent means, anddischargingthe condonser through asuit- receiver, as set forth.

. The method of utilizing radiant energy, which consists in simultaneously charging ing rise a eondenser' by means of rays or radiations. and an independent source of eleetrical en- and disoharging the eondenser through 55 that if suitable receiver, as set forth.

. The method of utilizing radiant energy. which consists in charging one of the arma- tures of an eondenser by rays or radiations, and form of Roentgen or Lenard tube; but it is the other by independent means, Controlling 60 obvious from the theory of action that in Or- the action or effect of said rays or radiations the to be very e See live the eleetrical itn- and disoharging the eondenser through as'nit- pulses exciting itshould be wholly orat least able receiver, as set forth.

. The method of utilizing radiant energy, which consists in charging one of the arina- 65 ployed, provision should be made for allow- ing the rays to fall upon the plate P only the other by independent means, varying the dtiring those periods when they are produc- intensity of the said rays or radiations to a dpe- tive of the desired resnlt. Evidently if the riodioally disoharging the eondenserthrough sj radiations of the source bo stopped or inter- a suitable receiver, as set forth.

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RIKOLA TESLA.

Witnesses:
M. LAWSOX DYER,
RICHARD DOKOVAN.

No. 685,958 Patented Nov. 5, 1901.

N. TESLA.

METHOD OF UTILIZING RADIANT ENERGY.

(Application fil "d Mar. 31,

(No Motfel.)

Fig.1

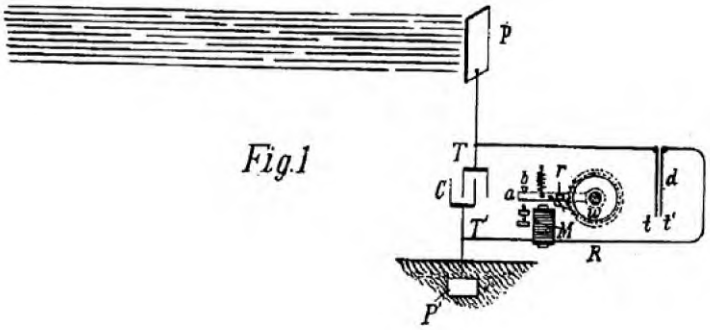
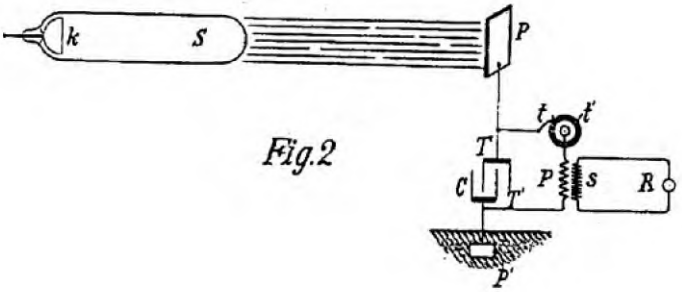


Fig.2



Witnesses.

Raphael Netter
M. Lawson Dyer

Nikola Tesla,

By Kerr, Page & Cooper Attys

r>< Kn"" nreM Co. PHOTO-LITHO. WASHINGTON, D. C.

Structure of the Tesla coil

What parts make up the Tesla coil:

With conventional coils, the cost spoils any fun at just a few thousand volts. But with Tesla coils, voltages of several million volts can be generated relatively easily. The much more effective voltage conversion of the Tesla coil is based on the principle of resonance.

With transmitting antennas, the antenna is always optimally tuned to the frequency to be transmitted in order to convey as much of the transmitter energy as possible into the ether. With receive antennas, attention is also always paid to optimal tuning in order to obtain the highest possible receive level. Through this principle, the Tesla coil achieves higher efficiency and higher voltage levels during the transformation voltage.

But to operate a coil at its resonant frequency, the length of the coil must be at least half the wavelength. Therefore, the frequencies start at 10kHz.

These high frequencies also reduce the danger of a lethal contact with a lightning produced in such a way, because currents of such high frequency do not disturb the organism (e.g. heart: 1 to 3 Hz) any more so directly as e.g. our alternating current with 50 Hz, which all muscles follow unconditionally. The frequency also causes the so-called skin effect, by which the current can no longer penetrate the tissue but runs on the surface. But depending on the size/design of the coil, dangerous burns can still occur!

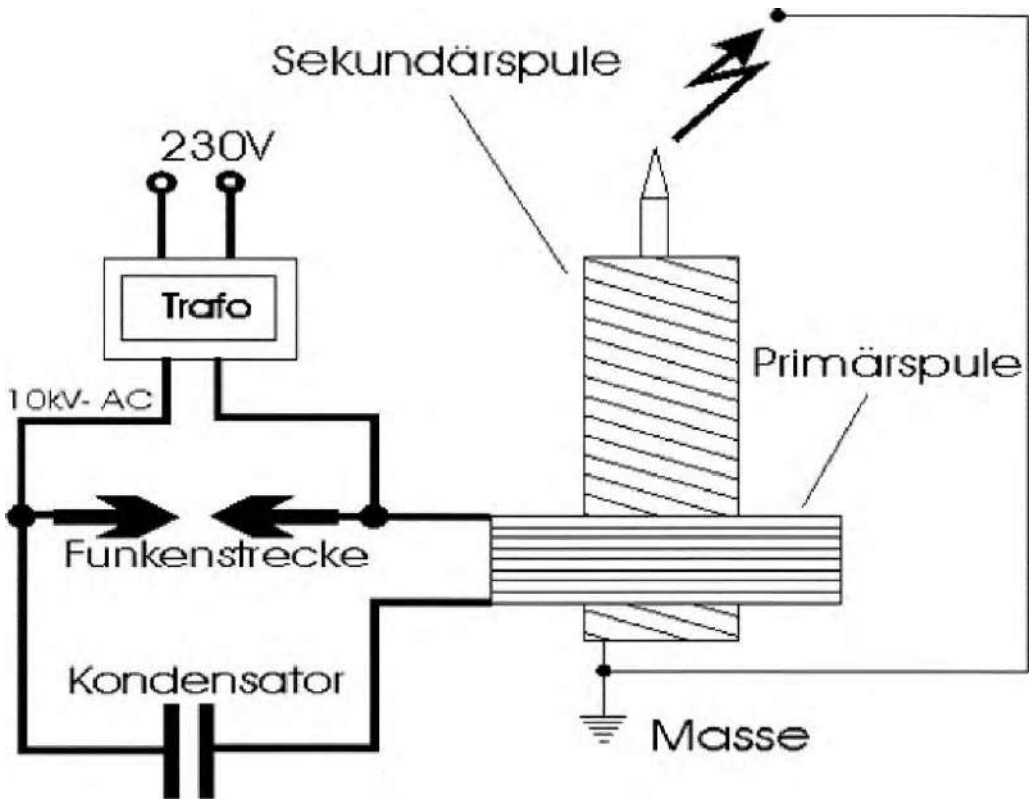
A Tesla coil consists of two parts.

In the first part, on the primary side, a high-frequency high voltage is first generated. For this purpose, a **capacitor bank is** charged via a **high-voltage transformer.**

The charging process is interrupted by a **spark gap** when a high voltage is reached. The capacitors then form an **oscillating circuit** with the **primary coil,** which consists of a few self-wound turns. This generates a high-frequency voltage.

The **secondary coil** stands inside the primary coil and is terminated at the top with a torus.

These are already the essential components of a Tesla coil.



Tesla coils work with voltages of several hundred volts. Even though due to the high frequencies even contact need not be fatal, I strongly advise you not to experiment with Tesla coils yourself without the help of your teacher.

Tesla coil function

In the past video about the construction of the Tesla coil, we saw in the video the individual components.
In principle, the Tesla coil now works as follows.

In the first part of the circuit, which also contains the primary coil of the actual Tesla transformer, a capacitor or optionally a capacitor bank, the series and parallel connection of several capacitors is first charged to several kilovolts.

A capacitor bank is often used to realize the required dielectric strength of several kilovolts.

The high voltage of several kilovolts is generated by means of a "normal" high-voltage transformer. This voltage is not yet sufficient for a spark gap of more than one meter. However, it is sufficient to charge the capacitor to a usable voltage and to ignite a small spark gap.

With the help of this small spark gap, the capacitor and the primary side of the Tesla transformer is separated from the high voltage transformer.

The capacitor and the coil then form a resonant circuit which oscillates at a high frequency due to the small inductance of the coil.

Thus, a high-frequency high voltage is obtained at the primary coil.

This primary coil is loosely coupled magnetically to a tightly wound secondary coil.

Loose coupling means that no iron core is used here to send as many magnetic field lines as possible through the secondary coil.

The coupling factor for a Tesla coil is only approx. 10-20 %.

A high-frequency alternating voltage is induced in the secondary coil by this coupling.

Use of the resonant frequency

The secondary coil is wound so neatly in a single layer that there is capacitance between each turn of the coil.

The secondary circuit is thus also an oscillating circuit whose resonant frequency is determined by the inductance of the coil and its capacitance.

The trick now is to tune the components on the primary and secondary sides so that the resonant frequency is the same.

The secondary circuit is thus excited at its resonant frequency. This leads to a voltage rise at the components and thus to high-frequency voltages in the lOOkV to MV range.

The principle of operation

The purpose of a Tesla coil is to generate a high voltage with a very high frequency.
To do this, a Tesla coil requires five parts, the transformer, the primary coil, the capacitor the spark gap and the secondary coil.
The capacitor is charged with the transformer, and when the voltage has risen to the point where the spark gap can be jumped over, the spark gap becomes conductive. At that moment the transformer is short-circuited and there is a direct connection between the capacitor and the coil. The capacitor gives off its charge to the coil, which consequently builds up a magnetic field that collapses again and charges the capacitor the other way round. Thus an oscillating circuit is created which exists until the energy is no longer sufficient to bridge the spark gap. The spark gap breaks down and the transformer can charge the capacitor again. The fluctuating magnetic field of the primary coil induces a voltage in the secondary coil at each build-up, which is correspondingly higher in voltage due to the winding ratio. Thus one easily obtains a voltage of 100,000V at 100 to 150 kHz frequency. are special effects to observed

- Clusters of lightning rise into the air

- Neon tubes start to glow brightly

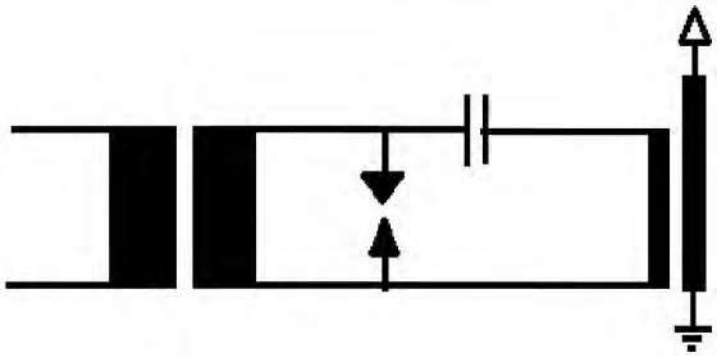
- Light bulbs become plasma balls

- In connection with a grounded cable, lightning lengths of 120mm can be observed with a simple setup.

- Check cards and electronics will be destroyed in close proximity!

Theoretical structure of the Tesla coil

2.1. Circuit diagram:



2.2. High voltage transformer:

The high voltage transformer transforms the mains voltage from approx. 230V to a high voltage of 6 - 40kV. The voltage should not be less than 6kV, otherwise there could be problems with the spark gap.

Transformers from neon signs (NST) are usually used as high-voltage sources. Another possibility are ignition transformers from oil heaters (OBIT), but they are not suitable for continuous operation. Line transformers or automotive ignition coils are also suitable for small Tesla coils. However, if you want to build a large Tesla coil, you have to use single-phase transformers or instrument transformers. These have a considerable power of 5 to 15kW.

2.3. Capacitor:

The capacitor is an important part of the primary circuit. Depending on the resonant frequency, it has a capacitance of 5nF to 200nF. It must be pulse-resistant due to the high current flow and tolerate four times the transformer output voltage due to peak voltages in the resonant circuit. Because capacitors with these requirements are either not used at all or are too

a very high purchase price to acquire, most develop their capacitors themselves. The Tesla coil builders therefore resort to salt water capacitors (Leyender bottle), or to so-called MMC capacitors.

Leyender bottle is a glass bottle filled with salt water. The salt water solution in each bottle is connected with wires and forms the first plate, the glass of the bottle forms the dielectric and the aluminum foil wrapped around the bottle forms the second plate. A bottle has a capacity of about InF and has a dielectric strength of up to 40kV. To produce this is very cheap, but the space required is enormous.

The MMC capacitor consists of many small Fkpl capacitors connected in series until the desired dielectric strength is reached, and these in turn are connected in parallel until the desired capacitance is reached. However, this solution usually consists of very many individual components and can also be quite expensive.

Spark gap:

The spark gap is the only active component of a Tesla coil, which is why there are countless construction proposals for it. It breaks down as soon as the voltage applied to it exceeds the breakdown voltage. The use of a quenching spark gap is advantageous. In this model, two electrodes are simply placed opposite each other at a certain distance (the distance can only be determined by experiment), and a small fan generates a strong air flow at the gap between the electrodes, causing the spark to break off. During operation, large amounts of ozone and ultraviolet light are generated. Therefore, it is advisable to operate the Tesla coil only in a sufficiently ventilated place and not to look into the spark discharge of the spark gap.

Primary coil:

The primary coil represents an inductance and decouples the high-frequency oscillations on the secondary coil. It should consist of no more than ten turns. However, this must be found out by experimentation. You have to work on the winding ratio until the two coils oscillate in resonance.

There are three different types of primary coils: Once the cylindrical coil in which the winding is mounted vertically. Then the flat coil and the conical coil with a pitch angle of about 30°, which has proven to be the best. The primary coil is located at the bottom of the secondary coil.

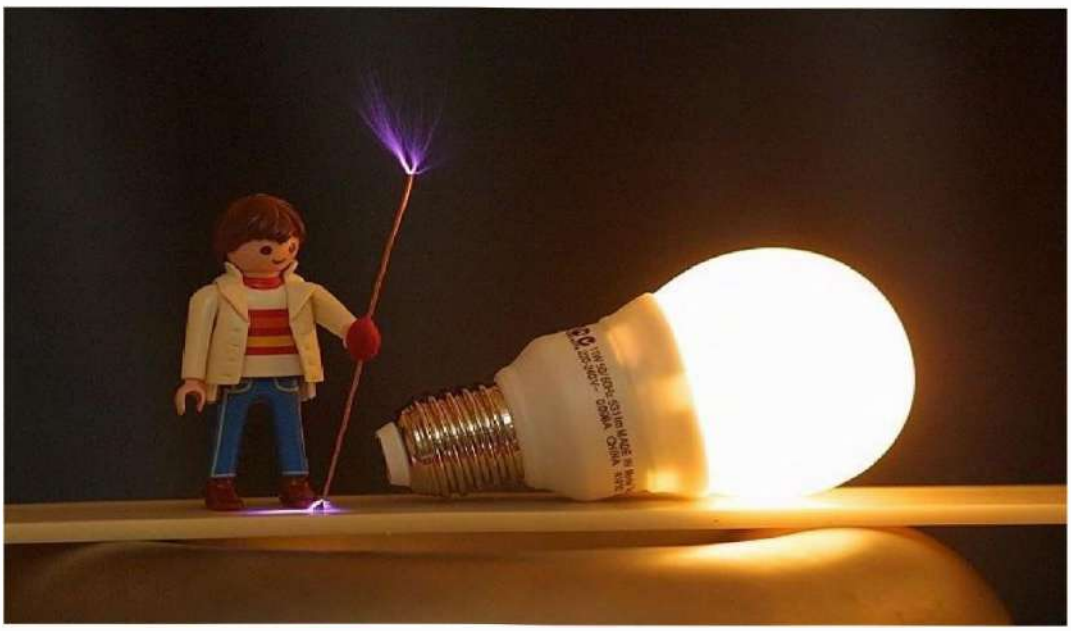
Secondary coil:

The secondary coil is the most striking part of the Tesla coil: It consists of enameled copper wire wound on an insulated hollow body. PVC sewage pipes proved to be the cheapest solvent for the coil body. The copper wire winding must be wound in a single layer with no overlaps or spacing between turns. Enameled copper wire of 0.2 to 0.8mm^2 should be used and about 1000 to 1600 turns. Finally, to prevent flashovers, the coil must be covered with an insulating coating.

The interaction of the components

function:

The construction of a Tesla coil is quite simple: A high-voltage transformer charges a high-voltage capacitor. When this reaches a certain voltage, a spark gap ignites and it discharges via the primary coil. This consists of a few turns of thick wire. The primary coil and capacitor form the primary resonant circuit. This oscillating circuit now induces its energy into the secondary circuit, which consists of the long secondary coil and a head capacitor. The natural frequencies of both oscillating circuits must be identical for coupling to occur. The voltage of an ideal Tesla transformer is calculated by the ratio of primary to secondary inductance. In my opinion, this is not much different from a normal transformer with core material, since here the turns ratio determines the voltage, which is ultimately responsible for the inductance ratio if the core and diameters are identical. So you can easily get a voltage of 1,000,000V at 100 to 400 kHz frequency.



Formula collections

The described concept of energy transfer between loosely coupled oscillators can also explain the voltage rise in the secondary circuit, even if there is no direct mechanical equivalent for it.

The following formulas represent the energy stored in the capacitor and coil:

$$W_c = \frac{C * U^2}{2} \qquad W_l = \frac{L * I^2}{2}$$

If a defined amount of energy is now transferred to the secondary circuit, then at a certain point in time the entire available energy is stored in the capacitor. If this capacitor is very small, as is the case with the secondary circuit of the Tesla transformer, then it is inevitable that this amount of energy causes a high voltage at it. Conversely, the very large inductance of the secondary coil results in much lower currents flowing than in the primary circuit at the moment when all available energy is stored in the magnetic field of the coil. From Thomson's formula, which is used to calculate the resonant frequency of a resonant circuit, it can be seen that if the resonant frequency is maintained, a reduction in the capacitance must be compensated for by a proportional increase in the inductance:

The energy storage in the primary capacitor

The special effects that can be observed with the Tesla transformer are particularly due to the fact that very high powers act very briefly and comparatively infrequently. Here, the energy storage in the primary capacitor plays a decisive role. The energy stored in the primary capacitor at the moment of sparkover at the spark gap can be estimated with the following formula:

$$W_c = \frac{C * U^2}{2}$$

If it is assumed that the spark gap breaks down when 6kV is reached, then at this point an energy of

$$U, = \frac{12.5nf600l}{2} = 0.23\ fs$$

stored in the capacitor.

The capacitor is completely discharged after a quarter of the period of an oscillation of the primary circuit. Then, from a simplified point of view, all the energy stored in it is stored in the magnetic field of the primary coil. If we further assume a resonant frequency of the primary circuit of 300 kHz, then % of the period duration in the primary circuit is 0.83 us. One can thus give an approximate order of magnitude of the maximum instantaneous power of

$$P = \frac{0,23Ws}{0,83\,\mu s} = 277\,kW$$

estimate. The magnitude of the short-time instantaneous power is far above the average absorbed power of approx. 0.5 kW.

How to build the Tesla coil

Disclaimer

Use of all tools in this project is at your own risk. Regarding building yourself: Whether you can do it depends of course on your skills and your possibilities (workshop, machines, material procurement etc.). In any case, all devices may be copied for private purposes. Commercial use is prohibited due to patent protection. All articles from this book are intended for informative purposes only. In this book you can try to build a magnetic motor, but we do not guarantee one hundred percent function. And in this book you can learn about the technology of magnetic motors, but we do not give any guarantee that these coils will really work. All the information in this book you can use yourself to build a simple coil, but it is still up to you to build a magnetic motor. Although every attempt has been made to verify the accuracy of the information given, neither the authors nor the publishers are liable for any inaccuracies. The authors and publishers disclaim all liability for any inaccuracy in the content, which includes, but is not limited to, errors or omissions. Loss of property, injury to self or others, and even death may occur as a direct or indirect result of the use and application of the content herein. Improvement work and work with renewable energy sources are dangerous. Since you are dealing with electricity, and a variety of other unknown conditions, seek the opinions and assistance of experts whenever necessary. The authors and publishers assume that you are aware of all the risks and possible harms associated with renewable energy work while working on this project. Please check your city, state, or country for laws that apply to home improvement and alteration work information. It is often necessary to obtain permits from local authorities to avoid legal consequences. It is also recommended that you do not do this project alone. Feel free to enlist the help of a professional electrician and other experienced experts to assist you with this project. Failure to do so may result in injury or death! Of course, you act at your own risk. Before you begin any renewable energy work, you should first check with your insurance carrier, homeowners association, or other persons or associations that may need to approve such work. Insurance coverage and premiums may be affected by changes to the home, so you must first check with your insurance agent. These construction instructions from this book are intended only for adults over the age of 18. If you are not of legal age, you may perform this work only with the permission and guidance of your parent or guardian. Children are not authorized to use our services without supervision. By choosing to use the information provided from this book, you agree to indemnify, defend, and hold harmless the authors, publishers, and any other entities related to them from any and all claims (whether justified or unjustified), judgments, actions, suits, losses, damages, and costs or expenses of any nature arising out of the use or misapplication of the information provided.

Protective measures before assembly

Before assembling, of course, you should follow some protective measures. Now follow some safety instructions. However, you should rather read these, since safety comes first in a known way.

Assembling a Tesla coil is usually not too difficult, but there are greater dangers with electricity. But before you even start with the assembly, it also depends on whether you have a little understanding of craftsmanship and whether you already have experience from the assembly and processing of machine parts. At best you are a person from the machine construction or a metal worker. But a person who has the basic knowledge is also sufficient. If this is not the case, work together with at least two or better several people, just to be on the safe side.

Of course, you can also master the assembly as a single person and also as a hobbyist, if you really want to. But this usually takes longer and will be more time-consuming until you are finished with the complete assembly. And if something happens to them, and you work with several people, this is of course much safer. Do you have basic knowledge of electrical engineering? You or another person should already have a basic knowledge of electrical engineering, so that you can, for example, read and understand the circuit diagrams correctly.

A small tip for the beginning: If you want to proceed step by step, calmly arrange all the material, tools and all other parts at your workplace before assembling so that you always have a good overview and know what part or tool you need for the next step.

Also when assembling you should also make sure that you have enough space to work. It is best to work for this in a small workshop, garage, basement or other rooms where you can work undisturbed and concentrated.

Then, for example, when you assemble the parts on a workbench, make sure you have enough clearance to assemble the parts. You should have at least 25cm of space around the workbench to properly assemble the parts. Also, assemble the parts on a straight plane. Furthermore, make sure that there are no magnetic objects around you. For example, do not leave magnetic screwdrivers lying around on the workbench.

Wearing safety glasses is also important because you will be working with strong magnets and when you need to mill or drill other parts. Of course, if a heavy part should ever fall, you also wear steel-toed shoes as a precaution.

Even with heavy parts you assemble can fall and hurt your fingers. If you modify the design and end up with a device with higher speed, you should watch out for loosening and flying away and protect yourself from it. And of course working with electricity can be very dangerous. Therefore, work in a dry environment and keep drinking bottles or other liquids away from the workplace.

You may also need to wear a respirator when working with acetone or strong adhesives. Of course, it is not so healthy to inhale such substances. For example, if you work with acetone, make sure that the room where you work is well ventilated. Otherwise, such substances accumulate in a room and you breathe it in, which can cause nausea and headaches and other consequences of your health.

Also be careful when working with batteries. Batteries are known to have toxic acids and can burn your skin.

General information on toxic substances and battery acids:
Soaked clothing soiled with battery acid should be removed immediately. After skin contact or in case of contact with skin, wash immediately with plenty of water, after inhalation of acid mists breathe fresh air or in case of nausea or headache consult a doctor. After eye contact, rinse under running water for several minutes and possibly also consult a doctor. If swallowed, drink plenty of water immediately and seek medical attention as soon as possible.

Important:
All information on this page is intended for experienced electronics engineers only! The author is not responsible for any damage or injury caused by the attempt to manufacture a Tesla coil! The author does not claim the correctness and completeness of the information. Tesla coils may only be operated in shielded rooms!

The experiments on this homepage are life-threatening, since partly very high voltages/currents flow! If you want to rebuild the projects, I can not take any liability for damages, as well as give no guarantee on function of the circuits listed here! A Tesla coil is a quite strong transmitter, sensitive electrical devices are strongly disturbed in closer environment!

Behavior during operation

Before operating the Tesla coil for the first time, you should be aware of the dangers that arise when operating the Tesla coil, as well as the necessary safety measures.

- During operation, always keep the 10m distance and keep an eye on the measuring instruments on the control panel.

- The secondary coil must always be well grounded, otherwise the high voltage will seek its own path and could possibly cause a fire.

- Ensure that there are no discharges between the primary and secondary coils, as this could potentially destroy the capacitor.

- Never touch the discharges! The so-called skin effect occurs, which means that the current cannot penetrate the body, but we would not recommend touching the discharges of the Tesla coil under any circumstances.

- Before working on the Tesla coil, always discharge the capacitors with a strong resistance of about 100kW.

- If the fuse in the house distributor has tripped, disconnect the mains plug immediately to prevent unintentional restarting of the coil and, if necessary, find the responsible fault.

- Always keep an eye on the capacitors, as they could explode if punctured or overheated.

- Always make sure that there is no sensitive electrical device (cell phone, CPU, digital...) within a radius of about 10m, as these could possibly be destroyed. Wearers of pacemakers should keep away from the Tesla coil.

- Do not bring flammable gases, liquids or solids into the vicinity of the Tesla coil! Fire hazard!!

- **Danger from electric shock:**

when touching live parts, it may also be sufficient to get too close to live parts at voltages as low as 1000 volts. If a current, especially direct current or alternating current of low frequency, flows through the heart, it can quickly lead to fatal ventricular fibrillation. Even when current stops flowing, ventricular fibrillation does not stop. Currents from about 30mA flowing across the heart

are fatal in most cases. Humans have a body resistance of about IkOhm, which means that there is already a danger to life from 50 volts. Particularly dangerous are charged capacitors, which can release their entire charge energy within a very short time. To prevent a capacitor from charging itself, they should always be stored short-circuited.

- **Danger from burns:**

Electric arcs can easily reach temperatures of up to 5000°C, causing severe burns and inflammation on contact.

- **Hearing damage:**

are possible due to very loud discharges (capacitors / electric arcs). This danger should not be underestimated. Even a capacitor of lOOOpF charged to 300V, which is discharged abruptly, produces a very loud bang. Therefore, one should always wear hearing protection.

- **Fire Hazard:**

by short circuits, sparks, electric arcs, overheated components, etc. Explosive vapors or gases can be ignited. Braising cables and components can release toxic fumes. Arcing can cause electrodes to melt, causing red-hot metal to drip onto the floor. Under certain circumstances, the metal of the electrodes can literally burn, which is associated with strong flying sparks.

- **Damage to electrical equipment:**

due to overvoltages and electromagnetic interference. Overvoltages can enter the devices directly, by spray discharges, spark impacts or in case of incorrect grounding via the mains, or can be generated by induction in the device itself. The consequences range from slight confusion, to complete destruction of the device. Devices with long cable connections are particularly at risk. In particular, electromagnetic interference and overvoltages on the power line can cause damage to many devices simultaneously, even over long distances.

- When making measurements on equipment, always use an isolation transformer to provide protection against single-pole contact.

- Highly recommended in any laboratory, is the use of a residual current circuit breaker also called Fl with 30mA residual current. This switches off the mains immediately if part of the current flows through the body.

- It should be a matter of course to use a circuit breaker that protects against cable fire in the event of a short circuit.

- Insulating shoes, furniture and floors additionally reduce the danger in case of single-pole contact. To avoid overheating of cables and contacts, only use cables with a sufficient cross-section, fit cable ends with wire end ferrules or solder them and connect them with luster terminals.

- To prevent electromagnetic interference from high-voltage equipment from entering the network and possibly damaging other consumers. It is advisable to use a mains filter. Such filters are available ready to buy, they are simply switched into the power line to the high-voltage equipment.

- If possible, work should always be carried out on equipment only when it is de-energized.

- Minimum distances to live parts:

Voltage (kV)	Distance (cm)
Until 10	5
Until 30	15
Up to 100	60
Up to 300	200

The dangers during operation

Electrocution

While the output current of a Tesla generator is relatively harmless, as already mentioned, fatal shocks can occur if the primary coil is touched! Peak currents of up to 400A flow in the primary circuit.

Ozone and nitrogen oxides

All electrical discharges in the air produce ozone and nitrogen oxides. Because of the short operating time, this generally does not cause any health hazards, but some experimenters complain of headaches caused by the irritant gas ozone. However, once the air has cooled down, there is no longer any danger!

Noise

Already the discharges of small Tesla generators can very loud loud, in order to avoid permanent hearing damage, you should wear hearing protection.

Interference
Since Tesla generators have the basic structure of a transmitter, they cause radio interference. However, since they do not have an antenna, this interference remains quite low.

UV radiation
The discharges in the spark gap generate UV radiation just like welding equipment, it must therefore not be observed with the naked eye over a longer period of time! Otherwise, retinal damage may occur.

X-rays
Tests have shown that Tesla generators do not produce X-rays! However, if vessels under vacuum are brought close to the Tesla coil, X-rays can be produced.

Tesla coil operation

The tuning
In order for the Tesla generator to produce the maximum output voltage, the primary circuit and secondary circuit must oscillate in resonance. Since the resonant frequency of the secondary coil can hardly be changed, and the primary capacitor also has a fixed value, the number of turns of the primary coil must be changed to tune the Tesla generator. While the innermost turn is usually hardwired to the primary capacitor, the second tap can be tapped via an alligator clip. Another point would be the spark gap which has to be adjusted optimally until the Tesla coil runs without failures.

Shop the parts

Where to buy the parts

You can buy very many of the parts also on the Internet. Also a cheap source of supply for the Tesla coil is:

Kessler electronic GmbH
Hubertusweg 2
58540 Meinerzhagen

Of course, it is always better to get a few more parts of each. Get yourself a few spare parts from the parts in case a part should break and you then still have a few of them left as a backup.

And a few more useful tips for the shopping list of parts:

Very many of the parts you can get to buy on eBay. If the parts are even used and in good condition, you can of course use them if you do not want to buy everything new. At least 99 percent of the time you will get all the parts from the internet. If you really can't find a part on eBay or Amazon, just search the internet for dealers that specialize in that particular product. Or as mentioned earlier, you can also look around a hardware store. But we don't want to specialize in just any retailer, as prices can always change. Feel free to look for the best deals at retailers yourself, otherwise our recommendation may not be the most current at the time. But in general, it is recommended to buy most parts from the internet, as almost everything is available on eBay anyway. Feel free to look around for international dealers on the internet as well.

Tool list

In this chapter you will learn what you need for the construction of the Tesla coil for minest recommended tools.

- Screwdriver

- Solder and a soldering iron to solder the circuit.

- A side cutter to cut the cables.

- A metal drill and drill to drill the holes in the aluminum heat sink (heat sink) to bind the circuit device firmly.

- If you want a brush with paint to coat the wood.

- Sandpaper to smooth the edges from the wood. You can safely use fine and coarse paper for this purpose.

- Hand deburrer to deburr the drilled holes.

- A cordless screwdriver to wind the wires of the coil. Of course, you can build your own coil winding machine. How to build one, you can read below.

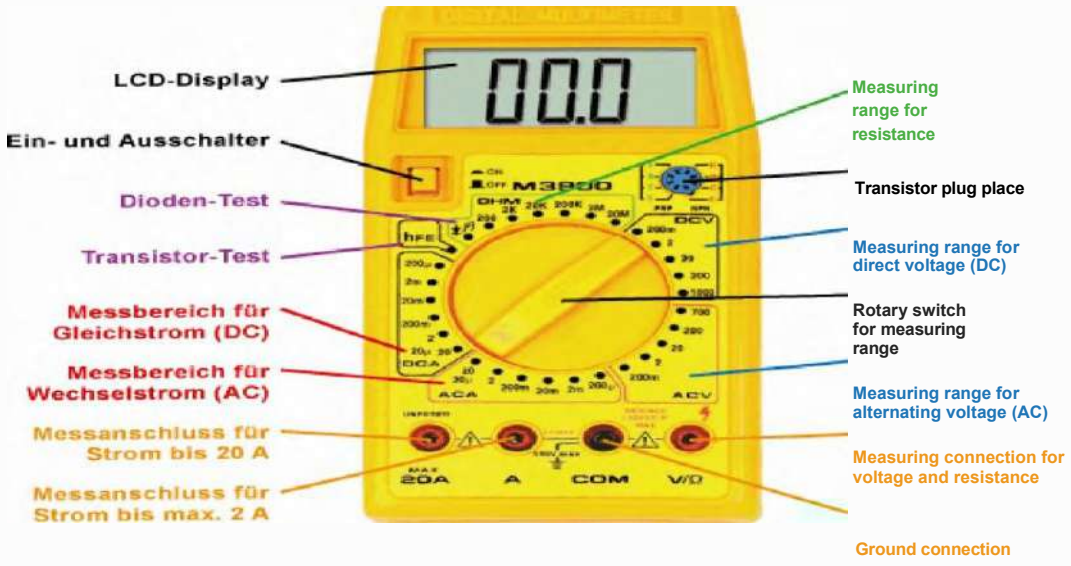
A carpet knife, for example, to cut the tape cleanly.

Additional tools: felt-tip pen or pencil, for marking and drawing. Aluminum foil is also needed for the Tesla coil. And for accurate work, a ruler, set square and level is advantageous. A hammer with nails, for mounting the boards of the frame. Of course, you can also fix the frame with screws, or even, if you wish, with wood glue.

Recommended operating resources

In this chapter you will learn which operating resources you need for the setup.

- A multimeter to measure volts and amps



A precision battery tester that can test and check battery capacity. It is important that this device can measure a capacity of 12 V lead-acid batteries and display the battery capacity as a percentage. For example, you can use the model 601 from BK Precision for this purpose. With this device you can also measure faulty batteries.

You can precisely measure batteries in seconds with this device.
The **computerized battery analyzer** can be connected to the PC via USB and works under Windows and is designed for testing accumulators.
It accurately records the battery characteristics and you can find cells or determine the best cell. In addition, the battery aging can be determined and batteries can be selectively charged and conditioned. The CBA even measures the temperature of a battery, using the OPTIONAL external temperature probe. Results can also be printed.

The analyzer can take into account different battery technologies: Lead, NiCd, NMH; Li-ion, Li-polymer, mercury, lead acid, etc. Starting from the button cell up to the automotive battery. It is helpful that all test results can be printed out graphically and corresponding stickers for the batteries can be created at the same time.
The heart is the C8051 based USB microcontroller with the on-chip ADC, it ensures the constant compliance of the discharge current. Basically, either the number of lines can be selected with automatic presetting of the cut-off voltage or set manually, which is a great advantage especially for professionals.

