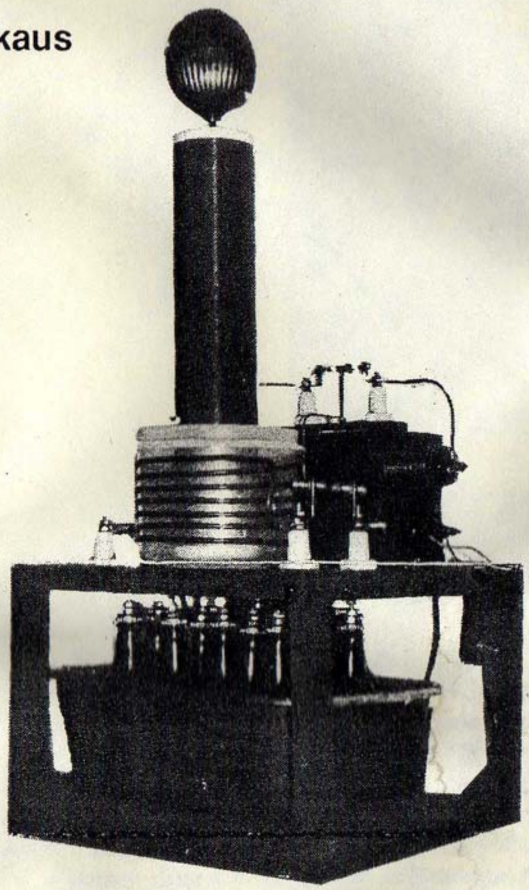
TESLA COIL

by George Trinkaus

Third Edition
Extensively Revised



Invented by Nikola Tesla back in 1891, the tesla coil can boost power from a wall socket or battery to millions of high frequency volts. In this booklet, the only systematic treatment of the tesla coil for the electrical nonexpert, you'll find a wealth of information on one of the best-kept secrets of electric technology, plus all the facts you need to build a tesla coil on any scale. And you can build one out of everyday stuff; the coil shown features a beer-bottle capacitor. A well-tuned coil's output is harmless but can perform amazing tasks. Light your home, farm, or ranch at a fraction of the usual cost. Disinfect water. Build a powerful radio transmitter. Learn about the souped-up tesla coil called the magnifying transmitter and how Tesla envisioned its use for wireless electric power and global communications...

Third Edition

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HIGH VOLTAGE PRESS

1. Tesla Free Energy

The tesla coil is a special transformer that takes power from a wall socket or battery and boosts it to a rapidly vibrating half million volts and up. This is not just a boost in voltage at the expense of amperage as in the conventional transformer. It is a real gain in power.

From the time we are children, we are told that you can't get something for nothing, that there is no such thing as a free lunch, as if these economic dicta were natural law. The tesla coil contradicts these precepts. It is the energy equivalent of the free lunch.

The huge electrical energy output of the tesla coil is most manifest in the spark streamers that flame out from its secondary terminal. This is a crackling display of electricity made visible, but the coil's inventor, Nikola Tesla (1856-1943), had many more practical uses in mind. The high-frequency output of even a table-top tesla coil can light up florescent tubes held several feet away without any wire connections. Tesla lit up his lab simply by hanging lighting tubes near an antenna-like wire energized by a tesla coil, and, conceivably, you could light up your home, farm, or ranch the same way. A coil could draw less than 100 watts but could light up a number of tubes. Tesla used a souped-up version called a magnifying transmitter to light up wirelessly 10,000 watts worth of bulbs 26 miles away. Adding lights or other "loads" on such a circuit presents no additional drain to the tesla coil any more than a radio broadcast is affected by the number of receivers tuned into it.

The Tesla coil has also been used for high-frequency electrotherapy, to generate x-rays, for high-voltage (Kirilian) photography, and in ozone generators designed to disinfect. Tesla is the inventor of the conventional AC power system, including the polyphase electric motor, and for this achievement he was as famous in his heyday as Thomas Edison. But instead of resting on his fame, Tesla went on to patent a whole new system of wireless electric power. Had Tesla's vision been fulfilled, fossil fuel and nuclear energy would be unnecessary, and the world would be powered by energy-magnifying systems using tesla coil principles. The driving energy he preferred for these was hydro-electric.

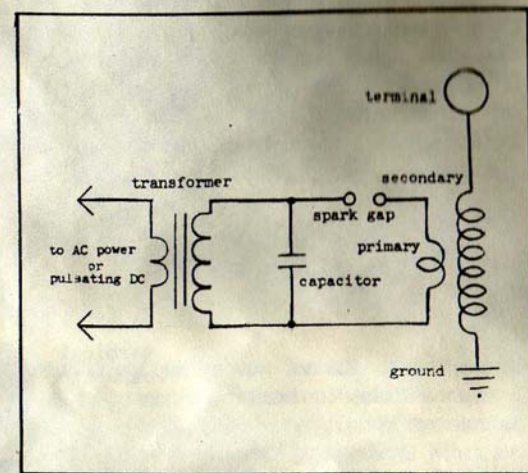
The tesla coil is also a powerful radio transmitter, and Tesla set out to build a worldwide broadcasting system. He nearly completed the construction of a spectacular 187-foot-high magnifying transmitter tower for global broadcasting on Long Island before his financier, who was none other than J. P. Morgan, pulled the plug. Tesla's career plummeted from there, and most of his inventions based on high-voltage, high-frequency tesla coil phenomena either disappeared altogether from official technology or were exploited in diluted form by others who claimed the fame. Among these were wireless power, radio transmitters and receivers (including multiplex systems), high frequency therapeutics, new systems of lighting and heating, and high-frequency electric trains and airplanes, to name a few. Documentation of some of these survive at least in patents, but upon Tesla's death his abundant lab notes and diaries were seized by the U.S. Government and only a small fraction have seen the light of publication. Still, with little encouragement from academic science or mainstream media, Tesla's ideas persist among the technologically curious, among experimenters, physicists, futurists, radio amateurs, and especially among the builders of the tesla coil.

Into this booklet I have collated information from Tesla's patents and his surviving notes, from the documented discoveries of tesla coil builders of the early decades of this century as well as of today, and from what I have learned from building tesla coils of my own. In this booklet there is not only a recipe for building a unit like one of my own – the one in the cover photo – but here you will also find the principles and rules of thumb by which a coil of any size can be constructed, from a table-top model delivering 150,000 volts to one capable of voltages in the millions. I also suggest the basics of that super tesla coil, the magnifying transmitter.

This material may make interesting reading whether you intend to build a coil or not, for it sheds light on electric phenomena rarely even hinted at in the conventional texts and even implies a radical departure from the dogma of official physics. By the same token, if you do build, bear in mind that some trial and error await you, for you are off the beaten path into the region of the experimental. Even the "recipe" tesla coil detailed in these pages leaves plenty of room for experimental development.

Not surprisingly, components specifically for tesla coils cannot be purchased off the shelf. You are definitely out of the realm of Radio Shack here. Still, you will be able to adapt most of the parts you need from stuff bought at mundane places like the hardware store, the auto parts store, and even at the supermarket.

2. How It Works



A tesla coil is simple. It has only five basic components. A conventional (iron core) transformer boosts line voltage to, say, 12,000 volts. This energy charges a high-voltage capacitor. A capacitor (also called a condenser) in its simplest form consists of two conductive plates separated by a layer of insulation. Electric charge builds in the capacitor: positive on one side, negative on the other. This charge builds to a potential that can break down the resistance of a segment of air at the spark gap. The capacitor's discharge of energy across the two electrodes of the spark gap is very sudden. Tesla wrote in one his patents for high-voltage capacitors that "the explosion of dynamite is only the breath of a consumptive compared with its discharge." Capacitors are common in modern circuitry, but the use of them as energy magnifiers on the scale Tesla did is a lost technology.

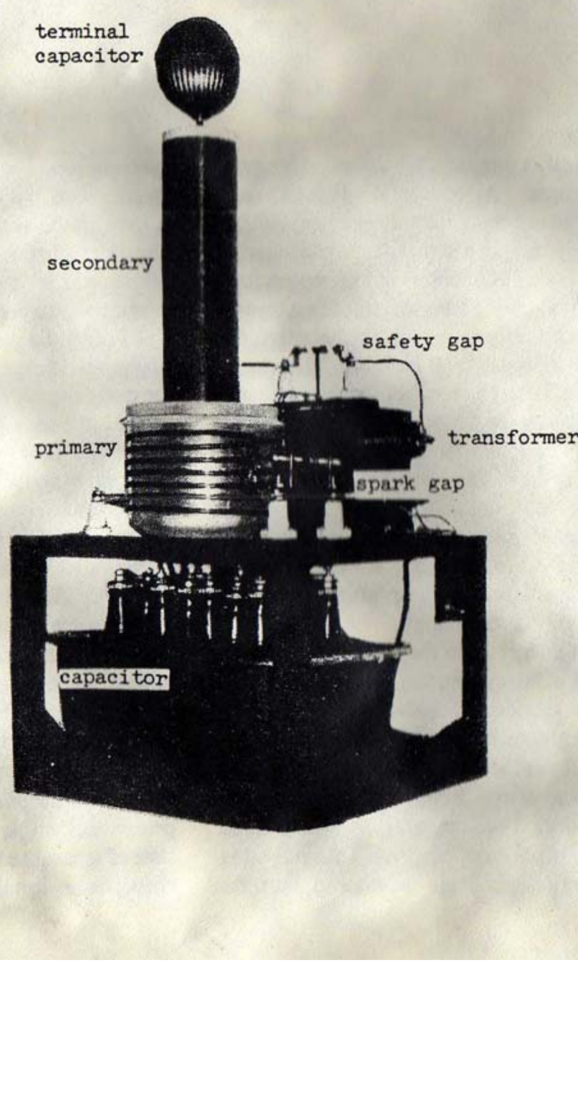
The burst of energy from the capacitor is vented into the few turns of heavy wire that is the primary coil. The setting of the spark gap – the air distance between electrodes – determines how rapidly these discharges take place. The closer the electrodes are to each other, the higher the frequency. Bouncing back and forth between capacitor and primary coil, then, is a rapid elastic interplay of electric energy. This pulsating energy of the primary circuit is induced into the secondary coil, which normally has up to 500 turns of slender wire, but may have more.

