The Tesla Coil

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A strangely loud buzz punctuated by piercing cracks, all in time with a curiously bright spark in the base of the machine, and seemingly miniaturized lightning bolts shooting from the top, all caused by one amazing invention originally designed by Nikola Tesla. The device is known as a Tesla Coil, which is a high voltage dual coil resonant transformer. This amazing transformer differs from a standard step-up transformer in a few ways, including its dependence on resonating frequencies, capacitance of its output terminal and several other factors. Though the coil may not have been originally designed to produce these miniature lightning bolts, or coronas, these are easily the most recognizable trait of a Tesla Coil.

First the coil needs a high voltage power source, which can be achieved by using a high voltage step up transformer to transform standard electrical outlet 120 VAC current, into a much higher voltage, somewhere in the range of 20,000 volts. One output lead of this step up transformer is wired back to the 3rd prong grounding lead of the plug. The other output lead of the transformer is connected to one lead of a resonance or choke coil, which is about 40 turns of magnet wire wrapped around a piece of 1.5" PVC pipe, this choke coil blocks any high frequency from interfering. The second lead of the resonance coil is then connected to a high voltage tank capacitor. One end of this capacitor is then wired to a simple high voltage switch known as the spark gap. The spark gap is primarily composed of two adjustable tungsten leads that are separated from each other by about $1/8$" to $1/4$" of open air. When the tank capacitor charges up enough voltage it will make an arc from the tungsten lead it is wired to, to the second tungsten lead. The second tungsten lead of the spark gap is then wired to an adjustable tap, which connects to some point on the outside of the primary coil. The primary coil is made up of two main parts. The first section is 3 turns of $3/8$" copper tubing whose turns are spaced apart by

about $^{1}/_{2}$ ". The second section is 8 feet of insulated 12 gauge copper wire, which has one end soldered to the inside end of the first section. It then coiled to make six full turns inside of the copper tube section. The loose end of the wire is then routed through the upper deck of the Tesla Coil base and is connected to a lead going back to the second end of the tank capacitor as well as the bottom lead of the secondary coil. The secondary coil consists of section of 3" schedule 40 PVC pipe that is tightly wrapped with 500 turns of 22 gauge magnet wire. The top lead of this coil is connected to an aluminum toroid. The second terminal of the tank capacitor that the end of the primary coil and the bottom lead of the secondary coil are connected to essentially becomes a ground for the resonating transformer. There is also a grounding wand connected to this terminal. The primary coil and the tank capacitor form one of the resonating circuits, which is called an LC tank circuit, while the other resonating coil is formed by the secondary coil and the toroid output terminal. Both of these resonating circuits are LC circuits, where the capacitor connected to the secondary coil is the output terminal or toroid.

