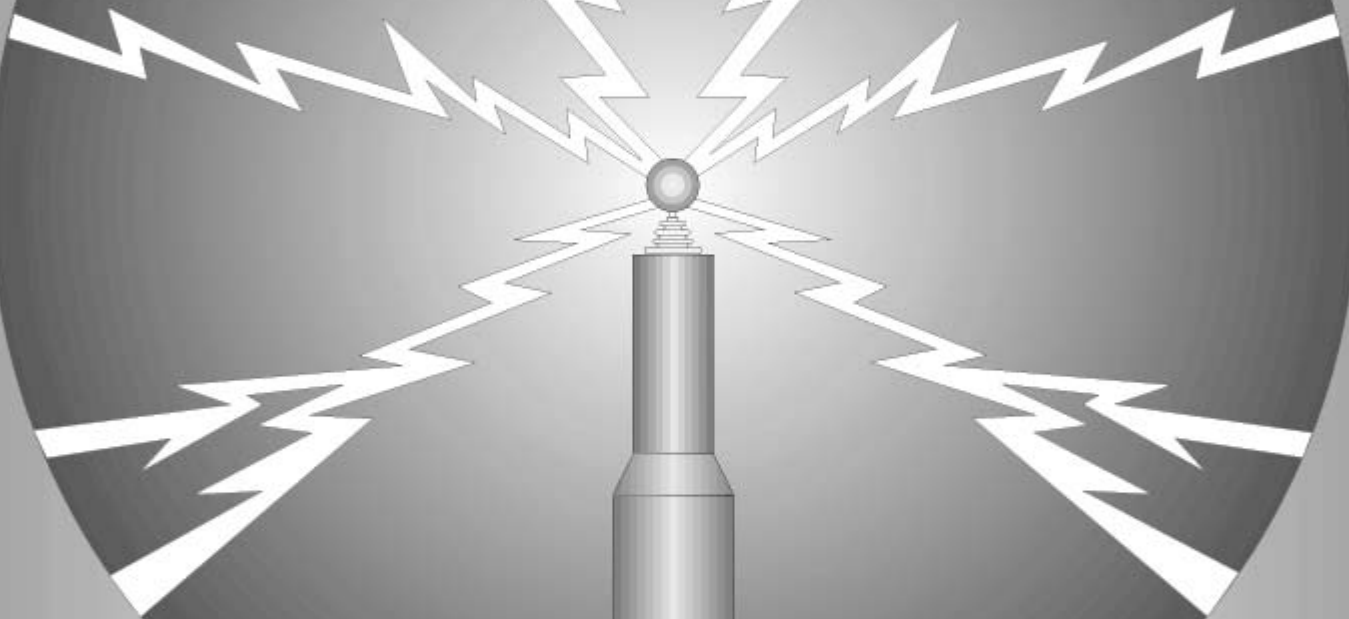


# TABLE-TOP LIGHTNING

HOW TO BUILD A POWERFUL, COMPACT

# TESLA COIL



**INCLUDES :**

PHOTOS, DRAWINGS &  
COMPLETE INSTRUCTIONS

HISTORY, THEORY, & MORE  
THAN A DOZEN EXPERIMENTS

UNIQUE DESIGN  
PRODUCES LIGHTNING  
BOLTS 24 INCHES LONG.

PERFECT FOR SCHOOLS,  
MUSEUMS, RESEARCH,  
SCIENCE PROJECTS, &  
SPECIAL EFFECTS.

## **CAUTION**

**THE APPARATUS DESCRIBED IN THIS MANUAL HAS COMPONENTS THAT CAN DELIVER DANGEROUS ELECTRICAL SHOCK. FOLLOW DIRECTIONS FOR SAFE CONSTRUCTION AND OPERATION. READ MANUAL BEFORE CONSTRUCTION AND NOTE ALL SAFETY MEASURES AND PRECAUTIONS.**

**THE READER SHOULD HAVE A BASIC UNDERSTANDING OF ELECTRICAL PRINCIPLES AND TERMINOLOGY BEFORE UNDERTAKING CONSTRUCTION.**

**THE AUTHOR ASSUMES NO RESPONSIBILITY FOR THE USE OF ANY OF THE MATERIALS OR METHODS DESCRIBED IN THIS MANUAL.**

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Miniature lightning bolts two feet long crackle from the Table Top Tesla Coil's discharge electrode.