Now the secondary coil has its own particular electrical character. It favors a particular rate of vibration. Like a guitar string, the length of the wire in the coil plays a large part in determining that frequency.

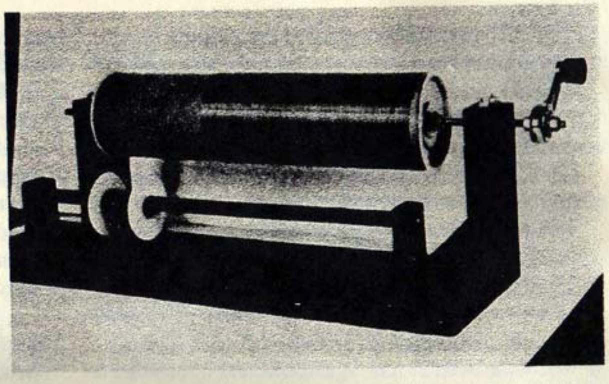
Forget the guitar string and think of a child on a playground swing. The length of the chain determines the rate that pendulum called a swing wants to go. The swing is the secondary. You, pushing the swing, are the primary. If your timing is wrong, the swing won't build momentum and will go awry. But if your timing is right, your pushes, coming at just the proper moment at the end of a cycle, will impart great momentum, and the swing will oscillate to great heights. You have achieved resonance. So it is with timing or tuning a tesla coil. The trick is to coax the primary into a state where the timing will be such that each time the rush between capacitor and coil takes place it will reinforce the oscillation of the secondary at just that right moment at the end of a cycle. In this resonant condition the oscillations can be made to swing up to tremendous values.

Ideally the primary is pulsing the secondary at that perfect moment in each and every cycle. In this ideal state of resonance the gain would be gigantic. But it is not necessary to pulse it at every cycle to get the gain any more than it would be necessary to push the swing at every cycle to get its amplitude to build. The primary can be oscillating at a fraction of the secondary's favored frequency, and, if the timing is right, you can still get the resonant gain. So you can have a relatively low frequency in the primary, and the secondary can be vibrating at its higher frequency. The tesla coil has been called a resonant transformer and it has also been called a high-frequency coil.

Resonance is the key to this phenomenal gain. Tesla said that there is "practically no limit to the power of an oscillator." This is the buried secret of Nikola Tesla. Through the magic of resonance, energy almost without limit is free for the asking.



3. How To Build It



The secondary coil is a good place to start. Its size will determine the scale of the whole project, and building it is one of the more patience-demanding tasks and best gotten done first. For the secondary coil form, you will need a length of plastic tubing or some other cylinder of insulating material. Before plastics, cardboard tubing was often used. This has to be dried slowly in an oven and sealed with several coats of shellac or varnish. Because of its easy availability in building-supply and hardware store, many tesla coil builders use PVC (polyvinylchloride) tubing for coil forms, and PVC does work, particularly the thin-walled variety. Superior insulating (dielectric) qualities are to be found, though, in acrylic (the thinner the better), in phenolic tubing, and in the so-called airwound coils. "Airwound" means the wire is held only by slender insulating supports. Airwound is regarded as dielectrically superior. The less form, the better.

Most home-built coils use long narrow secondaries because of the availability of small diameter tubing, but Tesla's patents show wide drum-like secondaries with length-to-width ratios on the order of 2 to 1.

You will wind something under 500 turns typically. Use a number 28 up to number 24 solid, insulated wire: enamel-insulated magnet wire or plastic-insulated. You can wind a secondary of an arbitrary number under 500 turns, or calculate more precisely if you want a particular frequency. You can ball-park the frequency that the secondary will favor by using Tesla's quarter-wave formula. It says that the length of the secondary wound up should be one quarter of the wavelength, or an odd multiple of that number. Decide upon your frequency in megahertz (Mhz), and divide this into 246. This will give you the quarter wavelength in feet. Find an odd number or fraction you can multiply this answer by that will give you a length of wire that will wind on your form to something under 500 turns. This will be the length of your secondary winding. This exercise is simplistic since something called capacitive reactance of the coil comes into play, the antenna is involved, and the coil will also want to vibrate at various multiples (harmonics) of its fundamental frequency, but it's an exercise that will at least give you something to go by.

You can now calculate the length of the tubing you'll need. Wind an inch's worth of wire on the tube. Count the turns, and you have the number of turns per inch. You can figure it out from there. Allow for an extra half inch of tubing on either side of the winding.

With mathematical procedures, you can design a tesla coil for specific primary and secondary frequencies, for voltage input, and for harmonious scaling of components. In practice, most of us build with the components we can easily get a hold of, some rules of thumb, and trial and error. If you want a mathematical view, see source cited on page 23.

To wind the coil, drill a hole in the tube a half inch from the bottom, tape the wire to the inside, pass it through, and proceed to wind. I know of no advantage to winding clockwise as opposed to counterclockwise, but there may be one. Many builders contrive some sort of jig to wind the coil on. It is possible, though, to wind the coil hand-held, but it helps to have a friend hold the spool and dispense the wire as needed. The trick in any method is to keep the wire under constant tension with thumb pressure as it is being wound on the form.

I built the winding jig shown in the photo using 3/8-inch steel all-thread as the winding shaft and 5/8-inch wooden dowel as the wire-feed shaft. The handle is a VW window crank.

Some builders turn a groove on the coil form with a lathe so there is extra space between turns, thus assuring minimal bleed-over and capacitive effects between turns. An easier turn-spacing technique is to wind monofiliment fishing line alongside the wire. Some builders put extra space between the turns just at the high-potential top end of the coil for the last 10 to 15 percent of the winding.

Drill another hole at the end of the winding and fasten the wire inside the form temporarily with a piece of tape. Spray the completed coil with several coats of some plastic spray coating. This helps keep the turns in place, protects the winding, and further insulates it. A number of light coats helps to eliminate the possibility of air pockets in the coil. These could cause operating problems, to the extent that Tesla often resorted to winding his coils under oil.

recipe secondary coil

Here are the specs for the secondary on my tesla coil shown in the photo: Coil form is PVC with a 3-1/2 inch outside diameter and 18 inches long. The winding on 17 inches of the form is 437 feet of #28 solid, plastic-insulated wire, 477 turns.

the primary coil

The primary coil is just a half dozen or so turns (rarely more than ten) of some very heavy conductor. Standards here are loose. Almost anything seems to work. I've seen primaries that were just bundles of insulated wire coiled at the foot of the secondary. A single turn works in some cases. Experiment for best results. Design will determine the electrical coupling of primary to secondary, an important factor. Some builders use bare wire or make elegant coils out of copper tubing. Either solid or stranded conductors can be used. Whatever you use, it should be highly conductive, offering negligible resistance to the pulsating current. Wind the primary in the same direction as the secondary.

Tesla preferred copper ribbon, and since I came across some heavy enamel-insulated ribbon at an electronics surplus store, I tried it out. It looked impressive, but was very difficult to shape, and in an early trial some hot electric bolts shot up out of the thing, sliced through the plastic of the coil form, and pierced the insulation on the secondary. This convinced me to go to a well-insulated primary conductor rather than enameled or bare. I recommend a plastic-insulated wire, stranded so it's easily worked, #8 or larger from the hardware store, or even thick #4 battery cable from the auto store.

Some experimenters have used flat spirals and even cone shapes that open upward, but most primaries are cylindrical. The coil form, if you use one, should be at least twice the diameter of the secondary. This raises a problem, since you can't easily find PVC or other insulating tubes in short lengths in these large diameters. Look around for any cylindrical something that meets your requirements. It is ideal to experiment with different diameters. I found my form on the housewares shelves at the supermarket (see below). Some builders with carpentry skills construct special structures of upright dowels for airwound primaries. If your solution is in wood, use a well-dried, well-sealed hardwood.

One old rule of thumb says the primary and the secondary should have equal weights of copper.