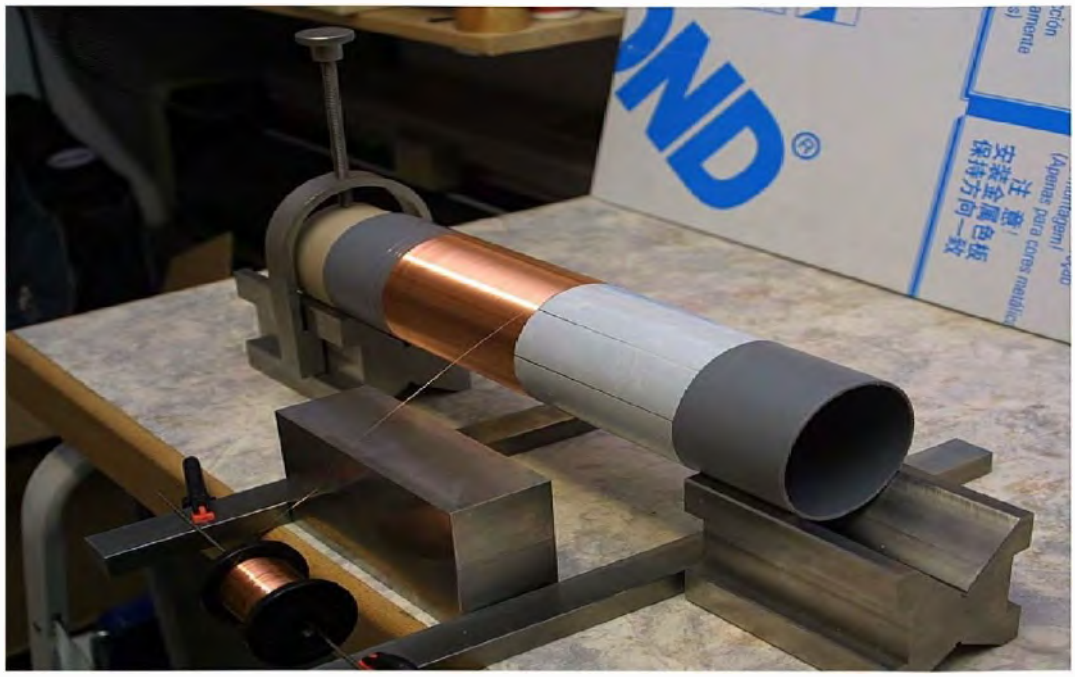
An oscilloscope (multimeter option) for measuring the speeds (revolutions per minute)

Coil winding

Now we come to another very interesting topic. And that is that we are now winding coils.

It is unimportant how the coil is wound. This means that no pattern or the like is necessary. The spool can simply be wound like a fishing rod. That is why the tolerance is large.

Counting with your eyes is very annoying and you may make mistakes. To help, simply use an audible trigger when turning (like a rattle on the spool). Alternatively, you can put a piece of tape on both ends of the spool that protrude about % inch. These will hit your hand during the spins and help count the spins.

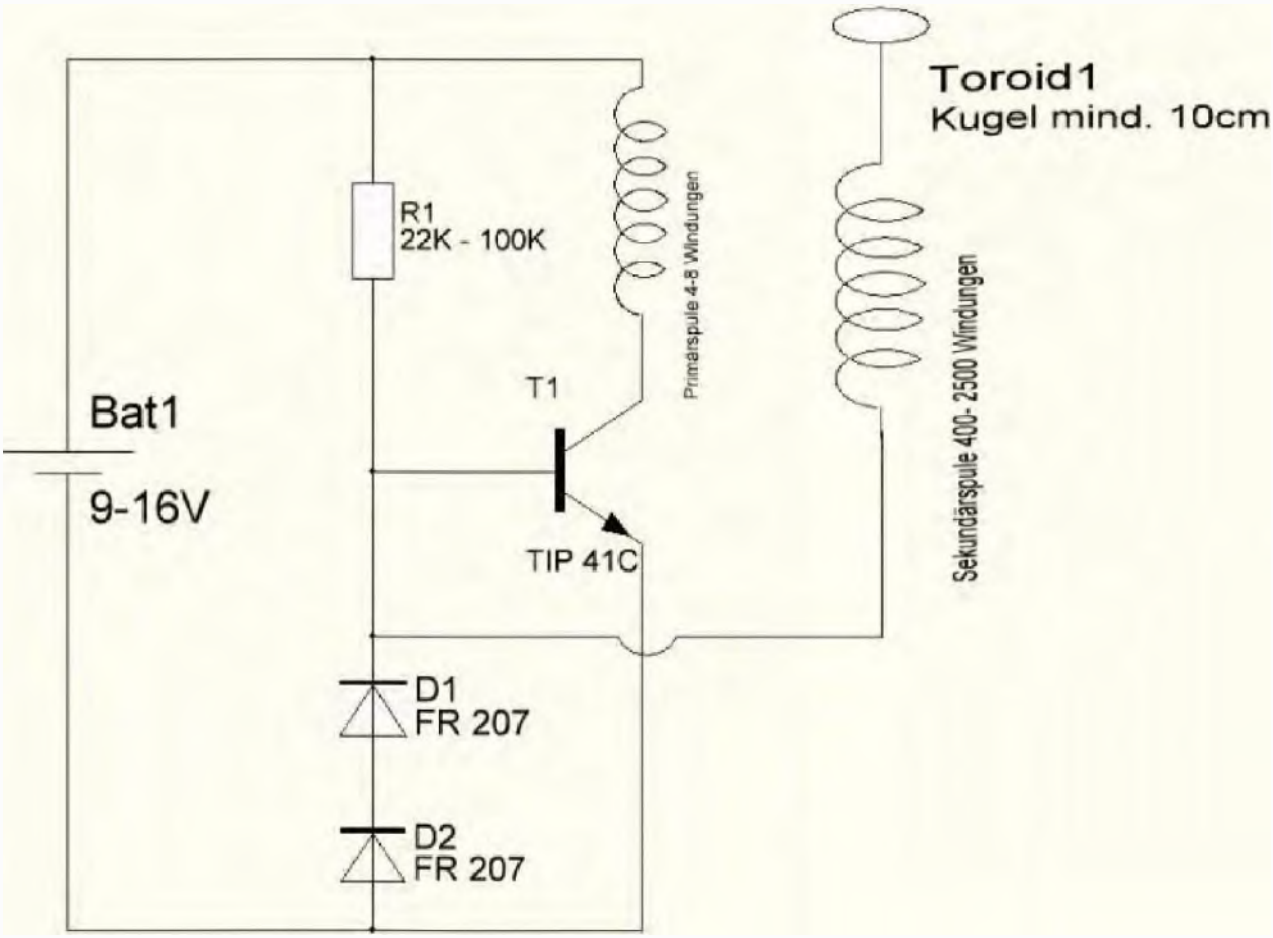


A PVC drain pipe with a diameter of 75mm was used as the coil former. The wire (CuL) has a thickness of 0.15mm and is provided with **1400 turns.** This results in **a coil length of 210mm.** The diameter to length ratio is thus almost the ideal value of 1:3. The white stripes on the PVC pipe is a double-sided adhesive tape to fix the wire.

And after 3-4 hours you have already done the winding of the coil:-)

How does the circuit work?

The current flows in the direction of the branching resistor / primary coil since the current always takes the path of the lower resistance, it first flows through the coil to the collector of the transistor TIP41C, but this is closed in the unconfirmed state. Since the current does not go any further, it must now flow through the resistor to the base of the TIP41C. But there is already a certain amount of energy in the coil windings. If now enough current has flowed through the resistor, the transistor TIP41C is switched through. This causes the entire current to flow through the primary coil and through the emitter of the transistor to ground. Since the current always takes the path of least resistance, no more current flows through the resistor towards the base and the transistor closes again. And everything can start again. This sudden interruption of the current flow through the TIP41C causes the magnetic field in the primary coil to collapse and induces energy in the ratio of primary to secondary turns in the secondary coil. The induced energy now flows to the toroid which acts as a kind of energy storage and is radiated from here. The lower connection of the secondary coil to the base serves as feedback to give the transistor the resonant frequency of the secondary coil. This process repeats 300,000 to 1,500,000 times per second! The frequency can be influenced by the size of the toroid and the number of turns.

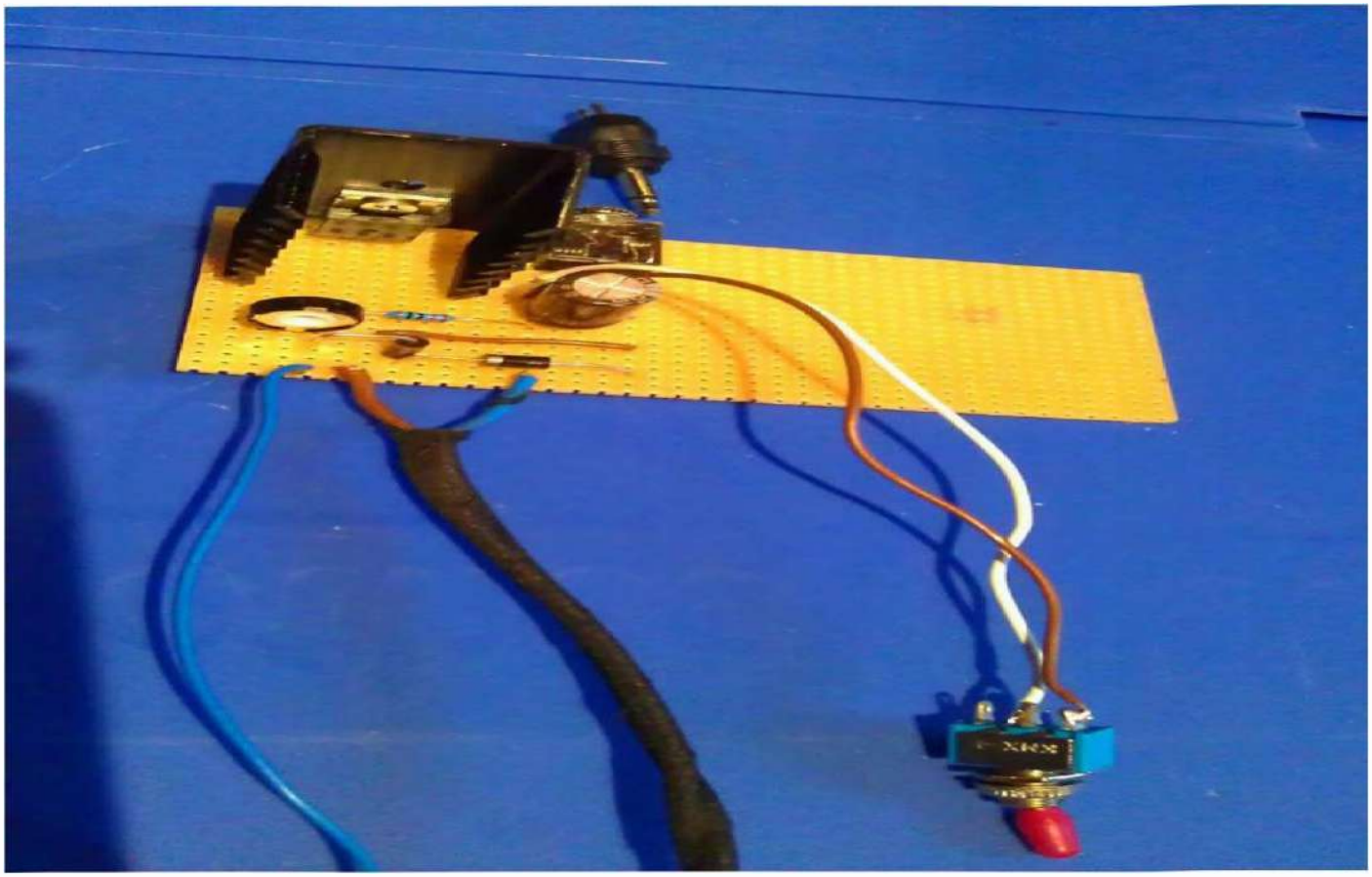


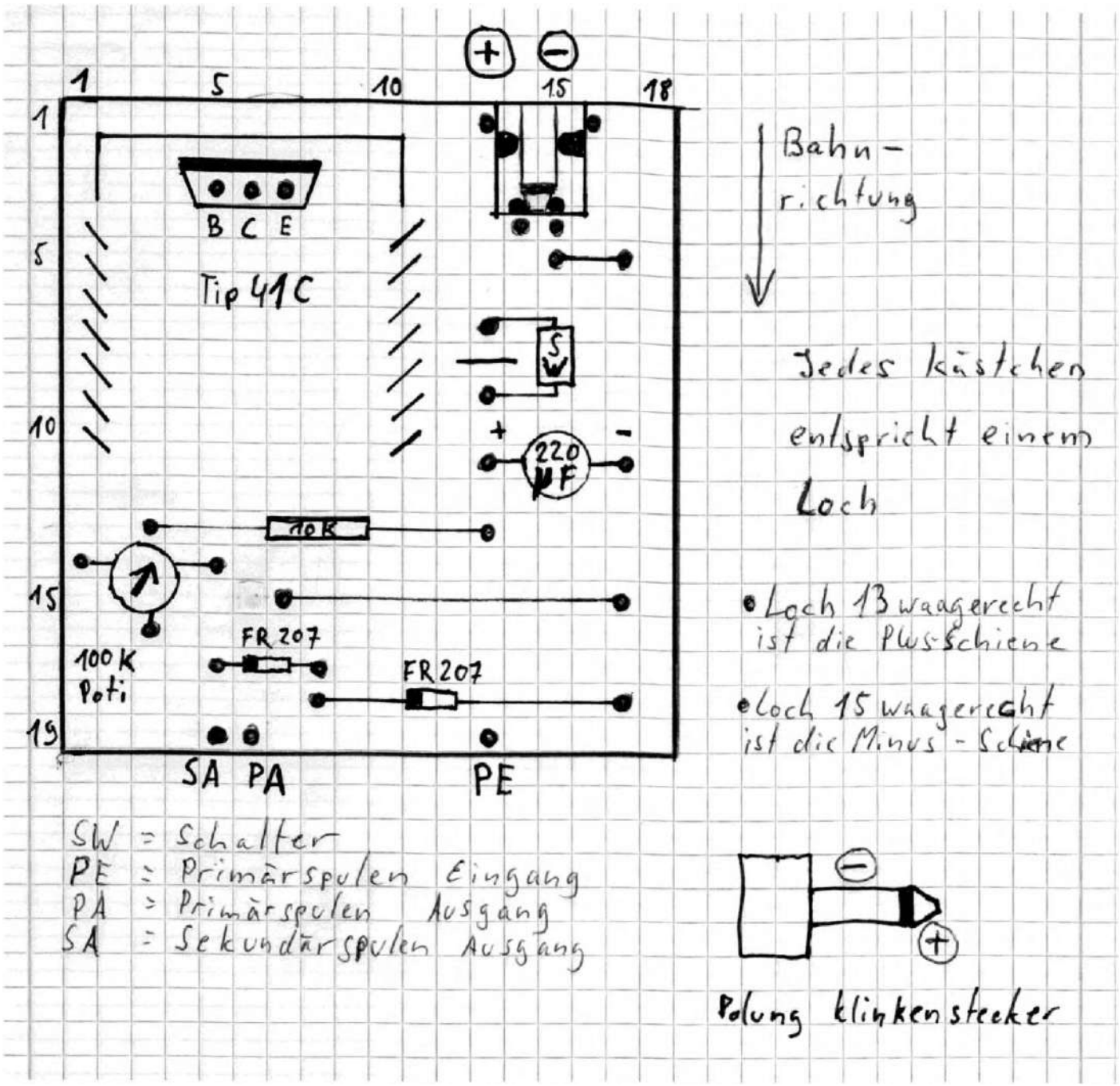
Parts list:

1. Ix enamelled copper wire on spool 0.2mm 110 - 130 meters
2. 2x diode FR207
3. 3xTIP41C (2xare as replacement!!!)
4. Ix heat sink V FI356
5. Ix punched tape board H25SR050
6. Ix switch MS 500A
7. Ix jack socket
8. Ix resistor 22K ohm
9. Ix Poti PT 15-S 100K
10. Ix stainless steel ball 6cm (optimal size 12cm, can be ordered separately!)
11. Ix copper wire solid 1,5mm for primary coil
12. Ix PVC pipe 40mm diameter
13. Ix switching power supply 12V 1000mA

Build circuit:

1. Screw TIP41C with some thermal paste (if present) onto the heat sink with enclosed screw and nut
2. Bend front legs at jack socket slightly outward with pliers
3. Solder in jack socket
4. Solder 2 short wires to the switch and solder them to the positive wire in the circuit board.
5. Solder the electrolytic capacitor and observe the polarity!
6. Solder in TIP41C with heat sink
7. Solder in 22k Ohm resistor
8. Solder in potentiometer and set to 0 Ohm (right stop)
9. Solder minus bridges (cable piece from longest single cable)
10. Soldering diodes
11. Solder secondary coil cable
12. Soldering the primary coil cable
13. Interrupt (scrape free) the circuit board between the switch cables (position 13 right, 8 down)
14. Check everything again afterwards!





Tip/Background Knowledge

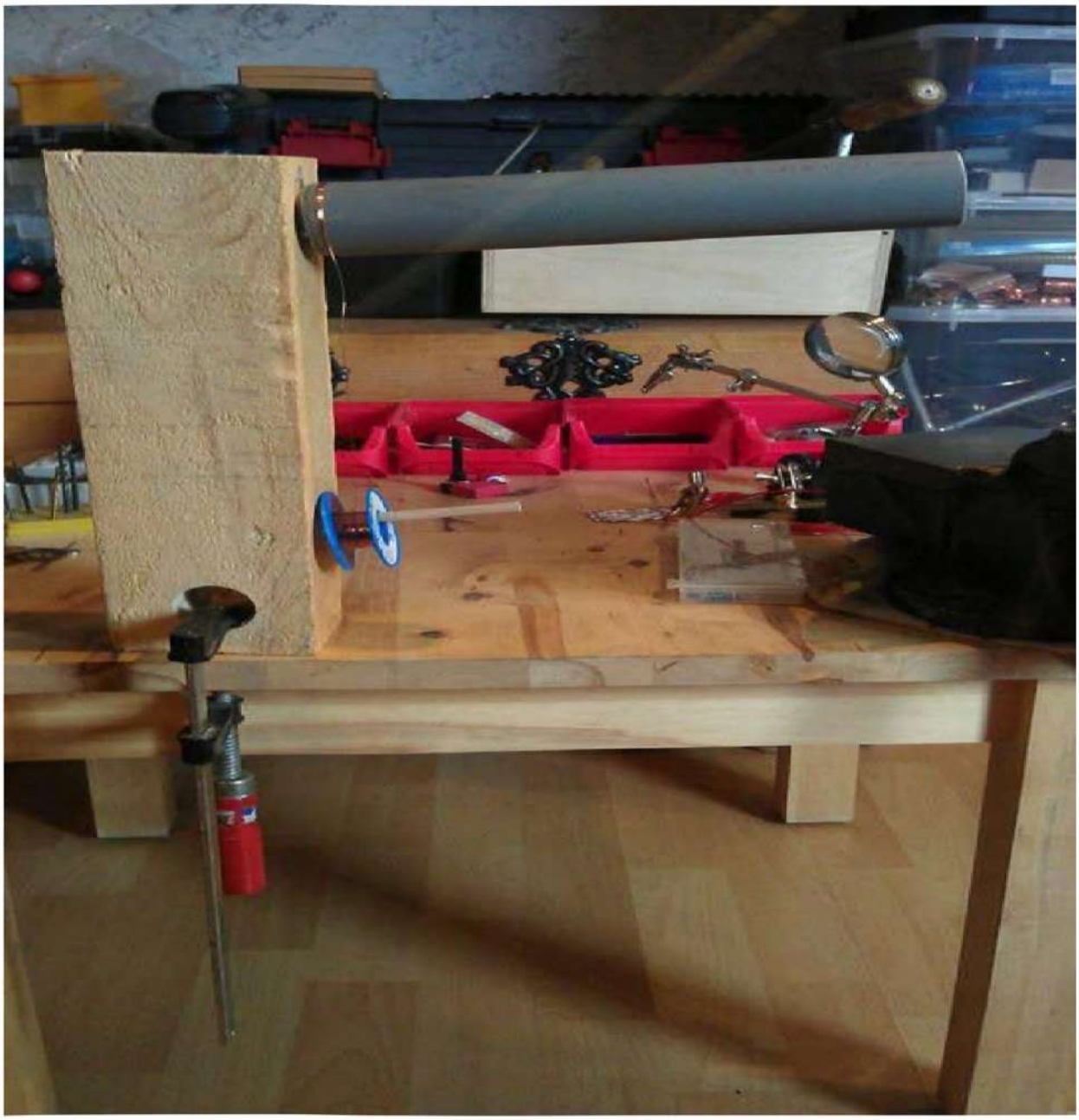
Adjust potentiometer depending on input voltage! At 12Volt the 22k resistor is enough.

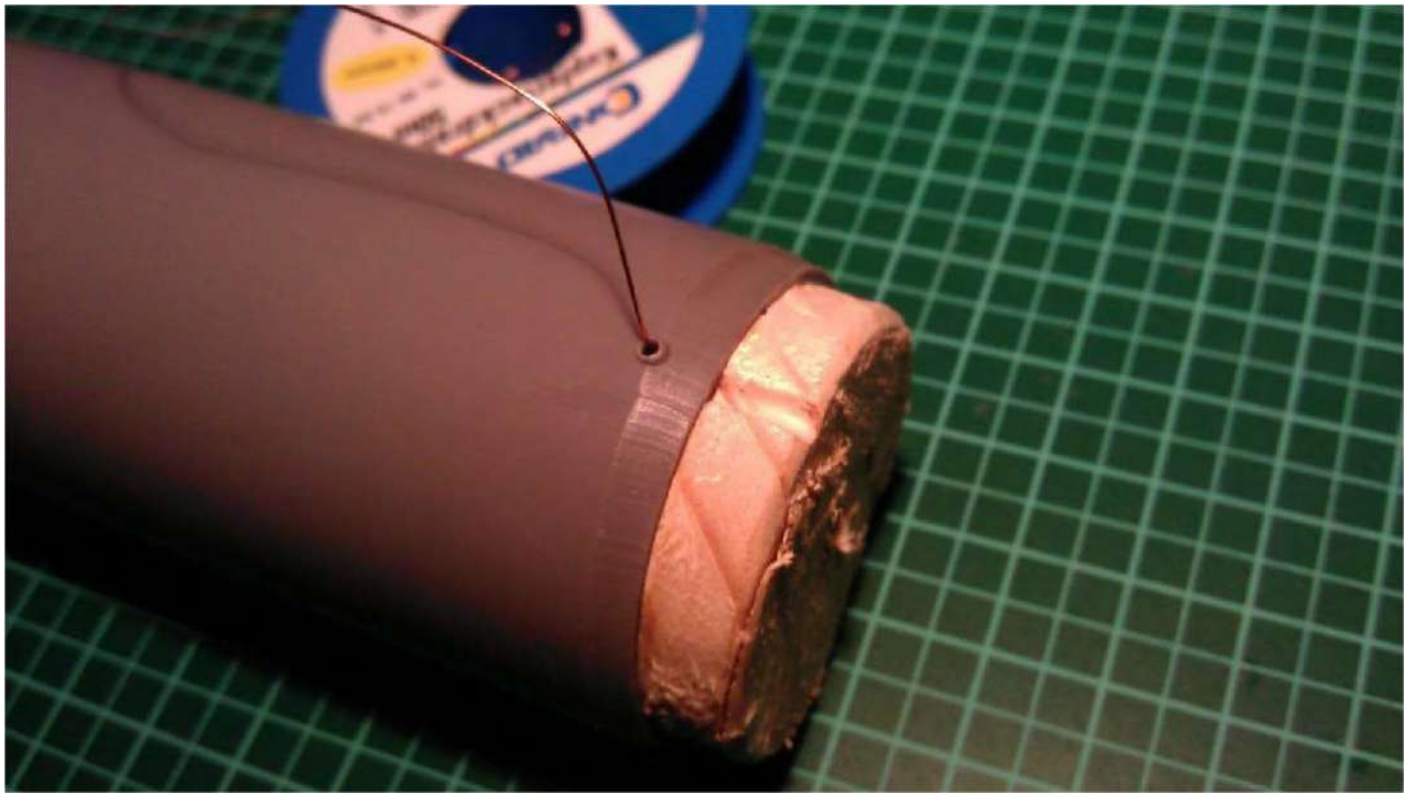
Build secondary coil:

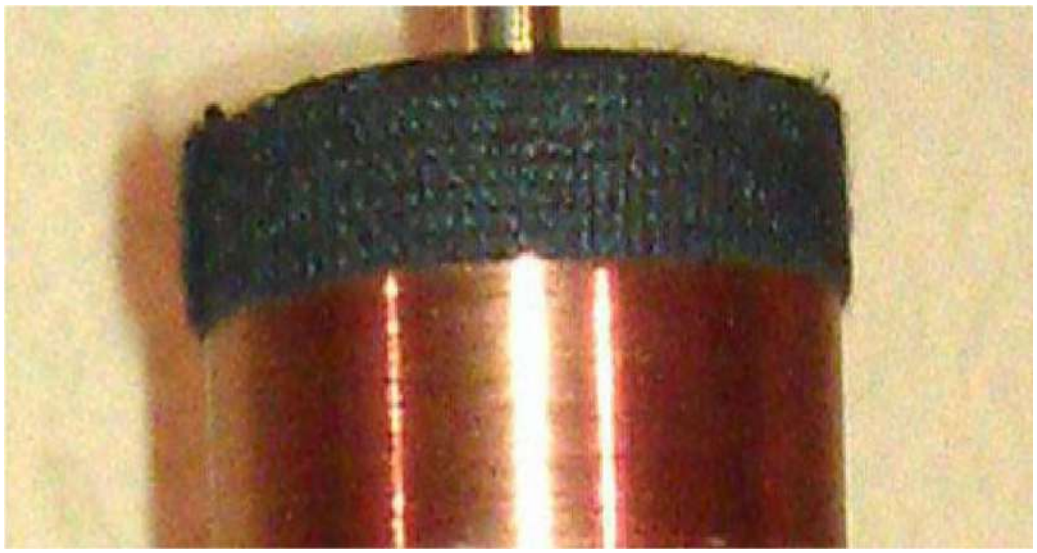
1. Push 10cm wire through the hole inside
1. Stick 10cm masking tape lengthwise over it and stick it in the tube smoothly upwards
3. If available, stick 3-4cm of double-sided tape over the hole on the outside of the tube. When reaching the end, stick new 3-4cm, this secures the wire if you ever let go of the wire when winding without fixing it with masking tape.
4. Wrap gloves or masking tape around all finger joints
5. Winding to reels or end of spool, I have built myself a winding stand it goes but

everything where you can push the pipe over it

6. Rest of 10cm push through the top hole.
7. Secure wire at top and bottom of hole with a drop of glue
8. Wrap black cloth tape once around the start and end of the coil (cut in half if necessary).
9. Make wire ends bright with emery paper
10. Measure resistance of coil ~62 Ohm
11. File notches into the wooden discs
12. Insert the wire ends of the coil through the hole in the center
13. Align wooden plate with notch to the hole of the wire feedthrough and insert into the tube
14. Fix with glue
15. Wrap wire 4-5 times around the screw in the stainless steel ball and screw tightly
16. Glue ball with screw onto the wooden disc (screw through center hole)







Calculations:
U=Pi x d
U=3,1415 x 40,3mm 0U=126,6Omm
W/cm = 10mm / 0.20mm 0 50 turns/cm 20cm coil
length = 1000 turns
L= 1000 x 0.12660m 0 126.6m wire length
Preparation/Tip
Gloves or joints wrapped with tape
Direction of rotation during winding should correspond to the direction of the coil In case of interruptions, always secure with masking tape

Background knowledge
Larger toroid = lower frequency More turns
= lower frequency

Tesla Free Energy Coil Build: With materials list, tool list, pictures, drawings, and collections of formulas.

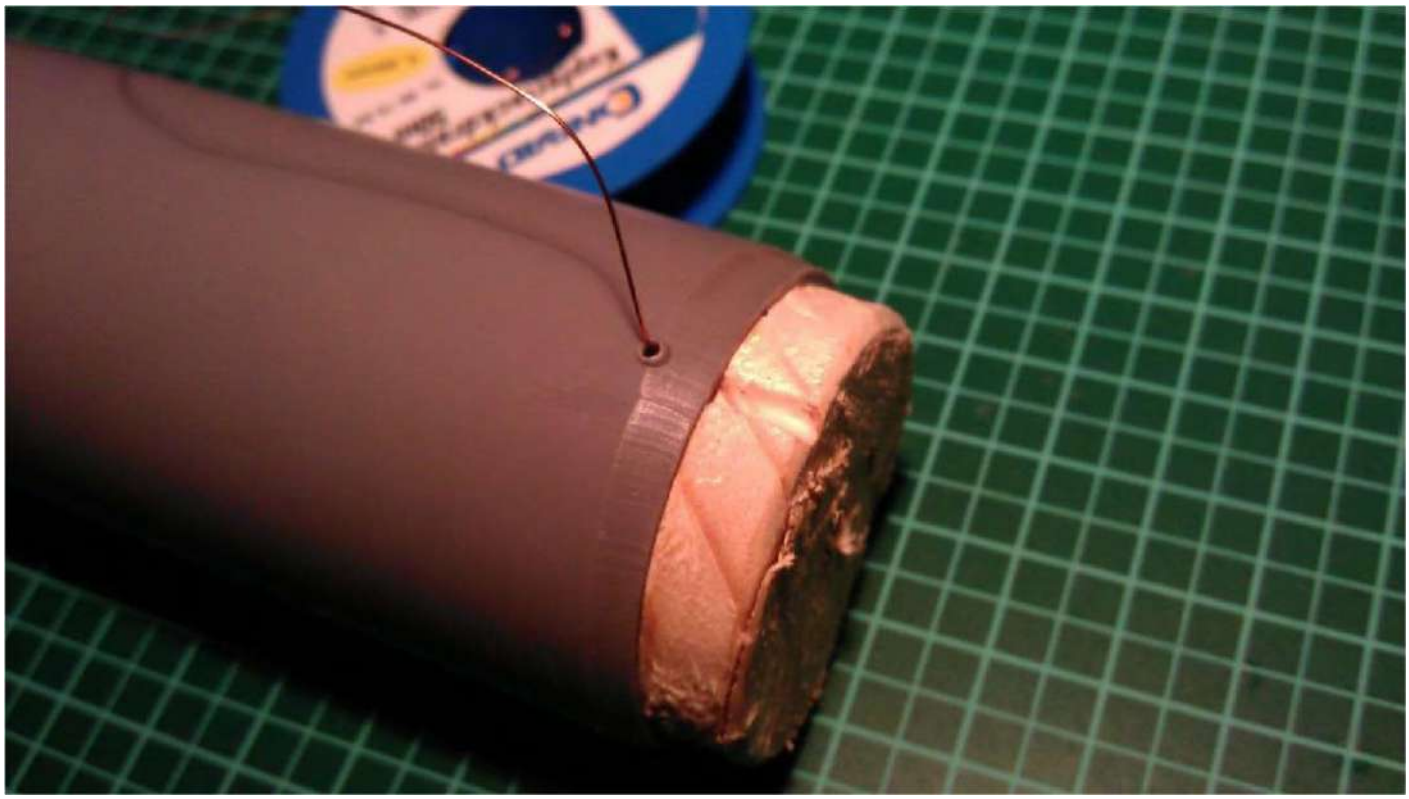
The cardboard tube should be painted beforehand or "embellished" with napkin technique and wood stain

1. Strip wire with sharp blade
2. Shape wire as smooth and straight as possible
3. Bend one end of the wire approx. 2mm by 90 degrees
4. Remove plastic film from cardboard coil
5. Drill a small hole at the top edge of the cardboard coil
6. Insert the angled part and wrap it completely tightly around the coil with 2-3mm gap

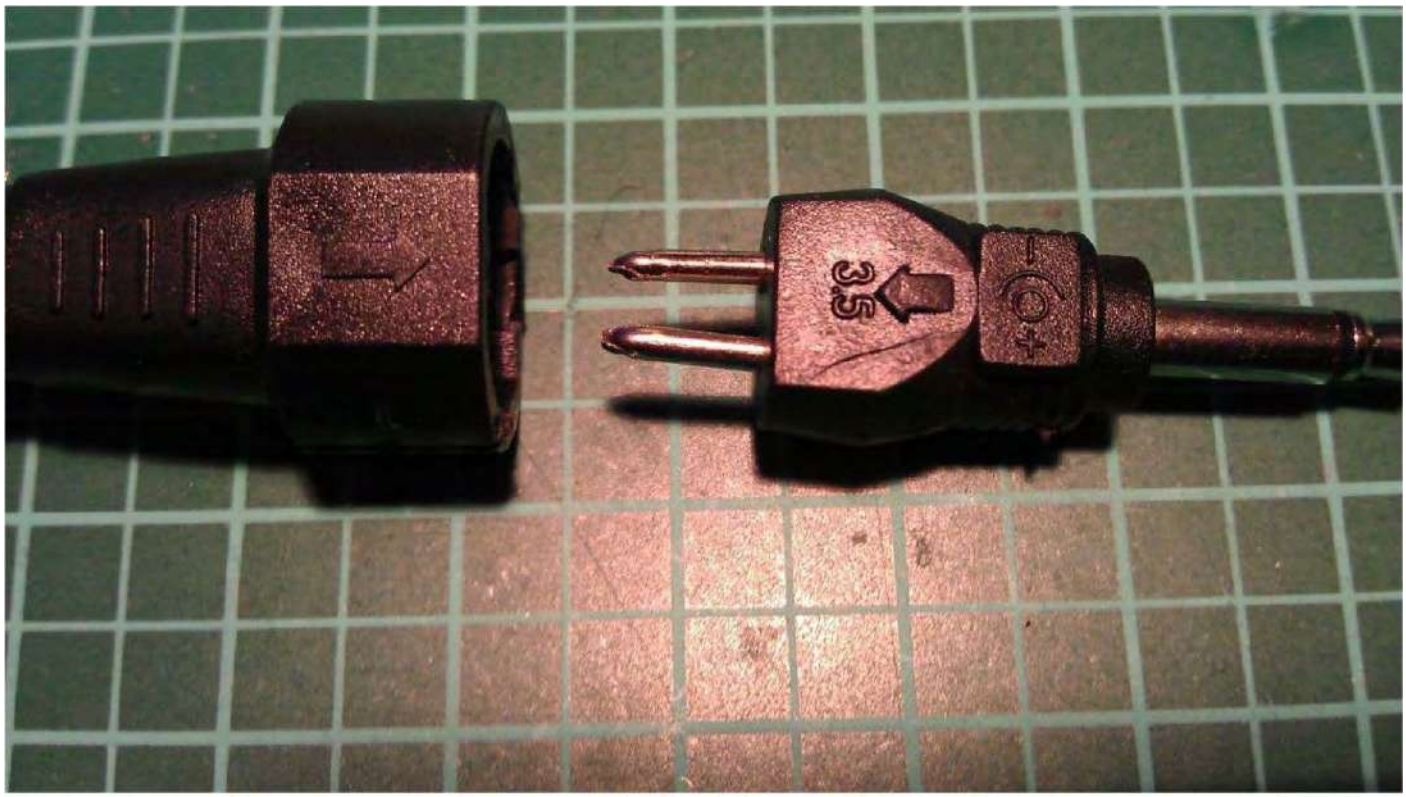
7. Mit den Windungen im oberen Bereich montieren!

Complete:

1. Glue lower wooden disc to base plate / box
2. Transfer hole in the middle to base plate / box and drill it
3. Place primary coil centrally over the wooden disc
4. Thread the lower wire of the secondary coil through the hole and put it on the coil on the wooden disc (groove must be aligned again so that the wire does not kink) (picture)
5. Soldering cables to the board
6. Feed the two primary coil leads from the board through the box cover and solder them to the primary coil.
7. Configure plug-in power supply (adjust 12V, select 3.5 inch jack plug and pay attention to polarity (picture)



Notice:
There is a 50% chance that the coil will not work and start.
The first thing to do is to change the wire to the upper and lower terminal of the primary coil!!!



Part 2 - Building the Tesla transformer

Teil 2 Der Tesla-Trafo

Motivation.