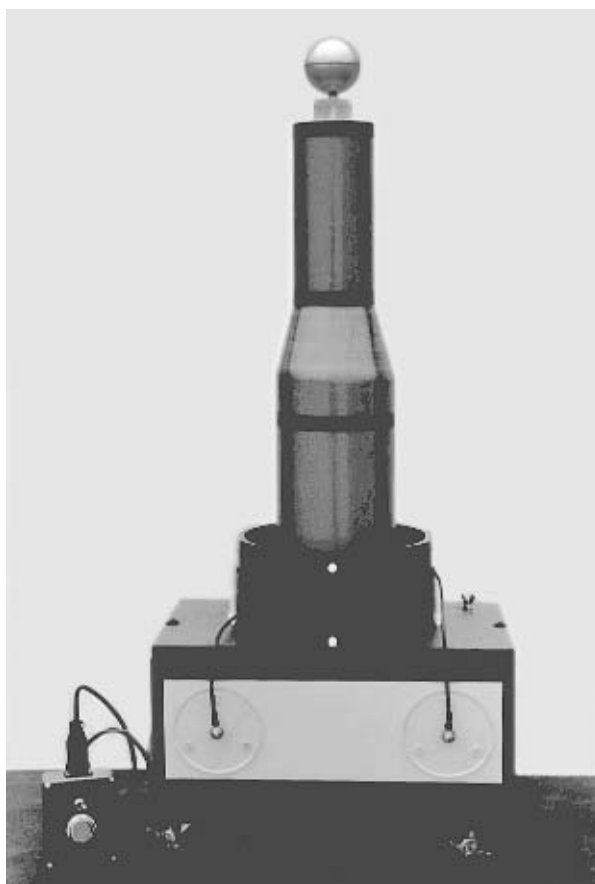


Table Top Tesla Coil with remote switch box.

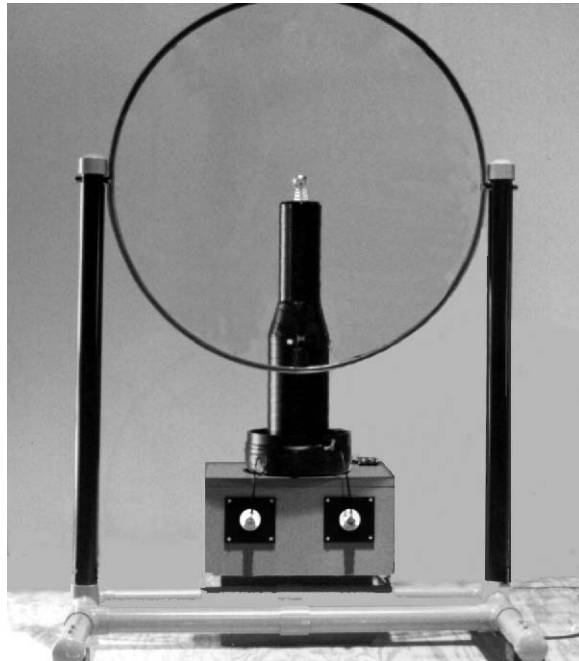


Table Top T.C. behind “Lightning Screen” (see Experiments).

### TABLE-TOP TESLA COIL

The high-performance Tesla Coils described in this manual produce lightning bolts up to 24" long and provide high-voltage pyrotechnics for dozens of dramatic experiments and special effects.

Because of their portability and low power requirements, the coils are perfect for classroom demonstrations, science shows, special effects, and research.

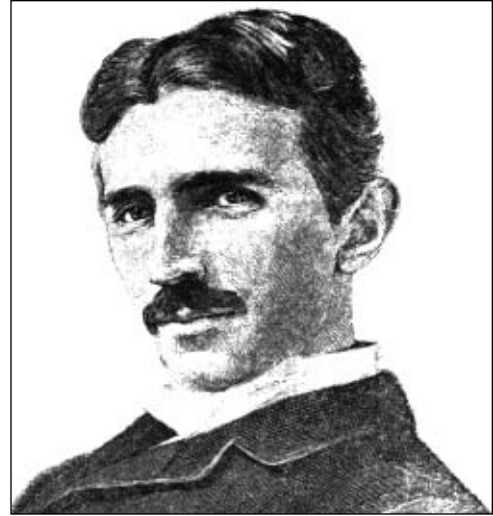
Two versions are included: “No. I” uses a Secondary Coil of simple construction, and “No. II” uses a more complex Secondary Coil offering slightly higher performance.

Power requirements: 110 VAC @ approx. 5 A.

Nikola Tesla invented his famous coil around 1890. Tesla used sundry versions of his coils for research into radio, X-ray production, radio control, gaseous discharge lighting systems, and wireless transmission of power.