The primary can have a role in fine-tuning the tesla coil. Turns can be added or removed. Many primaries have a moveable tap in the form of a clip on the wire from the capacitor that can be moved from turn to turn. Small sections of insulation can be removed from the winding to accommodate the clip. These sections should be removed in a stepping pattern so they are not opposite one another at adjacent turns. Some tesla coils have a secondary that can be moved up and down in respect to the primary. Both these methods tune by changing the "coupling" of the coils. A well-proportioned primary should have a height (vertical distance from the first turn to the last) that measures about one-half the primary's diameter.

recipe primary coil

My supermarket coil form is a Rubbermaid "Servin' Saver" 10 cup cylinder ($2.89), diameter 7 inches, height 5-3/4 inches. The top is cut open for the secondary to pass through or it is discarded. Onto my coil form are wound six turns of #8 plastic-insulated stranded wire. I have not seen a need for a movable tap as of this writing, but this may change.

the transformer

The transformer is one component that you will have to shop around for. Needed is one that can deliver something between 6,000 and 15,000 volts, at 30 to 60 MA. Don't despair; these transformers are everywhere, although you may not be aware of them. Neon signs (a Tesla invention) are driven by them. Oil furnaces are ignited by them. The neon is superior to the oil-furnace-ignition transformer, being made for continuous operation. Neon sign transformers put out 3,000 to 15,000 volts, 30 or 60 milliamps, with power ratings up to 1800 VA, builders preferring the upper range. Oil furnace ignition transformers usually run around 10,000 volts. If you have a problem finding any of these new at neon sign or oil furnace dealers, used at surplus electronics outlets or junk stores, or at wrecking or metals recycling yards (the best bargains), write to a manufacturer: France, 726 Fairview Blvd. West, Fairview, TN 37062 or Allanson, 26 Buffalo Ave., Freeport, L.I., NY 11520.

Neon transformers are packed in an insulating, weather-proofing tar and often fail because carbon tracks can form in this tar and cause a short. Manufacturers offer a "core and coil" version without the tar or case, but only up to 7500 volts. I know one builder who melts out this tar with potent solvents, but this is an unappealing job.

Transformers can be ganged up in parallel to power big tesla coils. I've heard of as many as eight hooked together to deliver two kilowatts.

Some builders wind their own transformers. Specs can be found in electrical texts.

Transformer outputs can be rectified. This serves up d.c. for the capacitor to oscillate with, removing the influence of the transformer's 60-cycle vibration. One good rectifier is the ECG-513 diode. These $10, 3-3/4-inch heavy duty diodes are rated 45 thousand volts and can be scrounged from some Quasar TV models. Note the d.c. is a particular shock hazard at these voltages. Also, I would hesitate to apply d.c. to a salt-water capacitor since electrolysis might occur, so there would be off-gassing of explosive hydrogen.

battery systems

A battery powered tesla coil can have great practical value. In remote areas where there is no electrical service, batteries can be charged by solar-electric or wind power and used to drive a tesla-coil powered high-frequency lighting system.

A simple but somewhat expensive method is to power an a.c. neon-transformer tesla coil with a power inverter. That's the transistor device used in luxury RV's and boats to convert battery d.c. into 120-volt, 60-cycle a.c. to run household appliances.

Tesla coils designed specifically for 12-volt battery power can use the automobile ignition coil as a transformer. Of course, the d.c. must be made to pulsate to drive an ignition coil. That is, you need something to do the job ignition points do in a car. An electro-mechanical vibrator can be specially built. Solid-state circuits can do the job, and by using integrated circuits (555 Timers, pulse-width modulators) it is possible to control primary frequency and wave shape, a real luxury.

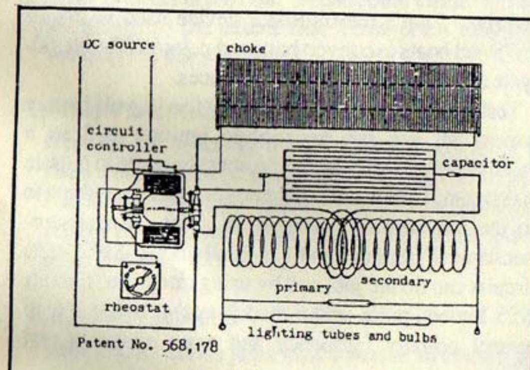
Old-time builders of battery coils used laboratory induction coils or the then-handy Ford spark coil. These had built-in adjustible vibrators. A few of these are still around. You'll need one that gives a 3/4 to 1 inch spark.

Battery tesla coils can be made from color-TV flyback transformers. Using only two transistors and two resistors, a flyback transformer becomes a little tesla coil in itself or the power supply for a small conventional tesla coil. These little ignition-coil and flyback tesla coils are great for experimenters who want to work with equipment less intimidating than the average neon project coil.

For much more on battery systems, lighting systems, and d.c. experimenter coils, get on our mailing list so you will be notified when we publish a putative title called "Son of Tesla Coil."

chokes

One of Tesla's patents shows a tesla coil that runs on d.c. by means of a choke. A choke is a coil that uses electromagnetic effects to influence a circuit. Tesla's circuit here has no transformer. Instead the d.c. source charges a large choke. When the d.c. is switched off, the choke's magnetic field collapses, releasing suddenly a current much higher in potential than that from any battery. This is conducted to the capacitor. A motor-driven rotary switch links d.c. source to choke, choke to capacitor, and capacitor to primary at just the right instants.



choke-driven tesla coil

In a.c. coils chokes are also useful. Chokes oppose surges and can help reduce the problem of 60-cycle waves disturbing the rhythm of the primary circuit. Even small chokes placed in line with the transformer outputs will help protect the transformer from kickback surges.

safety gap

One of the big bummers plaguing tesla coil experimenters is the accidental burning out of transformers. This is caused by high energy kick-back from the capacitor which fatally overloads the transformer secondary or burns carbon tracks. This can be easily prevented by means of a safety gap like the one sitting on top of the transformer in the photo on the cover. A safety gap is constructed like the main spark gap but has a center electrode which conducts overloads safely to a good earth ground. The safety gap should be adjusted to fire intermittently. With a safety gap and a pair of chokes, you can experiment freely with your coil and run it for long periods with peace of mind.

recipe transformer

The recipe transformer is an Allanson 12,000-volt neon sign transformer I happened upon in a junk store. Price: $20.00. The choking coils have 16 turns of number 10 insulated wire on 3/4 inch PVC. The safety gap is made from two brass angle brackets and three brass bolts, a piece of scrap brass strap and beautiful (although not absolutely necessary) porcelain stand-off insulators, which as you can see, adorn my tesla coil elsewhere and which I lucked out on at an electronics surplus store. The safety gap could just as well have been built with three brass angle brackets mounted on a slab of plastic or wood. If you want them, you can make your own stand-off insulators out of small glass or plastic bottles. Run a brass bolt up through the cap for a terminal. If it's a glass bottle, glue it to the chassis. If plastic, drill the bottom and put it on with a brass wood screw.

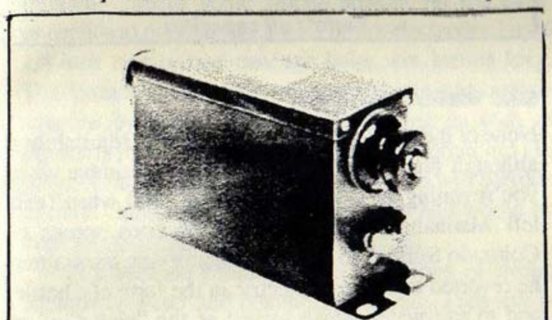
the capacitor

The capacitor is one component that many builders choose to buy these days, but commercial capacitors that can meet the tesla coil's high voltage requirements are difficult to find and expensive when you do find them, which makes building your own attractive. If you do buy, look for capacitors that alone or in combination give you capacities in these ranges: Small tabletop coils (on the order of my recipe coil and smaller), .001 to .01 microfarads (mfd.). Medium-sized coils, .02 to .03 mfd. Large coils, .05 and up.

Capacity can be built up by connecting capacitors in parallel. So wired, capacities are additive:

$$C = C1 + C2 + C3, \text{etc.}$$

It's difficult to find capacitors with a voltage-handling rating that is suitable for a tesla coil. You must have a capacitor that will handle at least the output of



neon sign transformer

your transformer. If you have a 12,000-volt transformer, you will have to find a capacitor rated 24,000 volts d.c., for the capacitor must have twice the d.c. rating for a.c. usage.

Since capacitors rated this high are almost impossible to find, you will have to gang them up in series. But capacitors in series have a decreasing effect on total capacity:

$$1/C = 1/C1 + 1/C2 + 1/C3, \text{etc.},$$

so you have to use high capacities to adjust for this loss. The best commercial types for this high-voltage, high-frequency work are pulse-discharge capacitors having polypropylene or polyethylene dielectrics, also mica transmitter capacitors, and ceramic. Look for these in surplus electronics stores, and good luck.

The traditional home-built capacitor is made of sheets of metal foil interleaved with sheets of glass. The glass here is the "dielectric". The material used for the dielectric is critical to its operation. Some are far more effective than others. The effectiveness of a particular material used for a dielectric determines how large a capacitor must be to achieve a certain capacity. Effectiveness is expressed in a material's dielectric constant. Air, which breaks down pretty easily, serves as the standard and has a dielectric constant of 1. Transformer oil is 2.2, castor oil is 4.7, formica is 4.8, mica is 6, glass is 7.8 and tantalum is a whopping 140. Polyethylene (2.2) is available in sheets, is lighter and easier to cut than glass, and will withstand high voltages (1/32 inch holds up to 45 KV.) Author Brent Turner (see page 23) says polyethelene makes the home-built glass capacitor obsolete.