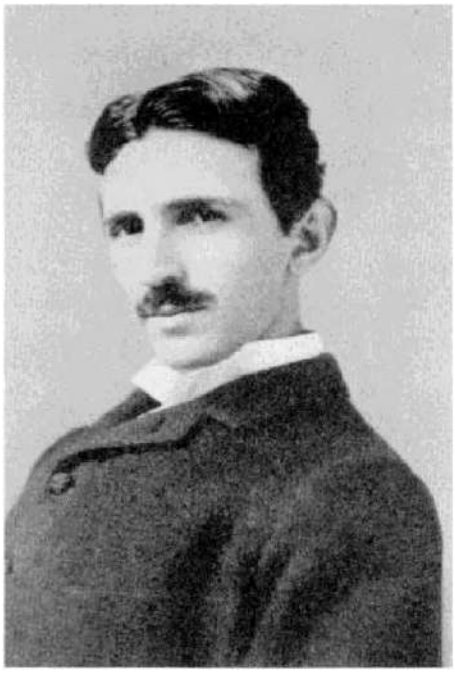
The visualization of resonance effects, electric fields and capacitive reactive currents.

The Tesla transformer is one of the most impressive experiments in high frequency technology. Resonance effects produce high-frequency voltages at extreme levels, typical values are 200 kV at 300 kHz. The resulting characteristic discharges, which occur in the surrounding air even without the presence of a counter-electrode, allow otherwise abstract concepts such as electric fields and capacitive reactive currents to be experienced sensuously.

What is also particularly impressive is that the Tesla transformer operates completely without the usual active electronic components in the sense of semiconductors or tubes; the high-frequency oscillation is generated with a spark gap as the only active component.

The visionary and pioneer Nikola Tesla.

The Tesla transformer was invented by Nikola Tesla (10.6.1856 - 7.1.1943) and a patent was filed in 1891. His vision behind it was the wireless transmission of energy via high-frequency fields, which was to take the place of the conventional power grid.



Nikola Tesla

This vision did not come true. But many of Nikola Tesla's other inventions have become indispensable in our everyday lives, such as the three-phase AC grid, the AC motor and the fluorescent tube.

The 150th birthday of Nikola Tesla lies within the project time of "Challenge High- Speed". This was a very special motivation for us to deal with his ideas.

A preliminary experiment: the generation of pulsed RF oscillations with a spark gap.

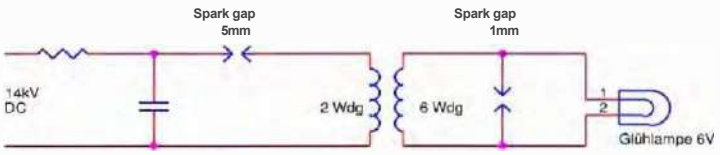
Motivation.

The first goal of this experiment is to demonstrate that damped RF oscillations can be generated with a spark gap. The second goal of this experiment is to demonstrate the, initially surprising, behavior of circuits when subjected to short and infrequent but high-energy RF pulses.

Both effects are crucial to the operation of the Tesla transformer.

The principle.

The following figure shows the schematic diagram of the experimental setup.



Schematic representation of the experimental setup

The capacitor [1 nF) visible in the picture is charged via a resistor. The resulting voltage rise at the capacitor leads to breakdown of the spark gap.
Due to the high conductivity of the ionized air of the spark channel, a very steep current pulse is generated. The capacitor is discharged comparatively quickly by the high current flow.
This causes the spark to break. The capacitor is charged again via the resistor until the spark gap breaks again. A periodic tipping oscillation with approx. 20 flashovers per second is generated.

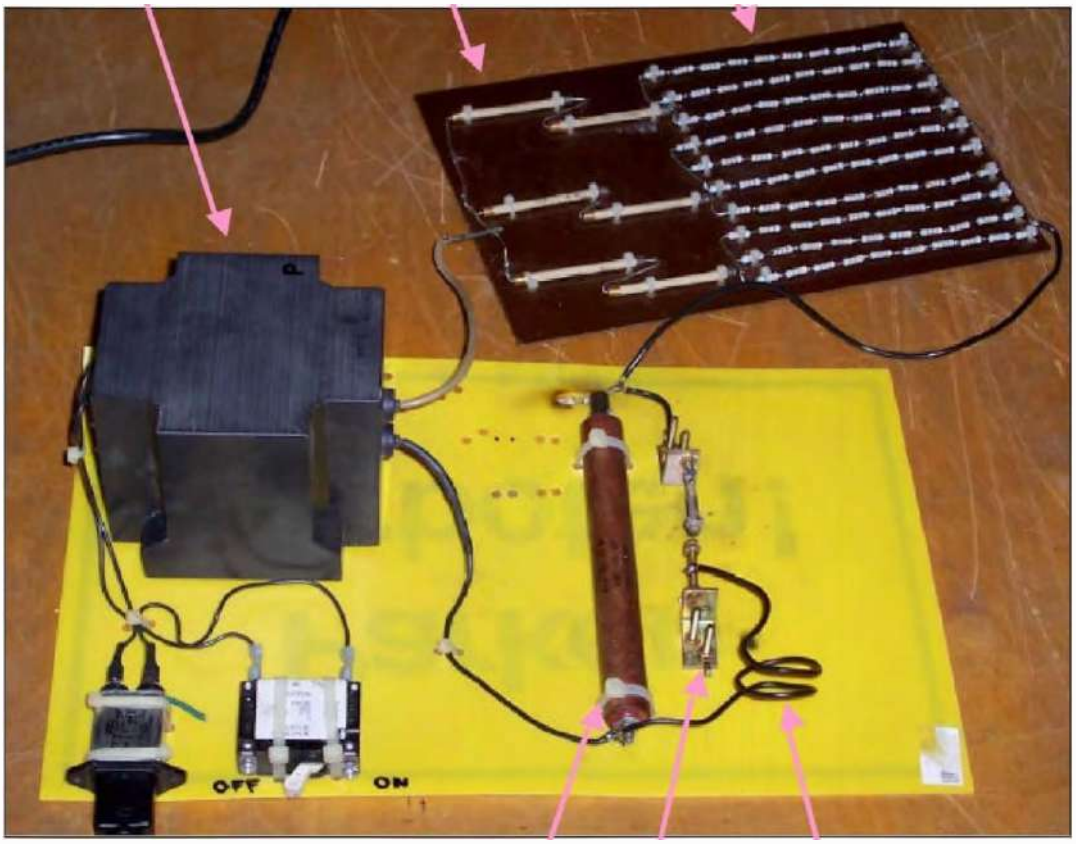
Due to the steep edge of the current pulse, it has a considerable amount of high-frequency energy, as can easily be seen by Fourier decomposition. The interaction with the inductance of the decoupling coils and the circuit leading through the spark gap with the capacitor results in an oscillating circuit with a natural frequency of approx. 7 MHz. This is excited to a damped oscillation by the flashover. The high-frequency energy is decoupled from the high-voltage circuit by the two magnetically coupled air coils visible in the picture.

A second spark gap and an incandescent lamp with a nominal voltage of 6V are used to detect the decoupled RF energy.

The experimental setup.

The following picture shows the practically executed experimental setup.

Net transfor-mator	Equal-JUDGE	Charging resistor



Conden-sator	Spark stretch	Decoupling coil (primary)

The practically executed experimental setup

In this picture, the secondary-side decoupling coil is not yet present. The mains transformer outputs a secondary voltage of 10 kV. This is rectified (with an interconnection of 6 selenium rectifiers as used in television sets) and fed via the charging resistor (composed of 100 commercially available resistors) to the capacitor

led. This allows it to be charged up to 14 kV. The capacitor is an oil paper capacitor with the characteristics 1 nF / 30 kV. The series connection of spark gap and decoupling coil is parallel to the capacitor. The spark gap consists of two threaded rods with cap nuts mounted on them. The optimum distance between the electrodes can be set by simply turning the cap nuts.

The use of cap nuts, with a practically hemispherical surface shape, is decisive for the success of the experiment. If, as was done experimentally, tips were used instead of the cap nuts, then practically no high-frequency energy components would be generated. The reason is that due to the high local field strength at the tips a pre-ionization of the flashover channel takes place. For a given distance, the ionization of the spark channel, in the presence of spikes, begins at lower voltages than would be the case with smooth surfaces of the electrodes. The current increase (di /dt] is thus smaller with the use of tips than it would be with smooth surfaces (with the resulting homogeneous field in the flashover channel). By visualizing the Fourier decomposition it is immediately obvious that a lower di/d leads to a decrease of the high frequency energy components.

The secondary-side spark gap, on the other hand, is designed with tips to achieve the most sensitive detection of the decoupled RF energy. The distance between the tips is about 1 mm. This means that the spark gap breaks down at a voltage of approximately lkV.

Findings.

The frequency of the damped RF oscillation can be determined to approx. 7 MHz by means of oscilloscopic measurement. In addition, high-energy individual pulses are present in the signal.

A seemingly paradoxical phenomenon appears: Parallel to the incandescent lamp, which is made to glow by the RF energy, a spark jumps over between the tips of the spark gap, which are 1 mm apart. Thus, a voltage of 1 kV (!) can be detected across the incandescent lamp, which has a nominal voltage of 6V.

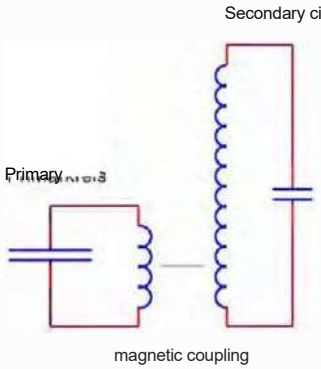
The *sparkover parallel to the bulb*

This phenomenon can be explained as follows: The high-energy RF pulses occur only about 20 times per second. Their instantaneous power is in the kW range, but the average power, related to the thermal time constant of the lamp, is less than IW. Therefore, despite the short-term high power, no thermal destruction of the lamp occurs.

This extreme ratio of instantaneous to average power is of high importance for the operation of the Tesla transformer and especially for the observed shape of the discharges.

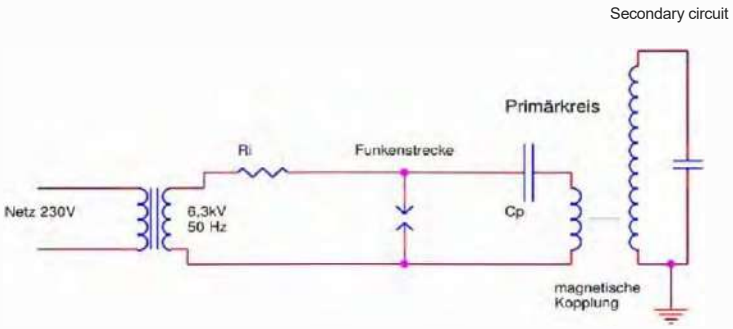
The principle of the Tesla transformer.

The Tesla transformer consists of two loosely coupled resonant circuits. The resonant frequency of both oscillating circuits is identical. In common practice, the order of magnitude of the resonant frequency is 300 kHz. The primary circuit has a low impedance, its coil has a low inductance, and its capacitor has a large capacitance. The secondary circuit, on the other hand, has a high impedance, its coil has a high inductance while its capacitor has a very small
capacity. In practice, it is usually designed as a metal ball mounted on the upper end of the coil.



The principle of the Tesla transformer

The primary circuit is fed with a pulse-shaped voltage of the order of 1 OkV. A damped oscillation is formed, which leads to a resonance-induced voltage rise in the secondary circuit of the order of 250 kV (!).



Tesla transformer with excitation by spark gap

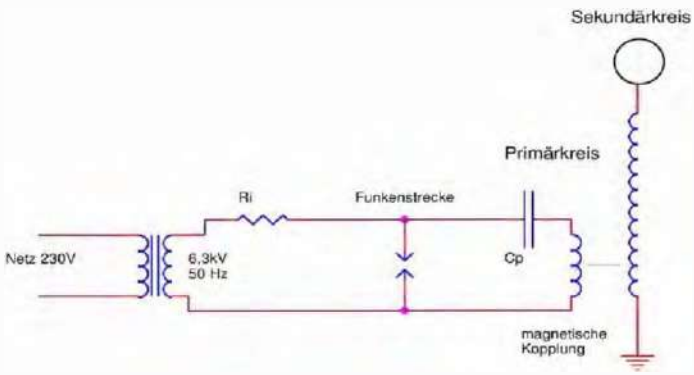
The pulsed excitation for the primary circuit is generated with a spark gap: The primary capacitor Cp is charged by the voltage delivered by the high-voltage transformer. This causes the voltage across the spark gap to rise. When the breakdown voltage of the spark gap is reached, a flashover occurs in it. The ionized, and thus conductive, air in the spark gap closes the primary-side resonant circuit. The energy stored in Cp is converted into a damped HF oscillation.

Due to the energy storage in the capacitor Cp, very high pulse powers of the order of 100kW are generated. This results in about 20 flashovers per second. The average power consumption from the mains is approx. 0.5 kW.

The spark gap is the only active component of the Tesla transformer. It operates as a threshold switch with hysteresis. The pulse powers occurring here in the WOkW range can only be controlled with difficulty using semiconductors or tubes.

The rapid extinction of the spark gap once breakdown has occurred is of decisive importance for the occurrence of a high secondary-side voltage. After extinction, the primary-side resonant circuit is interrupted again. This means that the energy in the secondary oscillating circuit can no longer be fed back into the primary oscillating circuit. It is then fully available to build up the discharges on the secondary side,

For this reason, a special spark gap was designed, which consists of several partial spark gaps connected in series, resulting in rapid extinguishing.



Tesla transformer with actual design of secondary side capacitance with a metal ball

The secondary-side capacitance is designed as a metal ball. The capacitance of the sphere is large compared to the capacitance of the lightning channels to earth and thus prevents detuning of the secondary-side circuit when setting up the discharge channels. With the 15 cm diameter sphere used, the capacitance to ground is approximately 8pF.

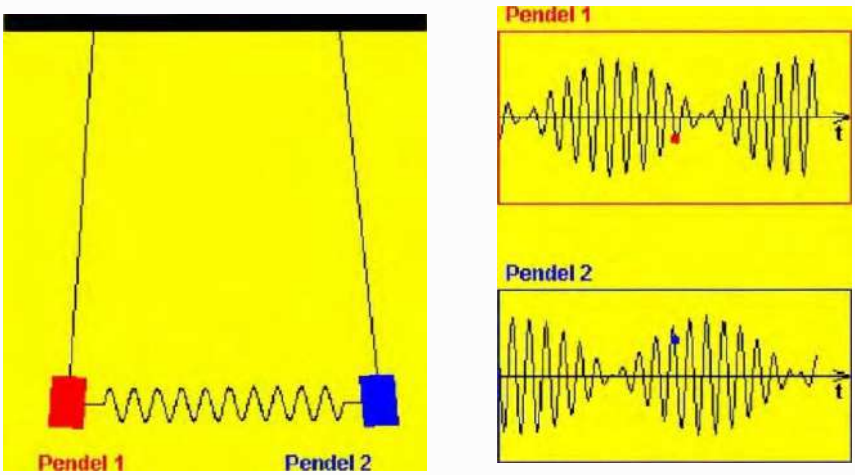
Some considerations on energy transfer between loosely coupled resonant circuits.

At first glance, the energy transfer between the loosely coupled oscillating circuits of the Tesla transformer appears to correspond to the energy transfer by means of magnetic coupling known from a conventional transformer. However, a closer look reveals that these are clearly different processes.

In common transformers, the primary and secondary currents and voltages are directly proportional to each other at any time, The proportionality between the respective primary-side quantity and the secondary-side quantity corresponds to the turns ratio. The coupling factor of a common transformer is 0.99 or higher. The coupling factor expresses the interpenetration of the magnetic flux of the two transformer windings.

With the loose coupling of oscillating circuits, completely different conditions prevail. The coupling factor of about 0.2 is significantly lower than that of the transformer. Therefore, there is no direct proportionality of the currents and voltages in both oscillating circuits. Therefore, with loose coupling, voltage increases are possible which exceed the winding ratios.

The energy transfer between loosely coupled oscillating circuits behaves similarly to the energy transfer between mechanical pendulums coupled by a spring. The following sketch represents these relationships graphically.



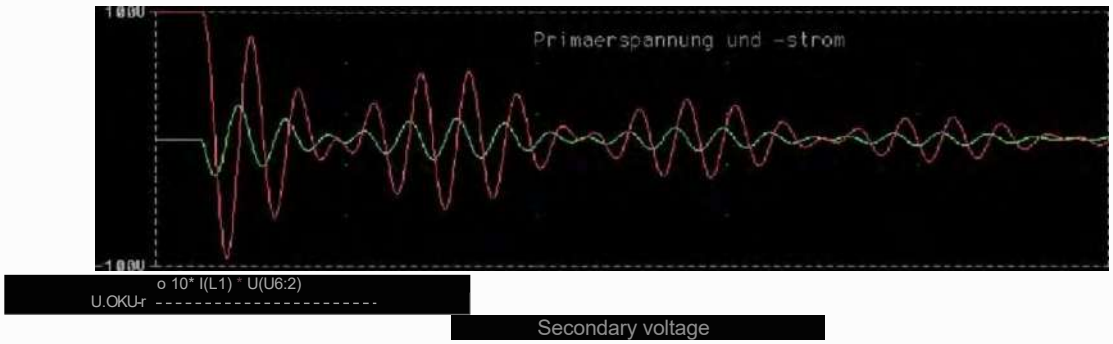
The behavior of mechanically loosely coupled pendulums

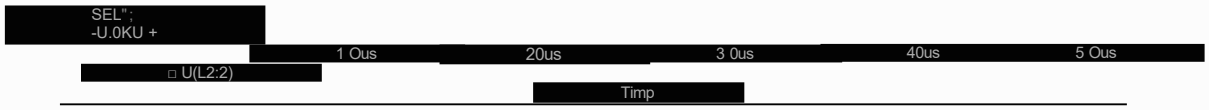
Source: http://www.walter-fendt.de/ph1 ld/qekopendel.htm , *there is also a very clear animation of this sketch.*

The pendulums have the same natural frequency. The oscillation energy alternates back and forth between the two pendulums at a frequency that is significantly lower than the natural frequency of the pendulums.

Exactly these ratios are found in the electrical oscillating circuits of the Tesla transformer. The frequency with which the oscillation energy oscillates between both oscillation circuits is the higher, the more tightly the oscillating circuits are coupled to each other.

The results of the simulation of a Tesla transformer in Pspice presented below show a clear similarity to the mechanical pendulum oscillations already presented.





Simulation of a Tesla transformer with

Pspice Source: www.hors.at

In the optimum case, the spark gap opens exactly when the oscillation energy of the primary circuit has been completely transferred to the secondary circuit. Then no more retransfer of the energy into the primary circuit is possible and the energy of the secondary circuit is then exclusively available for the formation of the discharges.

The analogy between the mechanical pendulum and the electric oscillating circuit is to be discussed. In the mechanical pendulum oscillation, the stored oscillation energy alternates between potential and kinetic energy. When the pendulum is in one of the two end positions, the velocity of the mass is zero, but it has the
Maximum potential energy. In the center position of the pendulum, the mass has no potential energy, but moves with the maximum speed, thus it has the maximum kinetic energy.

If you equate the potential energy with the electric field energy in the capacitor of an electric oscillating circuit and the kinetic energy with the magnetic energy stored in the magnetic field of the coil of the oscillating circuit, you get exactly identical ratios. The height of the pendulum mass then corresponds to the electric voltage in the oscillating circuit, the velocity of the mass then corresponds to the current in the oscillating circuit.

The described concept of energy transfer between loosely coupled oscillators can also explain the voltage rise in the secondary circuit, even if there is no direct mechanical equivalent for it.

The following formulas represent the energy stored in the capacitor and coil:

$$W_c = \frac{C * U^2}{2}$$

r */-
n; = --

If now a defined amount of energy is transferred into the secondary circuit, then at a certain point in time the entire available energy is stored in the capacitor. If this capacitor is very small, as is the case with the secondary circuit of the Tesla transformer, then it is inevitable that this amount of energy causes a high voltage at the capacitor. Conversely, the very large inductance of the secondary coil results in much lower currents flowing than in the primary circuit at the moment when all available energy is stored in the magnetic field of the coil.

From Thomson's formula, which is used to calculate the resonant frequency of a resonant circuit, it can be seen that if the resonant frequency is maintained, a reduction in the capacitance must be compensated for by a proportional increase in the inductance:

The energy storage in the primary capacitor

The special effects that can be observed with the Tesla transformer are particularly due to the fact that very high powers act very briefly and comparatively rarely. Here, the energy storage in the primary capacitor plays a decisive role.

The energy stored in the primary capacitor at the moment of sparkover at the spark gap can be estimated using the following formula:

If it is assumed that the spark gap breaks down when 6kV is reached, then at this point an energy of

$$12.5\text{^}6000\text{^^},$$
$$2$$

stored in the capacitor.

The capacitor is completely discharged after a quarter of the period of an oscillation of the primary circuit. Then, with simplified consideration, all energy stored in it is stored in the magnetic field of the primary coil. If we further assume a resonant frequency of the primary circuit of 300 kHz, then '/" of the period duration in the primary circuit is 0.83 us.
One can thus give an approximate order of magnitude of the maximum instantaneous power of

$$\text{^} = 277,\text{r}$$
$$0.8?\ /\ddot{\text{O}}$$

estimate. The magnitude of the short-time instantaneous power is far above the average absorbed power of approx. 0.5 kW.

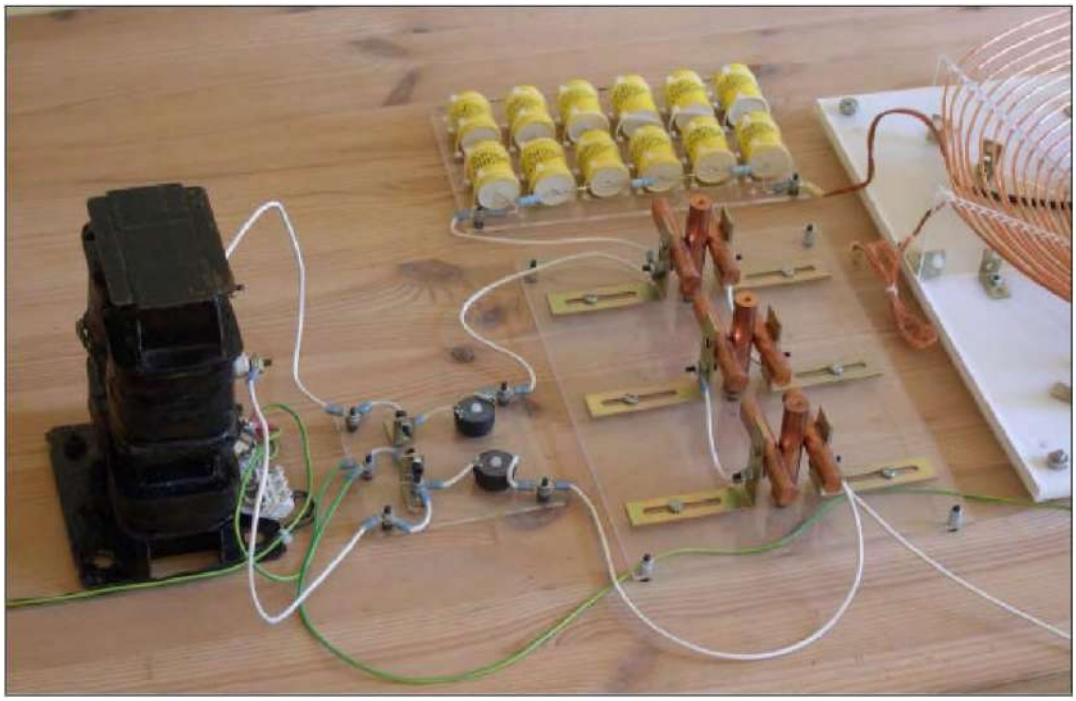
The practical execution.

The overall structure.

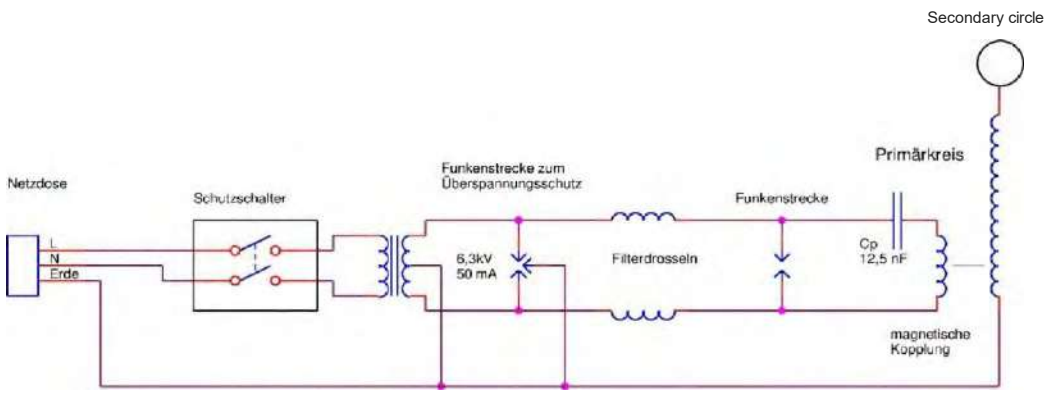
These following pictures show the overall setup of the Tesla transformer and the complete circuit diagram of this setup.

The mains transformer can be seen in the foreground. This is connected to a module on which there is another spark gap which protects the transformer from excessive RF energy fed back in the event of a fault. Two RF chokes, which are also located on this module, reduce the RF energy fed back into the transformer during normal operation.
The spark gap can be recognized by the large-surface electrodes made of solid copper material. The primary capacitor consists of 12 polypropylene film capacitors connected in series, which can be easily recognized by their yellow housing color. You can clearly see the helically wound primary coil and the long, cylindrical secondary coil with the brass ball at the head of the coil acting as the resonant circuit capacitor.

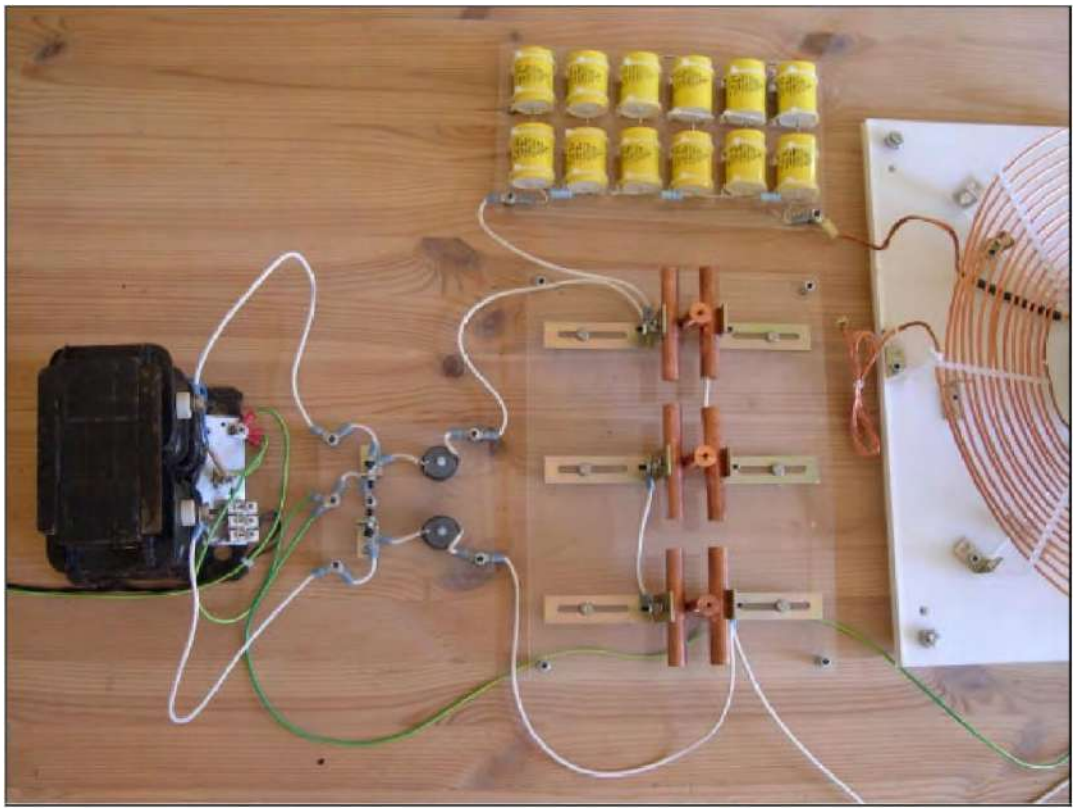
The overall structure of the Teslatrafo.



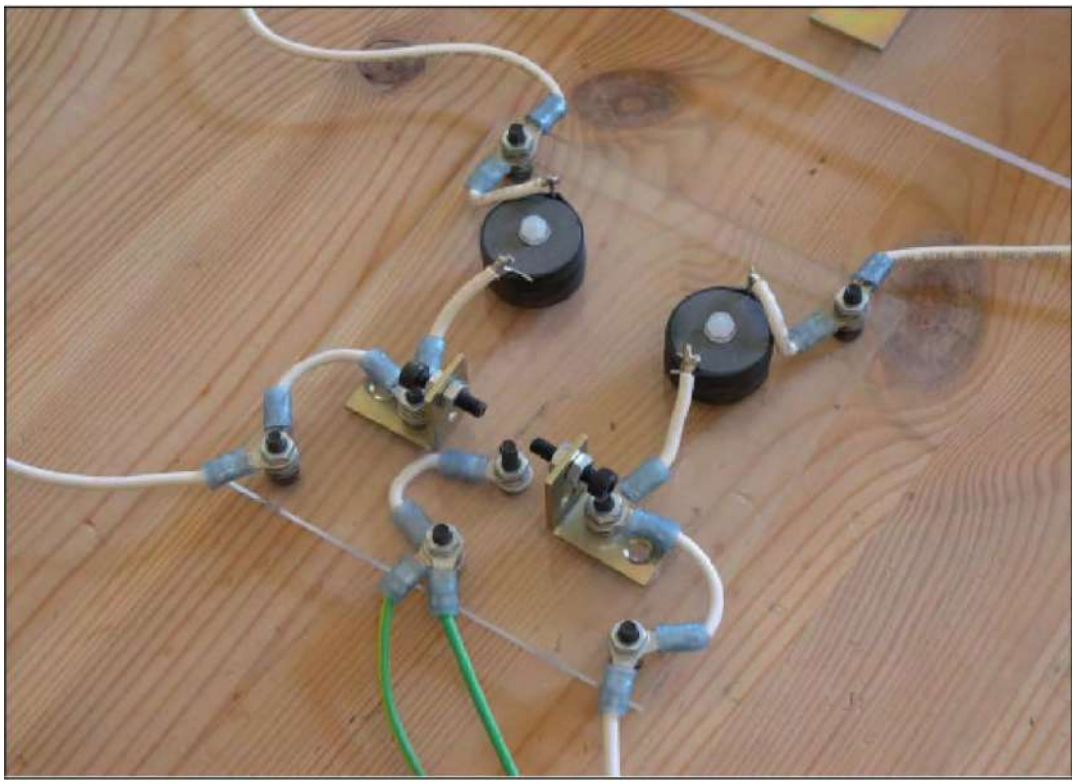
Detail view of power transformer, spark streoke and primary capacitor



The complete circuit diagram of the Tesla transformer



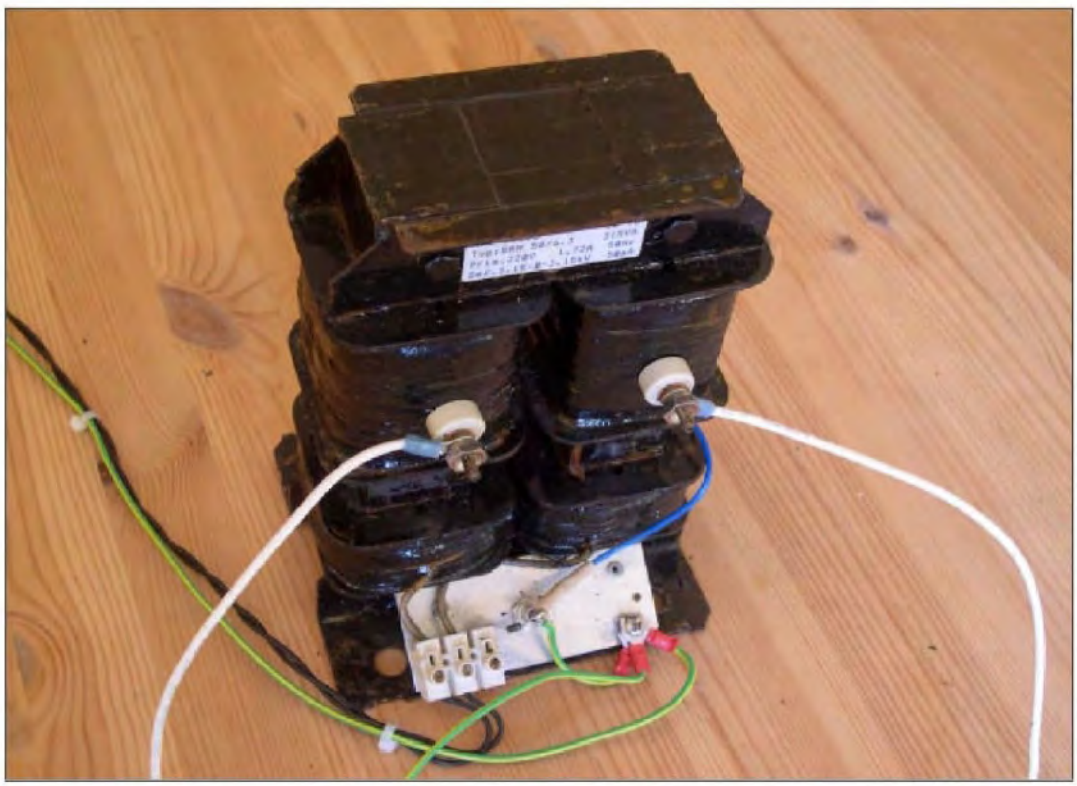
A look at the wiring from above immediately reveals the correspondence with the circuit diagram.



Detailed view of the safety spark gap and interference suppression chokes

The power transformer.

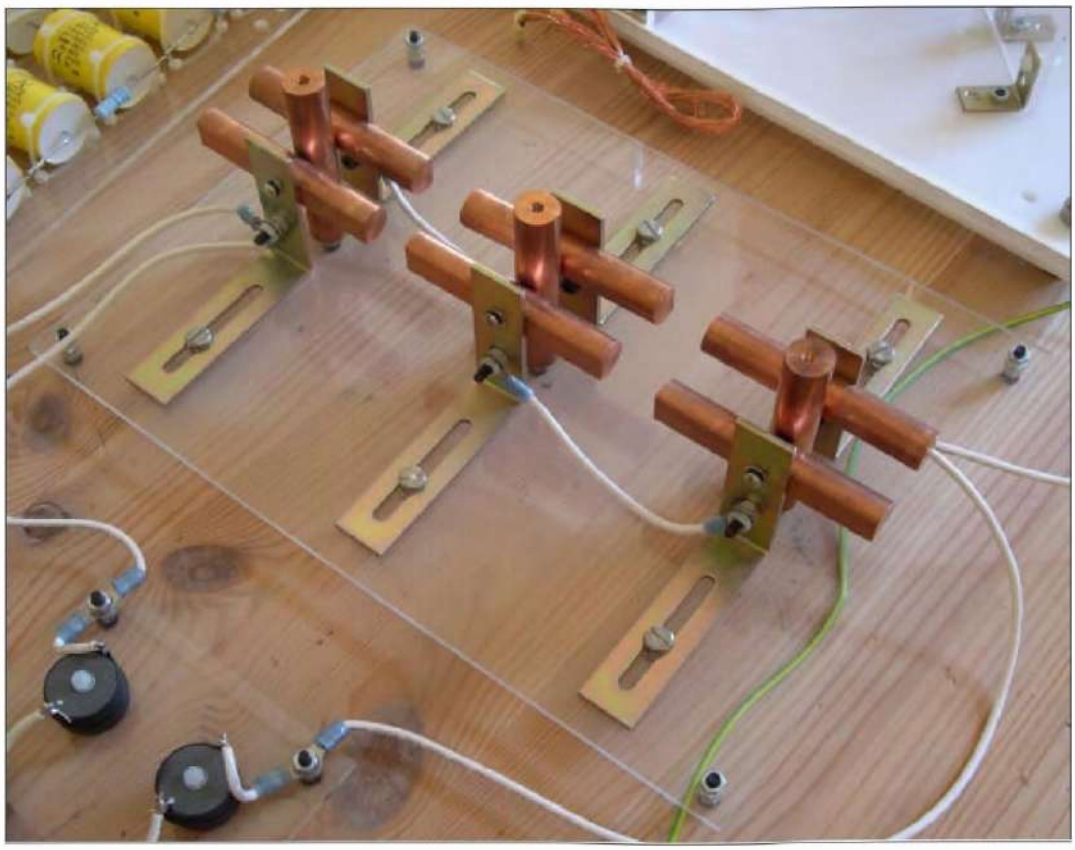
A commercial neon transformer with a secondary voltage of 6.3kV / 50mA is used. The yoke has been removed to increase the removable power. These transformers are normally used to power neon light signs.