Tesla's "Magnifying Transmitter," a huge Coil he constructed in Colorado Springs in 1899, produced thundering electrical discharges over 50 feet long.

Tesla claimed that experiments he conducted with the Magnifying Transmitter confirmed his theory that the earth could be resonated, and that electrical power could thus be transmitted to any point on the planet without wires, and with very small losses. His power transmission experiments, to this day, have not been duplicated, nor have his theories been disproved.

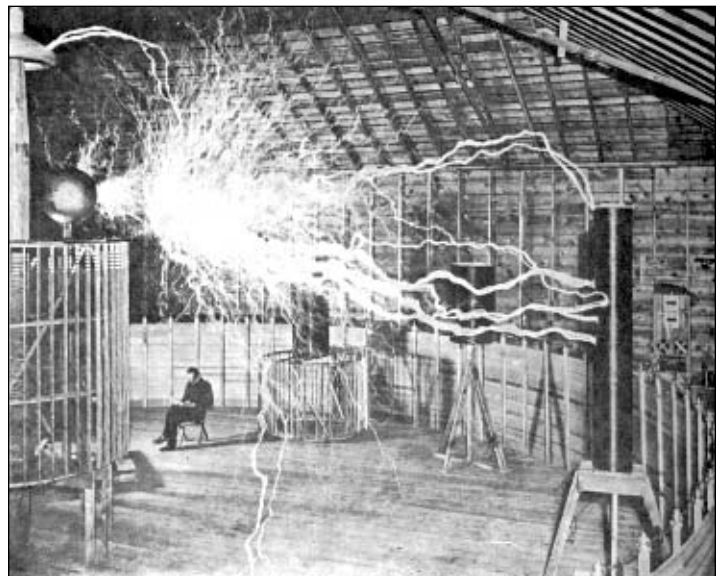


NIKOLA TESLA: 1865-1943

Tesla Coils have been used as radio transmitters, as drivers for nuclear accelerators, as diathermy and electro-dessication instruments in medicine, as research instruments in physics laboratories, and as demonstration apparatus in classrooms and science museums.

From the days of the silent movie to the present, Tesla Coils have provided dramatic electrical effects for film and stage. The early silent film, *Metropolis*, was probably the first to use discharges from a Tesla Coil to provide special effects. *Frankenstein*, *Aliens*, *Back to the Future*, *Terminator*, *Star Wars*, and many additional films have used Tesla Coil effects.

As archaic as spark-gap oscillators may now seem, Tesla's designs and methods were years ahead of their time. The wonderfully simple circuit belies the genius involved in its concept.



Tesla's Magnifying Transmitter discharging 25' streamers from the "Extra Coil." The 50' diameter secondary was wound on the surrounding wooden frame. Tesla is seated in the background in this double-exposure.

Variations of Tesla Coil circuits exist in virtually every radio, television, computer, and transmitter. Without the principles embodied in its design, modern electronics would be impossible.