The higher the dielectric constant, the closer the plates can be to one another, and the closer the plates, the smaller the plate areas needed to achieve a certain capacity. It's all in this formula which is good to have around if you're designing your own capacitor:

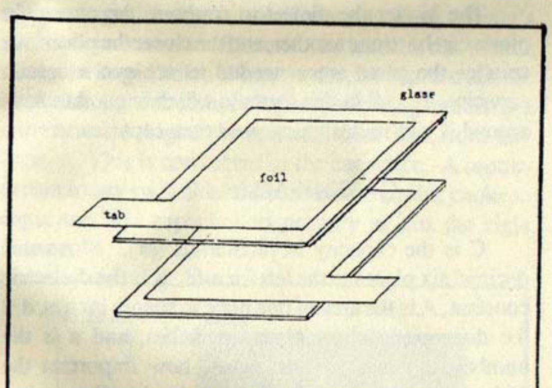
$$C = .224K\ A/d\ (n - 1).$$

C is the capacity in picofarads (pf). Move this decimal six places to the left for mfd. K is the dielectric constant, A is the area of one plate in square inches, d is the distance between plates in inches, and n is the number of plates. You can see how important the dielectric constant K is in this formula. An oil capacitor of ten 8x8 plates, 1/4-inch apart will give you 1135 pf or about .001 mfd., while glass would give you 4025 pf., or about .004 mfd., an increase by a factor of nearly four.

A capacitor with an oil dielectric would be awkwardly large and heavy, but effective and indestructible. Glass capacitors, though more effective ounce for ounce, can be broken through electrical as well as mechanical stresses.

glass and foil capacitor

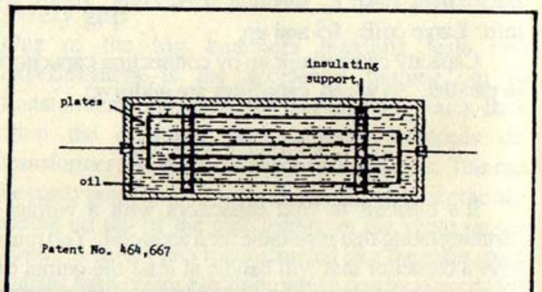
To make a glass-and-foil capacitor, cut out rectangular sheets of aluminum foil, making them about two inches smaller in length and width than the glass plates. On one corner of the foil sheets leave a tab about 3 inches long and an inch or so wide. Spread a varnish on the glass and, while it is still wet, lay foil, leaving an inch margin of glass all around. Roll the foil flat with a dowel or something, rolling from the center to remove all the air. Arrange the tabs left-right, left-right, the idea being that tabs of alternate layers can be connected together. Smear some mineral oil on the 1-inch margins left between foil edge and glass edge for added insulation. Bind the layers together with some insulated cord or ribbon. Attach a heavy wire to each set of tabs. Then drop the whole assembly into a plastic or wooden box filled with mineral oil. This will insure insulation. A polyethylene capacitor can be constructed on similar principles.



glass-and-foil capacitor construction

oil capacitor

To make an oil capacitor I refer you to Tesla's 1891 patent for same. I have not built one of these, though it is on my agenda, nor have I seen any among the many tesla coil plans I've studied. Tesla's patent says he has found solid dielectrics like glass and mica to be "inferior" for his demanding uses, and that "highly efficient and reliable" capacitors can be made using oil as the dielectric. Size and weight didn't worry him, nor should they necessarily worry you. The plates in Tesla's oil capacitor can be of rigid metal – aluminum sheet or plate will do – and they are held in position by "strips of porous insulating material."



Tesla's oil capacitor

salt water capacitor

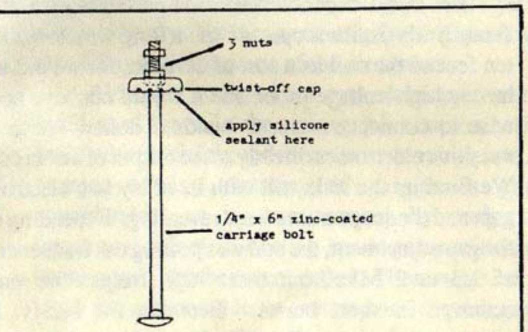
None of the above capacitors offer much adjustability, although this is a feature that is very desirable when you're tuning the completed coil. In 1900, when Tesla left Manhattan to go to the wide-open spaces of Colorado Springs to build his magnifying transmitter, he reverted to a glass dielectric in the form of a bottle, and to salt-water which served as the "plates" of an adjustible electrolytic capacitor. Into a big galvanized tub of salt-water, he set a bunch of big mineral water bottles which themselves contained salt-water. Salt-water is a conductive medium, an electrolyte. (Tesla had earlier patented a couple of electrolytic capacitors.) The salt-water in the bottles constituted one set of "plates", the salt-water in the tub the other set. The bottle glass was the dielectric. A connection was made to the tub, and each bottle had an electrode through its opening with a terminal on it. By connecting bottles in and out of this parallel circuit, Tesla could vary the total capacity by known increments.

recipe: beer-bottle capacitor

Taking a cue from Tesla, I constructed a salt-water capacitor on a smaller scale. Galvanized tubs being rare, I bought at the supermarket a plastic dishpan and lined it with aluminum foil. The dishpan is from our friends at Rubbermaid and measures 11-1/2x13-1/2 x 5-1/4 inches. It costs $3.39. A 1/4 x 1-inch brass bolt through a hole already in the dishpan's lip serves as a terminal for the foil. Into the dishpan fit nicely sixteen empty Henry Weinhard Ale bottles; any bottles used should have the long-neck design. Quality of the glass for electrical purposes may vary significantly from brand to brand, and I make no special claims for what I used. Tesla had his mineral water bottles sent from New York because he believed a particular brand's glass superior. Today, Pyrex would be ideal.

Remove the labels. Punch (do not try to drill) 1/4-inch holes in the screw-on caps for the electrodes to go through. Smear some silicon sealant on the caps' underside to prevent leakage. For the electrodes I used 1/4-inch *zinc-coated* carriage bolts, six inches long. The threaded end goes up through the cap and is attached by nuts on both sides, leaving an inch of threading for the terminal, which takes another nut (16 bolts, 48 nuts.) Even the zinc-coated bolts will corrode in time. Stainless steel would be better and would be available from marine hardware sources.

In a suitable container, mix 3 gallons of strong solution of water and common table salt. (Sea salt is somewhat more conductive if you have enough around.) Fill each bottle to a depth of 4-3/4 inches. You now top off the bottles with an insulating layer of mineral oil.



electrode for beer-bottle capacitor

Screw the caps with terminals back onto the beer bottles. Fill the dishpan with saltwater to within about 1/4-inch of the top.

Use some heavy conductor to interconnect the bottle terminals. Short pieces of stout (#10 to #6) wire with lugs crimped on the ends would be practical. I made links by pounding flat some 1/4-inch copper tubing that was handy and punching out holes to fit over the terminals.

Assuming a K of 7 for the beer bottle glass, each bottle is worth about .0005 mfd. The 16 together give about .008 mfd. This turns out to be much more than necessary for the recipe coil, which never needed more than 6 to 10 bottles. The 16-beer-bottle capacitor has plenty of reserve for use with future larger coils, but you may want to scale down to a more compact capacitor on the same principles. I have my eye on those 10-ounce Kikkoman soy sauce bottles. They have these perfect little plastic screw-on caps and pouring inserts that are asking for electrodes. But that's down the line a way...

recipe: other capacitors

I've built a glass -and-foil capacitor that consists of 15 sheets of 1/8-inch window glass 6-1/4 x 6-1/4. The foil "plates" are just 4-1/4 x 4-1/4. Connection tabs are arranged so that I have three wires coming out of the capacitor from each side, and these can be connected so that six different capacities can be tapped, from .00075 up to .0025 mfd. Tabs are wired with mini alligator clips. The whole elaborate thing, tied together with nylon cord, sits in yet another Rubbermaid Serv'n'Saver container (9 x 9 x 3-1/2) filled with mineral oil. This capacitor is installed in the bipolar coil shown on page 19. Besides being overly elaborate for most needs, this capacitor's plates are unusually small and numerous. You will have an easier task if the plates are fewer and larger.

For the oil capacitor I will suggest mineral oil for the dielectric because of its availability and cheapness. Castor oil has well known dielectric properties and an impressive K of 4.7, but is a quite expensive pharmaceutical item, especially considering the quantity needed here is 7 or 8 quarts. Mineral oil has a K of 2.2. With such a low K value the oil capacitor, of course, becomes considerably more bulky than glass, especially since plates will be separated by three times the distance, but such a capacitor should be worthwhile anyway because of its ability to survive any electrical stress.

Required are 24 plates, 9-1/2 x 11-1/2 inches. These could be cut from aluminum sheet from the hardware store, but aluminum or copper plate would be better. Separate the plates by 3/8 inch, using strips of some porous material. This lamination and its mineral-oil bath could fit into the same Rubbermaid dishpan used to contain the beer-bottle capacitor.

capacitor problems and hazards

Even if you are using commercial capacitors, be aware that they are being stressed under high voltages and at high frequencies and may fail or become dangerous, whatever the voltage ratings. Dielectrics heat under high frequencies. (There is an industrial heating process called high-frequency dielectric heating.) Watch all capacitors for excessive heat. An oil capacitor may be unstable in frequency because of convection currents in the oil due to dielectric heating.

Homemade capacitors should be closely observed for internal flashing. It's advisable to have see-through containers. Mineral oil can ignite and burn. Look for flashing in the immersed glass-and-foil capacitor and in the beer bottles, and shut down if you see it. The problem may be a bad connection or bubbles that need to be worked out of the oil.