The mains transformer

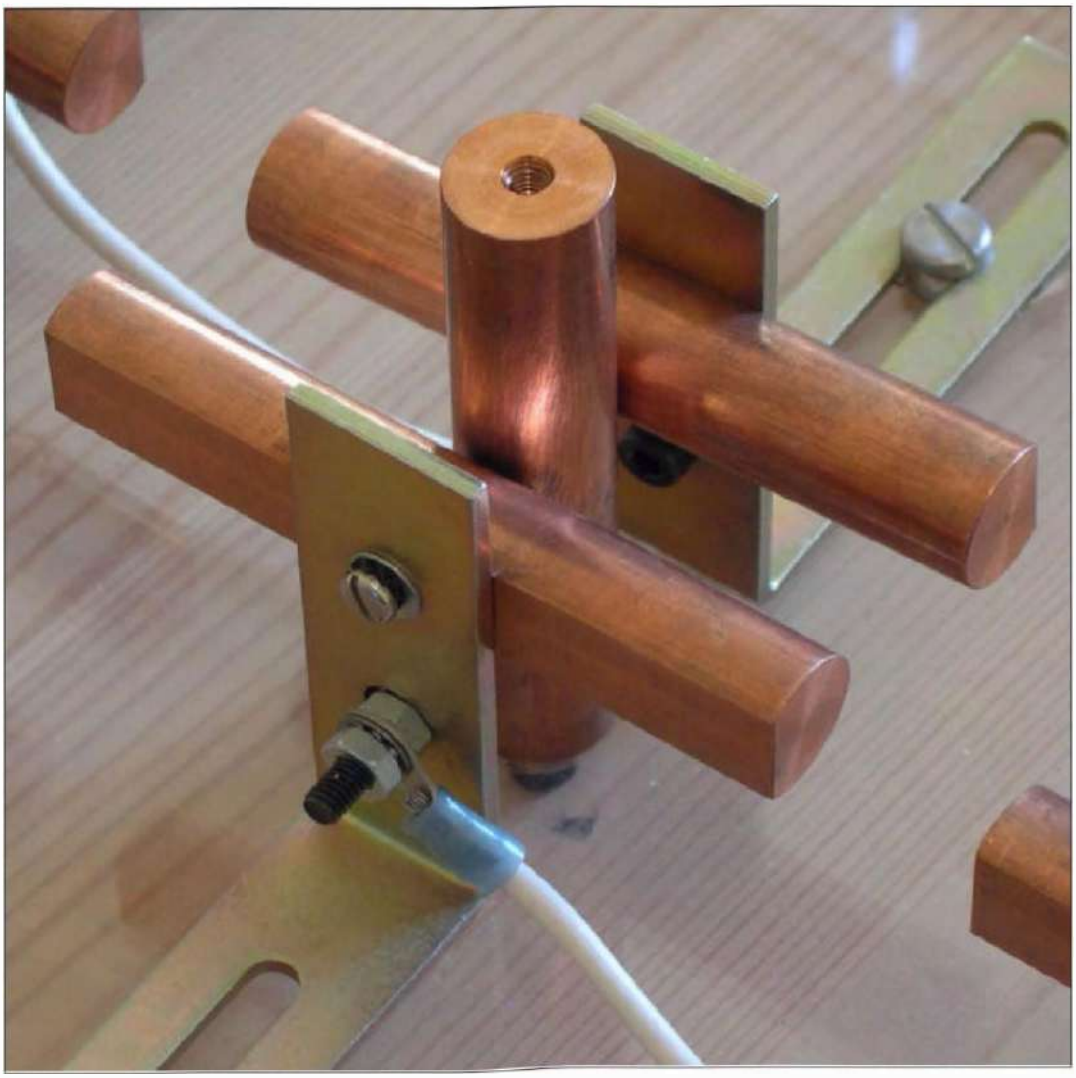
The spark gap.

To achieve fast quenching of the discharge, 6 partial spark gaps were connected in series. Large area electrodes made of Cu solid material were used to ensure good heat dissipation. The orthogonal arrangement of the Cu round bars leads to a homogeneous field in the flashover region. This avoids pre-ionization of the flashover channel. The spacing of the partial spark gaps can be adjusted individually. The best results were achieved with a spacing of 0.2 to 0.3 mm in each case.

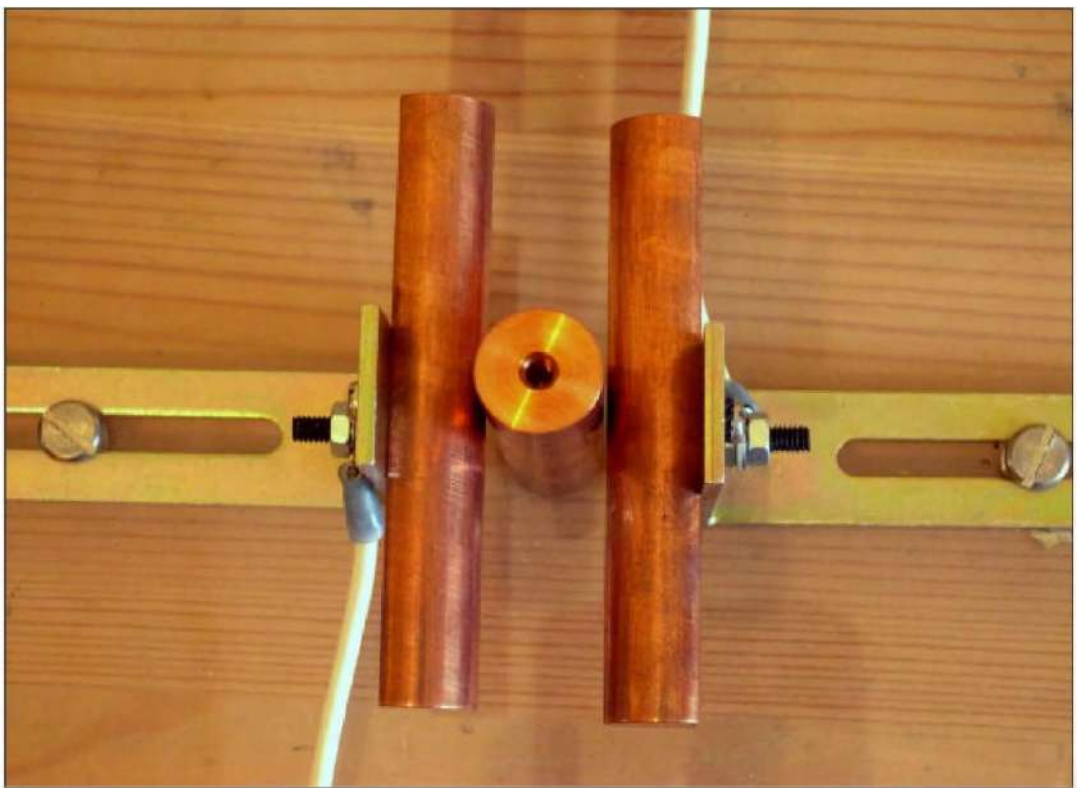


The spark gap.

In the course of operation of the Tesla transformer, the importance of the quenching behavior of the spark gap was shown by the fact that after an operating time of approx. 20 min. the length of the discharges decreases by approx. 50%. If the spark gap is then dismantled and the residues adhering to the copper surface are removed with steel wool, the original length of the discharges is restored.



Detailed view of a partial spark gap.



Detail view of a partial spark gap from above.

The primary capacitor.

The primary capacitor was realized by connecting in series 12 standard polypropylene capacitors 1 50nF / 750V AC, purchased from the catalog distributor RS-Components. A capacitor with a capacitance of 12.5nF and a dielectric strength of 9kV AC is thus obtained. The use of polypropylene as a dielectric results in the lowest possible dielectric losses within the capacitors and is therefore an important factor for a high quality of the primary-side resonant circuit.

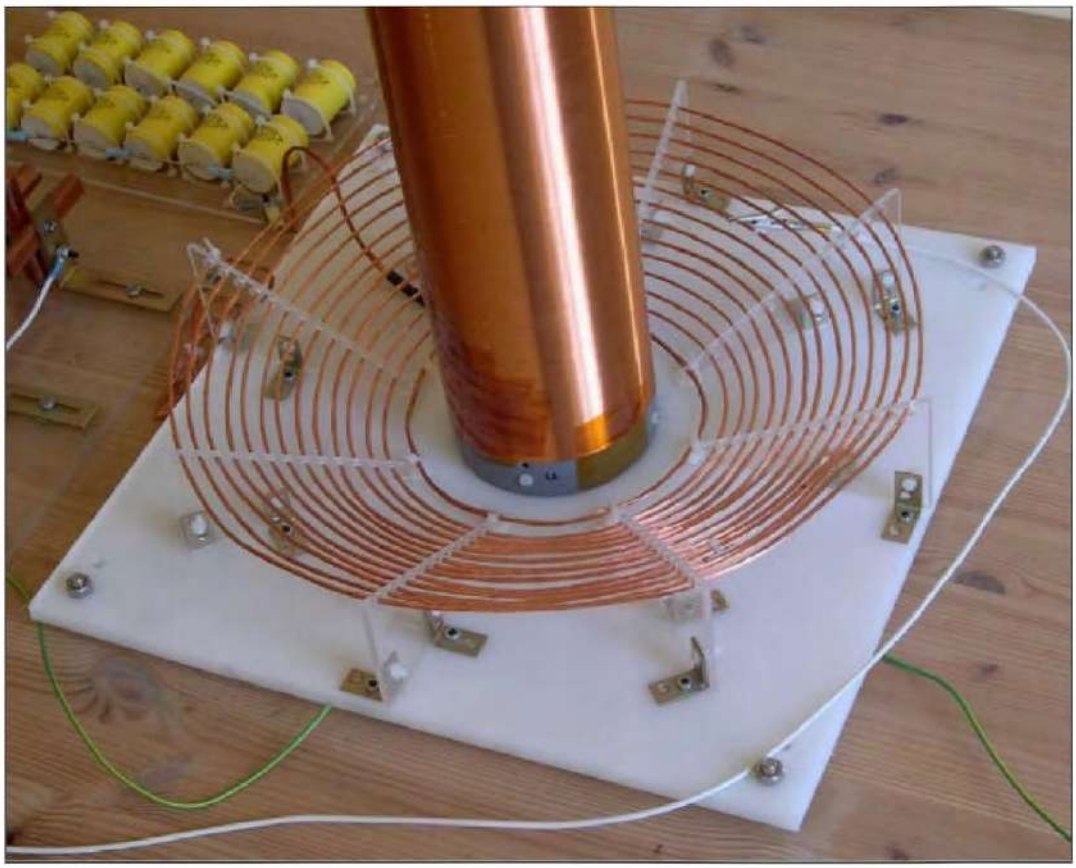
The primary capacitor.

A high-voltage resistor with a value of 56 MOhm was connected in parallel with each of 4 series-connected capacitors to ensure that the capacitors discharged under all circumstances.

A single capacitor in detail

The primary coil.

The primary coil is wound in helix design with a slope of 30°. This design represents the optimum compromise between close magnetic coupling (desirable energy input) and low capacitive coupling (undesirable energy dissipation). Capacitive coupling becomes more detrimental as the secondary coil height increases. Fine tuning of the primary-side resonant frequency to the secondary-side resonant frequency is accomplished by primary-side tapping using an alligator clip. The coil was wound with semi-rigid stranded wire with a large surface area,
to keep losses due to the skin effect small, This stranded wire was kindly donated by the company KBE-Elektrotechnik GmbH, (www.kbe-elektrotechnik.de)

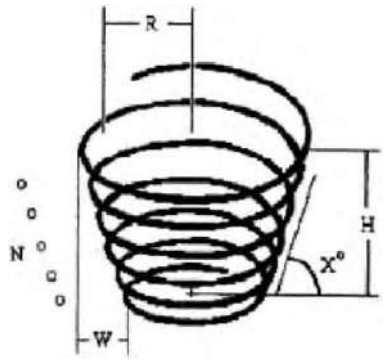


The primary coil.

The computational estimation of the primary circuit.

The number of turns and the dimensions of the primary coil as well as he value of the primary capacitor were based on the empirical values published in many places on the Internet, which do not differ significantly. As the calculation below shows, one actually gets the expected resonant frequency in the order of 200 kHz. The resonant frequency is deliberately set lower than the expected resonant frequency of the secondary circuit of about 300 kHz, so that one can then adjust the resonant frequency of the primary circuit to the secondary circuit by tapping the primary coil.

Z_p = Jrz.sinfr)]' + [Z , cos(.r)]: with Z. = ' '^A '- and Z, = -
v ' 9E + 10/Z ' 8Ä + 11F



Lp = inductance of the primary coil in pH L I = helix factor

L2 = spiral factor

N - number of turns

R = average radius in inches H = effective height in inches W = effective width in inches X = angle of inclination in degrees 1cm = 0.394inch

Figure 19: The primary coil

With N = 9.33

R = 20cm'0.394 = 7.88inch

H = 7cm'0.394 = 2.76inch

W = 12crrro,394 = 4.73inch

X= 30°.

the inductance of the primary coil is L_P = 49.1 pH. This results in the resonant frequency of the primary circuit:

$$f_{res.P} = \frac{1}{2\pi\sqrt{L_P C_P}}$$ - ---------- 203J5JW;
2rr$_v$ >'l *2.5nF A9AuH*

The secondary coil and the head capacity.

The secondary coil has a length of about 55cm and a diameter of 11.5cm. It consists of approx. 1100 turns of enameled copper wire with a diameter of 0.5mm. A sewer pipe from the hardware store serves as the coil body. The coil was wound by hand by 3 persons within 4 hours. To protect against corona discharges, the upper area of the coil was masked with Kapton tape. Before winding, the coil former was carefully cleaned to exclude discharges and leakage currents on the surface of the coil former.

A brass ball with a diameter of 15cm serves as the head capacity. The ball was purchased from Ball-Tech Kugeltechnik GmbH | http://www.ball-tech.de |. (Type 612150 with M8- internal thread).

The capacity of the sphere to the earth can be calculated according to the following formula:

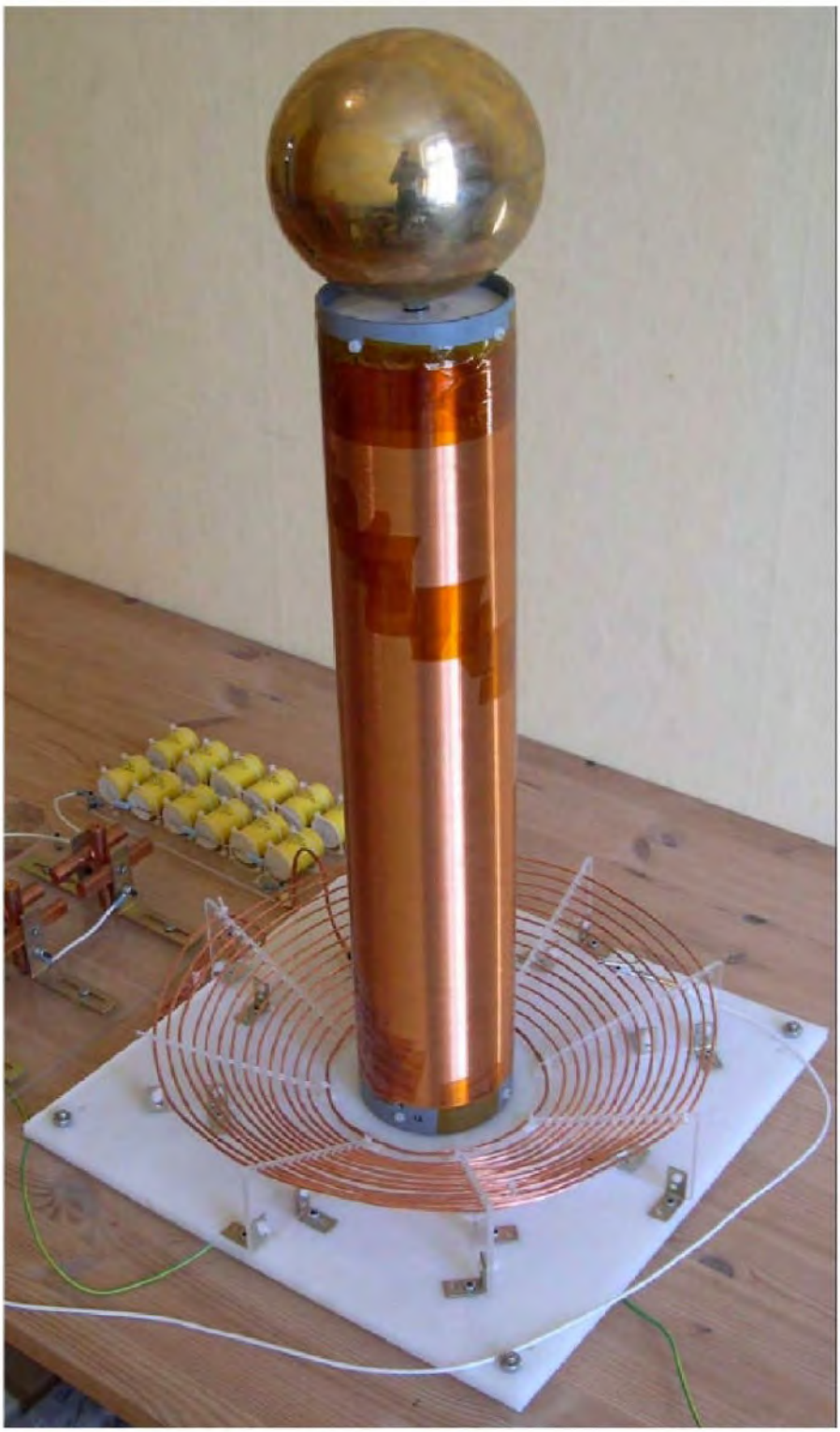
$$C_{kugei} \quad \frac{25.4}{9}$$

Ckugei - Capacitance in [pF]

R radius in [inch]

lcm = 0.394 inch

For the diameter of 15cm present here, this results in a capacity of 8 pp



View of the secondary circuit,

The computational estimation of the secondary circuit.

The secondary circuit was also dimensioned on the basis of the empirical values published widely on the Internet. In the following, the resonant frequency of the secondary circuit is estimated by calculation:

Cs.ges = Cs + Cs' with

$C_{s\ .Bes}$: Total capacitance of the secondary
circuit C_s : Head capacitance (ball capacitance)
Cs': Self-capacitance of the secondary coil

with Cs = spherical capacitance in pF
R = 7,5cm*0,394 = 2,96inch = radius of the sphere in inch
1cm = 0,394inch

$C_s = 0.29L$ - 0.4LR + 1.94^y- = 8.6 pF

with Cs' = self-capacitance of the secondary coil in pF
R = 5.75cm'0.394 = 2.27inch = radius of secondary coil in inches
L= 55cm*0.394 = 21.67inch = length of secondary coil in inches
1cm = 0.394inch

It results for the total capacitance of the secondary circuit $Cs_{,ges}$ = 16.9pF.

The inductance of the secondary coil can be calculated using the following formula:

with Ls = inductance of the secondary coil
Po = 4n'10^{-7} Vs/Am = magnetic field constant p_r =
1 = permeability number
N = 1100 = number of turns
A = nr^2 = TT$(0.0575m)^2$ = $0.01m^2$ = cross-sectional area of the coil
with r = 5.75cm = radius of the secondary coil
l = 55cm = length of the secondary coil

Daraus folgt für die Resonanzfrequenz des Sekundärkreises:

$$f_{res,S} = \frac{1}{2\pi\sqrt{L_S C_S}} = \frac{1}{2\pi\sqrt{16.9\,pF \cdot 27.6mH}} = 233{,}04kHz$$

The calculated resonant frequency of the secondary circuit is of the expected order of magnitude and is desirably higher than that of the primary circuit if its winding were effective without taps.

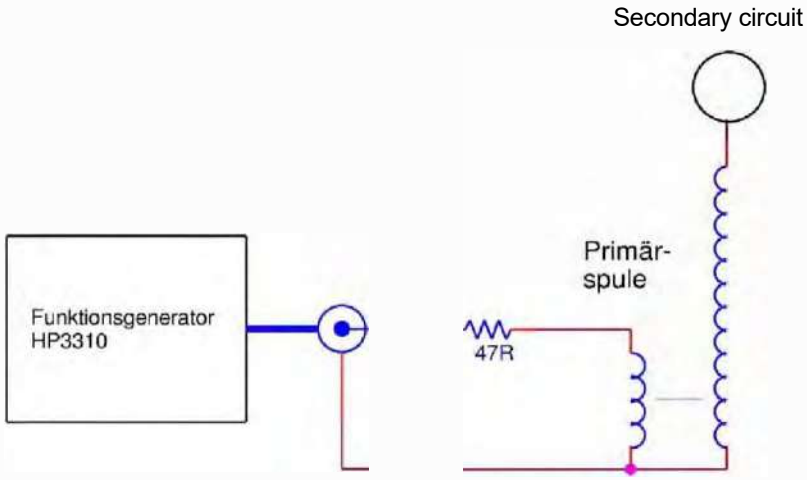
The experimental determination of the resonant frequency of the secondary circuit.

Before the first commissioning of the Tesla transformer with high voltage, the resonant frequency of the secondary circuit with low voltage was determined experimentally.

For this purpose, the primary coil, without a primary capacitor connected in series, was fed by a function generator via a series resistor.

The natural resonant frequency of the primary coil is orders of magnitude higher than the resonant frequency of the secondary circuit, so that the primary coil in this experimental setup acts purely inductively in terms of magnetic excitation of the secondary circuit.

In the resonance case of the secondary circuit, the current consumption of the primary coil is minimal, which is expressed by a minimum of the voltage drop across the series resistor. If the function generator is adjusted so that this minimum occurs, then the resonant frequency of the secondary circuit has been found.



Setup for determining the resonant frequency of the secondary circuit

The resonant frequency of the secondary circuit determined with this setup was 239 kHz, which is almost exactly the value expected from the calculations....

Subsequently, the primary circuit, with inserted primary capacitor, was adjusted to the secondary circuit by selecting the optimum tap point according to the above method.

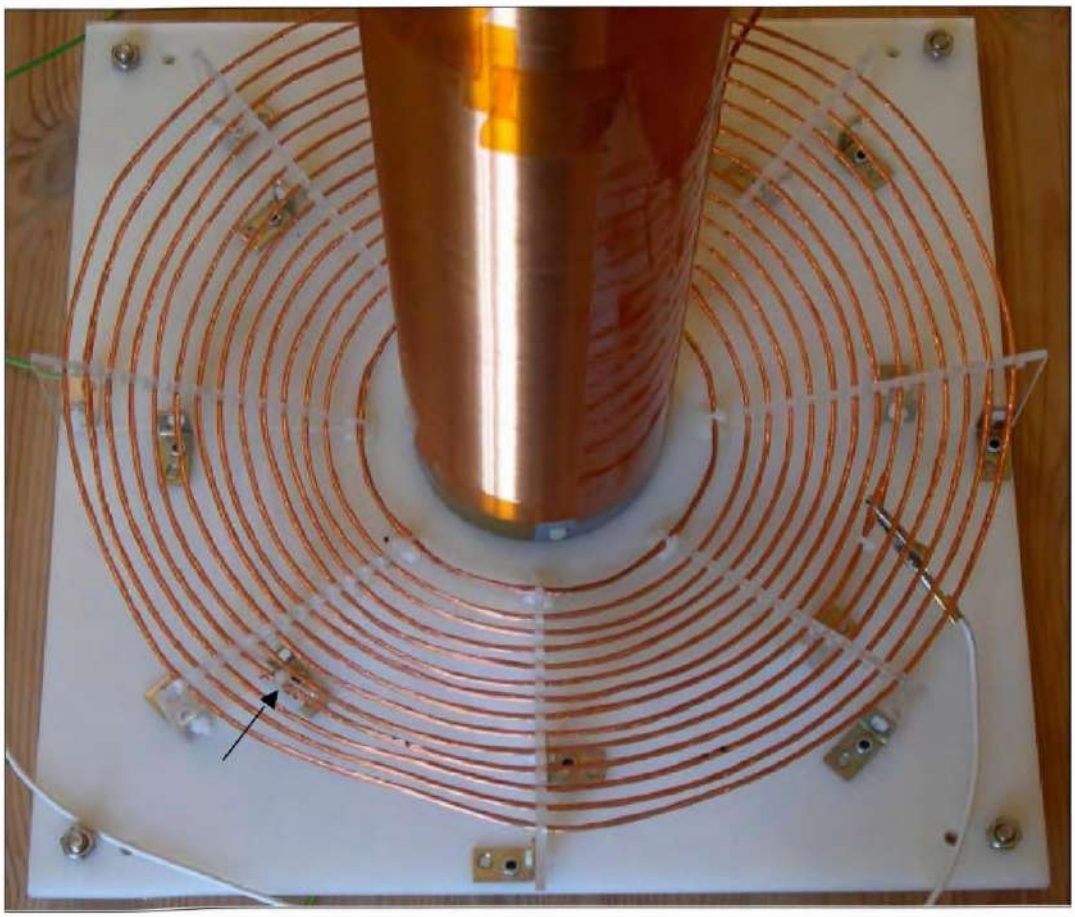
The resonance behavior of the coupled resonant circuits was clearly visible.

The output voltage of the function generator was 30Vpp. Already during excitation with this voltage, considerable field strengths appeared in the area of the head capacitance, which caused a glow lamp held in the hand to glow at a distance of several cm from the head capacitance. Furthermore, small sparks of about 1 mm length could be drawn from the head capacitance.

During later operation with high voltage, the tapping point found in this way showed an immediate function of the tesla transformer. Surprisingly, however, the strength of the discharges could be reduced further by reducing the primary-side inductance by

Shifting the tap point by a few turns towards the lower end of the coil can be increased considerably.

Whether a further reduction of the inductance would have resulted in a reduction of the discharge strength was not tested, since a possible further increase of the discharge strength would have destroyed the secondary coil. Therefore, the optimization was arbitrarily stopped at the tap point now defined as final.



The final tap point on the primary coil can be identified by the position of the crocodile clip making the contact. The optimum tap point when operating with a function generator is marked with an arrow.

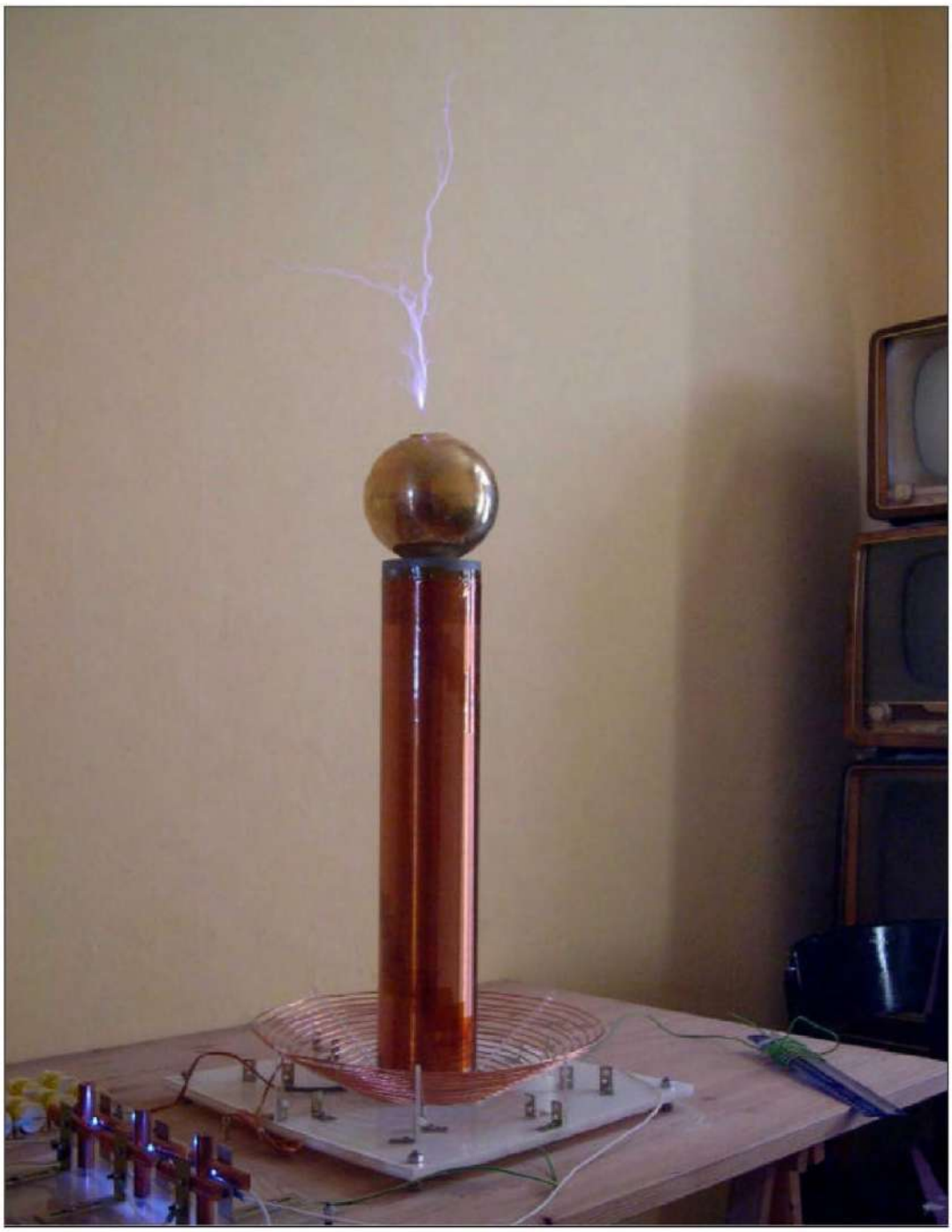
Findings.

Even without the presence of a counter-electrode, tree-shaped discharges build up in the area of the sphere, so-called streamers. They are caused by the high current density of the capacitive reactive currents in the area of the sphere. Therefore, no streamers can occur with DC voltage.

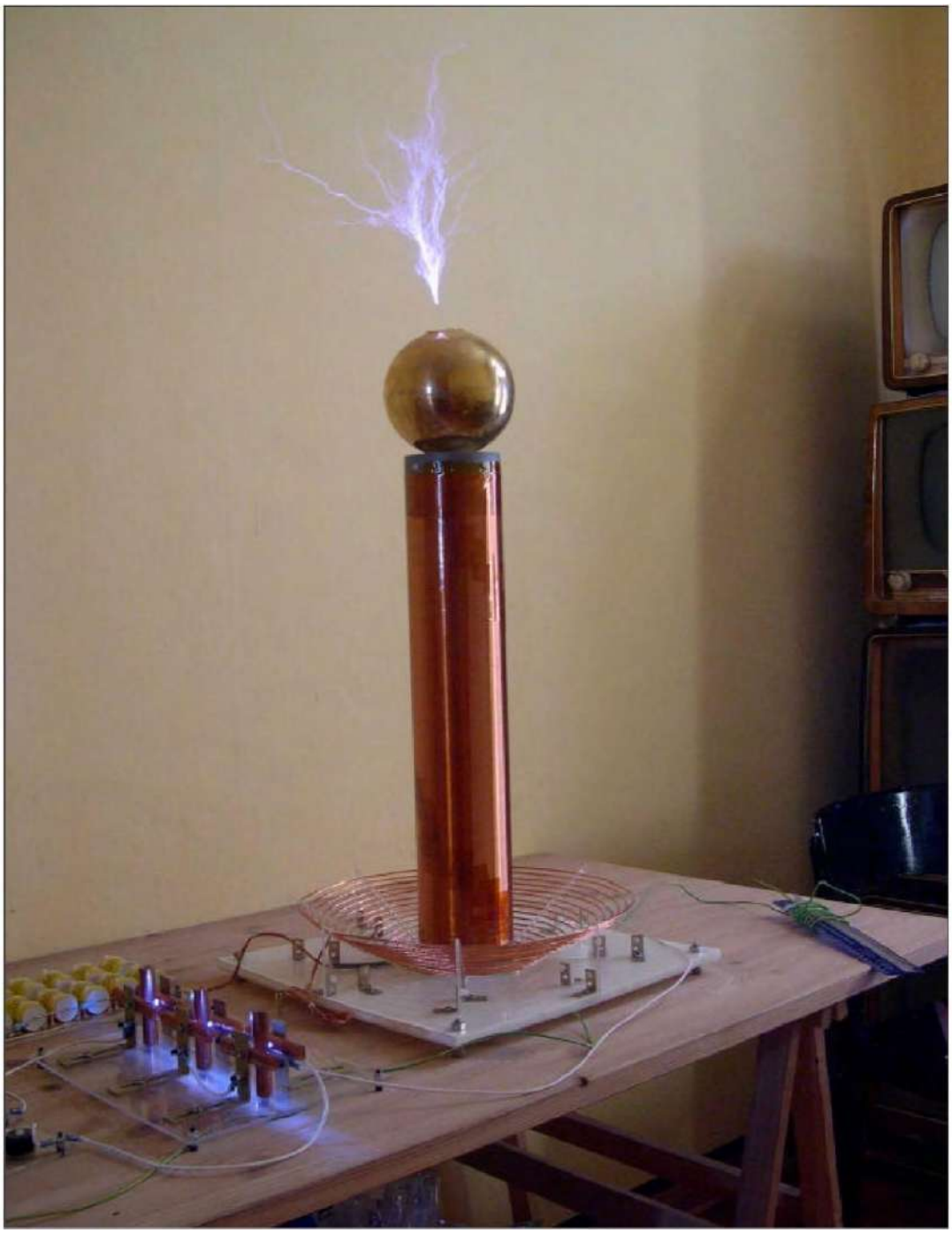
The branching of the outer lightning channels results from different paths during successive discharges. The "main channels" near the origin remain even in
ionized during the pause between discharges and are therefore stationary. Based on the main channels, the streamer grows in height from the origin until equilibrium is reached at about 40 to 60 cm height of the discharge channels.

To create a starting point for the streamers, a short piece of wire was attached to the sphere. A very high electric field strength is formed at its tip. After about 30s of operation, the piece of wire at the tip begins to glow and melt.

This image, taken with medium exposure time, comes very close to the actual impression. The discharges within the spark gap are also clearly visible.



Einzelne Entladungen erreichen erstaunliche Höhen.



The shape of the discharges is constantly changing. New shapes of the discharge channels with fascinating, filigree aesthetics become visible all the time.