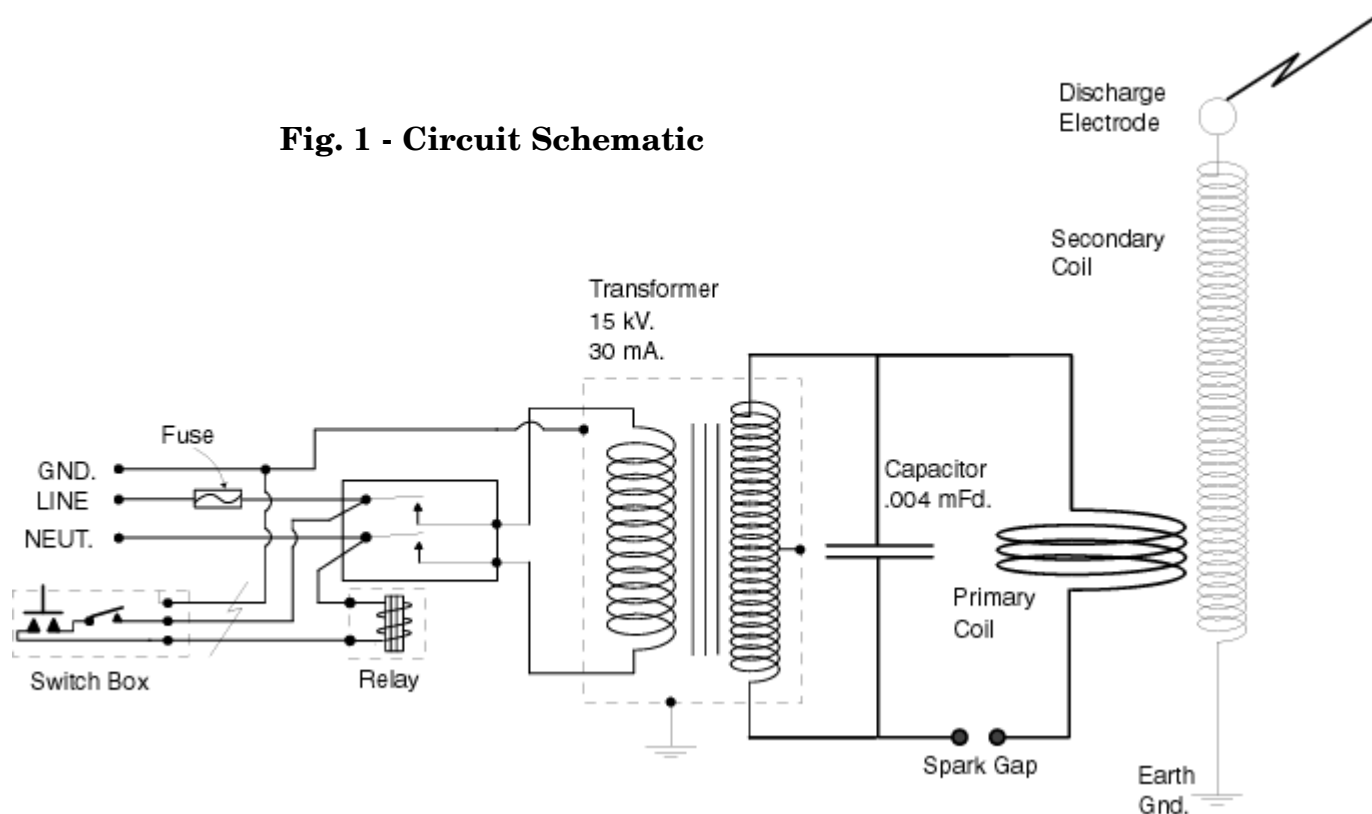
## THEORY

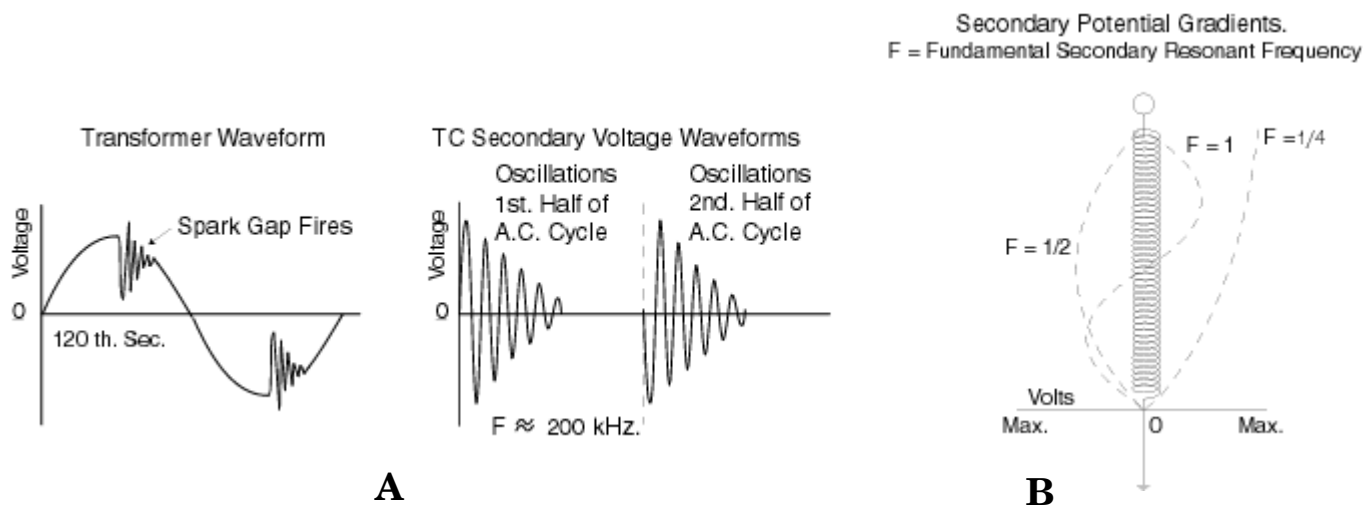
The Tesla Coil is a resonant air-core transformer that creates high voltage, high frequency current by using tuned circuits.