One type of transmitting capacitor is in a glass cylinder containing an insulative oil having PCB's. Take care.

Tesla reported "exploding" bottles in his salt-water capacitors. I have not experienced this in mine, but take precautions, especially if you stress the capacitor with exceptionally high voltages.

High-voltage capacitors can hold their charge for long periods even after the device is turned off and thus present a shock hazard. Short them out and you'll see a spark. Discharge a tesla coil's capacitor by shorting out the spark gap. I use a screwdriver tip while holding the insulated handle. I see the telling spark with my commercial capacitors but not with my comparatively leaky homemade.

spark gap

The simple gap in its elementary two-electrode form will give you a tesla coil that works, but any improvement you can make in this component will result in a boost in output and a stabilizing of frequency. The spark gap is really a type of semi-conductor. Ideally, it conducts suddenly and returns to nonconductivity immediately, so the capacitor can charge right up again for the next firing. But what happens is that air between the discharging electrodes becomes heated and offers a comparatively low resistance path for the current. This results in an arc being formed which prevents the capacitor from properly recharging. To upgrade performance you must quench that arc. Tesla gave a huge amount of attention to perfecting the spark gap, which he regarded as a necessary evil.

A friend, Jim Campos, who is an electronics inventor, took an interest in the tesla coil project and invited me to set up my coil in garage space next to his lab.

Jim and I experimented with perfecting the gap. From Jim's oscilloscope, we ran a long wire to within ten feet of the coil as a sort of antenna, for we did not have a high-voltage probe and it would not have been wise to connect seventeen hundred dollars worth of sensitive electronics directly to the output of a tesla coil. We fired up the tesla coil with its noisy two-electrode gap, and the scope traces were revealing. Depending on the gap adjustment, the coil was putting out frequencies of 1/2 to 2 Mhz., but these high frequencies only occurred in short bursts. Between the bursts the vibration dropped to zilch. The bursts themselves came at a rate as low as 2,000 per second. I had been getting shocks off the output, which I should not have, and this explained why. The high frequencies (above 2 or 3,000 cycles) won't register on the nervous system, but the low-frequency "envelope" packed a wallop. The problem, we surmised, was the gap, and indeed each little improvement we made there stabilized the frequency, increased the output, diminished the shock problem, and reduced the noise. The primary circuit, fouled by an arcing gap, was not pulsing the secondary in a rhythmic resonant fashion. It didn't swing. Imagine its performance with better quenching of the gap.

There are several ways to quench the gap. Any provision that takes away the heat of the gap, like cooling fins, helps to quench. Tesla found that directing a stream of compressed air into the gap blows out heated gasses and helps to quench. Tesla also employed a magnetic "blow out" using a magnetic field to quench the arc. Magnets flank the gap, putting a North-South field across it. The magnets are stationed close to the gap and are shielded from it with little sheets of mica.

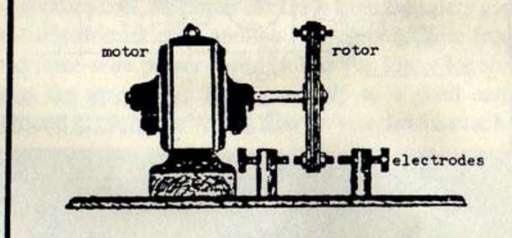
series gap

Breaking down the single gap by inserting a series of in-line pairs of electrodes helps to quench. A good series gap can be improvised from spark plugs. An evolved form of this is an air-tight gap which has a number of sealed sparking chambers insulated from each other with gaskets made of some heat-resistant material, the whole lamination being tightly clamped together. Cooling fins can be built into such a gap. These gaps run almost silently. Tesla experimented with gaps in which thin films took the place of the air spaces.

Although rotary gaps are often preferred by builders of big coils, the series gap is simpler, easier to build with precision, and there are no moving parts. The current-carrying capacity of the series gap is considerable, as is demonstrated by early high-frequency induction-heating spark-gap oscillators or "converters," as they were called. These were rated up to 15 kw and could have as many as 30 spark gaps in series, gaps consisting of one-inch tungsten disks, water-cooled. The spark-gap converter of induction heating is a simple circuit that resembles the primary circuit of a tesla coil. These were replaced by vacuum-tube oscillators, which resemble tube-type tesla coils. Get a hold of either type and you could drive a tesla coil to the moon.

rotary gap

The rotary gap has spinning electrodes that break the circuit before arcing can take place. Tesla patented a number of sophisticated rotary gaps, including rotors immersed in flowing oil, rotors that dip into pools of mercury, and even mercury jets, but a good rotary gap can consist of brass studs on a plastic disk that is spun between two adjustable electrodes (like those used in



rotary gap

the simple gap) by a small electric motor. Use a sturdy disk at least 1/4-inch thick and about six inches in diameter. On the perimeter mount 20 studs cut from brass all-thread, the thicker the better, and held on with brass nuts. A tougher metal than brass would be superior. I have heard of carbide electrodes being used in such a gap.

A ready-made rotary gap may exist in the auto distributor, which is pure Tesla, but to my knowledge has not been exploited by builders.

The speed of the motor driving a rotary gap can be varied. This gives greater control over the rhythm of the primary circuit. An auto transformer is ideal to control an a.c. motor, but you can achieve some control on the cheap with a light-dimmer unit.

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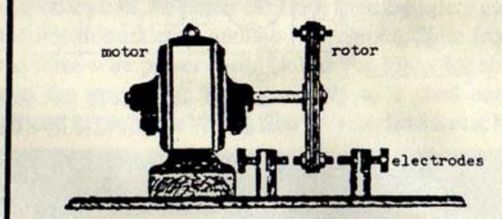

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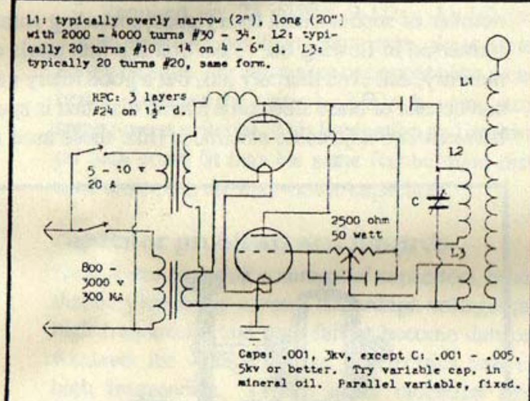
tube-type coils

The tesla coil has evolved little since Tesla's time, but, not surprisingly, one significant development eliminates the problematic spark gap altogether. This development is the vacuum-tube tesla coil, which uses a conventional oscillator circuit to pulse the primary coil. I have never seen one of these in action, but they



typical tube-type tesla coil

must deliver smooth-running performance compared to the spark-gap type. They would also seem to be far more adaptable to modulation for voice radio transmission.

In fact, the tubes these tesla coils use are radio transmitter tubes, big triodes. To get sufficient power for larger coils, two or more are ganged in parallel.

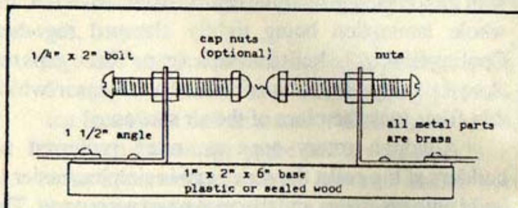
To run these tubes, you need a step-up transformer to supply a potential to the tubes' plates of 800 to 3000 volts, and you need a filiment supply of 5 or 10 volts. Some of the tubes I've seen specified in various projects: 10Y, 100TH, 211, 304TL, 304TH, 801A, 807, 810, 811A, 826, 833A, VT-4C, and 3-500Z. One source: 807's are sold by mail from Antique Electronic Supply, 688 W. 1st St., Tempe, AZ 85281. Price: a reasonable $7. A reader told me he got an 811A on special order through Radio Shack for $22. An old tube manual in the library will give the voltage info, but remember that you can drive the plate about 30% over the rated voltage. Look for transformers in electronics surplus stores. The value of the capacitor in the plate circuit is varied in the tuning process.

If the spark gap can be defeated by the vacuum tube, can it also be defeated with solid state? The answer is, yes. MOSFETs are available that can handle enough power to drive small demonstration coils or to help tune larger coils at low power. Heavy heat sinking is required for these high current levels.

recipe spark gaps

Parts for the recipe simple gap shown are available at any hardware store.

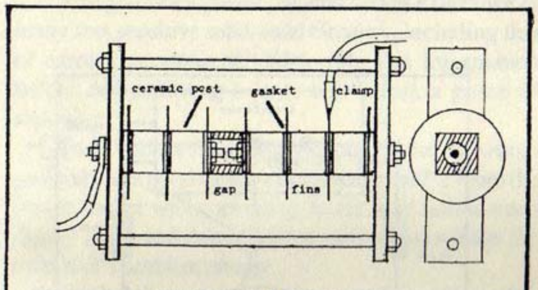
I have experimented with an airtight series gap. The electrodes are 1-inch segments of 8/32 brass all-thread fitted with brass cap nuts. These don't hold up very well and have to be burnished after every 15 to 30 minutes of use depending on the energy levels handled. The ceramic post is an item of kiln "furniture" suggested by a potter. It's called a one-inch post and has a hole through it that can accomodate the electrodes. These posts are used to prop up pots in kilns, and you can get them at a ceramics supply store for under a dollar. The



recipe simple gap

gaskets are cut from another ceramics item, a refractory called A-970 paper. This gap runs silently and ozone-free, and it's quenching effect is visible in increased output.