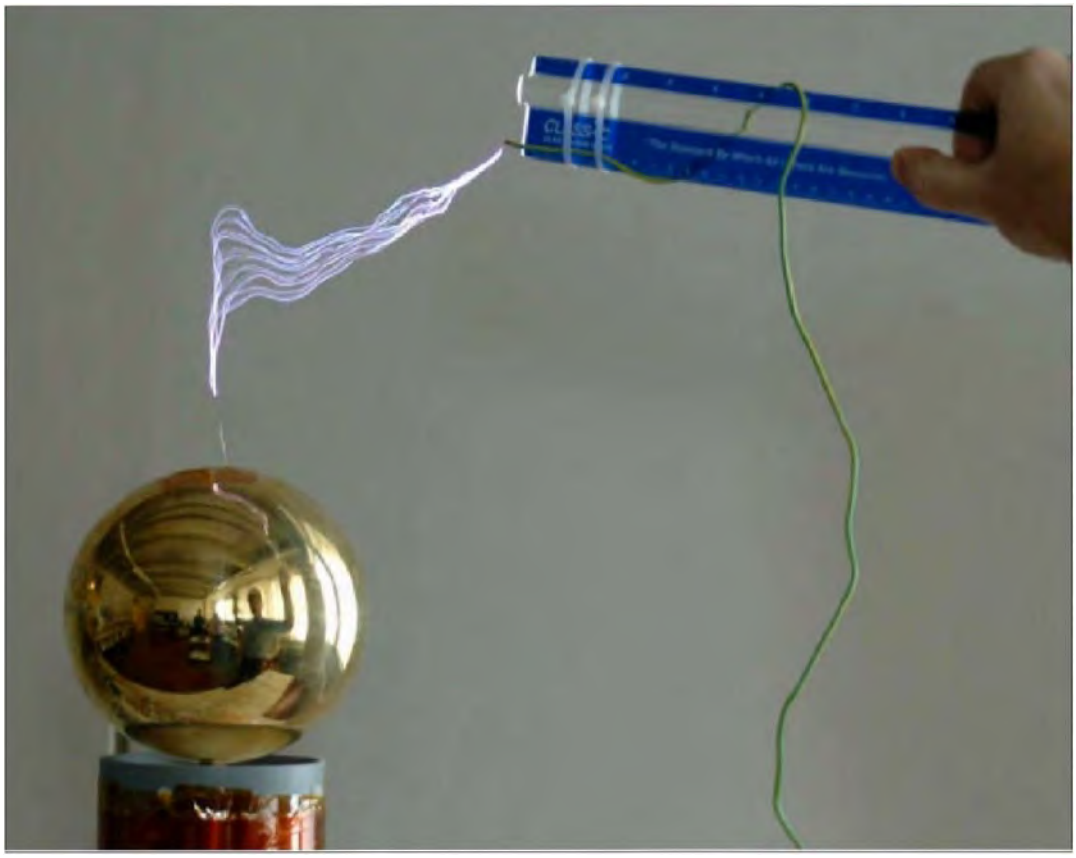
Mit kurzer Belichtungszeit aufgenommene Streamer. Die verästelte Struktur ist gut zu erkennen.

Detailed view of the streamers. The entrainment of the main channels located near the end of the wire by the air vortices occurring as a result of the heating can be clearly seen.

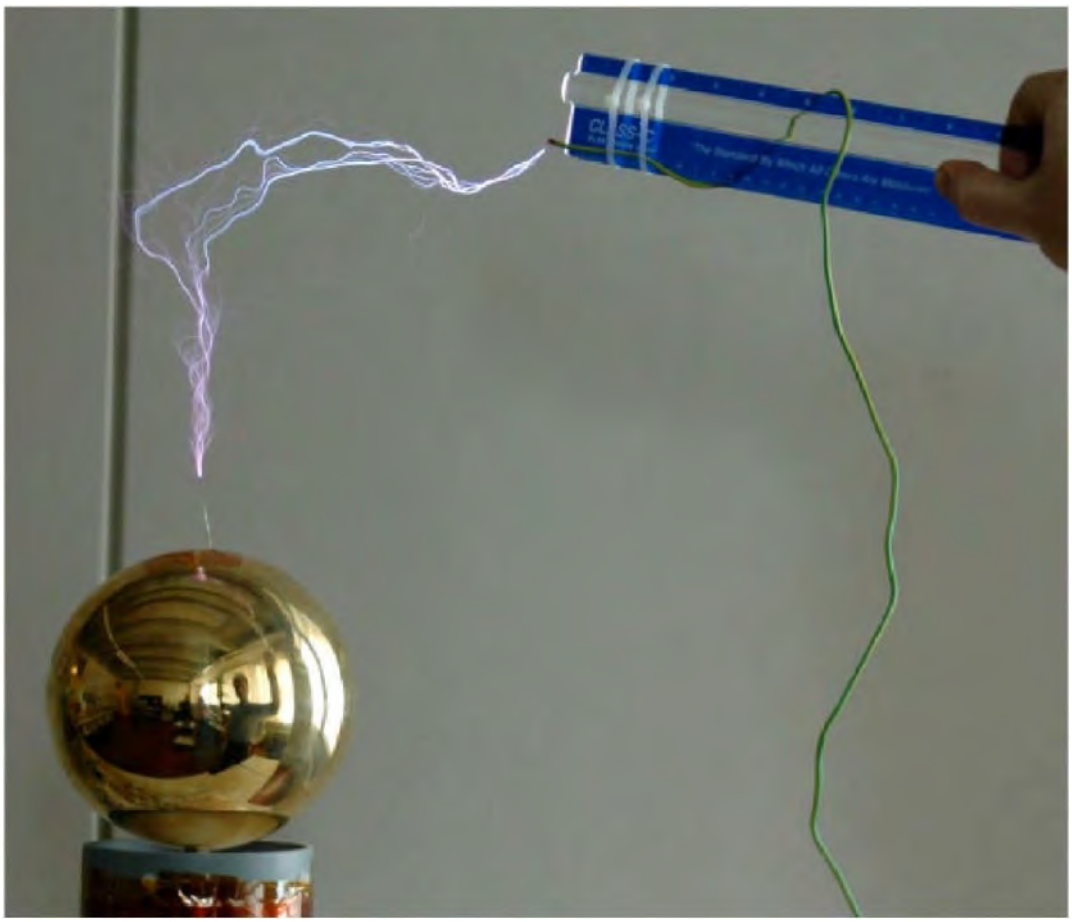
Streamers taken with a very long exposure time. The successive discharges appear simultaneously on the image.

Streamers are formed even without a field-amplifying piece of wire, but their discharge strength varies greatly.

When a grounded counter electrode is approached, powerful arc discharges of approx. 25cm length occur. From this, a voltage of approx. 250kV can be estimated.



Discharge to earth, taken with medium exposure time. This image corresponds to a large extent to the actual impression. The different channels of the successive discharges can be seen well. The channels move upward with the air heated by the discharges.



Here you can see the transition between the discharge in the form of streamers and the direct discharge to earth, as it occurs when the counter electrode approaches the head of the Tesla coil.

Part 3 - Building another Tesla coil

- Construction of another Tesla coil

Table of contents

1 Introduction

Nikola Tesla was born on July 10, 1856 in Smiljan, Croatia. He was a temporary employee of Thomas Edison and invented the three-phase motor as well as the multi-phase system for energy transmission (cf. [1, p.349]). The Tesla coil was invented and built by him towards the end of the 19th century. It is also called 'tesla transfor- mator', which however leads to the wrong assumption that the function is only based on the principle of the transformer.

The Tesla coil has found only very few applications in the world of the 20th century. One of them is the heating of tissue with the help of high-frequency currents in medicine (cf. [3, p.42]), but Tesla coils are mostly used in the field of film as effect generators or in teaching as demonstration objects. [1]

In principle, a Tesla coil consists of a single-layer wound, coreless coil of relatively high inductance with a usually toroidal or spherical electrode attached to one end. The coil is excited by an AC voltage whose frequency is equal to the resonant frequency of the coil. This can be done by feeding this AC voltage into a second coil of smaller inductance (primary coil), which is placed around the secondary coil. In most cases, the primary coil is part of an oscillating circuit tuned to the resonant frequency of the secondary coil. The oscillations are then inductively coupled out to the secondary coil, which is excited in this way. If the lower end of the secondary coil is grounded, a high-frequency high voltage is applied to the upper end (i.e. where the high-voltage electrode is located).

One of Tesla's intended applications for the coil was the wireless transmission of power over long distances using radio waves.

2 Practical construction of the Tesla coil

2.1 Circuit diagram of the structure

The picture above shows the individual components of the Tesla coil. On the left side are the supply lines, which are connected to the 230V mains, next to it is the mains filter, which is supposed to keep the high frequency away from the mains. It is not absolutely necessary for the function of the coil. Also to be seen is the high voltage transformer, the

[1] Addendum: The operating principle of the Tesla coil is also used to ignite HMI lamps (used in the film industry as lighting fixtures) and xenon lamps in cinema projectors.

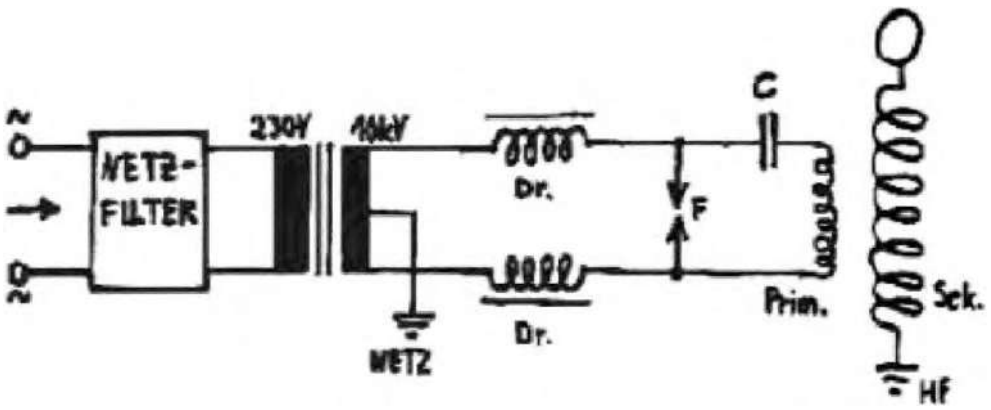


Figure 1: *Circuit diagram of the Tesla coil*

the mains voltage is transformed up from 230 volts to 10 kV, the downstream chokes Dr, the spark gap F, the capacitor C, the primary coil as well as the secondary coil. The mains grounding (at the transformer) is connected to the grounding line of the power grid, while the RF grounding must be much more massive (e.g. with a ribbon cable made of copper), since strong, high-frequency currents flow through it.

2.2 The individual components and their function

2.2.1 High voltage source

For the sake of simplicity, the high-voltage source usually consists of a high-voltage transformer. It transforms the mains voltage from 230 V to the secondary voltage, which is in the kilovolt range and should not be less than 6 kV to allow problem-free flashover at the spark gap.

In the present setup, six ignition transformers, as used in the burner systems of central heating systems, have been connected in parallel. It is essential to ensure that the correct high-voltage cables are connected together so that the individual voltages are in phase. This is tested experimentally by putting two transformers into operation and bringing the high-voltage cables closer together. If there is no clearly visible sparkover, then the cables can be connected to each other. A mains filter was also connected between the 230V mains and the transformers in order to keep the feedback effects on the mains as low as possible.

According to the nameplate, a single transformer is capable of delivering a maximum current of Arafo = 20 mA on average at a voltage of t7t.$_{ra}$ fo = 10 kV. If several transformers are connected in parallel, their maximum output currents add up, i.e. six transformers are capable of supplying a current of Z_{ges} = 6-20 mA = 120 mA. This corresponds to an output power of

$$P_{gea} = \text{^trafo} \blacksquare \text{/ges} = 10^3 \text{ V - 120 - IO"}^3 \text{ A} = 12001\text{V}.$$

The mentioned transformers have a so-called 'magnetic shunt', which limits the maximum possible output current, so that short circuits (a spark can be considered approximately as a short circuit) do not damage the transformers. It should be noted that the transformers may only be operated continuously for a maximum of 3 minutes, after which a waiting time of approx. 6 minutes is necessary (33% duty cycle, see type plate).

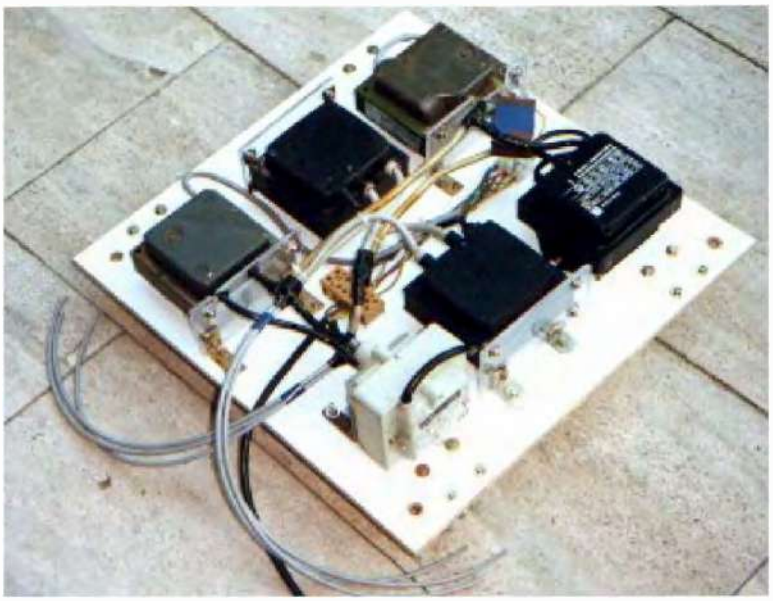


Figure 2: *The iloch voltage transformers*

Figure 2 shows the six transformers mounted on a wooden panel. The two high-voltage lines visible at the bottom of the picture, each consisting of three bundled high-voltage cables, were later replaced by high-voltage cables with a larger conductor cross-section. The black line at the bottom of the picture is the 230V supply line.

2.2.2 High frequency chokes

The two reactors shown in Fig. 1 have the task of keeping the high-frequency oscillations of the primary circuit away from the high-voltage transformers (and from the power grid) and minimizing the damping effect of the transformers on the oscillations.

In practice, each of the two chokes consists of two chokes connected in series. This is necessary to achieve the required total inductance.

The first choke consists of a ferrite rod on which as many turns of enameled copper wire as possible have been applied in a single layer after prior wrapping with electrical tape. The electrical tape is to prevent the weakly conducting ferrite rod from short-circuiting the choke and thus considerably impairing its function. It is important that the ferrite rod is wound in only one layer and with spaces between the individual turns to avoid flashovers.

The second choke consists of a ferrite toroidal core, which was also wrapped with electrical tape before being wound with enameled copper wire for the above reasons. [2]

2.2.3 Spark gap

The spark gap assumes the function of a switch that periodically opens and closes. It strikes as soon as the voltage applied to it exceeds the breakdown voltage.

The use of a quenching spark gap, which causes the sparks to extinguish very quickly, is advantageous. If no quenching spark gap is used, the Tesla coil tends to work only very unevenly, according to our own experience.

The rapid extinction of the sparks can be technically achieved by using several small, solidly designed, serially connected spark gaps or by directing a continuous flow of air onto the spark gap. In both cases, the heat generated is quickly dissipated, thus preventing the air at the spark gap from ionizing too easily and the short, pulse-like discharges from turning into a continuous spark discharge.

In the present model, a spark gap was used for simplicity, which works with an air flow (cf. [24, airblst.txt]). This consists of

[2] Addendum: The chokes have been dimensioned too small in the present setup. Other hob- byists use much larger chokes.

two solid steel electrodes facing each other, with a small ven- tilator generating a powerful air flow at the gap between the electrodes. During operation, large amounts of ozone, nitrous gases and ultraviolet light are generated. Therefore, it is advisable to provide adequate ventilation and not to look into the spark discharge.

Figure 3: *Spark gap, chokes and line filters*

Figure 3 shows the chokes (top right) and the spark gap (a little further down). Behind the spark gap is the small fan, which is supplied with current from the low-voltage transformer, which is also visible. On top of the transformer is a Graetz bridge rectifier for rectifying the 50Hz low voltage. Behind the transformer, the line filter can be seen. Low voltage transformer, rectifier and motor are not drawn in figure 1, because the corresponding circuit is trivial and not important for the Tesla coil itself.

2.2.4 Capacitor

The capacitor is part of the primary circuit. The capacitance value influences the frequency of the primary circuit, which must be tuned to the frequency of the secondary coil.

Normally no standard capacitor can be used as a capacitor, because it does not have the necessary dielectric strength, so that a self-made capacitor had to be used.

This consists of aluminum foil as the conductive component and polyethylene as the dielectric. A layer of aluminum foil and 10 layers of polyethylene were alternated.
0.1mm PE [34] foil on top of each other. If one thinks of the aluminum layers as consecutively numbered, the even-numbered foils and the odd-numbered foils were connected to each other, so that two con- tacts are obtained. The resulting stack of PE and aluminum foils is held together using polycarbonate sheets, threaded rods and cable ties. By pressing them together, most of the air between the layers is removed, thus avoiding flashovers. The smaller distance between the aluminum layers also increases the overall capacity.

The 'foil stack' can be seen in Fig. 4. The two connections can be seen on the right. The cable tie in the middle of the capacitor prevents the polycarbonate plates from bulging.

The stack was placed in a plastic housing, the two above-mentioned con- tacts were led out of the housing with the aid of short threaded rods, and the housing was filled with transformer oil.[1] which do not consist of a molded part Oel kriec The transformer oil prevents flashovers and corona discharges (which could damage the foils due to the heat generated) due to its good insulating behavior (approx. 70 kV per cm). Finally, the PE container used as a vessel was hermetically sealed by melting it to prevent leakage of the extremely creep-capable oil.

Originally, two such capacitors were planned, which were then to be connected in parallel to increase the total capacitance. However, after one of the capacitors was irreparably damaged by a breakdown and there was not enough time to build a third one, only one capacitor is used in the present setup. This is only noticeable in a reduction of the output power or the achievable spark length.

The capacitance of the capacitor is calculated according to

$$C = So \blacksquare \frac{\pounds R \blacksquare \_}{d} A - n$$

A is the area of a single layer of aluminum foil in m^2 , n is the number of foil blocks (each consisting of 10 individual foils 100/zm thick) and d is the distance between two adjacent layers of aluminum foil. Since this distance is equal to the thickness of a foil block and this consists of 10 foils each, $d = 100 - 10^6$ m ■ 10 = 100 - 10"[5] m.

[3]Polyethylene

[4]Addendum: It can only be advised against leading the contacts to the outside at points that come into contact with the oil: The feedthrough cannot be kept tight in the long run! In addition, a vacuum should be used to remove the air bubbles between the film layers to avoid breakdowns due to local overheating (caused by corona discharges).

Figure 4: *The inner workings of the capacitor*

Assuming an area A = 0.05 m - 0.155 m = 7, 75 - 10^{03} m^2 , and n = 72, d " 100 - 10^{-5} m and e_R " 2.3, by substituting into the above equation we obtain

$$C = \varepsilon_0 - 2.3 - \frac{7.75 - 10^{\circ 3\ m2} - 72}{100 \blacksquare 10^{\sim 5}\ m} = 11.36 - 10^{9}\ F \text{ " } 11\ nF$$

This value was checked experimentally by measuring the charge (charging the capacitor, measuring Q and U, C = 2). A deviation from the calculated value was found (the value obtained by measurement is C = 9.8nF). This can be attributed to the aluminum foils of the capacitor, which are not cut to the millimeter, to the waviness of the PE foil (and the associated larger d) and the influence of the transformer oil.

The finished capacitor can be seen in Fig. 5. On the front side you can see the two connections. You can also see the olfülhmg and the edge of the container, which was melted with the help of a soldering iron. The green adhesive tape is intended to protect the container from damage by the metal mounting brackets.

2.2.5 Primary coil

On the one hand, the primary coil forms the inductance in the primary circuit and, on the other hand, has the task of coupling out the high-frequency oscillations to the secondary coil.

With regard to the coupling properties, it should have not less than 10 win- dings (cf. [15]). Its inner diameter is usually much larger than that of the secondary coil, so that the secondary coil can be placed in the center of the primary coil to ensure optimum coupling. One of the two

Figure 5: *The finished high-voltage capacitor*

The primary coil is permanently connected to one end of the primary coil, the other end is designed as a tapping terminal, so that the inductance can be varied continuously by changing the number of tapped turns.

A cylindrical primary coil is generally used (especially for smaller Tesla coils). To prevent spark discharges from the high-voltage electrode to the primary coil, however, a flat coil is often used whose radius increases helically with each turn.

In the practical design, a compromise solution was favored: a cone-shaped coil that expands more and more towards the top. Taking into account the effects of the skin effect, the coil was constructed from 6mm copper tubing, since the surface area of the conductor is larger than when using a simple wire. As a result, the resistance to high frequency is lower, which increases the ef- fectiveness of the Tesla coil. In order to avoid flashovers and to ensure convenient and safe attachment of the tapping terminal, a distance of 1 cm was selected between the individual turns of the primary coil.

2.2.6 Secondary coil

The secondary coil is the most obvious part of the Tesla coil at first glance. It usually consists of enameled copper wire wound on an insulating hollow body. According to [24, file coilbldl.doc] at least a wire thickness of 0.6 mm should be used, furthermore approx. 900 turns proved to be ideal.

Furthermore, according to [24, file coilbldl.doc], care should be taken that the ratio of height to diameter is between 6:1 (small coils) and 3:1 (large coils). The coil should therefore not be too long and narrow, otherwise it would not be excited evenly enough. According to [24, Da-

1]

tei coilbldl.doc] Tubes made of PE, polystyrene, polypropylene, polycarbonate (Lexan), or acrylic glass were found to be favorable, since they cause the least losses in the RF range. PVC should be avoided because of its high losses, but was preferred in the practical design in terms of availability and price.

The copper wire winding must be wound in a single layer (to avoid breakdown) and without overlaps or gaps between the turns. In the present setup, 0.6 mm enameled copper wire was carefully wound onto the bobbin using a drilling machine. Finally, the coil was covered with a polyurethane coating to prevent moisture absorption and to protect the coil against flashover. A toroidal high-voltage electrode was placed at the top of the coil at a single distance apart and connected to the upper wire end of the coil. The lower end of the wire must be well grounded. It is not advisable to use a simple metal ball as an electrode, since it facilitates the migration of the discharge down to the coil. In addition, it does not detach properly from the field of the coils and thus works as a short-circuit winding against the field of the primary coil (cf. [18]).

The secondary coil oscillates in self-resonance during operation, i . e. the windings act as inductance, the capacitances between the windings and the capacitance of the electrode with respect to the earth together as capacitance. Thus a kind of oscillating circuit is created, which has a certain resonant frequency. The determination of this frequency is described in the chapter 'General calculations and measurements'.

2.3 The interaction of the components

When switched on, the capacitors in the primary circuit are initially uncharged, so that the entire current provided by the transformers is used to charge the capacitors. During the charging process, the voltage at the capacitors (and thus also at the spark gap) increases continuously until the breakdown voltage of the spark gap is finally reached and a spark flashes over.

The spark thus closes the oscillating circuit consisting of the capacitor and primary coil, which immediately begins to oscillate at its resonant frequency, excited by the charge stored in the capacitor.

While the spark discharge is in progress (i.e. while the circuit is oscillating), the capacitors are not recharged by the high-voltage transformers, since the resistance of the spark, as already mentioned, is negligible at such high voltages and thus hardly any voltage drop occurs across the spark gap which could charge the capacitors. Finally, the spark discharge (and thus also the oscillation in the primary circuit) stops, the capacitor is recharged and the process starts again.

The damped oscillations of the primary circuit are inductively coupled out by the primary coil to the secondary coil, whose natural resonant frequency matches the resonant frequency of the primary circuit. The secondary coil is thus excited and begins to oscillate in resonance. This generates strong, high-frequency alternating magnetic fields in it. This causes induction of high-frequency voltages, which are further amplified by self-induction in the secondary coil. One end of the secondary coil is grounded, so that a high-frequency high voltage is present at the other end against ground.

2.4 General calculations and measurements

2.4.1 Determination of the resonant frequency of the secondary coil

The resonant frequency of the secondary coil is best determined experimentally as described in [3. p. 50 f.].

For this purpose, the ground terminal at the lower end of the coil is connected to the output of a signal generator, the ground terminal of which remains unconnected. Now bring the probe of an oscilloscope (whose ground terminal also remains open) to within 1 m of the high-voltage electrode of the secondary coil and fix it with the aid of a tripod or similar. It is very important that there are no metal parts in the vicinity (approx. 1 m), as these would falsify the measurement. The primary circuit must also be brought to a sufficient distance.

The signal generator and oscilloscope are each set to the lOOmV range and the output frequency of the signal generator (sinusoidal signal) is varied. At a certain frequency, a strong, very sudden increase in the amplitude of the signal displayed on the oscilloscope can be observed. This frequency then represents the reso- nance frequency of the secondary coil. In the present case, this frequency is about 205 kHz. A more precise determination is not useful, since the frequency is in any case relatively strongly influenced by the electrical properties of the environment.

2.4.2 Determination of the resonant frequency of the primary circuit

To determine the resonant frequency of the primary circuit, the signal generator (again sinusoidal signal) and oscilloscope are connected to the primary circuit with the aid of a 56 kQ resistor, as shown in Fig. 6.

The spark gap must be short-circuited so that a closed oscillating circuit is created. The experimental setup is based on the proposal in [3,

1.51, Fig. 58], but was slightly modified. In the measurement method used here, the structure remains connected to the transformers, since the shift in the resonant frequency of the primary circuit caused by the transformers is also to be measured.

As with the measurement of the resonant frequency of the secondary coil, the frequency of the signal generated by the function generator is varied until a clear increase in amplitude can be observed on the oscilloscope. The frequency at which the largest amplitude occurs is the resonance frequency.

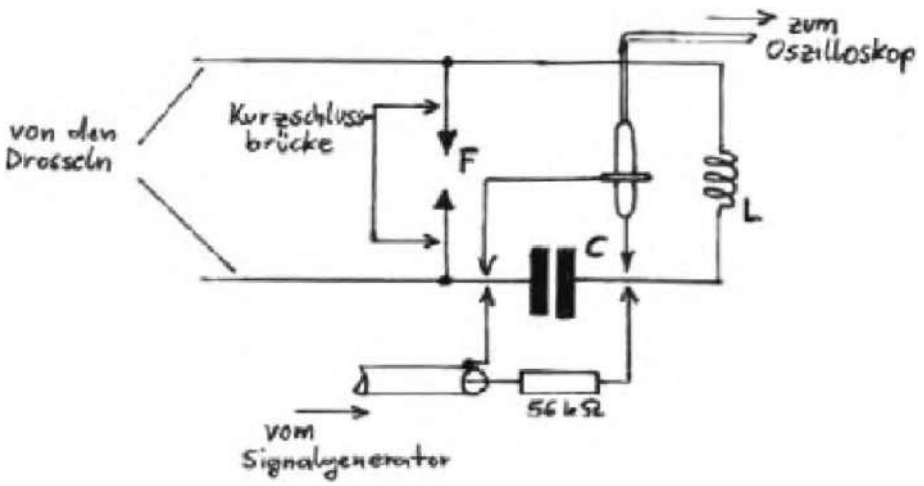


Figure 6: *Measurement of the resonant frequency of the primary circuit*

The tapping terminal is attached in such a way that the current flows through the entire primary coil during the first measurement, so that the maximum possible inductance is obtained and the smallest possible frequency can be measured. For the second measurement, the number of tapped turns is selected as small as possible and thus the maximum possible frequency is determined.

In the present case, the minimum frequency of the primary circuit is approx. 160 kHz, the maximum frequency approx. 650 kHz. Here, too, a more precise determination is not useful, since the frequency is dependent on external influences and, for example, already changes constantly due to the loose lead cable of the tap-off terminal. To determine the ideal tapping point, the function generator is finally set to the reso- nance frequency of the secondary coil and the tapping terminal is offset until the amplitude of the signal displayed on the oscilloscope is at a maximum.

3 Tesla coil operation

3.1 Precautions during commissioning

Before connecting the coil to the mains, you should be aware of the hazards that can be caused by the coil and the necessary safety measures.

The main danger comes from the high voltage used in the primary circuit. It can be assumed that all currents exceeding 40 mA are potentially dangerous. Currents of 100 mA and more are already lethal for humans within only one second with a relatively high probability! If you touch with your hands the secondary terminals of a high voltage transformer, which supplies 10 kV, then with an assumed body resistance of lOkfl and a sufficiently powerful transformer a current of

$$J = \frac{\hat{U}_{HV}}{R_{Body}} = \frac{10\ \mathrm{kV}}{10\ \mathrm{k\Omega}}$$

This current cannot be supplied by the transformers, since the output current is limited to 120 mA is limited. However, these 120 mA then flow safely and cause death with a high probability even with brief contact.

This is one of the reasons why the following safety rules (see [3, p.55 f.], [16] and [24, math.txt]) should be followed during commissioning:

- Never touch any part of the primary circuit while the Tesla coil is in operation.
- Do not work near high-voltage lines (danger of flashover!)
- Always ground the secondary coil well, otherwise the high voltage will find its own way to ground and may cause a fire. The grounding should be done by a solid, silver-plated copper strand, which is connected to a well grounded object (stair railing, water pipe or similar).
- Before allowing the Tesla currents to flow through the human body, it is essential to measure the size of the 50 Hz component they contain. Not only the high frequency but also partly 50 Hz mains frequency gets into the primary circuit! Since there is practically no skin effect at a frequency of 50 Hz, this component can lead to electric shocks.

- Ensure that there are no discharges between the primary coil and the secondary coil when the tesla currents are to flow through the human body. In case of discharges between the coils, the secondary coil is no longer galvanically separated from the primary circuit, so that by the spark discharge
  the full amperage (at 50 Hz!) of the primary circuit may flow. If necessary, prevent discharge with a polyurethane-sprayed acrylic/P VC tube between the secondary and primary coils.
- Never draw the discharge of a strong Tesla coil on yourself, because even if normally only little current flows in the body itself due to the skin effect, the current entering the body increases and can exceed the permissible values.
- Never allow the sparks from the coil to jump directly onto the body (always onto metal pieces!), otherwise the high spark temperature will cause localized burns.
- Always unplug the Tesla coil before working on it and, if necessary, discharge the capacitor with a power resistor of 100 kfl or more.
- If the fuses of the power supply circuit blow, immediately pull out the plug to prevent unintentional, unexpected restarting of the coil.
- Pay attention to the capacitors, as they can explode in case of spontaneous breakdown and/or local overheating.
- Do not look into the spark gap discharge, as it emits a lot of UV light.
- Ensure adequate ventilation as the spark gap produces large amounts of ozone and nitrous gases.
- For larger coils, hearing protection should be worn during operation.
- In the case of unknown lay distances, run the secondary coil ground close to the high-voltage electrode to avoid unforeseen sparkovers.
- Make sure that there are no sensitive electrical devices in the vicinity or that they are operated on the same circuit. This applies in particular to digital technology such as CPUs or household appliances with digital control. Television sets should also be disconnected from the mains. Persons wearing pacemakers should leave the room at all costs!
- Do not bring flammable or explosive gases, liquids or solids into the vicinity of an operating Tesla coil - risk of explosion and fire!

3.2 Tuning the Tesla coil

The primary circuit of the Tesla coil has already been largely tuned by measuring its resonance frequency. However, if no oscilloscope is available, the most favorable tapping point at the primary coil can also be determined experimentally by alternately changing the tapping point and then operating the coil until the maximum spark length is obtained.

3.3 Experiments with the Tesla coil

3.3.1 Determine the stroke width

Determining the striking distance of the coil is done either without aids by simply estimating the length of the sparks emanating from the high-voltage electrode, or by allowing the sparks to jump over a grounded piece of metal at a known distance. The second-mentioned method yields slightly longer ma- ximum spark lengths, but it should be noted that the sparks thus produced are particularly hot and may damage the electrode, which is made only of thin aluminum tape and plastic. The spark length determined by the second method is approx. 70 cm.

3.3.2 Peak discharges

The effect of electrodes with an extremely small bending radius (i.e. tips) can be observed very well using the example of the Tesla coil. For this purpose, with the coil switched off, a piece of wire is placed on the electrode which has been bent so that it is stable on the electrode and one of the wire ends points upwards. When the coil is switched on, sparks immediately shoot vertically upwards from the tip of the wire and m a y even strike the ceiling, flashing brightly, as can be seen in Fig. 8. This so-called tip effect results from the very small bending radius of the wire end, which creates an extremely high field strength at the point in question, which ultimately promotes the occurrence of a spark.

3.3.3 Wireless power transmission

The strong electric fields and the emission of radio waves in the range of the resonance frequency (approx. 200 kHz) enable a wireless transmission of energy. This was Nikola Tesla's original intended application for his coil. The effect can be demonstrated, e.g., by using an ordinary

fluorescent tube is placed near the coil and the latter is put into operation. As can be seen in Fig. 9, the fluorescent tube begins to glow with a clearly visible flickering effect, although there is neither a galvanic connection to the coil nor sparkovers on the fluorescent tube. The glow of the tube must therefore result from the strong E-field. Another possibility for energy transfer is the construction of a second Tesla coil, which has the same resonance frequency as the first coil and collects the electromagnetic waves again and converts them into electric currents.

Figure 7: *The finished Tesla coil shortly before commissioning*

Fig. 8: *Peak discharges with the aid of a piece of wire*

Fig. 9: *The strong E-fields make the fluorescent tube glow*

Part 4 - Building a Tesla transformer

Table of Contents:

1. What is a Tesla coil

A Tesla coil is a high voltage impulse transformer named after its inventor Nikola Tesla (* July 10, 1856; t January 7, 1943). It is used to generate high-frequency alternating voltage.

A Tesla coil basically consists of 2 circuits, so-called oscillating circuits. These two oscillating circuits should optimally oscillate at the same natural frequency.

1.1 Sense and purpose of a Tesla coil

Nikola Tesla wanted to achieve two things with this "transformer".

1 .) During Nikola Tesla's life, the so-called "Electricity War" developed between him and Thomas Alva Edison. Edison wanted to spread his direct current, which in his eyes was also less dangerous than Tesla's alternating current. Edison had, in the course of the "war", several animals executed by alternating current. The most famous case is the cruel execution of the elephant "Topsy".

Tesla and his research were thus on the brink of extinction. But the tide turned in Tesla's favor. Through his public demonstrations, he was able to convince the American people that his alternating current was safe.

Furthermore, this is also how his second name "Magician of Electricity" came about, because he made light bulbs glow just by "merely" touching them.

2 .) Tesla wanted to transmit energy wirelessly. He succeeded in this within certain limits. There are reports that in a distance of 10 km a whole field full of light bulbs was shining. However, during this attempt the energy consumption of his system was so great that the public utilities of Colorado Springs, which supplied him with electricity, burned down.

2. Theory of a Tesla coil

In order to understand the function of a Tesla transformer, one must first d e a l with oscillations and oscillating circuits, since everything else is based on them.

2.1 What is a resonant circuit

A resonant circuit is a parallel or series connection of a capacitor and a coil. It is mostly used to generate electrical sinusoidal oscillations. In order to be able to explain a resonant circuit well, I will use a small analog example:

And that is on a spring pendulum or a spring-mass oscillator, as a real physicist would probably call it.

When we pull the weight down on the spring and release it, the tension very soon starts to oscillate at a certain frequency, namely its *resonance frequency.* It is not possible to change the frequency without external forces, it is determined by the *mass of* the weight and the *spring constant (* = strength) of the spring.