The coil in this manual uses a neon sign transformer to step up 120 volts from the AC outlet to 15,000 volts. This voltage is applied across the terminals of a capacitor. When the capacitor's charge reaches approximately the transformer's peak voltage, it discharges across a spark gap and through the primary coil. During the discharge, the primary coil and capacitor oscillate at a frequency determined by their combined values.

The primary coil, which has only a few turns, is inductively coupled to a secondary coil that has hundreds of turns. When the spark gap fires, the sudden pulse of current through the primary coil causes a voltage to be induced in the secondary. The value of the induced voltage is a function of the secondary coil's "Q" factor and, to a degree, the turns ratio between primary and secondary.

**Fig. 1 - Circuit Schematic**





**Fig. 2 - (A) Transformer and secondary waveforms (B) Voltage gradient along secondary coil when secondary is excited by the fundamental frequency, by 1/2 the fundamental, and by 1/4 the fundamental.**

If the primary circuit (coil and capacitor) oscillates at one fourth the natural resonant frequency of the secondary coil, and one end of the secondary is grounded, a high voltage loop appears at the secondary's open end, with the node at the grounded end (Fig. 2B).

The Table Top Tesla Coil secondary has a natural "ringing frequency," or resonant frequency, of around 800 kHz. Each time the spark gap fires, the primary circuit creates a series of damped oscillations at around 200 kHz, or one fourth the frequency of the secondary coil. Because of the 1/4 wavelength tuning, voltage induced in the Secondary reaches a peak at the top of the coil, the bottom being held at ground potential.

The theoretical maximum voltage the system will develop under perfect conditions is the product of the system's "Q" times the impressed voltage (approximately 15 kV): In actual practice, this is never the case. There is some debate regarding the degree to which turns ratio influences voltage developed by a Tesla Coil. There seems to be an optimum number of turns, given any combination of circuit values, but the author is unaware of any definitive formula.

High frequency currents will jump farther than an equivalent DC voltage, so the "rule of thumb" of three feet per million volts doesn't necessarily hold. The estimated voltage developed by the Table Top Coil is 300 kV.

Some formulas are included below for those wishing to delve into the Tesla Coil's operating parameters or customize the coil presented in this manual.

## FORMULAE

The Primary Coil and Capacitor form a tuned circuit that oscillates at a frequency according to the following formula:

$$F = \frac{1}{2\pi\sqrt{LC}}$$

Where:

F = Frequency in Hertz

L = Primary Coil Inductance in Henrys

C = Capacitance in Farads

Inductance of the No. I Primary Coil can be calculated by the formula:

$$L = \frac{(rn)^2}{8r + 11b}$$

Where:

L = Inductance in Henrys

n = number of turns

r = distance from the center of the coil to the middle of the winding

b = width of winding

Inductance of the No. II Primary Coil can be calculated by the formula:

$$L = \frac{(rn)^2}{9r + 10d}$$

Where:

L = Inductance in Henrys

r = Radius of Coil in inches

n = Number of turns

d = Length of Coil in inches



The "Q" or Merit Factor of a coil:

$$Q = \frac{X}{R}$$

Where:

X = Reactance of Coil in Ohms at the resonant frequency

R = DC resistance of the Coil in Ohms

The reactance of a coil:

$$X = 2\pi FL$$

Where:

X = Reactance of Coil in Ohms

F = Frequency of the applied current in Hertz

L = Inductance of the Coil in Henrys

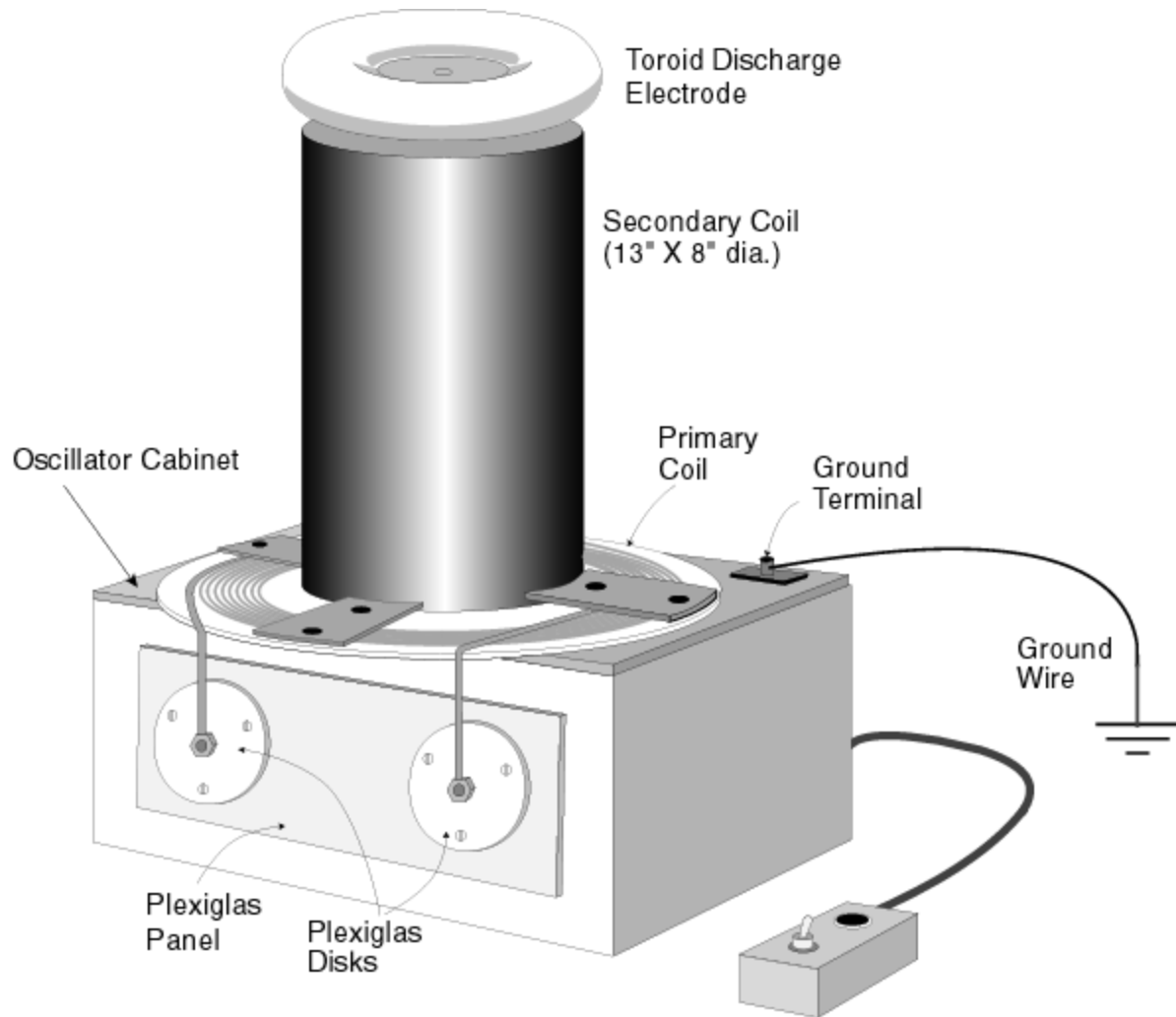
Calculation of Q is at best approximate, as factors such as lumped capacitance, coupled-in impedance from the Primary Coil, and increased impedance from the skin effect can greatly alter the actual figure.

Note: Do not use a capacitor larger than .004 mfd. with the transformer specified in this manual. The capacitor determines how much power will be drawn from the transformer, and going oversize will quickly burn out the transformer.

## CONSTRUCTION

Maximum Tesla Coil voltage is theoretically reached when the greatest Secondary inductance for a given length of wire is obtained. This suggests using a coil with a relatively large diameter in relation to its height.