Though a spark-plug series gap does not run silently or ozone-free, it is my present gap of choice for all-around simplicity, availability of parts, and durability. Use nonresistor plugs. I use the narrow AC 44TS. These require a hole of 13 mm (.5118 inch), and you can



experimental series gap

force-thread them into the plastic block. Since special drills are needed for plastics, I had the plastics supply shop drill eight 1/2-inch holes and widened them out myself with grinder and file. Acrylic will do for the block, but I used polycarbonate because it can take 90° more of heat. You can gap the plugs precisely with a feeler gauge. They will need to be regapped and cleaned periodically.

the terminal capacitor

The terminal capacitor is that ball or whatever that sits on top of tesla coil secondaries. Metallic and usually hollow, the terminal capacitor is a sort of antenna that draws up and radiates the energy of the secondary coil. In fact, if the tesla coil is to be used as a transmitter, the terminal capacitor is the antenna, only in this case it is set high above the ground as an "aerial capacity," as Tesla called it. On his Colorado Springs magnifying transmitter, Tesla used a 30-inch ball made of copper foil over a wooden form. It was coated with an insulating layer of rubber. The capacity of the terminal is a factor in performance and should be experimented with. A rule of thumb is that the terminal's diameter should be as large, if not larger, than the diameter of the secondary coil. Used for terminals are: hollow brass door knobs, polished world globes, pairs of stainless steel salad bowls, and I've read of one experimenter who made a toroid (donut-shaped) terminal by connecting together four chimney pipe elbows.

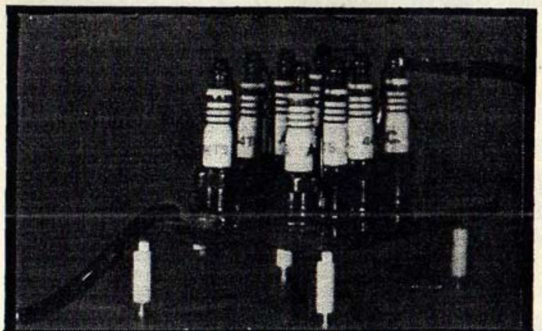
recipe terminal

Yes, what you see on top of the recipe coil is a copper toilet float. Highly recommended. A 1/4 x 2-inch brass machine screw fits into it nicely and will hold it on to what you use to plug the top end of the secondary. I used a plastic item from the hardware store's plumbing shelves called a 3-inch plastic ABS test cap.

the recipe circuit

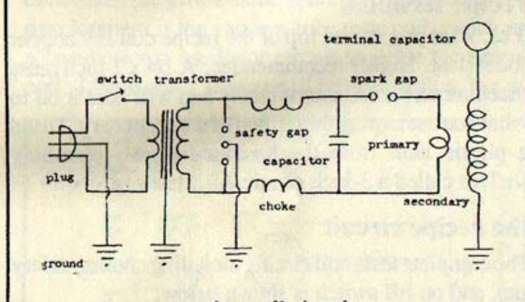
The complete tesla coil circuit, including chokes, safety gap, and on-off switch is shown below.

The following should be connected to a hefty ground terminal on the chassis: the bottom lead from the secondary coil, the center electrode from the safety gap, the transformer case, and the green ground wire from the three-wire power cord. Unless you know for sure that the green wire leads promptly to a good earth ground in the house wiring system, you should attach a



spark-plug series gap

heavy conductor to this terminal and run it to a cold water pipe or to a conductive rod sunk three or more feet into the earth. Soak the earth around the pipe or rod with water to promote better grounding. Good grounding is important for safety, transformer protection, suppression of TV and radio interference, and performance. Tesla's ground at Colorado Springs consisted of a 20 x 20-inch copper plate sunk twelve feet into the earth. Over the top of the plate he spread a layer of coke. He ran water over the spot continuously. Any body of water makes a good ground.



recipe coil circuit

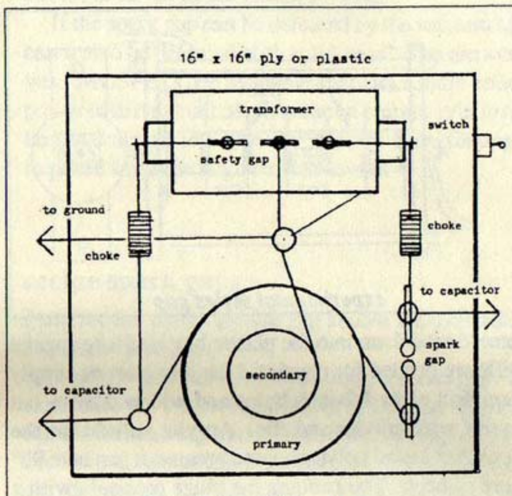
construction notes

For a structure on which to mount the components, use plastic sheet or plywood, dried and sealed. You can simply mount all parts on a single level, breadboard-style, or build a two-level chassis as I did for the recipe coil. Keep all wire connections as short as possible but keep the components separated enough to prevent arcing. For a good hook-up wire try neon cable; it's rated 15kv.

The two-level recipe chassis is constructed of 1/4-inch plywood on a frame of 1 by 2's. I put a sheet of plastic on the underside of the top level to ensure insulation between capacitor bottle terminals and components on top, but this may not be necessary, particularly if there is sufficient vertical clearance.

The transformer is mounted with heavy (5/8-inch) bolts, the rear set of bolts passing through the frame. Under the secondary coil, I glued on a piece of 3/4-inch board to provide a good foundation for coil mounting. The coils are attached by means of a turning (courtesy of Edwin Ellis) that fits snugly into the bottom of the secondary form and pegs through holes drilled in the bottom of the Serve 'n Saver into the chassis. You can make do with any wooden or plastic thing that can be jammed into the bottom of the secondary form so it can be attached. If you use wood screws or bolts, make them brass.

It is a good idea to mount hefty rubber feet under the chassis.



recipe coil layout

hazards

The entire primary circuit is a shock hazard and should not be touched while in operation. To safely adjust the spark gap while running, Jim contrived a 15-inch long handle of narrow plastic tubing with a screwdriver head imbedded in one end. A good practice honored by electricians at work around hot circuits is to keep one hand in a pocket at all times.

The secondary terminal should put out harmless high frequencies but may carry a low-frequency component that could shock. When well tuned, you can hold a piece of metal in your hand while streamers play off of it, and streamers can arc painlessly to the bare skin. However, limit skin exposures to brief periods and don't stick your head near the terminals because your eyes could be injured by streamers.

That faint chlorine odor around a sparking coil is ozone, the main toxic ingredient in smog. Run the coil in a well-ventilated area.

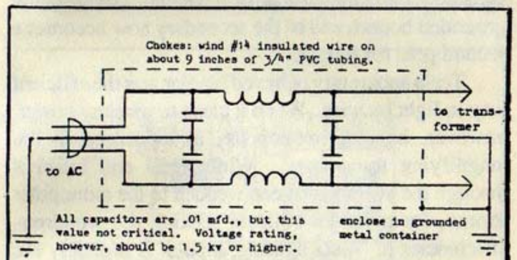
The spark gaps can give off strong ultra-violet light; avoid sustained exposure to eyes and contrive a plexiglass cover for the gaps if possible.

Energy from a potent coil can dud at a distance of many feet sensitive solid-state circuitry, including that of cardiac pacemakers. Announce this information before demonstrating a large coil before a group of strangers.

Tesla coils are unfriendly to computers. It would probably be a good idea to disconnect your PC from the power socket while operating an a.c. coil and to keep floppy disks and other memory units away from the tesla coil's ambient energy.

Discharge capacitors before touching. See *other capacitor hazards*, page 12.

You may put a neighbor in a hazardous mood because of TV or radio interference. Most interference goes out over the power lines and can be prevented by putting a heavy-duty line filter between the wall plug and the tesla coil. This will also suppress any kickback of high voltage into the power lines that might make it



heavy-duty line filter

past the grounded safety gap. If complaints persist, the remaining "ambient" interference can be dealt with, to some degree, by shielding. The entire device can be enclosed in metal screen or in a sheet-metal container which is grounded. High voltage lines running from the tesla coil to lighting fixtures, etc., should ideally be shielded and their shielding grounded. However, shielded cable for such high-voltage applications is not easily found and may have to be improvised. Incidentally, shielded cable is a Tesla invention.

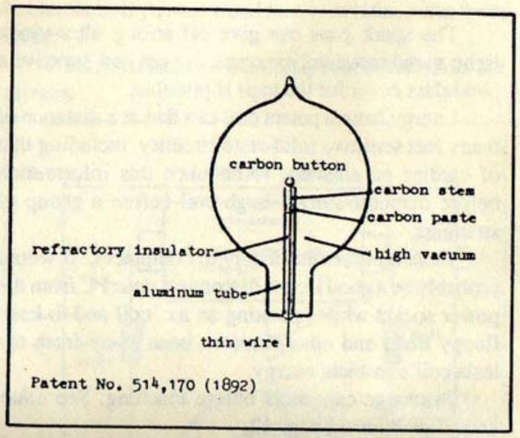
tune the coil

A gauge of performance is streamer length and intensity. Connect a length of stiff heavy wire to the ground terminal, bend it so it curves around a safe distance from any of the coil's apparatus and ends up pointing at the secondary terminal from about six inches away. Strip about an inch of insulation off this end and file a point on it. Turn on the coil and watch for length, regularity, and brilliance of the streamer as you adjust the spark gap, put in more capacitance, move around the adjustable primary tap, if you have one, and change terminal capacitors.