An oscillation always takes place where restoring forces act. However, these do not always have to be sinusoidal oscillations. A spring has the property that the force *(restoring force)* it exerts is proportional to the distance it is pulled apart. For our spring pendulum this means that the force of the spring is also proportional to the deflection of the pendulum (i.e.: double deflection of the pendulum => double force).

Oscillations that have this property are called *harmonic.* Harmonic oscillations always have a sinusoidal form. But there are also non-harmonic, damped and forced oscillations.

Transferred to the electric oscillating circuit this means: An electric coil has very similar properties as a weight or mass. A coil does not "like" fast current changes (keyword "*self-induction").* The coil induces a voltage in the opposite direction due to the magnetic field that builds up, which counteracts the current), e .g. if we let a current flow through a coil, it will only increase slowly.

Inertia corresponds to this property: If you push a car, for example, it will not start rolling immediately, but it will first want to stay in place until it slowly picks up speed *(inertia).* The work we have done to make the car roll is stored as kinetic energy. However, if we stop pushing, the car still rolls a little further until it has "used up" or released all of its kinetic energy. The movement is therefore also maintained for a short distance.

A coil also behaves analogously. The electrical energy was stored in the coil's magnetic field. If we switch off the current, the coil reduces its magnetic field again - and thus induces a voltage which maintains the "old" current flow for a short time until the complete magnetic field is reduced again.

Accordingly, the mechanical equivalent of the capacitor is the spring. A capacitor, as soon as it is charged, always wants to compensate for the difference in charge (also a restoring force) and return to its initial state. The voltage stored in its electric field drives a current. It is the same with a spring: once tensioned, it wants to return to its initial state and can also convert all the energy stored in it into movement.

2.2 Resonance

The resonant frequency is the frequency at which a resonant circuit can be most effectively excited to oscillate. At this frequency, the least energy is required to maintain the oscillations.

A quite simple example would be a swing: Ideally, one pushes a swing at the highest point, of course, since this is the most sensible way to apply one's force. The energy ("force") already applied is stored in the swinging parts, so it is not lost. If we now push on and on, the amount of energy increases more and more, the amplitude of the oscillation increases. But the frequency does not change! At some point, the amplitude will have become so large that the swing will turn over. The oscillation has become so strong that the oscillating system destroys itself because some component could no longer withstand the increasing energy. This is called a resonance catastrophe.

However, if we push the swing before the highest point, we slow down the swing; to reach the same height, we would have to apply a greater force and work against the swing.

The resonant frequency is calculated as follows:

f_0 = 1/(2pi sqrt(L* C))

L is the inductance of the coil, C is the capacitance of the capacitor. f_0 is the resonance frequency. This formula is called "Thompson's oscillation formula" in professional circles.

Example calculaq:

A capacitor with 100 nF and a coil with 15 pH are installed in the primary circuit. Now we want to calculate the resonance frequency (*natural frequency).* f_0 = 1/(2 pi* sqrt(100* 1 0^A -9)* (15* 10^A -6)) = 129949.467 Hz, i.e. approx. 130 kHz.

If we were to apply a sinusoidal voltage of 130 kHz to this resonant circuit, the arrangement would resonate.

The more precisely we achieve this frequency, the more efficiently the transformer will work later. However, there are additional effects, such as the bandwidth - this indicates how far one may deviate from the resonant frequency.

2.3 The Tesla transformer

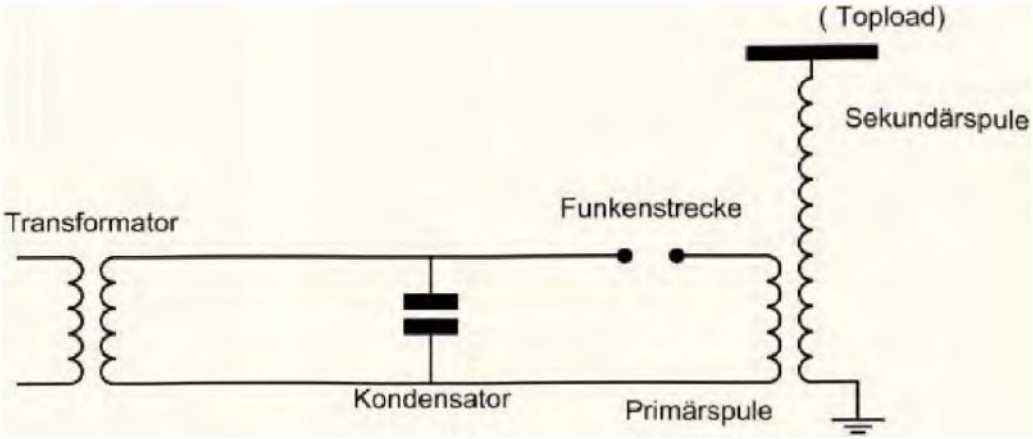


Figure 1: Schematic diagram of a Tesla transformer

Those who, like me, once believed that a Tesla transformer would work according to the classical transformer principle, were far wrong. My explanation for the high voltages and the high currents was then:

Large capacitor and high voltage => a strong short current surge. As soon as the voltage is high enough, the spark gap ignites and the capacitor discharges into the primary coil - which builds up a strong magnetic field due to the strong current. Due to the high turns ratio of the two coils and an already high input voltage, the output voltage had to be really astronomical!

In my opinion, the spark gap only served as a "chopper" (to turn DC voltage into AC voltage) and the capacitor only to send as strong a current as possible into the primary coil.

I tried it, and believe me, it doesn't work!

A Tesla transformer basically consists of two loosely coupled oscillating circuits, the primary circuit and the secondary circuit. For the transformer to work efficiently, both oscillating circuits should have the same resonant frequency (they are then in *resonance).* How this frequency is calculated, I have already described above. What a coupled oscillating circuit is, I explain in the further course of the text under the heading "Functional principle".

2.4 Secondary circuit

Since the secondary resonant circuit primarily determines the behavior of a Tesla transformer, we will also start with it here. The secondary resonant circuit consists of a secondary coil, a single-layer wound air core coil and a secondary capacitor. Many

Tesla transformers have additional capacitance in the form of a toploads, usually a sphere or "toroid".

If you now ask yourself how the toploads should represent a capacitor - if it is only has **a** single capacitor plate? There is a very simple answer to this:

The other plate is the entire environment of the transformer and thus also the experimenter itself! There are even Tesla transformers which do not have a top load. According to Thompson's oscillation formula, the resonance frequency should be infinite, because there is no capacitance?

But it is not!

A coil also has a capacity! And this is even relatively large! Between the individual windings of the coil small capacities are formed - and moreover again from the coil surface against the entire environment. One may imagine this approximately in such a way:

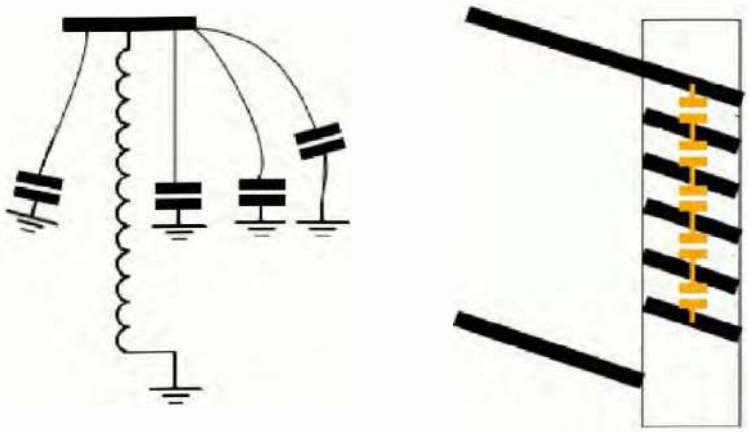


Figure 2: Secondary capacitances of a Tesla coil

2.5 Primary circuit

Let's imagine we have a secondary coil with a resonant frequency of 130 kHz.

Let us now take a closer look at the Tesla coil. As we know, the European supply network oscillates at 50 Hz. However, 50 Hz is not exactly 130 kHz. To solve this problem, we will take a closer look at the spark gap and its task.

As you can see, the feeding transformer is connected in parallel to the capacitor. This means that the transformer charges the capacitor. When the maximum voltage is reached, the spark gap should now ignite - this is used to discharge the capacitor at maximum charging voltage via the primary coil. The spark gap works as a switch, so to speak. The distance between the electrodes should be chosen in such a way that this is possible. This is best done experimentally - a distance of 1 kV/mm can be used as a guide.

Now some people will wonder why this is realized with such a simple "switch". Well, this switch is cheap and powerful. The moment the spark gap ignites, the air between the electrodes is ionized. This means that its resistance drops to a minimum. The air becomes conductive.

The supply transformer is short-circuited by the extremely low resistance, i.e. it is excluded from further events. The capacitor is connected in parallel with the coil. This means that the two form a resonant circuit - the primary resonant circuit.

We have chosen a secondary circuit with a resonant frequency of 130 KHz - if you have been paying attention, you will know immediately that the resonant frequency of the primary circuit must also be 130 KHz.

So we have to construct a resonant circuit in the primary circuit with exactly this resonant frequency.

It is best to start from the primary transformer used: The capacitor must be adapted to this. The time needed by the transformer to charge the capacitor at full short-circuit current is of great importance:

A capacitor that is too small will be charged too quickly, so that the spark gap will not go out at all and simply continue to burn, or simply put far too little energy into play.

A capacitor that is too large and a transformer with a very high output voltage in turn ensure that the transformer takes a very long time to charge the capacitor. This makes good operation of the coil impossible.

2.6 Operating principle

The switch (the spark gap) is initially open. For the spark gap to ignite (i.e.: become conductive, switch closes), a certain voltage must be applied to it. This voltage is about 1kV/mm distance between the electrodes. As soon as this voltage is reached, the spark gap strikes. The air between the electrodes becomes ionized and thus conductive. This is why the spark gap continues to conduct current, even if the ignition voltage has long since fallen below it.

While the spark gap is burning, it short-circuits the transformer and the capacitor with the coil in parallel - The two form a resonant circuit.

From this oscillating circuit - depending on the *coupling factor* - energy is always transferred from the primary to the secondary circuit. The coupling factor determines the amount of energy that is transferred with each oscillation. This energy is naturally taken from the primary circuit.

This process continues until all the energy is in the secondary circuit. Ideally, the spark gap *"Quenscht")* is now extinguished - this separates the con- densator from the coil again, the oscillating circuit is interrupted. Since there are now no more oscillations that could be coupled with the secondary circuit, there is also no more energy transfer - the energy is "trapped" in the secondary circuit.

There it usually discharges in the form of a streamer, is "heated" in ohmic losses (wire resistance) or is radiated as RF energy.

Unfortunately, the spark gap does not always go out at the first "zero crossing" - the primary oscillating circuit is therefore still open. The cause is often that there are still ionized gases between the spark gap. In this case, energy is again transferred from the secondary circuit back into the primary circuit - the game then continues until the ohmic losses have damped the energy to such an extent that the spark gap goes out.

Of course, this is not desirable, because in this way a lot of energy is converted into heat, which is then no longer available in the secondary circuit. In addition, the entire cycle takes longer - the capacitor could have been recharged in the meantime.

These "zero crossings" are called *"notches"*, the process of energy transfer and the resulting oscillation *"beat".* The goal of each

the "Tesla Coilers", which aims for good efficiency and spark length, is that the spark gap goes out right at the first zero crossing (*first notch)* - because otherwise the energy is transferred back to the primary circuit and from there back to the secondary circuit.

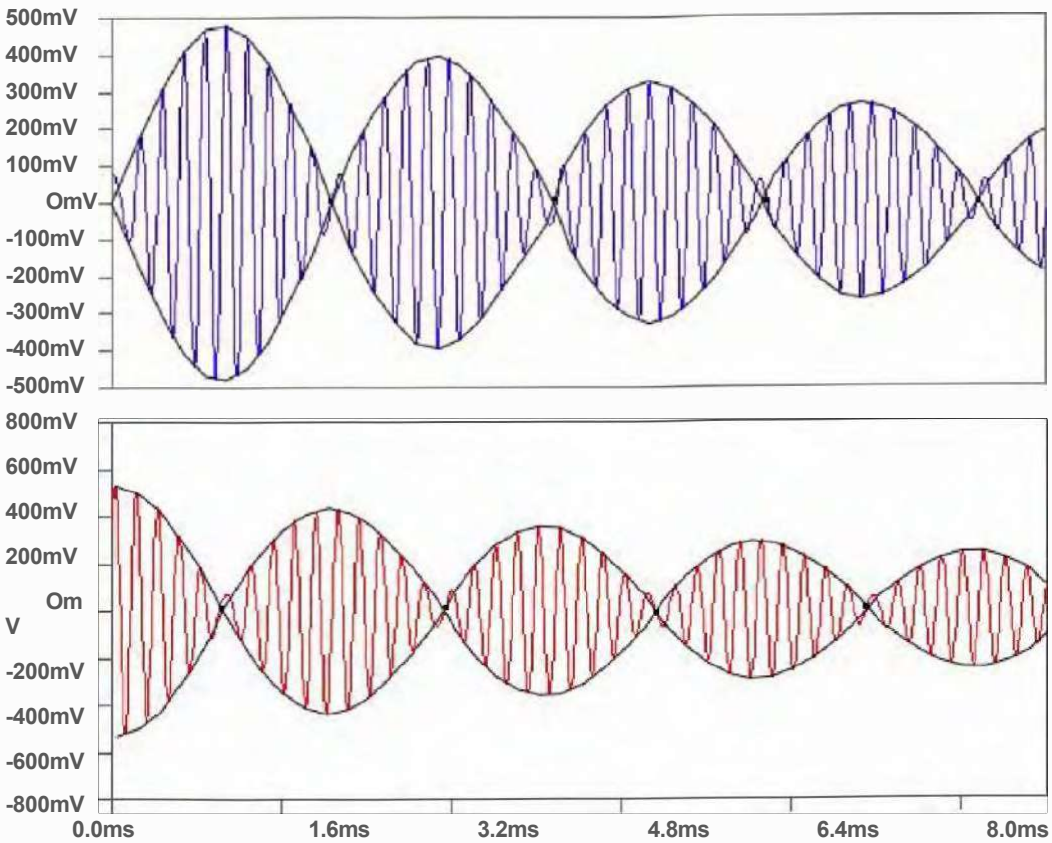


Figure 3: Graph of a beat without the spark gap going out. The lower, red graph is the primary, the upper, blue one the secondary coil.

Therefore, the spark gap is the most critical component of a tesla transformer, which must be precisely tuned. To facilitate the "squeezing" of a spark gap, fans are often installed - for cooling, but also to blow away the ionized gases.

Other "Tesla coilers" swear by "rotary sparc gaps" - a spark gap consisting of a rapidly rotating wheel with contacts. If the contacts are opposite each other, the spark gap ignites. Ideally, the wheel has continued to rotate until the first zero crossing, so that the spark gap goes out. However, the calculation and operation of such rotating spark gaps also means a lot of effort. Static spark gaps, on the other hand, i.e. without moving parts, are susceptible to c h a n g e s i n humidity.

2.7 Power adjustment

As mentioned above, Tesla transformers work very efficiently. However, the efficiency can be increased again by matching the primary capacitor to the high-voltage transformer. This allows the entire available capacity of the transformer to be used. This capacity is calculated as follows:

C = I / (2*pi*f*U)

"f" stands for the mains frequency, i.e. 50 Hz in Europe. With this formula you can calculate the maximum capacity, which you can use, but should not!

Why ?

With this formula an impedance matching is achieved, i.e. the capacitance is calculated which is necessary to eliminate the complete reactance at 50 Hz. Then there is only the ohmic resistance.

However, high-voltage transformers limit their maximum output current with the inductance. If this is omitted, much higher currents are possible.

A 500 W neon transformer can then also draw 3 kW, but not for long.

At the same time, this capacitance creates an oscillating circuit with a resonant frequency of 50 Hz. Via the inductance (secondary winding of the transformer) of the circuit, more and more energy is pumped into the circuit, just like with a Tesla transformer. The voltage and current can build up dangerously, which can lead to the destruction of the transformer or the capacitor!

2.8 Discharges

Why do sparks actually discharge into the air? There is no grounding point into which they can "strike". The voltage generated by a Tesla transformer is too low to produce such large discharges. Furthermore, the discharges are still frequency-dependent.

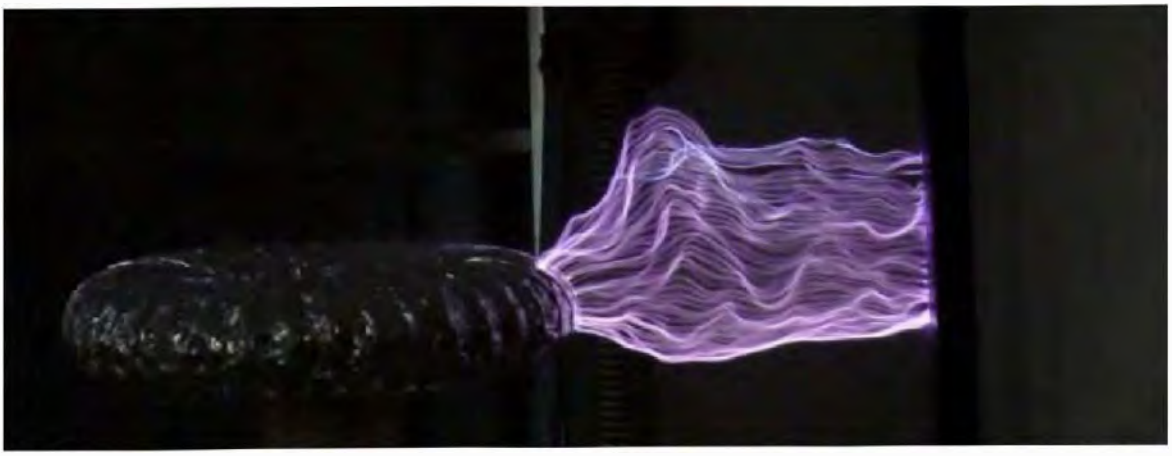


Figure 5: Corona discharges

The discharges are "corona discharges (spray discharge)". As soon as the electric field strength is high enough, a corona discharge occurs at a sharp point, the "breakout point". The corona discharge itself acts like a capacitance. The high frequency at which a Tesla transformer operates and the capacitance of an ionized air channel can maintain a sustained current that causes further corona discharges.

Current can now flow through this ionized air again and produce another corona. This process continues until the maximum possible length of the streamer (spark) is reached, the next ignition of the spark gap takes too long, or the ionized air is blown away by the wind. The ionized air becomes neutral again and the process starts from the beginning.

2.9 Why resonate?

The resonant frequency is the frequency at which a resonant circuit can be most effectively excited to oscillate. At this frequency, the least energy is required to maintain the oscillations.

Why is the energy consumption lowest in resonance ?

In a Tesla transformer, we are actually dealing with parallel resonant circuits - the capacitor is thus connected in parallel with the coil, (see Fig. 2) In the AC circuit, a coil and a capacitor have a resistance, the so-called reactance. This is frequency-dependent:

A capacitor has a very low resistance at high frequencies, but blocks low frequencies. With the coil, it's the other way around:

It conducts low frequencies particularly well, but blocks the high frequencies.

This reactance of coil and capacitor is equal in the resonance case, so two resistors of equal size are connected in parallel - the total current is thus divided into two partial currents of equal size. If the frequency is now increased, the capacitor becomes less resistive and the coil more resistive. The current now flows through the capacitor. As a result, the total resistance is smaller than at re-sonance - and thus the energy requirement increases. If the frequency is reduced, the capacitor becomes more highly resistive and the coil more low-resistive - here the current logically flows through the coil. This also has the consequence that the total resistance becomes smaller than at resonance and thus the energy requirement increases.

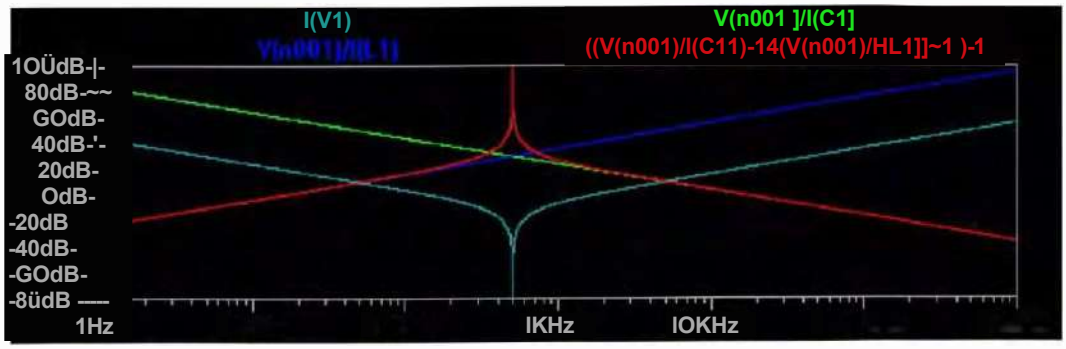


Figure 6 : Here you can see again the curve of the resistance (capacitor = green, coil = blue, total = red, current = turquoise). You can clearly see that the required power is lowest at resonance (- 50 0KHz).

2.10 Output voltage

Again and again I am asked: "What is the output voltage of your Teslatra- fos?" I can only answer: "I'm sorry, I can't answer this question, because I can't measure the output voltage". Of course, this is immediately followed by the counter-question: "Is it not possible to calculate the output voltage?" My answer: "yes and no".

Why does an e-technician give such an imprecise answer? Because he does not

know! Of course, the output voltage of a Tesla transformer can be calculated as

follows:

The energy in the primary circuit is transferred to the secondary circuit relatively loss-free (spark gap, ohmic losses). It can therefore be assumed that the energies remain almost the same. The energy of a capacitor is calculated as follows:

$W = (C / 2) * U^2$ W = energy; in our case that of the capacitor Example:

Capacitor C = 1 00 nF; Voltage Uampl = 8000 V W =

((100* 10^{A} -9) / 2) * 8000^{A} 2 = 3.2 joules

Since the energy is transferred to the secondary circuit almost without loss, little energy is lost. In our secondary circuit, the inherent capacitance of the secondary coil and the capacitance of the toploadrepresent the total capacitance. Since the total capacitance is very small, the voltage must be correspondingly large so that the energy remains approximately the same. By rearranging the formula W = (C / 2) * U^2 in:

U = V(W / (C / 2))

with a secondary capacitance of 26.67pF, the output voltage would be

U = V(3.2 / ((26.67* 10^{A} -12) / 2)) = 489 867.332 V " 500 kV.

Since this process is not completely lossless, the final result should be multiplied by 0.9. However, this is only valid if both oscillating circuits are very well tuned for resonance.

Now, however, it can happen that the topload discharges only after "X" load cycles and since we cannot calculate the variable "X", we cannot reliably calculate the output voltage of a Tesla coil. Furthermore, streamers can also break out of the topload before it reaches 500 kV, which would cause the voltage in the topload to collapse. The only safe method would be to measure the output voltage, but since this is not easily feasible, the output voltage of a Tesla coil remains a mystery.

3. Construction of a SGTC

3.1 Basic processing of wood and plexiglass

How do I edit the following materials?

3.1.1 Wood

Woodworking is relatively simple, at least for our purposes. For sawing, you should be able to call a scroll saw or jigsaw, in the best case a scroll saw his own. For coarser cuts, a circular saw is advantageous. Since freehand sawing always deviates a little from the ideal cut, you should cut wood with about 0.5 mm oversize. The excess can then be sanded off either with a sanding block or a belt sander. Finally, break the edges of the cut surfaces so that you cannot injure yourself.

3.1.2 Plexiglas

Machining Plexiglas is much more difficult than machining wood. Here you should first determine the thickness of the plate to be cut. I have made the experience that Plexiglas up to 3mm thickness can still be cut reasonably well with a scroll saw. Again, cut with oversize, maybe even 1mm, depending on how much experience you have. Then cut off the excess. For Plexiglas over 3mm thick, the jigsaw should be used. Here it is important to use a wood saw blade. This blade removes a lot of material without producing a lot of heat. This is because the heat causes the saw blade to "melt" into the plexiglass. If the Plexiglas is more than 8mm thick, it is recommended to cool it with water. To do this, simply cool the saw blade with water every few centimeters of cutting. Basically, the processing of Plexiglas is also very simple, if you know how!

3.2 Tool

You should have at least the following tools:

- Mouth/ring wrench in the required sizes

- Screwdriver
- Wood, as well as metal drills in the required diameters
- Drilling machine
- Thick superglue
- Fretsaw
- Jigsaw
- Grinding block
- Caliper
- Angle iron
- Sandpaper of different grit (120 to 600)
- Metal saw
- Vise

Optional, but very useful accessories:

- Scroll saw
- Belt grinder
- Screw clamp
- Circular saw
- Pedestal drilling machine

3.3 Building instructions

In this section I would like to explain you some tricks, which facilitate the construction of a medium-large Tesla coil and also contribute positively to the appearance of your Tesla coil. Nevertheless, everyone is of course free to build his own system.

3.4 Preparation

So first of all you should always calculate your planned Tesla coil theoretically, for example with this nice JavaScript (www.raacke.de). ("Online calculator" -> "Tesla transformer"). Once you have calculated your tesla transformer, you can actually start to order or buy the parts you need. For example:

- High voltage transformer
- MMC (Multi-Mini-Capacitor)
- PVC drain pipe
- Enamelled copper wire
- Copper wire
- Plexiglas
- Threaded rods
- Miscellaneous screws
- 230V fan
- Copper pipe
- Aluflex pipe
- Cold-device socket
- 2MOhm resistors
- Plywood
- Rollers

3.5 Planning the base plate

If you have all these things, then the construction can start. First you should take your MMC, your high voltage transformer, the threaded rods and the rollers. First you place the transformer and the MMC on a plywood board in such a way that there is enough space for the later cabling and above all that the threaded rods and rollers can still be screwed to the board. It is best to draw the positions on the wooden board with a pencil. Now it is best to cut out the piece of plywood you have just drawn. However, it is recommended to cut it square, so all sides are the same length. Then draw the mounting holes for the rollers on the back of the board. The rollers

should always be positioned in the 4 corners. Then draw the mounting holes for the high-voltage transformer. Then connect the opposite corners of the wood with a line. The center of the wooden board is marked in this way. Now comes the tricky part. The threaded rods that will later separate the two "floors" from each other must be positioned so that they do not get in the way of the rollers, but are still as far away as possible in the corners. Now the lines come into play. You simply drive down these with your threaded rod until you no longer have to "drill through" the roller on the underside.

3.6 Drilling

First, drill the mounting holes for the transformer through which the screws will later fit. Here you should not use wood screws, but screws with metric thread, for example "M6". Then drill the holes for the rollers. Again, use wood screws for this. The holes should be drilled with the core diameter of the wood screws. However, you should not drill your wooden board completely through, but only drill a blind hole. Now comes the complicated part, the threaded rods. For this you should think about your "upper floor", on which the primary coil and the secondary coil will be fixed later. The "upper floor" can, but does not have to be made of Plexiglas. In any case, Plexiglas looks much nicer afterwards and it insulates excellently. It is important that the upper floor and the lower floor have the same dimensions. Once you have cut your upper floor out of Plexiglas or wood, you place the two plates (upper and lower floor) precisely on top of each other and fix them with screw clamps. Now drill the holes for the threaded rods through the upper and lower floors at the same time, which increases the accuracy of fit. It is recommended to use a drill press for all drilling.

3.7 Spark gap

Building the spark gap is by far the most challenging part. Usually a spark gap with 5 gaps is sufficient to "fire" a "Middi-SGTC (engL spare gab tesla coil)". Consequently, 6 pieces of equal length should be cut from a copper tube. It is recommended not to cut the pieces shorter than 12 cm. The copper tube should have an outer diameter of > 12 mm. The larger the cut piece, the slower it heats up during operation of the Tesla coil. First, place the copper tube on as straight a surface as possible. Now draw a straight line on the tube with a pencil. To do this, simply hold the tube, place the pencil sideways on the ground, and then move it along the tube. Now you draw in your sections. In our example, 6 sections of equal length and cut them with a pipe cutter or a hacksaw. Make sure that the line on the pipe remains intact. Then, from each end of the section, mark a line 1 cm away that crosses the line. These points mark drill holes. Since the sections are to be mounted on Plexiglas later, it is recommended to cut a thread into them. M3 is usually sufficient. For the drill diameter, calculate M3, i.e. 3mm outer diameter of the screw, times 0.8. With 2.4mm we have to drill the hole we just marked. Then cut the thread with a lot of feeling. Now our copper pieces are ready.

Since our spark gap should be adjustable, it is mounted on rails. For this purpose, you should make 4 Plexiglas strips of the same size. For this it is best to use thick p l e x i g l a s s , for example 4 mm. To explain the now following section is a bit complicated, so just a nice detail shot:

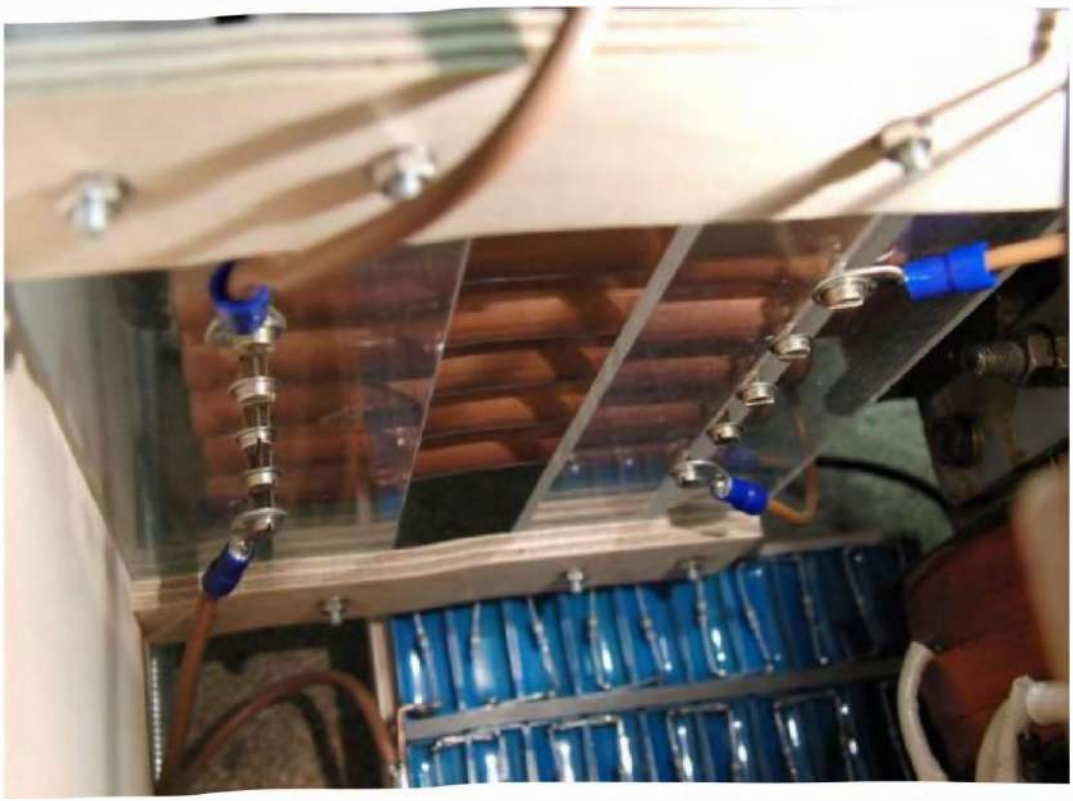


Figure 7: Spark gap of horizontal copper tubes in detail

Now our spark gap is ready. However, we still need a fan that cools our spark gap and, above all, blows away ionized gases such as O_3 or NO_2 as these have a negative effect on the function of the spark gap. The fan should be mounted above the spark gap. A fan with 230V is recommended, since no transformer or electronics are required.

3.8 Primary capacitor

The MMC can be mounted in 2 ways. Either you can fix it lying on the base plate with hot glue, but this does not look very nice. But you can also build a suitable housing.

Figure 8: MMC, 10 pieces in series (string), three strings parallel

For the following reasons, care should be taken to keep the connections in a Tesla transformer as short as possible:

- Keep stray capacitances and stray inductances to a minimum
- the longer the cable, the higher the ohmic resistance and the stray components

The following safety measures should be incorporated:

A 2 MOhm resistor should be soldered in parallel across each capacitor. This resistor discharges the capacitors after the operation of the coil. In addition, the resistors also provide a voltage divider. Since capacitors have relatively large manufacturing tolerances, it could be that one capacitor has a higher capacitance than another, which has the following effect:

For capacitors in series connection applies: The charge Q (Coulomb) is equal on each con- densator.

The capacitance of a capacitor is defined as: C = Q/U, i.e. charge per voltage. Let us

convert this formula to: U = Q/C

If one capacitor has a larger capacity than another, its share of the voltage it receives is smaller. Another capacitor (with lower capacitance) will therefore receive more voltage.

The resistors prevent in this case the possible destruction of this capacitor by overvoltage.

3.9 Transformer

Now the high-voltage transformer is attached. To do this, you should look for the last free edge on your base plate. Place the transformer in the desired position where it will be screwed later. Then mark the mounting holes of the transformer on the wooden board with a pencil. Finally, drill the holes and then fasten the transformer. The base plate is now almost finished.

3.10 Threaded rods

Now you need to determine the optimum length of the threaded rods. To do this, find the point on the base plate that sticks out the highest and measure the height. Now add 7cm so that the upper floor has a little distance to the highest point. Now cut the threaded rods with a hacksaw. To do this, clamp the threaded rods in a vice. But be careful not to crush the threads. To prevent damage, it is best to wrap the threaded rod with a few layers of cloth and then clamp it in the vice.

3.11 Primary coil

Building the primary coil is, in my opinion, the part of building a Tesla coil that requires the most care. To do this, proceed as follows. In order to be able to wind the coil in one go without bending the primary coil cable to get to the next outer turn, the guides for the copper cable are offset on each holder to compensate for the difference in length of a full turn.

To do this, first determine the space that should be between each turn. There is no guideline for this. So you are free to decide how far you want the space between the turns to be. Personally, I leave at least as much space as the diameter of the cable, for example 6 mm. This results in a drilling distance of 6 mm + 3 mm + 3 mm, i.e. 12 mm in total. So now you know that you have to compensate for 12 mm difference in length for a full turn in order to get to the next outer hole. If I use 8 holders, for example, the holes shift outward by 1.5 mm per holder.

Then connect the transversely opposite corners of the Plexiglas plate with a line. The center of the plate is marked like this. Our primary coil will be screwed or glued to this point later.