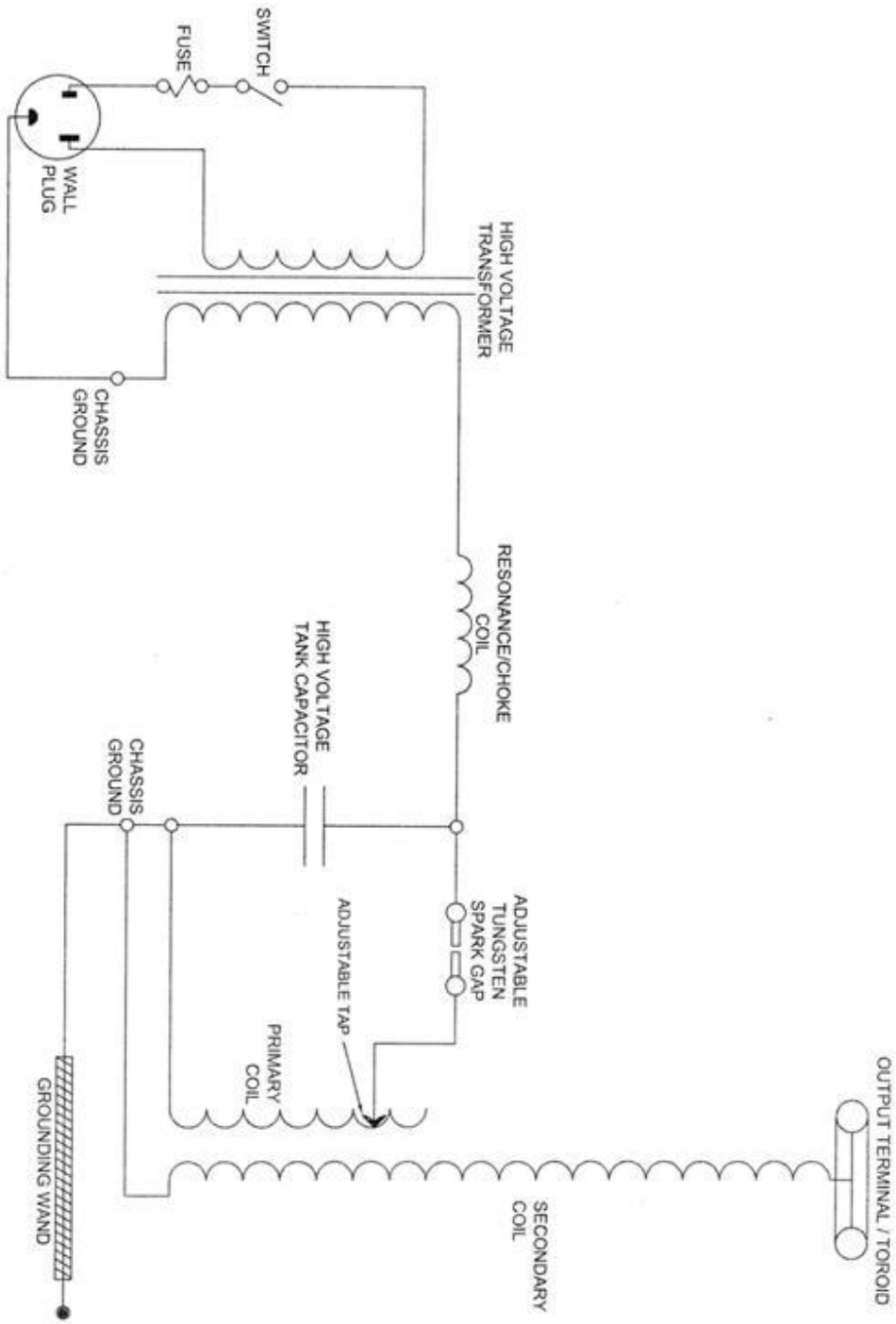
These dual resonating circuits are the primary difference between a Tesla Coil and a standard step up transformer. Unlike other transformers the only about 10 to 25% of the magnetic field created by the primary coil interacts with the secondary coil. As the spark gap conducts the electricity then oscillates through the circuit created by the primary coil and the tank capacitor. The resonance frequency of this circuit is determined by the capacitance of the capacitor and the inductance of the coil. This resonating AC current running through the LC tank circuit, transfers much energy to the second resonating LC circuit composed of the secondary coil and the output terminal. Despite the low interaction between the two coils a well constructed Tesla Coil can transmit up to 85% of the energy from the primary to the secondary coil. The resonance frequency of this circuit is determined by the capacitance of the output

terminal, or the toroid, and the self inductance of the secondary coil. It is only when the two circuits resonate at the same frequency that the Tesla Coil gives optimum performance at. This fact is what creates the need to have an adjustable tap on the outside of the primary coil.

To match the resonating frequency of the two coils, the operator of the coil can adjust where the tap connects to the primary coil, adjusting this tap effectively eliminates or adds fractions of the coil which alters the inductance. This inductance is tuned to create a match between the two coils resonance frequencies. The other point of tuning and adjustability to the coil is the separation of the two tungsten leads of the spark gap. As the gap distance is lowered it requires less energy to create the arc between the two, essentially lowering the operating voltage of the coil as well as increasing the frequency of creating the arcs. As the gap distance is increased it requires more energy to create the arc between the two, which requires a longer period of time for the capacitor to charge to the energy required, decreasing the frequency of its firing. When both the spark gap and the primary coil tap are adjusted properly the Tesla Coil is capable of making coronas of about 12" in length, with an output voltage around 250,000 to 300,000 volts.

David Long and Caleb Selby collaborated on this project. Though either of us were capable of completing all steps to the project, we decided it was best to split the work responsibility up. Though we would still work together on most steps of the project, the responsibility for each individual part was assigned to one of us. Caleb was in charge of the physical assembly of the Tesla Coil base, the 120VAC wiring, and the turning of the secondary coil, correspondence with the metal shop for the toroid, and managing the heat of the toroid during inflation . David was in charge of the high voltage wiring, the primary coil, pressure control during toroid inflation, and the final assembly of the coil. We both worked together to

tune the coil.



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