As you fiddle and tune, you can hear the parts come into harmony; the machine hums. For most adjustments, you'll have to turn the coil off and discharge capacitors to avoid shock hazard.

In an 1896 patent, Tesla shows a way of fine-tuning that I have not seen implemented by builders, although the principle is basic to radio tuning. Across the secondary coil he puts a variable capacitor consisting of two cymbal-like disks that face one another and are adjustable as to distance apart. He gives no clues as to their dimensions, but notes that at these high potentials not much capacitance is needed to affect performance. The same patent shows tuning by means of a variable choke in the primary circuit. An iron core, movable within the coil, varies its inductance and the primary's frequency. (See page 24.)

4. Tesla Lighting



The high-potential, high-frequency energy of the tesla coil makes possible a whole new system of electric lighting, a system incomparably more efficient than the one in place. Incandescent lamps burn low-resistance filaments that devour energy. Even fluorescent tubes burn filaments (cathodes) to create the electrical flow that sets their internal phosphorous coatings aglow.

Tesla's system uses high-voltage, high frequency electric energy to light up certain gasses, like neon, in a rarefied state. In addition to gas tubes, Tesla also used this special energy to light up solid substances, like carbon, in bulbs at near-vacuum.

Tesla's early high-potential lighting systems predated the tesla coil. They consisted only of the power stage of that circuit – step-up transformer, capacitor, and spark gap: a spark-gap-oscillator power supply. (Today's neon systems are stuck back there using only the high-voltage transformer.) Such a power supply could be connected to electrodes inserted into both ends of a lighting tube, but Tesla discovered that just a single wire into one end could also do the trick.

When the tesla coil was developed, it was discovered that it could be done with two wires, a single wire, or, *viola*, no wires at all.

Most of Tesla's lighting-system patents show a two-wire system employing a type of tesla coil called bipolar. This variant resembles the familiar monopolar in all respects except that the secondary is mounted horizontally instead of vertically, and the primary is situated at the center instead of at one end. The normally grounded bottom end of the secondary now becomes a second pole for output.

Tesla apparently believed bipolar was the efficient way to light by wire. When it came to wireless power, however, he used monopolar, as evidenced in the magnifying transmitter. While tesla coil builders through the years have been wedded to the monopolar format, for practical builders seeking the wondrous efficiencies of Tesla lighting, bipolar is probably the way to go. Shown on the opposite page is an example of a bipolar tesla coil built by the author.

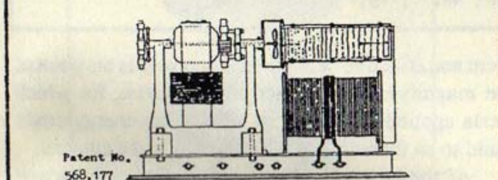
Tesla patented several filamentless light bulbs to go with his system. Of course, these never went into wide manufacture. That there is no Tesla bulb you can use if you are thinking of building a Tesla lighting system should not be a cause for despair, however. Conventional florescent tubes work just fine in Tesla systems. And you can even use discarded tubes straight out of an office building's dumpster, because it does not matter if they are burned out in the cathode department.

If the tesla coil is bipolar, connect a line to each end of the tube (both prongs). If monopolar, connect a line from the output terminal to one end and ground the other.

Tesla's patents do not specify ideal frequencies for lighting. I've done a little experimenting with lighting flourescent tubes, and it suggests that vibrations down around 30,000 cycles may be among those that work well. Note that the secondary of the bipolar tesla coil illustrated vibrates at a higher frequency and may not be ideal for lighting applications as designed; a much longer secondary winding would be required. Its spark-plug series gap, however, might be appropriate for a tesla-coil lighting plant, as would a well-built rotary.

ozone disinfector

Another practical use of the tesla coil is in generating ozone. Ozone can be generated deliberately as well as inadvertently by spark discharge. Although ozone is now regarded primarily as a toxic air pollution menace, in Tesla's time an occasional whiff of the gas was believed to be beneficial for consumptives, and ozone had other medical uses as a disinfectant.



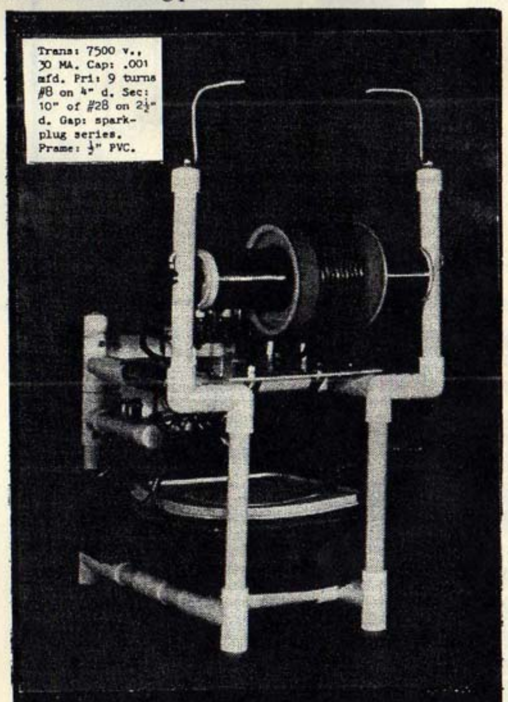
ozone generator

The idea has been resurrected, for you can now buy a device that disinfects water for your spa by bubbling electrically generated ozone through it rather than using chlorine additives. If a spa, why not a swimming pool? And what about using ozone to disinfect drinking water?

Tesla probably had medical uses in mind when he patented an ozone generator in 1896. A bipolar tesla coil is connected to two parallel plates forming a sparking chamber in an insulated tube. The same motor that drives the rotary gap spins a fan that propels air into the chamber.

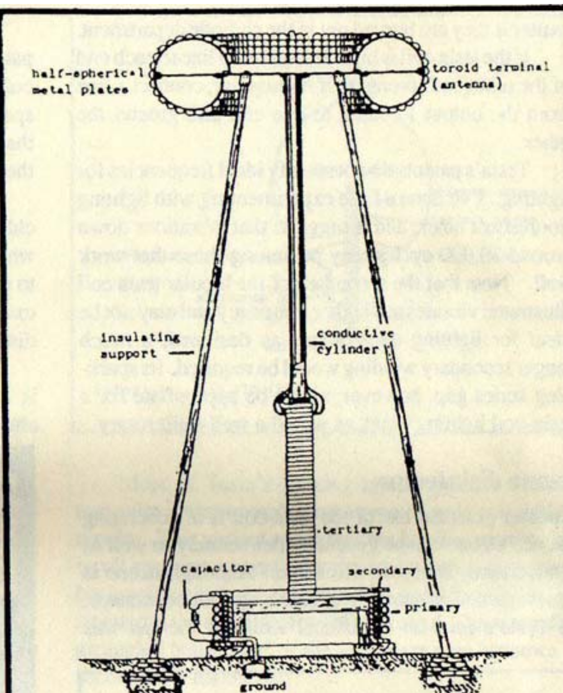
Purification of water, commonly done with chlorine in the U.S., is done with ozone in Europe, which met chlorine as a toxic gas in WWI and isn't eager to meet it again. There is a growing concern about the toxicity of chlorinization, and ozonation is being discussed as an alternative.

Ozonation of the blood to treat a variety of diseases is a therapy that's being used more and more in alternative healing practices.



author's bipolar tesla coil

5. Magnifying Transmitter



Patent No. 1,119,732 (1902)

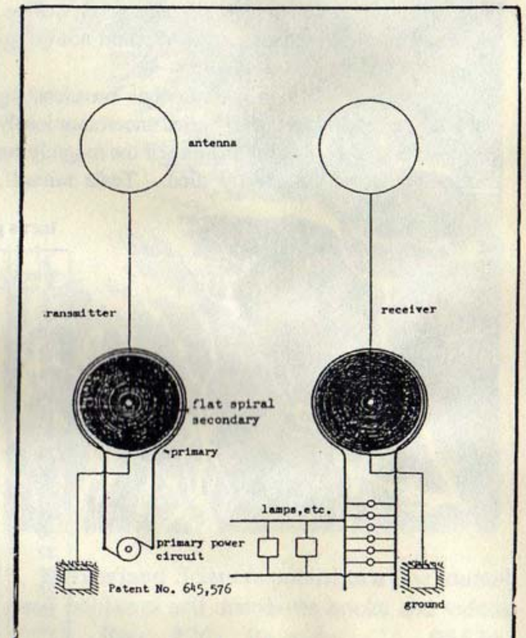
This is just a big tesla coil having a third coil designed to oscillate in resonance with the secondary. This "extra" coil," as Tesla called it, can oscillate just by being placed in the vicinity of a tesla coil, but, in the magnifying transmitter, its lower end is connected directly to the top of the secondary. The primary and secondary are closely coupled.