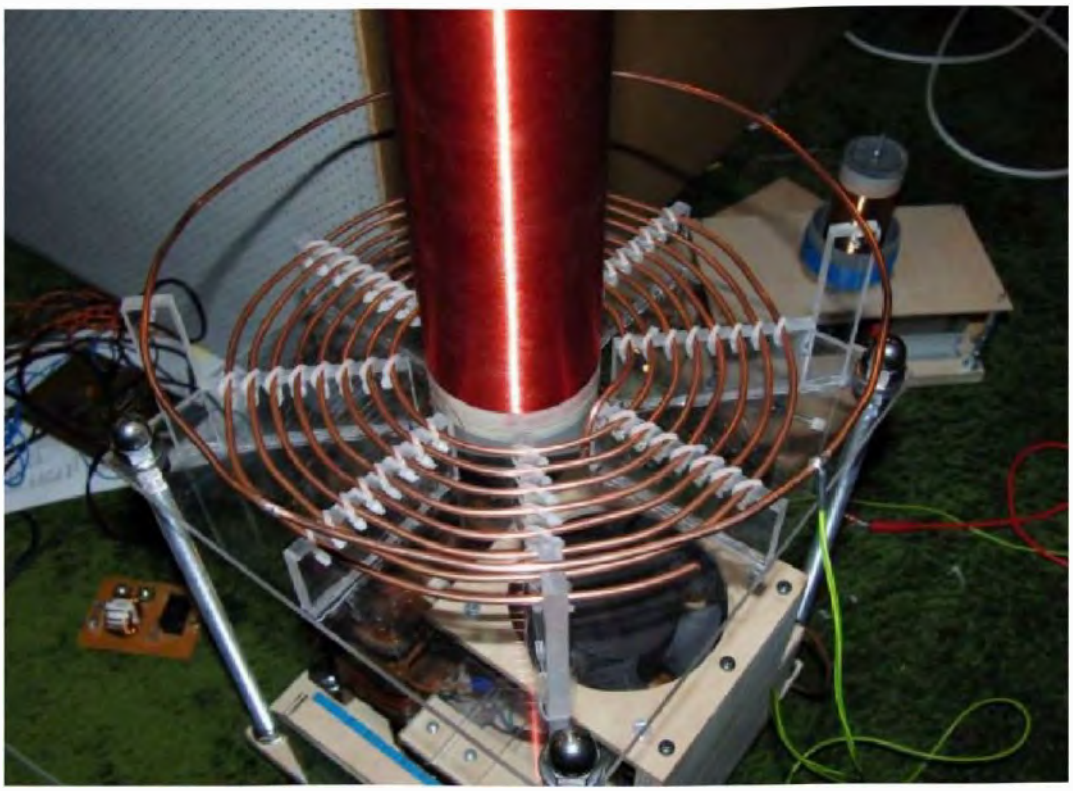


Figure 9: Horizontal primary coil on plexiglass spacer

3.12 Secondary coil

Figure 10: "Artful" winding machine for secondary coils, but it works!

The secondary coil looks like a lot of work. Hundreds of turns have to be wound precisely. However, this is a matter of half an hour once you get the hang of it. For this you need a drill with adjustable speed.

Suppose you want to wrap a PVC pipe that measures 7.5 cm in diameter. First cut out 2 circles from spear wood that are larger than the diameter of the pipe to be wound, e.g. 8 cm. Then take a threaded rod, preferably M8, and clamp the tube to be wound onto the threaded rod with the help of the 2 wooden circles. This arrangement again one clamps in his drilling machine. After that you should make a suspension for your wire reel. Once this is done, you attach the wire to the pipe with about 10 cm oversize, preferably with scotch tape. Now the difficult part begins:

The first 4 mm of the coil should be wound by hand, then the drill is used. If you want to use the drill, it is advisable not to guide the wire with bare fingers, but to put a piece of kitchen roll paper in between (otherwise the tension will be too high). The rest is a matter of feeling. However, winding a coil is great fun once you get the hang of it!

When the coil is ready, it should be thoroughly sprayed with polyurethane varnish immediately after winding. This additionally insulates the wire and above all prevents the wire from slipping off the tube due to temperature changes.

1.13 Topload

The topload is best built from aluminum flex tube. This is inexpensive, easy to form and also looks passable. Since Aluflex tube, as the name suggests, is a tube and not a ring, it must be formed into a ring. But how do you connect the 2 ends to a ring? These 2 ends can simply be sewn together with nylon thread. To keep the diameter of the ring, you should add a plexiglass disc inside. This can be glued very well with hot glue to the Aluflex ring. In the center of the disk you drill a hole, as needed, so that you can later attach it properly to its secondary coil.

1.14 Wiring

Finally, only everything must be wired. For the power supply one should
Use 1 mm^2 cable, for the primary circuit 2.5 mm^2 . Now we come back to the topic of grounding the Tesla coil. The high voltage transformer should be grounded via the mains ground. The secondary coil, however, should have its own separate ground. For this you should get a grounding cable, which has a big alligator clip at one end. With this one can "clamp" to fences, gates etc. without further problems. "clamp". Now our Tesla coil would be ready.

4. "Pimp my Teslacoil"

Once you have finally built your first Tesla coil, you naturally want to achieve the best possible results. Now, however, the coil works only very poorly. This is a very sobering experience. But this can be prevented by the following measures:

4.1 "LC - Tuning"

4.2 "Spark gap tuning"

4.3 LC - Tuning

One reason why the Tesla coil delivers only very sobering results may be that the two oscillating circuits are not well tuned to each other. In order to set up the two oscillating circuits, the following experimental setup should first be reproduced:

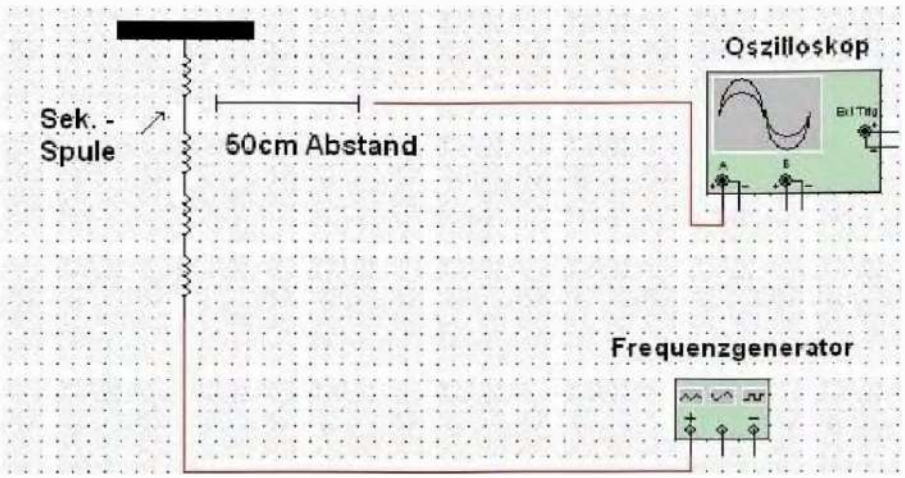


Figure 11: Determining the resonance frequency of the secondary coil

It should be noted that this measurement should be carried out outdoors, since mechanical objects influence the natural frequency of the secondary coil.

Now "sweep" the frequencies with the frequency generator. If you look at the oscilloscope meanwhile, the amplitude of the sine wave is highest at a certain frequency. This is our resonance frequency!

Now we only have to change the frequency of the primary circuit accordingly. To do this, we measure the primary capacitance with an LC meter. Now we calculate the necessary primary inductance by converting Thompson's oscillation formula. We measure this inductance again and measure it on the primary coil. Done!

Figure 12: Determination of the resonant frequency of the secondary coil on the live object with sine wave generator and oscilloscope

4.4 Spark gaps - tuning

Even if our Tesla coil is 100% tuned, the function can still be negatively affected by a poorly adjusted spark gap. The cause lies in the distance of the electrodes to each other. If the electrodes are too close together, the spark gap ignites too early, so the capacitor cannot be fully charged to the "stop". The distance must be chosen so that the spark gap does not ignite until the capacitor is fully charged. That means, you have to move the electrodes so far apart, until the spark gap does not ignite anymore and then move back a little bit. Done!

5. Trials

5.1 Energy transmission

The most impressive experiment is certainly wireless power transmission - which was also the real purpose of a Tesla transformer.

For this experiment we need a normal Tesla transformer and a 2nd secondary coil, which is also tuned to the resonance frequency of the Tesla transformer. If we place this coil somewhere near the tesla coil and ground it, we will notice that no or hardly any discharges occur from the topload of the tesla transformer - but the 2nd secondary coil is eagerly sparking.

A similar experiment can be performed with a light bulb: A piece of cable about 50 cm to 1 m long is soldered to the lower contact of a base of a normal light bulb. If you now hold the other contact of the bulb without touching the cable, the lamp lights up.

What happens here?

There is a coupling between the coils: Similar to the way energy is transferred between the pri- mary and secondary coils, namely via an *inductive coupling,* energy is transferred between the two secondary coils. However, this is a *capacitive coupling.*

The strong alternating electric field of the transformer causes a small current flow in each capacitor, the *displacement current.* Between the two secondary coils is also a capacitor - between the toploads and the surface of the coil.

This, admittedly very small capacity, is however sufficient to generate a small current flow - and thus to excite the 2nd coil to oscillate. The displacement current is also what makes the lamp light up: The cable is a capacitance to the transformer, you yourself represent the capacitance to ground.

5.2 Plasma

Figure 13: Plasma discharge in a light bulb without sparkover to the tesla transformer

If you hold a clear bulb near a Tesla transformer, there are discharges in the bulb like in a plasma sphere. These discharges are often a little stronger than those from the topload - because the field emission has an easy game in the suppression of the bulb.

If one touches the glass, it gives at the place capacity is magnified against earth, des-.

a particularly strong discharge - because the

because of which more current can flow (displacement current). Even if the current does not flow through the glass, but the displacement current provides the current flow, it can happen that the plasma inside the lamp burns tiny holes in the glass bulb. This is not noticeable at first. Over time, however, air will flow in.

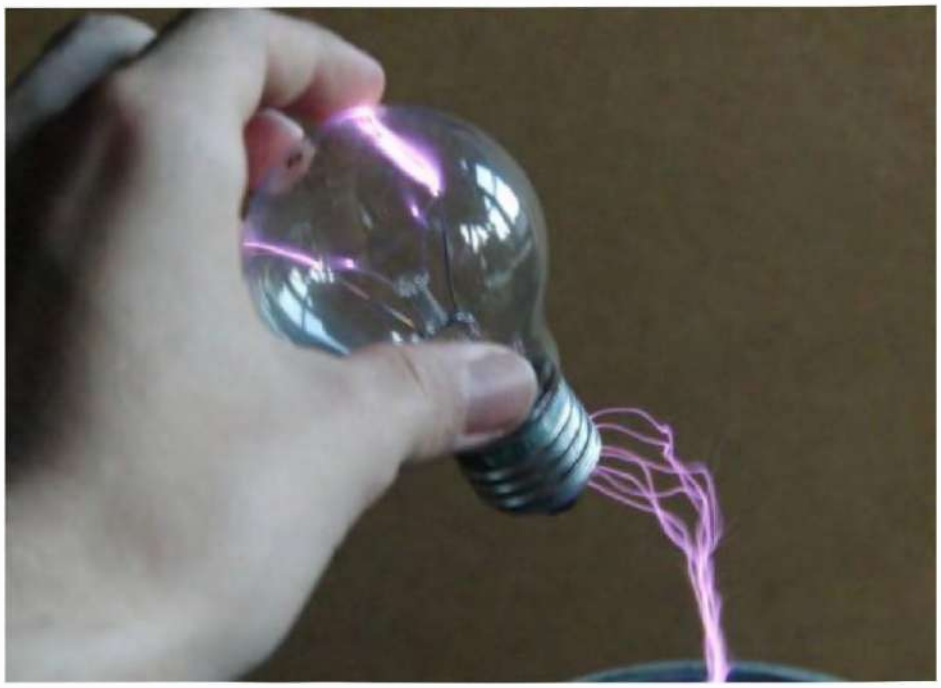


Figure 14: Plasma discharge in a light bulb

5.3 Gas discharge lamps

Figure 15: Detection of an RF field of a Tesla transformer

If you hold a fluorescent tube or energy-saving lamp near a Tesla transformer, it lights up brightly. This is again due to the displacement current in the lamp, which stimulates a gas discharge.

6.1 Dangers

High-voltage experiments may be fascinating and fun, but they are also not without danger. If you handle high voltage incorrectly, you can quickly put yourself and others in danger. Therefore, here are the most important dangers and tips for dealing with high voltage.

There is no such thing as absolute safety - if you want absolute safety, you should stay in bed and pull the covers over your head!

Some of the points listed here are certainly a bit exaggerated - the most important thing is to let common sense prevail! Who does not have this - pfo- ten away!

6.2 Arcs

Figure 16: Arc with two neon transformers, temperature over 2500 degrees Celsius

A burning arc first of all involves quite obvious dangers. Apart from the danger of electric shocks, electric arcs are of course insanely hot! Depending on the flowing current and the gas, an electric arc can reach almost 2500°C. This also poses a fire hazard if the arc touches wood, for example. Or the electrodes become hot, and possibly cause wood fasteners to burn (all this has already happened).

However, an electric arc harbors other dangers that are not apparent at first glance. The enormous heat of the plasma releases a not inconsiderable amount of ultraviolet and infrared radiation. L o o k i n g directly into an arc for a long time can cause eye damage.

In an electric arc, air is also "burned" to form nitrogen monoxide, which immediately reacts to form nitrogen dioxide. This is highly toxic. Even the smallest amounts can cause headaches. In higher concentrations it turns brown. At this concentration, extreme caution is required, as the NO_2 can lead to death by pulmonary edema, and is carcinogenic (long-term effect, lung cancer).

Furthermore, ozone (O_3), a molecular variant of oxygen, is formed. This is also highly toxic. However, both gases can be smelled very clearly even in the lowest concentrations, so there is no direct danger. Nevertheless, good ventilation is recommended.

6.3 Teslatrafos

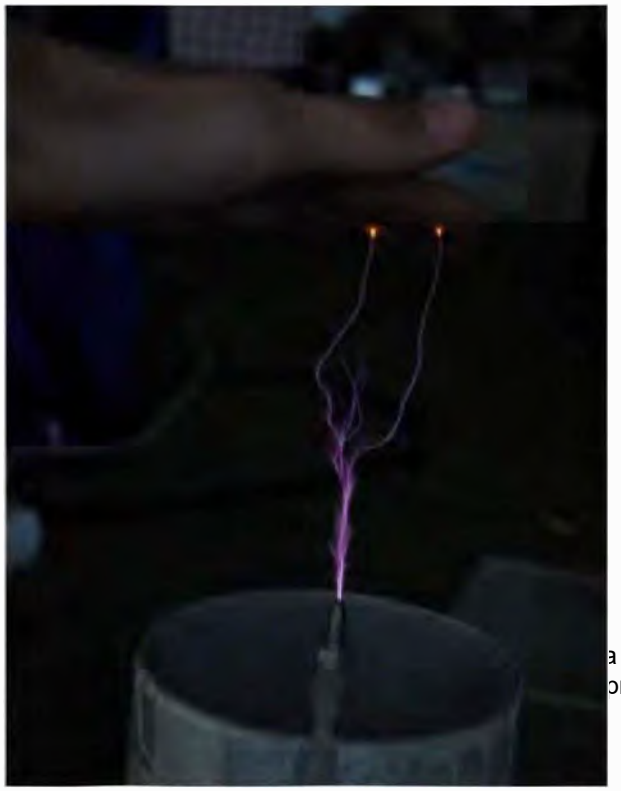


Figure 17: Touching the strea- mer of a small tesla transformer

Often the skin effect is quoted in connection with scatterers and that the high-frequency currents of a Tesla transformer can only flow on the skin of a human being. This is not correct! The currents still penetrate at 100 kHz some cm deep into the tissue! That one cannot perceive this is due to the fact that the current is too high-frequency for the nerves. That is, it changes polarity faster than the nerves can follow. But still there is an ohmic component that heats up the body, and also the nerves.

Touching a streamer directly by hand is also only recommended for really small transformers. At this point I would like to remind you about the temperature of an arc, because this can occur with larger coils if you touch their streamers.

a Tesla transformer are relatively harmless, the primary transformers used, an encounter is most

One danger is vastly underestimated with Tesla transformers, especially SGTCs:

The streamers are conductive! If you touch a streamer however, and another one hits the primary circuit, then there is a conductive connection between you and the primary circuit! And since most of the high voltage transformers don't have a galva- nic separation, the current will also use this connection!

Part 5 - Building another Tesla transformer

Part 5 - DIY of another Tesla transformer

Quotes from Dr. Nikola Tesla

(Electric poiucr iö cbcrijiulicic present in nnlimitcb qiiantitico nni) e n n briue luurlb's inncfjineri) WtHjuitt tljc nceb of conl, oil, qns, ov rtitii utljcv fncls.

©ne lunii-secunb of puiuev is nut ntnclj. '2ls nuvninlhi tl)iinrjl|t nf,
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'ZJr. '.*ikofa (ijesla*

Table of contents Chapter 5

1. Historical background

1.1 The person Dr. Nikola Tesla

Dr. Nikola Tesla was an American
Electrical engineer and inventor who is considered a pioneer in the field of electrical engineering.

Tesla was born in Smiljan (Croatia) in 1856. He studied at the Technical University in Graz and at the University of Prague. After working as an electrical engineer for three years, Tesla emigrated to the United States in 1884, where he later became a naturalized citizen. For a short time he was employed by Thomas Alva Edison, but gave up this position to devote himself exclusively to experimental research and invention. He died in 1943.

Fig 1: The first usable of the Three-phase worl developed since 1881 by the American physicist and electrical engineer Nikola Tesla, who was born in Croatia.

Tesla designed the first practical system for three-phase power transmission, for which he applied for a patent in 1888. The rights to this epoch-making invention were bought by the American inventor George Westinghouse, who first demonstrated the system at the World's Columbian Exposition in
Chicago (1893) presented.
Tesla's many inventions include the Tesla transformer (1891), which can raise the voltages of high-frequency currents to several million volts.

A unit of measurement in physics has also been named after Tesla. This is the SI unit of magnetic induction (magnetic flux density) Tesla with the unit T.
From the unit consideration it follows:

Typical values of magnetic induction are $10'^{13}$ Tesla for fields generated in the brain, $10'^{7}$ Tesla for fields produced by electric lighting and appliances in living rooms, $10'^{5}$ Tesla for the earth's magnetic field. Magnetic fields of about one tesla cause alignment of individual cells; in the laboratory, fields up to several hundred tesla can be generated; the strongest magnetic fields of up to 10^{11} tesla occur z. e.g. in neutron stars.

2. The Tesla transformer

2.1 Sense and purpose of a Tesla transformer

If a capacitor is discharged by a circular copper loop, the amplitudes of the discharge current oscillating with frequency *f* = --= sound in time *In-JLC*

$T = -$ to e^1 [R is for this frequency due to current displacement, the

skin effect (chapter 2.5), about IO times larger than the DC resistance]. After a very short time the oscillation has practically decayed. If the wire loop of such an oscillating circuit is made the primary coil of a transformer, in which a coil with many turns is placed as the secondary coil, a very high voltage is induced in it due to the high frequency and the resulting large rate of change of the induction flux. Particularly high voltages, which give rise to meter-long tuft discharges (streams) in the free atmosphere, are obtained when the natural frequency of the coil coincides with the frequency of the primary circuit (resonance). Figure 2 shows the circuit diagram of a Tesla transformer. The low frequency transformer (OBIT or similar) charges the capacitor of the oscillating circuit, which discharges oscillatory via the primary coil and the spark gap.
If the secondary coil is replaced by a coil with a few turns of thick wire, strong low-voltage currents are induced in it, into which the human body, for example, can be switched on. These **high frequency currents** find an important application in medical therapy as **diathermy currents.** While direct currents or low-frequency alternating currents of 10 to 100 mA passing through the human body have a lethal effect, high-frequency currents of up to more than 10 A can pass through it without causing damage; the lower limit of harmless frequency is 10^5 Hz. While externally supplied heat raises the temperature only a few millimeters below the surface of the skin, the Joulian heat developed by the high-frequency currents heats organs located deep inside the body.

2.2 The principle structure

The structure of the Tesla transformer has already been partly discussed in chapter 2.1. The Tesla transformer consists of two resonant circuits. The primary oscillating circuit is supplied with current from a high voltage source and consists of the primary coil, the capacitor and the spark gap. The secondary oscillating circuit is somewhat hidden between the torus, the secondary coil and the ground.
Figure 2 shows the schematic structure of a Tesla transformer and the circuit diagram for its operation, with a matall spike drawn instead of a torus. A primary resonant circuit (primary coil, capacitor and spark gap) can be seen, which is closed when the spark gap conducts. The secondary oscillating circuit is somewhat hidden, it consists of the inductance of the secondary coil as well as its stray capacitance and the capacitance of the terminal (here: metallic torus) to ground. The capacitances are added here.
With an initially non-conducting spark gap, the high-voltage source (e.g . an oil burner transformer, as used in this project) charges the capacitor in the primary oscillating circuit until the spark gap ignites and thus becomes conductive. A high-frequency oscillation begins in the now-closed primary resonant circuit, which is gradually transferred to the secondary resonant circuit by the inductive coupling. When the energy of the primary circuit is completely transferred to the secondary circuit, the spark gap (ideally) becomes non-conductive again. This is called "quenching the sparks" (from the English "to quench"). The secondary oscillation now subsides again and the game starts all over again. The spark gap should ignite 2 times per 50 Hz period of the alternating current with optimal adjustment of the two oscillating circuits, so that 2 deflections per second occur at the Tesla transformer.
However, since the capacitance of the secondary resonant circuit is much smaller than the capacitance of the primary resonant circuit, the same frequency is present here as a much higher voltage - 10 kV primary voltage can easily be turned into several 100 kV, which discharge in spectacular sparks. The sparks are made of ionized air and are often carried a little further and further by the air circulation and buoyancy prevailing in the environment, so that each charge looks slightly different. In fact, however, discharges that are already present continue to be used by discharges that follow. At some point, however, these also break off and the discharges appear in other places of the torus.

The expected secondary voltage can be approximated by the formula

$U_{sek} = \text{“} Pnmcalculate$. With the values of the present Tesla transformer

results in **U_{se} k " 285 kV.** The expected streamer length can be approximately calculated using the formula $l_{spark} = 0.8806 \blacksquare fnput[kH']^{\#6052}$. It was adjusted from units of inches to meters. Accordingly, the streamer length for this project is Isprak " **33.25 cm.**

In reality, the streamer length, depending on the primary transformer used, amounted to about 20 cm.

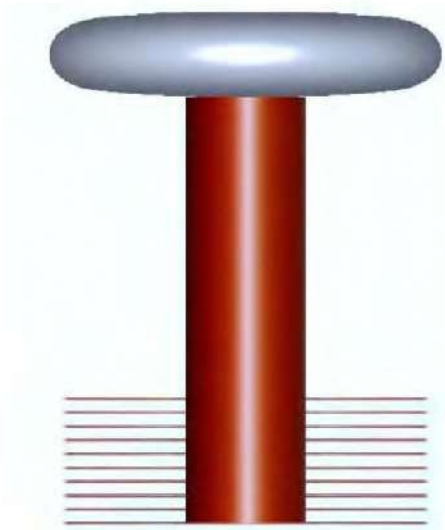
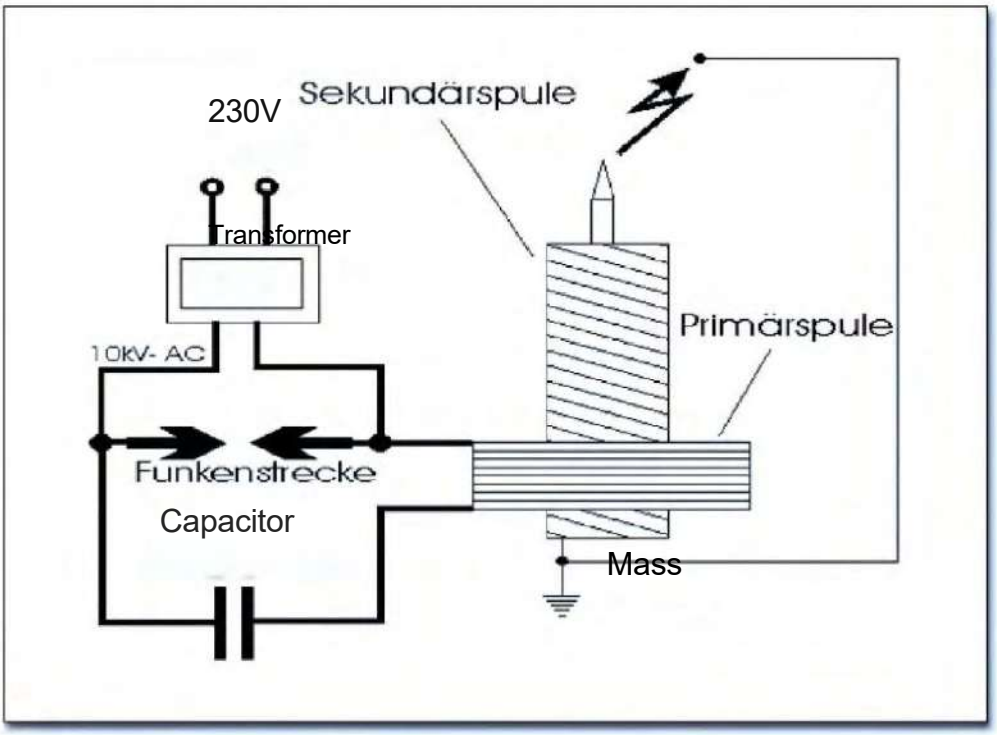


Fig. 2:

Left: Scale schematic of the Tesla transformer (without capacitor, spark gap and primary transformer}.
Below: Complete circuit diagram of the Tesla transformer (instead of metal tip, a metallic torus is used in this project).



2.3 The individual components

2.3.1 The primary transformer

An old oil burner transformer, discarded from an oil heating system, was first used as the primary voltage source. The abbreviation for this type of transformer is OBIT (Oil Burner Ignition Transformer).

The oil burner transformer is primarily connected directly to the mains, whereby the yellow-green protective conductor must be connected as well. Secondarily, it supplies 10 kV_e tr open-circuit voltage and 20 mA short-circuit current between the two high-voltage terminals. The center tap of the secondary winding is grounded (connected to the core and the protective conductor), so there is only 5 kV between each terminal and ground.

Oil burner transformers are internally current limited and thus short-circuit proof, but only for a maximum of one minute; afterwards they must cool down for 2-3 minutes.

Several transformers can be connected in parallel to achieve a higher output current. Only identical types should be used. Furthermore, the correct phase position must be ensured. This is checked by connecting the transformers to the mains and bringing the high-voltage connections to be connected closer together. If arcing occurs, reverse the polarity of one transformer on the primary side or connect another pair of terminals. With proper parallel connection, the open circuit voltage remains the same and the short circuit current multiplies with the number of transformers.

The transformers can also be connected "in series" to achieve higher voltages, although care must be taken here to ensure correct connection so that the transformers are not short-circuited.

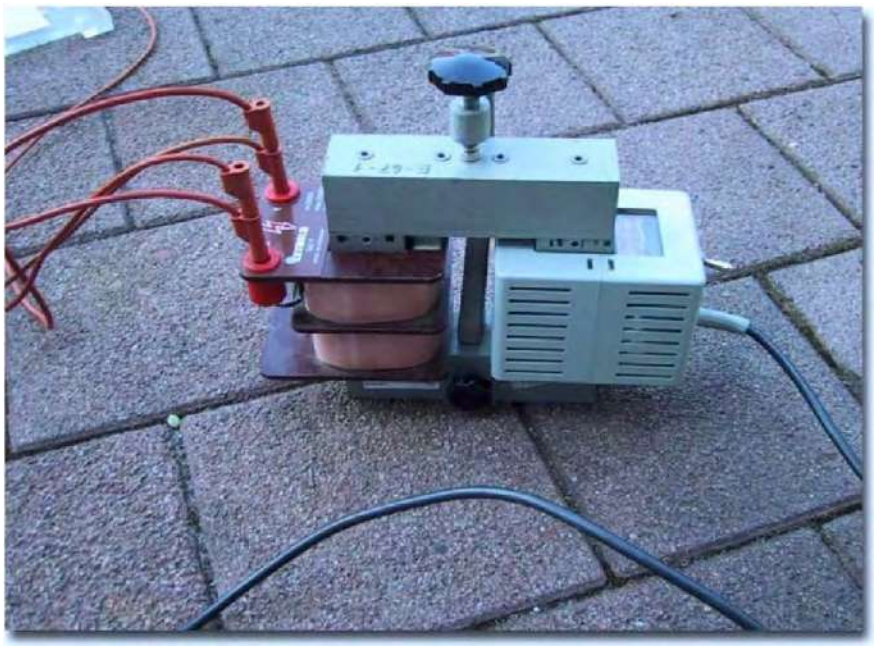
It should be noted that between the high-voltage cables in addition to the voltage of 10 kV_{eff} an already lethal current of 20 mA is present, which is why you should never touch the primary resonant circuit when the mains plug is connected.

Secondly, a self-built transformer from the school was used. For this, two coils were plugged onto a metal core, the first coil having 500 turns and the second having 23,000 turns.
According to

$$\frac{U_{eff,1}}{TT} \quad \backslash T \quad {}^{e}ff\,2 \quad \frac{U_{effb}}{\backslash T}$$

results in a secondary-side rms voltage of 10,120 volts.

This transformer proves to be much more powerful: In the spark gap the sparks jump over more often and faster. The streams at the torus can be increased to flashes of about 15-20 cm length, compared to the OBIT mentioned above with flashes of about 10 cm length. Furthermore, the flashes are brighter and more intense and the electromagnetic radiation reaches further, which has been proven by experiments with light bulbs (see chapter 3.1).



Figs. 3 and 4:

Single shots of the two primary transformers.
Above the OBIT, below the school transformer.

Figs. 5 and 6:

Top: Both primary transformers side by side.
Below: The complete structure of the Tesla transformer.

2.3.2 The primary coil

The primary coil consists of 20 vertical turns of 3 mm thick iron wire. The distance between the individual turns is 1 cm, which gives the coil a height of 20 cm with an outer diameter of 33 cm. It thus obtains an inductance of about 38.5 ^H for 10 tapped turns. If all 20 turns are tapped, the inductance is approx. 104.95 p.H.
According to calculations, the resonant oscillations of the two oscillating circuits are the same if 10 turns are tapped off the primary coil. In experiments, it has proven to be effective to tap the upper 10 turns in this construction, since they are at the same height as the lower turns of the secondary coil and thus there is better inductive coupling.
The spiral coil is held by 4 wooden slats, into which notches were cut at the coil spacing and the corresponding wire thickness, so that the coil stands in a stable frame and the coils do not touch each other.
It is recommended to use a slightly bendable wire. Although steel wire is relatively heat resistant, it is quite difficult to bend into a round spiral due to the inherent tension if you do not have a lathe to help you.
The coil is introduced into the primary resonant circuit by connecting the lower terminal to one side of the OBIT (or alternative transformer) and one side of the spark gap. The other terminal is connected to the series-connected capacitor, using a crocodile clip to vary the number of turns and thus adjust the resonant frequency between the primary and secondary resonant circuits.

Fig. 7:

Single shot of the primary coil.

2.3.3 The secondary coil

The secondary coil, together with the torus and the ground, represents the (somewhat hidden) secondary resonant circuit.
It consists of a 0.35 mm thick enameled copper wire, which is wound on a 55 cm long PVC drain pipe in approx. 1110 turns. The coil itself is 40 cm long, as the remaining 15 cm are planned as "placeholders", with 10 cm for the base and 5 cm for the distance to the torus.
The secondary coil achieves an inductance of approx. 33.12 mH and an inherent capacitance of 7.52 pF, which is added to the capacitance of the torus. Without the torus, a resonant frequency of approx. 318.84 kHz is present in the secondary resonant circuit. The DC resistance of the coil is 68.8 Q, the resistance caused by the skin effect (see chapter 2.5) is about 19.45 £2.
When winding the coil, it is important to ensure that the windings are directly next to each other and do not overlap, otherwise corona discharges can occur, which can strike the secondary coil and damage it or even destroy it irreparably. Finally, the entire coil was sprayed with insulator plastic spray in several layers to fix the windings and prevent flashovers.
Two cables (1.5 mm^2) are soldered to the two ends of the coil in order to be able to connect a ground cable to the lower end and the torus to the upper end.
The secondary coil is centered in the primary coil. In order to realize a stable stand and to be able to avoid a continuous alignment at each set-up, a round wooden foot with the inner diameter of the secondary coil is screwed centered on the wooden plate of the primary coil. Now it is possible to simply plug the secondary coil onto it and operate the apparatus without the risk of the

Secondary coil falls over.
The secondary coil must be mounted on the lower side grounded at the lower be grounded. In doing so one should no socket electronics, as the high-frequency currents can damage sensitive currents can destroy sensitive sensitive electrical devices. Better suited simply the lightning conductor or the grounding of the heating pipes. For outputs from 1 kW, you should use an extra high voltage safe grounding should be installed. For this you can use a long metal rod some meters from the from the house in in the ground.

Fig. 8:

Individual images of the secondary coil with the torus attached.

2.3.4 The capacitor

As capacitor are commercial high voltage and impulse-resistant MKP capacitors are used. Better suited would be FKP capacitors, which, compared to MKP capacitors with metal-dusted foil, have a metal foil, which is more breakdown-proof. However, MKP capacitors also work very well in a pinch.

When selecting the capacitor, care must be taken to ensure that the AC dielectric strength is above the peak voltage ü of the primary transformer, which can be calculated from $\ddot{u} = U_{ejr}$ -y/2, otherwise the capacitor can blow very quickly. The DC dielectric strength of such capacitors is often much higher than the AC dielectric strength. Capacitors where the DC dielectric strength is more than twice the AC dielectric strength often prove to be rather unsuitable, although unfortunately no others were available for this project without incurring high costs.

The required capacity can be approximated by the formula - = -- "-C = —

$$\text{®C}_{\text{Ieff Ulff.}a>}$$

calculate. For the maximum power, the impedance of the capacitor should be equal to the primary transformer impedance.
With Ueff = 10,000 V , Igff = 0 .02 A and m = 2-TI-50HZ, this results in a capacitance of approx. 6.37 nF. However, a higher capacitance cannot hurt, since it leads to longer streams from the torus, among other things.

To build the MMC (Multi-Mini-Cap), capacitors of the type MMKP-383 with 0.47 piF and voltage strengths of U_D c = 1000 V and U_A c = 350 V from the company *BCcomponents* are used. For this purpose, a series circuit of 50 pieces is soldered on breadboards. Of this series circuit, 2 circuits are connected in parallel so that, with 100 capacitors used, a dielectric strength of U_{DC} = 50,000 V and U_A c = 17,500 V is obtained with a total capacitance of 18.8 nF.

To be on the safe side, the solder joints on the breadboards should be sprayed again with the insulating lacquer spray, which was also used to seal the secondary coil, to avoid flashovers.
The capacitors were stacked on top of each other in a wooden rack to create the shape of a "tower". This way they take up little space and stand stably.

Since commercial high voltage and high frequency capacitors are often very expensive and this version of a capacitor is therefore very costly, there are of course other ways to build a capacitor:

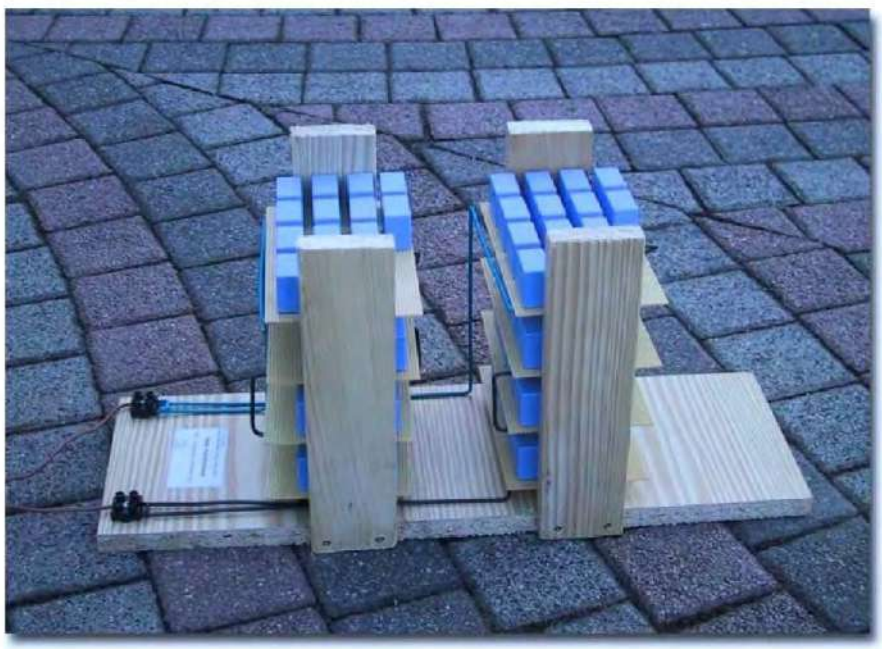
On the one hand, you can use homemade plate capacitors made of alternately laid aluminum and PE foil. Here, every second aluminum foil is connected; the PE foil represents the dielectric. After everything is wired, it must be strongly compressed so that there is no more air between the plates. The whole thing should now be immersed in oil (motor oil,...) and sealed airtight. Only the two connections may protrude. The oil prevents the penetration of air and also provides good protection against breakdown between the electrodes due to its poor current conductivity.