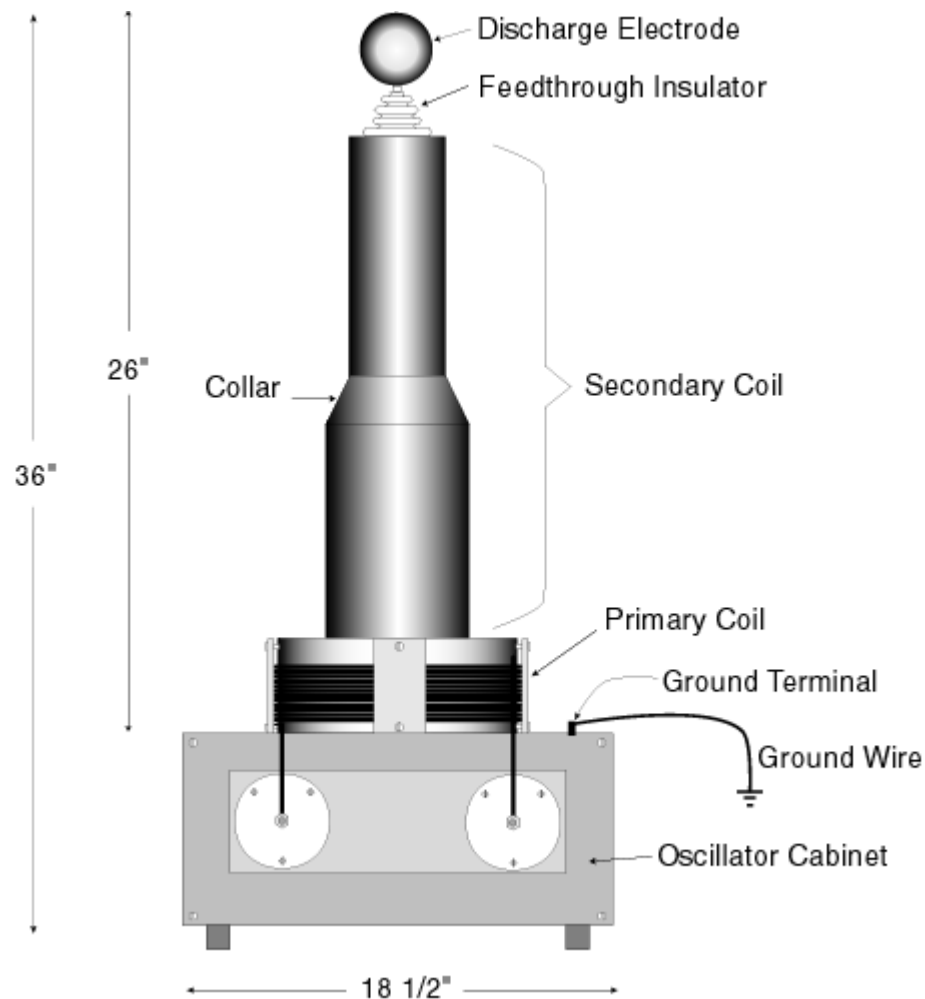
No. I uses a Secondary Coil Form 8" in diameter and 13" long (Fig. 3). This configuration offers good performance, is inexpensive, and is easy to wind.



**Fig. 3 - No. 1 Tesla Coil**

Tesla Coils will bleed electricity from the top winding unless a discharge electrode of greater diameter than the coil is used. The discharge electrode for No. I can be an aluminum plate 8 1/4" in diameter or a toroid approximately 8 1/2" diameter by 1 or 2" diameter.

You can experiment with electrode sizes and configurations, but keep in mind that an over-size discharge electrode will affect the coil's performance by introducing too much capacitance into the secondary system.