While a tesla coil's secondary always interacts with the primary, thus dampening the vibration somewhat, this extra tertiary coil can vibrate freely. Extra coils, writes Tesla, "enable the obtainment of practically any emf., the limits being so far remote that I would not hesitate to produce sparks thousands of feet in this manner." The problem, then, becomes one of containing this immense electrical activity. Containment and effective radiation of this power is the point of the magnifying transmitter design shown, for which Tesla applied for patent in 1902. This energy could build to an incredible 4,000 amperes in the antenna.

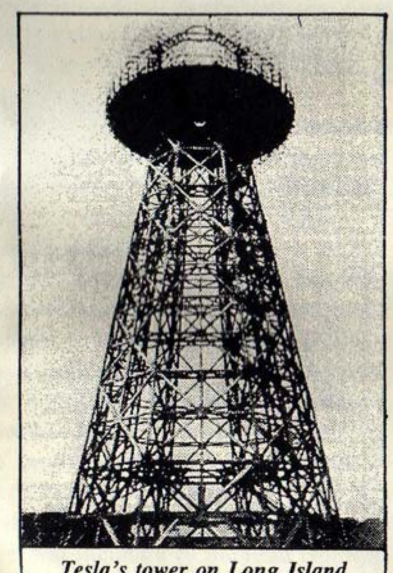
At the base of the tower, the primary is wound directly on top of the secondary; to properly insulate one from the other is an engineering challenge. The tertiary or extra coil extends upwards to a conductive cylinder which connects to the antenna. This antenna is especially designed to contain and radiate the transmitter's huge energy. It is a toroid covered with half-spherical metal plates "thus constituting," writes Tesla in his patent, "a very large conducting surface, smooth on all places where the electrical charge principally accumulates."

Tesla says that his magnifying transmitter is capable of producing "immense electrical activities, measured by tens and even hundreds of thousands of horsepower." Great caution must be taken in firing up and tuning the giant coil, Tesla advises. If potentials were to build in the wrong part of the circuit, all hell would break loose. If the points of maximum pressure were developed somewhere on the tertiary coil instead of at the antenna, "a ball of fire might break out and destroy the support or anything else in the way." This destructive action, he says, "may take place with inconceivable violence." He therefore advises that when breaking in the transmitter, the power be brought up very slowly and carefully.

If his biographers are to be believed, Tesla, at Colorado Springs, cranked up his magnifying transmitter to the max and succeeded in creating crashing bolts of lightning that nearly rivaled those of nature. In the process his transmitter burned out the municipal generator.



wireless power


Tesla's tower on Long Island

The magnifying transmitter could be construed as a sort of electrical pile driver designed to set into vibration the electrical condition of the earth itself. The terminal capacitor is not an antenna in the usual sense but provides electrical leverage against which the transmitter can pump ground. At the proper frequency, which Tesla determined to be around 150,000 cycles per second, the earth would respond resonantly to the transmitter's vibrations. Thus stimulated, electric forces could be made to swing up to tremendous amplitudes. Tesla's wireless power was based on this principle, as was his global broadcasting system. Wireless power, of course, was just radio broadcasting on another scale. to receive the power, all you had to do, essentially, was to bury a metal plate in the earth, raise up an antenna, and put a tesla coil tuner between. Power could be drawn off anywhere within the transmitter's range. The number of consumers tuned in would not be reflected in drain on the transmitter.

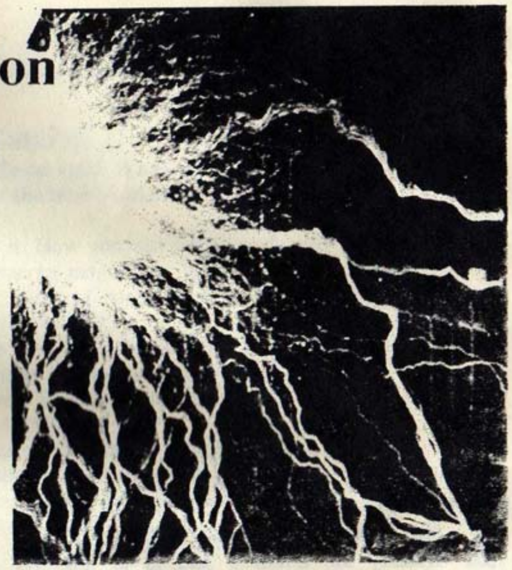
Although Tesla's ill-fated global broadcasting tower on Long Island was dismantled unceremoniously during World War I, the technology of the magnifying transmitter never completely died. Tesla himself, according to some sources, was supposed to have been working on wireless power experiments in Canada in the 1930's. There are rumors of secret experiments conducted by the Soviet government, and one hears from time to time of just plain people who have grouped together to build large magnifying transmitters and experiment with wireless power.

turns per inch table

wire#	enamel	insul.*
8	7.6	7
10	9.6	9
12	12	11
14	15	14
16	18.9	17
18	23.6	20
20	29.4	24
22	37	30
24	46.3	36
26	58	44
28	72.7	52
30	90.5	60
32	113	68
34	143	78
36	175	90
38	224	100
40	282	111

*approximations
Insulation thickness varies.

6. For More Information



Patents that are cited in the illustrations of this book may be ordered by patent number from the **U.S. Patent Office** (Washington, DC 20231).

For Tesla's *Complete Patents,* various titles on the tesla coil, and many other Tesla-related publications: **Twenty First Century Books** (P.O. Box 2001, Breckenridge, CO 80424, www.tfcbooks.com).

For a how-to more respectful than this one of the rigors of mathematical circuit design, see **Brent Turner's** *A Tesla Coil Handbook* (P.O. Box 3612, Fullerton, CA 92834, www.apc.net/turner.)

The **Tesla Coil Builders Association** publishes a monthly newsletter with lots of info on members' projects, design tips, and reprints from the past (3 Amy Lane, Queensbury, NY 12804).

Tesla Coil Secrets by R.A. Ford resurrects some of the lost literature of the tesla coil with commentary, from **Lindsay Publications,** which carries many pertinent titles (P.O. Box 12, Bradley, IL 60915).

Borderland Sciences publishes a fine journal and publishes and distributes books and videos (P.O. Box 220, Bayside, CA 95524, www.borderlands.com).

Also from **High Voltage Press**: *Tesla: The Lost Inventions* and *Radio Tesla* by George Trinkaus and Tesla's *The True Wireless* edited by Trinkaus

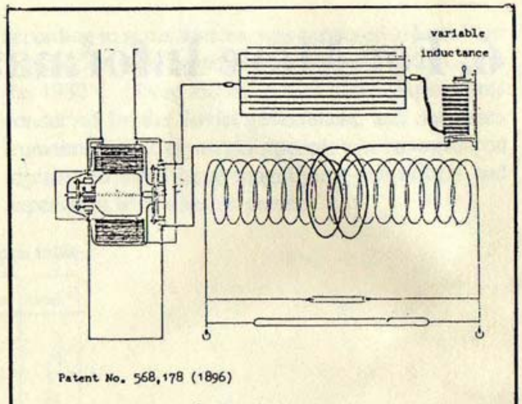
Some of the most advanced work in tesla coil technology is authored by the **Corum brothers**. For titles, see the Tesla Reprint Web Page of PV Scientific instruments at ww1.arcs and sparks.com.

Liberty Library distributes some Tesla titles (300 Independence Ave., Washington, DC 20003).

Omni Publications is a distributor (P.O. Box 566, Palmdale, CA 93550).

Rex Research publishes reprints on demand of rare literature about lost technologies (P.O. Box 19250, Jean, NV 89019).

7. Tuning Notes

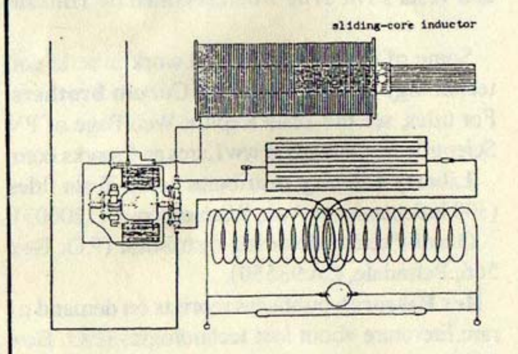


variable inductance

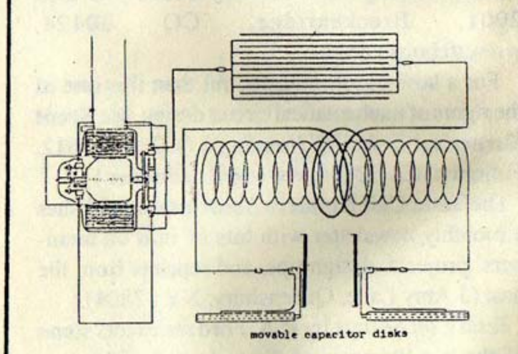
The output of a tesla coil depends on how closely tuned to resonance its circuits are. Usually the builder's aim is to tune for maximum resonance and maximum output. But in practical systems it may be desirable to modulate output. In an 1896 patent, Tesla shows some ways of achieving control by detuning, or deresonating.

An ideal tuning method would be to make the capacitor variable, but, Tesla observes, "if the condenser were of relatively large capacity, this might be an objectionable plan." Similar results can be obtained, though, by putting controllable inductances or capacitances in the circuitry.

Tesla shows two variable-inductance devices placed in the primary circuitry. The second is a sliding iron core version of the choke in the d.c. tesla coil shown on page 8. The third method places a variable capacitor across the secondary.



sliding-core inductance



variable capacitor

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