Another possibility is the construction of a bottle capacitor, also known as a Leydener bottle. Here, bottles must be wrapped with aluminum foil from the outside (possibly fix with spray adhesive). A salt water solution is filled into the bottles and the bottles are sealed.

A threaded rod is drilled through the lid, which with the salt water solution is one electrode. The other electrode is supplied by the aluminum foil; the glass of the bottle is the dielectric.
A such bottle (1 liter bottle) provides an approximate dielectric strength of 10,000 volts and a capacitance of 1 nF. A clever series and parallel connection allows comparable capacitances and dielectric strengths to circuits of commercial capacitors.
The advantage of these capacitors is their inexpensive and uncomplicated manufacture; the disadvantage is their unwieldy size and enormous weight.

Figs. 9 *and 10:*

Single shots of the M MC condensate rs.



2.3.5 The spark gap

The spark gap is the only active component in the entire Tesla transformer and therefore requires special attention. Figure 11 shows the schematic structure of a series spark gap and a rotating spark gap.

The series spark gap used consists of 5 copper tubes, each 7 cm long and 2.8 cm in diameter. They are screwed onto a Plexiglas plate at intervals of 1-2 mm. The protruding screws allow to vary the tap on the tubes by means of crocodile clips and thus to tune the Tesla transformer. In general it can be stated that a multi-stage spark gap brings more energy and thus longer streams than only 2 electrodes, between which the high voltage jumps only once.
The air conductivity of voltage is 1 mm per 1 kV.

Due to the input voltage of 10 kV, which is not yet so high, you can use a static spark gap without hesitation, but you should cool it with compressed air or a vacuum cleaner so that the sparks always break off well and the copper remains cold. Because the colder the electrodes are, the better they allow the sparks to jump, which is absolutely necessary for charging and discharging the capacitor.
For higher input voltages, a rotating spark gap should be used, where the sparks are guaranteed to break off due to the rotating electrodes. In addition, the rotation creates automatic cooling, which is a great advantage.

The spark gap takes over the task of constantly charging and discharging the primary circuit capacitor. It becomes conductive as soon as the capacitor is fully charged. In the primary circuit, which is now closed, a high-frequency voltage starts to build up, which is gradually transferred to the secondary circuit by the inductive coupling. When the energy of the primary circuit is fully transferred to the secondary circuit, the spark gap (ideally) becomes non-conductive again and the whole process starts again. The spark gap should ignite 2 times per 50 Hz period of the alternating current if the two oscillating circuits are set optimally, so that 2 deflections occur on the Tesla transformer per second.

During operation, the spark gap, like any other component, must not be touched, as lethal voltages and currents are present! One should provide for a good ventilation of the room, since beside nitrogen oxides also ozone develops, which can lead to tiredness, headache and breathing problems. Furthermore, it should be mentioned that UV radiation as well as X-rays are produced during operation (due to the impact of accelerated electrons on metal). Because of the UV radiation, one should therefore not look directly into the sparks, even if it looks impressive.
During prolonged operation, it is recommended to wear hearing protection, as the spark gap generates a huge noise due to the sparks jumping over it.

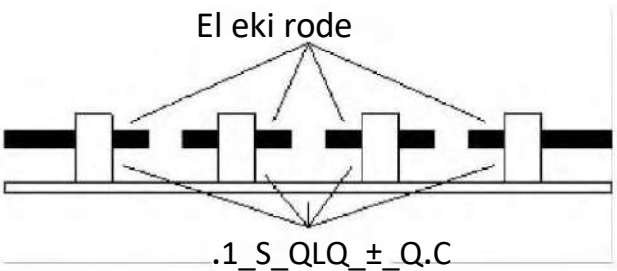
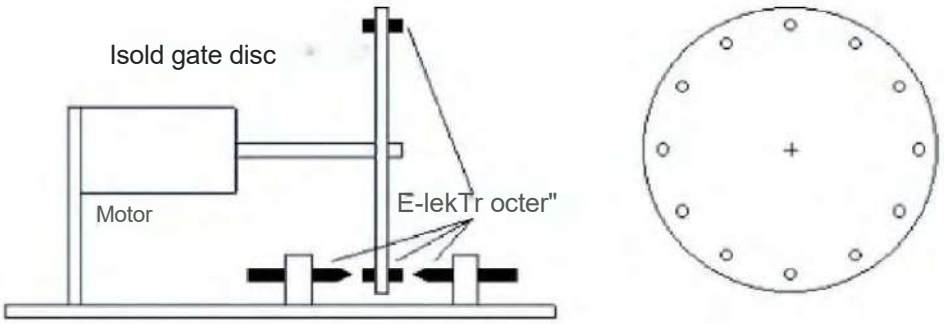
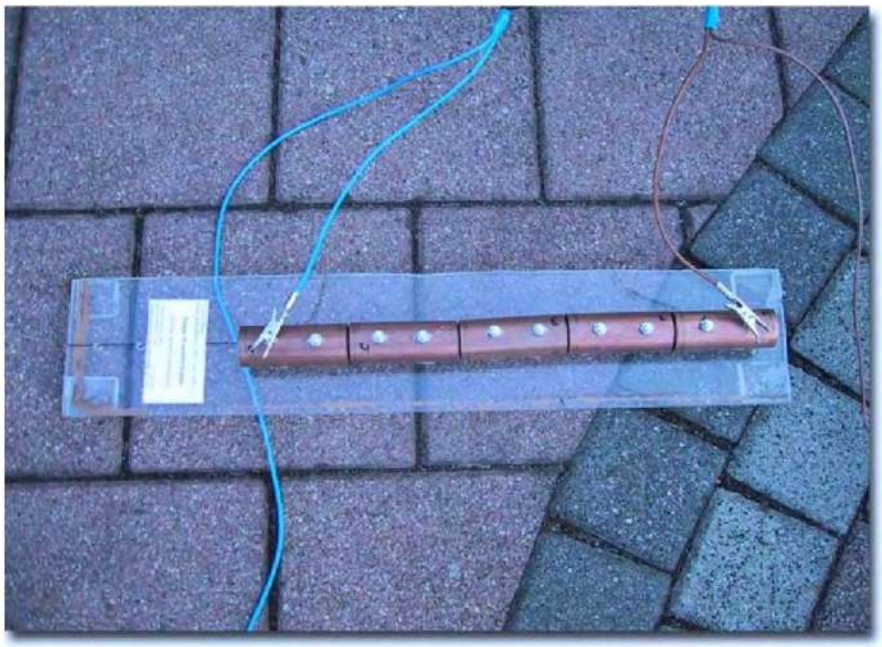


Fig. 11:
The schematic structure of a series spark gap (left) and a rotating spark gap (below).





Figs. 12 and 13:

Single shots of the series spark gap. Above in switched-off state, below in function.

2.3.6 The torus

The torus is used to ultimately dissipate the high induced voltages from the secondary coil. It consists of an Aluflex tube with a diameter of 8 cm. The torus has an outer diameter of 36 cm and thus has a capacitance of approx. 15.62 pF, which is added to the capacitance of the secondary coil to form the total capacitance. With the torus, there is thus a resonant frequency of approx. 181.76 kHz in the secondary oscillating circuit.
The two ends of the Aluflex hose are connected by conductive aluminum adhesive tape, which is available in any good hardware store. It is essential that the two ends of the hose, which are joined together to form a ring, are conductively connected to each other, otherwise a further inductance will be created.
The torus is connected to the secondary coil by a wire and plugged into the PVC pipe of the secondary coil by a holder. The holder consists of a Plexiglas circle with a diameter of 20 cm and a centered screwed-on wooden base to be able to plug the torus onto the secondary coil. The holder was glued into the torus with two-component glue.

A ring-shaped electrode such as a torus is preferable to a metal sphere, because the sphere also allows discharges downwards, which increases the risk of impacts into the secondary coil. This is then already irreparably defective after a few impacts.

Fig. 14:

Assembled and connected Tesla transformer (primary coil, secondary coil and torus).

2.4 Safety instructions

For the operation of the Tesla transformer, there are some important points of safety, which must be strictly observed.

- This protocol, as well as many other literature sources (books, internet, ...), offers a construction manual for a fully functional Tesla transformer. However, the reconstruction should only be carried out by persons who have sufficient prior knowledge and sufficient physical knowledge and understanding, especially in the field of e-teaching. The own reconstruction takes place on own danger. The author of this protocol does not assume any liability for any damage caused.
- During operation ...
    - o... no component may be touched, as lethal voltages and currents are present. Always keep a safe distance of 1 meter from the electrical equipment.
    - o ... no chip cards or sensitive electrical devices (computers, cell phones, video devices, pacemakers, ...) should be in the room or have a safety distance of at least 10 meters. The enormous magnetic fields as well as the high-frequency electromagnetic oscillations can disturb sensitive devices and even destroy them irreparably!
    - o ... especially during the first operation, a connected grounding cable should be near (approx. 10 cm distance) the torus, so that you don't get unexpected flash ranges. This safety precaution should be taken especially during the first operation, later you can experiment at your own risk and remove the grounding to achieve longer streams.
    - o ... keep all limbs close to the body. Because of the strong magnetic fields, when the arms are spread out, a different voltage may be induced in one arm than in the other arm; this will cause currents to flow through the body at heart level.
    - o ... you should make sure that the room is well ventilated, as the spark gap produces ozone as well as nitrogen oxides, which can lead to fatigue, headaches and breathing problems. Furthermore, it remains to be mentioned that UV radiation as well as X-rays (due to the impact of accelerated electrons on metal) are produced during operation. Because of the UV radiation, one should therefore not look directly into the sparks, even if it looks impressive.
      During longer operation it is recommended to wear hearing protection, because the spark gap makes a huge noise due to the sparks jumping over.
- While the transformer is switched off, the capacitor should always be short-circuited, otherwise lethal charges may be generated during the rest phase due to the *dielectric memory effect.*
- Because of the risk of internal flashover, do not use switches, only a power plug.
- By the way, contrary to popular belief, it is *not* harmless to let the discharges of a Tesla transformer pass through the body. The frequently cited *skin effect* (see chapter 2.5), according to which high-frequency currents flow only at the surface of conductors, is ineffective because of the low conductivity of the human body. Moreover, the output voltage of Tesla transformers operated with spark gaps often contains a 50 Hz component, which is much more dangerous than the high frequency.

2.5 The skin effect

At high frequency, the current does not spread over the whole cross-section of a cylindrical conductor with the same density, but pushes itself to the surface. The cause of this **skin effect** is internal self-induction.

A magnetic field passes through a surface element dr ds in the wire interior, the change of which induces an electric vortex field E_{ind} . On the side facing the axis, it is oppositely directed to the applied field ***E***, on the other side it is rectified. The resulting field must therefore increase outward from the axis, as must the current it generates. At high frequencies, the current is almost completely applied to the

surface is displaced. At depth $d = \frac{I}{\text{V Ar Ao®}}$ it is already at e'[1] dropped (S, |ir

resistivity and permeability of the wire, a angular frequency). Another consequence of internal self-induction is a phase shift between current and voltage.

The skin effect causes a wire to have a higher resistance for high-frequency alternating current than for direct current. If the thickness *d of* the effective conducting layer is small compared to the wire diameter, the cross-section no longer determines the resistance, but the circumference. Therefore, thin-walled tubes or stranded wires are used as high-frequency conductors.

The complete theory of the skin effect is rather complicated. Therefore a short version is given. Even at the highest technically achievable frequencies, in good conductors the displacement current D plays no role against the current density *j.* This can be seen from the comparison of *b* = *a>s₀* E with *j* = *aE.* For ®<< -" 10^{18} s'[1] is D "j.

eo

Maxwell's equations are then red ***H = j,***

red ***E*** = 1 red ***j*** = -^oH

Elimination of ***H*** leads to red red ***j*** = cr^rHoj. The time derivative corresponds to a

Multiplication by *a>,* the twice spatial (red red) of a twice multiplication by the reciprocal layer thickness on which the current drop occurs on e^{1} :

$$-j \sim \frac{1}{nxr/i^{j}\, d}$$

This is the relationship given above for *d,* here for a plate.

2.6 Theoretical consideration

For theoretical consideration, the most important values of the Tesla transformer are summarized here in tabular form.
The data was calculated using a Java script widely used on the Internet to calculate Tesla transformers.

Details of the primary oscillating circuit	
	33 cm
Inner diameter	1 cm
Gap between turns Wire diameter	3 mm
Number of turns	20 turns
Winding angle (0° = flat; 90° = vertical)	90°
Height above secondary coil start Coil height	0 mm 20 cm
Inductance	
• at 10 tapped turns	38.48 H_g
• at 20 tapped turns Capacitance of the capacitor	104,95 uH 18.8 nF

Details of the secondary oscillating circuit	
	11 cm
Diameter of coil former Gap between turns Wire diameter	< 0.01 mm 0.35 mm
Winding length	40 cm
Number of turns	approx. 1110 turns
Inductance	33.12 mH
Thickness of the torus	8 cm 36 cm
Outer diameter of the torus aspect ratio	3,62
Medhurst K	0.68 pF/cm
Self-capacitance of secondary coil	7.52 pF
Torus capacitance Resonant frequency without torus Resonant frequency with torus	15.62 pF 318.84 kHz 181.76kHz
DC resistor	68.8 Ohm
Resistance due to skin effect Q	19.45 Ohm
Primary capacity required	428,71 19.92 nF
Coupling factor between primary and secondary coil	1 9

By tapping approx. 10 primary windings, a resonance oscillation of approx. 187.1 kHz can be set between the two oscillating circuits from a mathematical point of view. Experimentally, the longest flashes were also measured by tapping the upper 10 primary turns.
All values are approximate and may vary slightly.

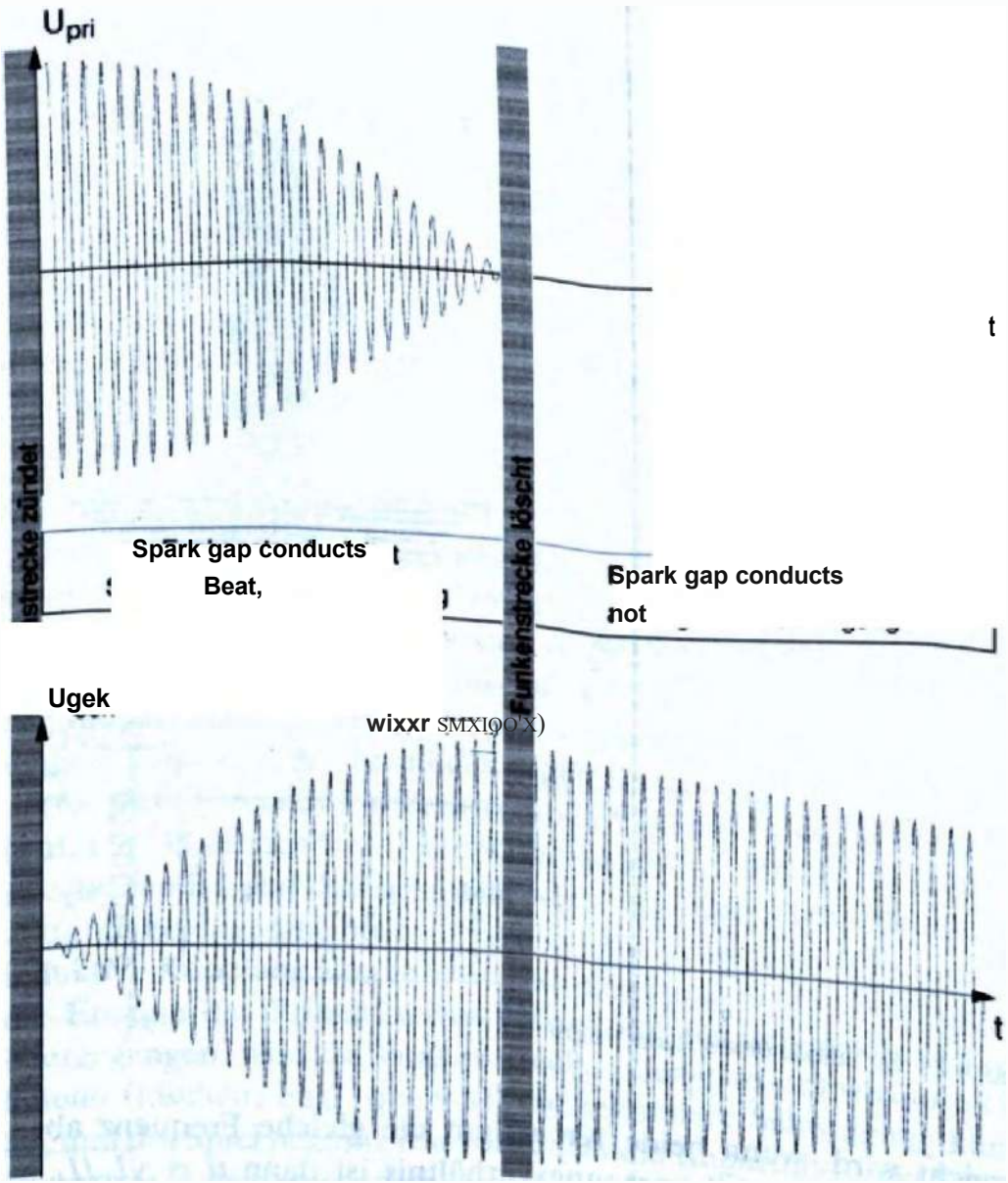


Fig. 15:

Voltage curve at the Tesla transformer (idealized, without secondary spark discharge)

3. Test evaluation

3.1 Experiments with the Tesla transformer

One can perform a variety of experiments with the Tesla transformer, demonstrating the effects of the strong magnetic fields, electromagnetic radiation, and high-frequency voltages.

Due to the high-frequency electromagnetic radiation, a standard neon tube, of course without any cables connected, should start to glow when brought close to the torus.

If you hold a light bulb to the torus, it should start glowing, looking like a plasma ball.

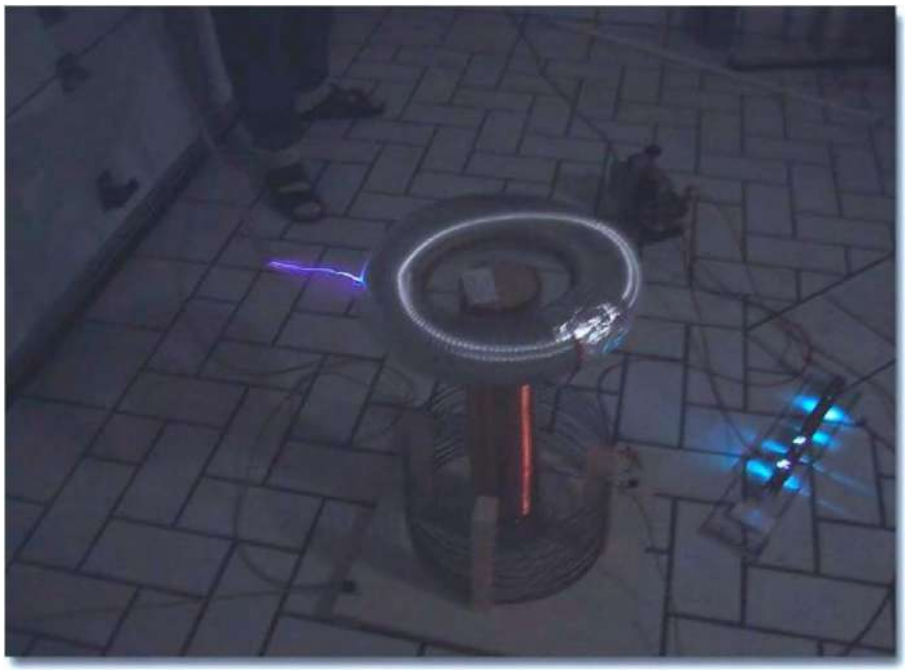
Fig. 16:

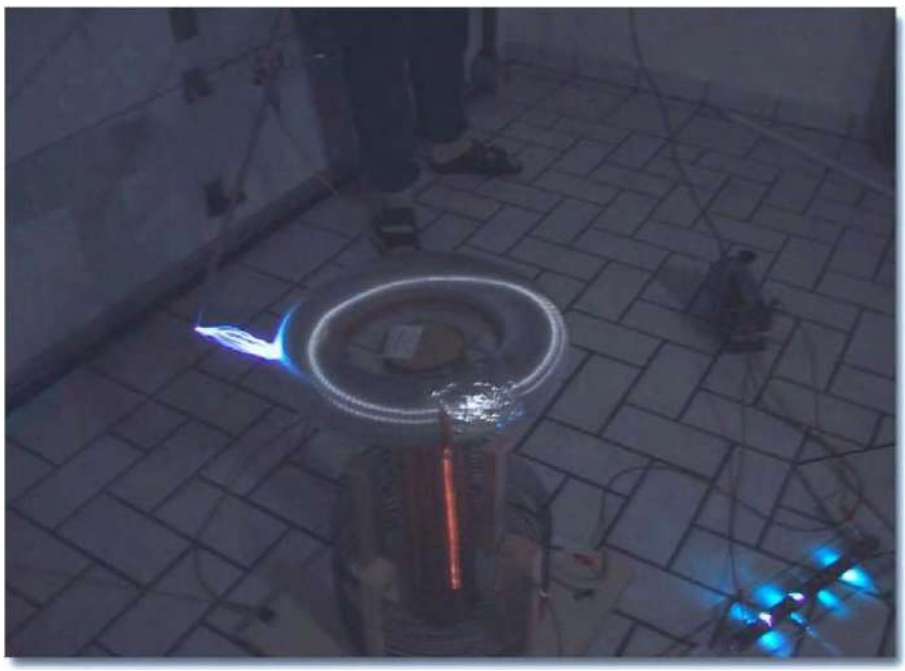
Single shot of a light bulb near the torus.

Furthermore, realistic lightning strikes as known from nature can be simulated. For even larger and therefore more lifelike impacts, a Marx generator is advantageous, as it is capable of generating much higher voltages.

Fig. 17:

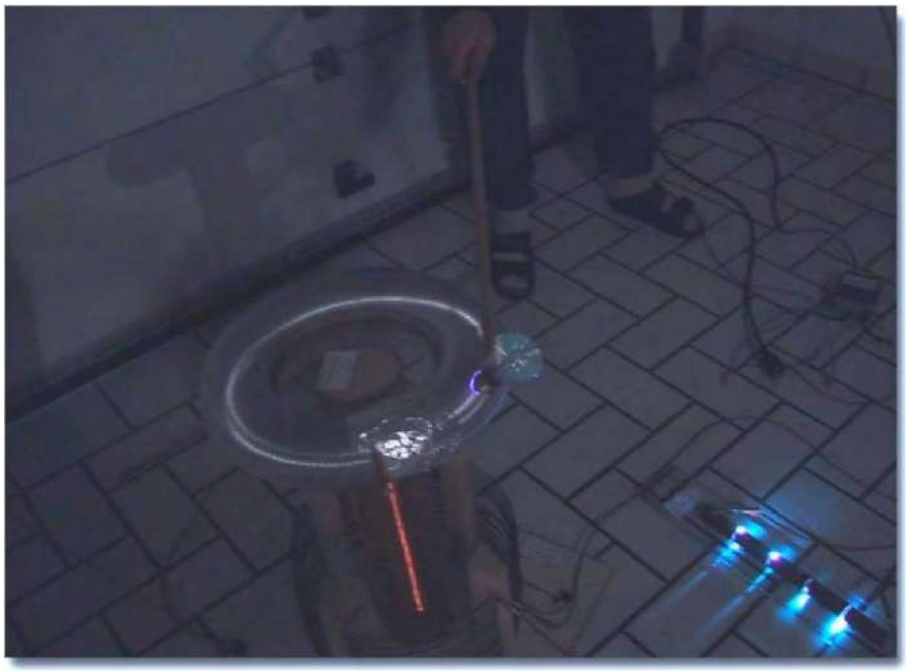
Discharge to earth.

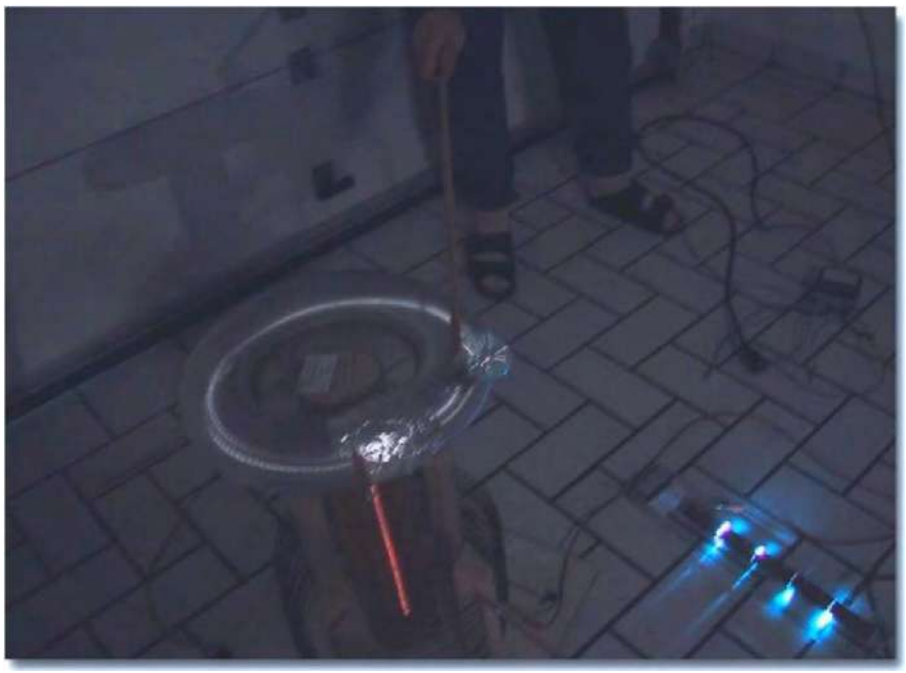




Figs. 18 and 19:

Discharges against earth at different distances.





Figs. 20 and 21:

A light bulb near the torus starts to glow like a plasma ball due to the electromagnetic radiation.

Figs. 22 and 23:

Top: A neon tube near the torus also begins to glow. Bottom: The spark gap in operation.

3.2 Scientific findings

In addition to the possible experiments with which high-frequency electromagnetic radiation and magnetic fields can be detected, high-frequency currents are used in medicine, as mentioned in chapter 2.1.

If the secondary coil is replaced by a coil with a few turns of thick wire, strong low-voltage currents are induced in it, into which the human body, for example, can be switched on. These **high frequency currents** find an important application in medical therapy as **diathermy currents.** While direct currents or low-frequency alternating currents of 10 to 100 mA passing through the human body have a lethal effect, high-frequency currents of up to more than 10 A can pass through it without causing damage; the lower limit of harmless frequency is 10^5 Hz. While externally supplied heat raises the temperature only a few millimeters below the surface of the skin, the Joulian heat developed by the high-frequency currents heats organs located deep inside the body.

From a physical point of view, the inductive coupling of the primary and secondary coils can be used to demonstrate the induction of high-frequency voltages, which can reach the megavolt range. Furthermore, the enormous electromagnetic radiation as well as the high magnetic fields can be demonstrated by the experiments shown.

4. Error consideration

4.1 Possible sources of error and suggestions for optimization

The spark gap is a very sensitive component, for which precise construction should be ensured. The distances between the electrodes should not be too large, but also not too small. Per kV 1 mm of air can be ionized. In addition, care should be taken to ensure good cooling so that the sparks break off well.
A rotating spark gap brings higher power to the Tesla transformer.
To increase the power and the output voltage even more, you can use a so-called level shifter, which acts similar to a voltage doubler.

Provided that the capacitors meet the dielectric strength requirements in the coupled state, care should be taken to ensure that the solder joints are not cold. Furthermore, the capacitance should not be too low, otherwise only short or no discharges are achieved. Thus, the primary capacitance influences the discharge length and thus the induced voltage.

When inductively coupling the two coils, care should be taken to ensure that the secondary coil is centered and isolated, i.e. "connected" only by inductive coupling, in the primary coil. The coupling factor is calculated from the ratio of the cross-sectional areas and should be a maximum of 0.16.
With the coils, care must be taken to ensure clean and tidy winding. The windings of the secondary coil must be exactly next to each other and must not overlap, otherwise corona flashovers may occur, which will irreparably destroy the secondary coil.

In general, no cables should be directly next to each other and even when using Lister clamps, at least one clamp should always be left out; otherwise, flashovers can also occur here, which has a negative effect on the performance of the Tesla transformer.
For cabling, stable insulated cables should be used, the thickness of which corresponds at least to a 1.5 mm^2 cable.
One should always use insulating substrates such as stone floors or the like so that there is no undesirable grounding anywhere, which can severely affect the performance of the Tesla transformer and cause cables to break through.
The grounding of the secondary coil should dissipate the currents well. Therefore it is recommended to use a lightning conductor or the grounding of the heater. For larger Tesla transformers an extra grounding is advantageous. For this purpose, you can stick a very long metal rod vertically into the ground.

The two oscillating circuits must oscillate in resonance. This is the only way to achieve long and effective discharges. The resonance is adjusted with the help of a crocodile clip on the primary coil by tapping off more or fewer turns. Attention: Please only touch and change the components when the mains plug is disconnected. Contact, especially with the primary oscillating circuit, can be fatal!

As described in 2.3.1, it has proven useful to test other primary transformers as well, which may help the Tesla transformer to achieve more power and thus longer streams.

Furthermore, you should generally pay attention to precise processing of the entire components. It is best to make an exact plan beforehand of how each component should look and be built.

5. Small collection of formulas

The following is a list of the most important formulas needed to build and calculate a Tesla transformer. On the next page the quantities are described with the legal units.

$L = P_0 P r - A^{N2}$

Inductance of a long coil

$L .. \frac{AoAr\beta^{Ar2}}{8}$

Inductance of a flat coil

$/ = \frac{5}{27Ty[LC}$

Resonant frequency

$P = U I$

Electrical power

$\ddot{u} = V2\ U_{eff}$

RMS and peak values of voltage and current

$Cges = C\,1 + {}_{G2} + \ldots + C''$

$ges^{=} f\,1\ ^{-} U_{\bar{7}} \ldots = \underline{Q}ges$

$= 21 + Qi + - + Qn$

Parallel connection of capacitors

$\frac{111\,1}{Cges} \quad \frac{1}{{}^{C}I_{C2}} \quad \frac{1}{C''}$

$U\,ges \sim 1\ "t\ f^{y}\ 2 + \ldots + 1,$

$0^{\wedge}=21=02 = --- = \&.$

Series connection of capacitors

$C = {}_{47T\pm 0E_r} r$

Capacity of a free standing sphere

$U_{sek} = U_{prim} \cdot \sqrt{\frac{C}{prim}}$

Approximate value of the voltage induced in the secondary coil

$^{!}Spark = 0.8806\ \blacksquare/npw/[A'IF]^{\,t0/(152}$

Approximate streamer

length Magnetic flux

density

$0> = {}_{B\,\blacksquare\,\ddot{A}}$

Magnetic flux

Legal units and supplementary explanation

Size	Unit	Meaning
L	Henry (H)	Inductance
Ho	$\frac{Ky}{At}$	Magnetic field constant = $4?r\text{-}10^{7}$ -^- At
Rr	1	Permeability number (For air, $p_{.r}$ =l)
N	1	Number of turns
1	m	Length
A	m^2	Cross section of the coil
D	m	Diameter
C	Farad (F)	Capacity
f	Hertz (Hz) = s'^{1}	Frequency
P	Watt (W)	Power
U	Volt (V)	Voltage
I	Amps (A)	Current
ü	Volt (V)	Peak voltage
i	Amps (A)	Peak current strength
ueff	Volt (V)	RMS voltage
leff	Amps (A)	RMS current strength
Q	Coulomb (C)	Cargo
r	m	Radius of the sphere
Co	$\frac{ÄS'}{Fm}$	Electric field constant s_0 = $8.8542\ 10^{12}$ - $\frac{}{Vm}$
E_r	1	Dielectric constant (For air, s_r =l)
B	Tesla (T)	Magnetic flux density
<l>	Weaver (Wb)	Magnetic flux

Power saving tips

In this chapter you will still learn how to save additional power.

Let's start with the light bulb.

If you still have old incandescent bulbs in use, you can replace them with LED lights. The LED light is much more effective than incandescent bulbs and lasts much longer. Remember, nevertheless, to always turn on the light only when you really need it. For office work on the computer, for example, there are also LED lamps with USB ports, which means that you do not need an extra power supply, because it takes the power from the computer.

If you have air conditioning, it makes sense not to use old air conditioners. And the colder or you set it, the more electricity it consumes. This is usually logical, but many people do not pay attention to this. There are also air conditioners where you can program in the times with a thermostat when it should run.

The clothes dryer also consumes a lot of electricity. On hot days it is worth drying the laundry in the air.

You should also rather dispose of an old dishwasher, oven, washing machine or old refrigerators and buy newer appliances with better energy efficiency, because generally old appliances consume a lot of electricity.

With refrigerators, it is also advisable to cook large portions and then freeze them, so you do not have to use the stove several times.

If you also have an old refrigerator and in addition an old freezer, it is better to dispose of them and get a large refrigerator with large freezer
(2 in one) to buy.

Also, rather dispose of old TVs and buy, for example, a flat-screen TV with better energy efficiency.

In order to further save electricity from electrical appliances, it is also worth buying a power strip with a switch to turn off the complete circuit of the appliances instead of keeping them on standby. Because in standby mode, the devices still continue to consume electricity. (This can account for between 10 - 15 of the electricity bill).

When buying newer appliances, look for the energy efficiency classes: the best are still the A+++ appliances, which consume the least electricity.
(See picture below)

If the refrigerator is dusty and dirty at the back of the coils, it will also automatically consume more power. You can simply wipe the coil with a towel or vacuum it with a vacuum cleaner. There are also recommended temperature values for the refrigerator. For the refrigerator compartment it is recommended a temperature of
To set 4-5 degrees. For the freezer compartment, the recommended temperature - 15 degrees.

Closing words

Now we have reached the end of this book. We thank you for your interest in reading this book and hope that we could give you an insight into the world of Tesla and free energy.

If you have not understood terms or explanations, or would like to read again, feel free to scroll back or also look on YouTube more assembly instructions. There are heaps of them. Continue to inform yourself and stay up to date.

"Just imagine if the government of an industrialized country could no longer levy a mineral oil tax when applying Free Energy inventions and their further developments! That would be the end of the super rich and the beginning of a general prosperity."

"Again and again there were developments and inventions which were not in the interest of the world conspirators because they brought too great advantages to man. The human being should not have it too comfortable. The more he has to work for the preservation of his existence, the more dependent he becomes on the satanic power."

"Millions of people could live a life worth living where they now have to starve or freeze to death in agony. It's all about money every day everywhere you look. Very few people know the truth."

But fortunately there are also many people who believe in free energy and also support this and try to take it into their own hands. Who does not dare, does not win! Only together we are strong! Let us not be exploited further and fight against it!

So now, as you begin to implement what you have learned in this book, try and share with everyone else what it means to discover the world of free energy!

We wish you success and thank you for your interest!

Free energy for all!