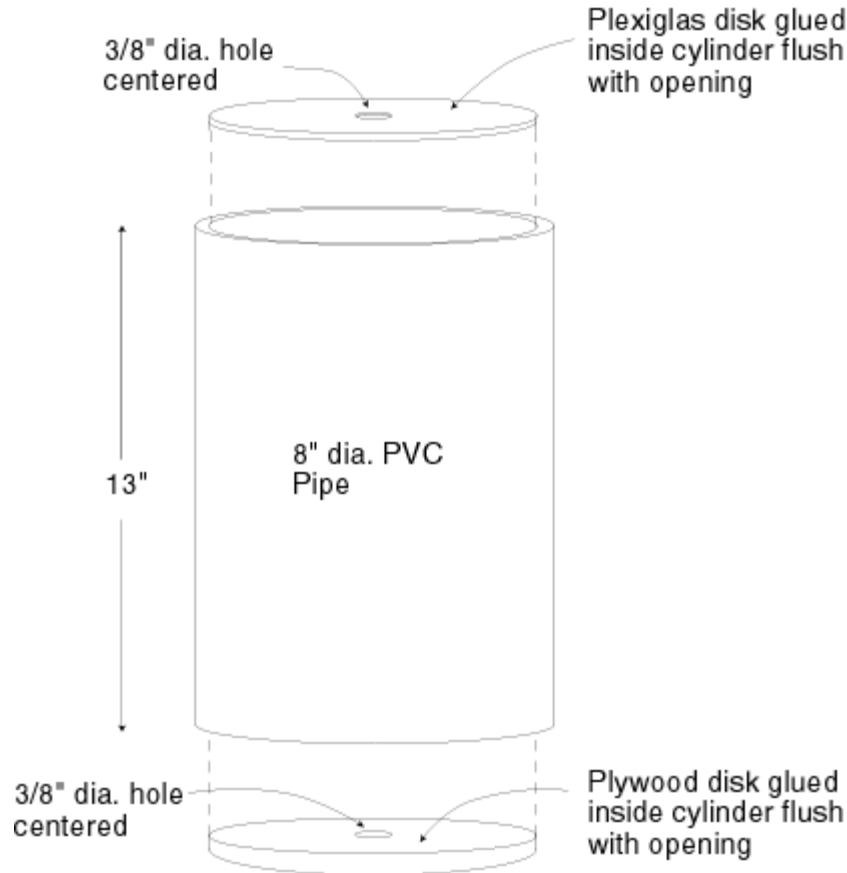
**Fig. 4 - No. II Tesla Coil**

One design compromise is to use a secondary that tapers from a large diameter to a smaller diameter, i.e. a cone. Cones, however, are very difficult to wind.

The No. II design has an unusual compromise—a large diameter cylinder attached to a smaller diameter cylinder (Fig. 4). The transition from large diameter to small is accomplished with a short “collar.”

This secondary configuration allows the use of a better-proportioned discharge electrode. Partly for this reason, the No. II unit offers better performance.

Although No.II works very well with no discharge electrode at all, considerable bleed-off from the top winding will be experienced if the electrode is less than three inches in diameter.



**Fig. 5 - No. I Secondary Coil Form**

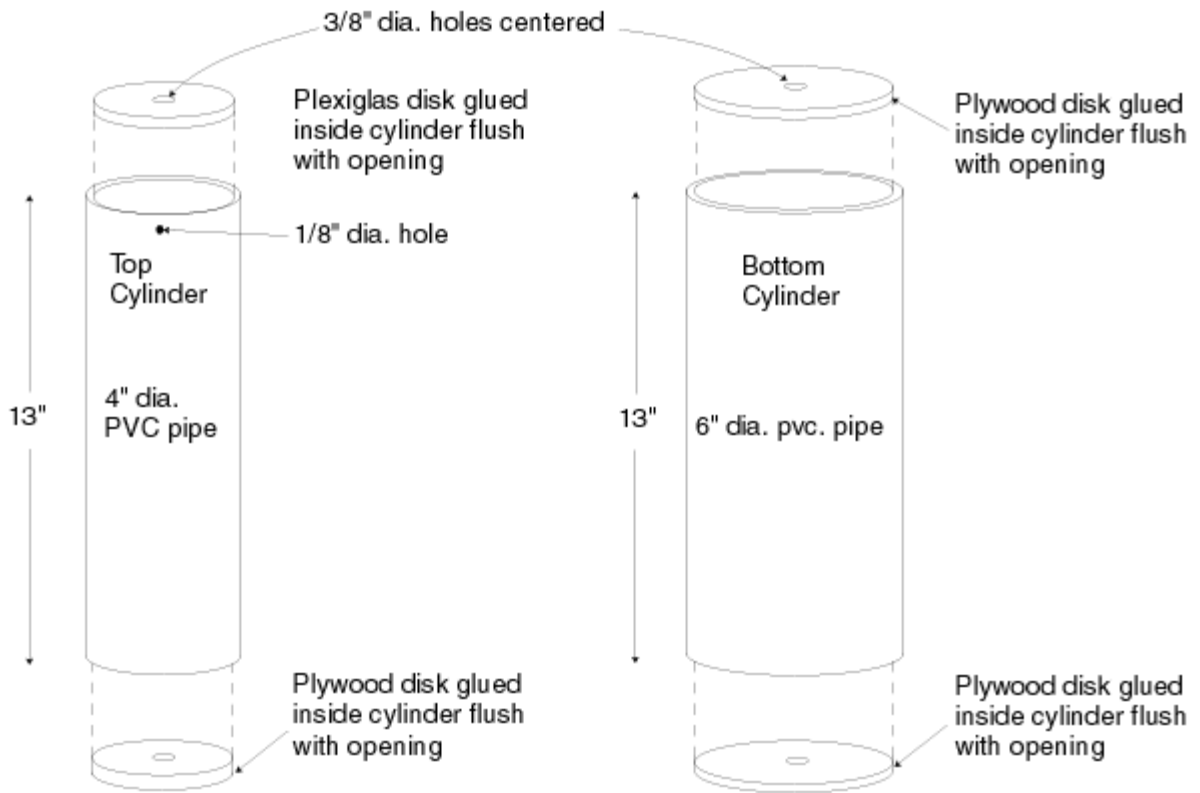
**Many different secondary coil designs are feasible, and the builder is encouraged to experiment—maybe he'll discover a design that will work even better than the ones presented in this manual.**

## **SECONDARY COIL FORMS**

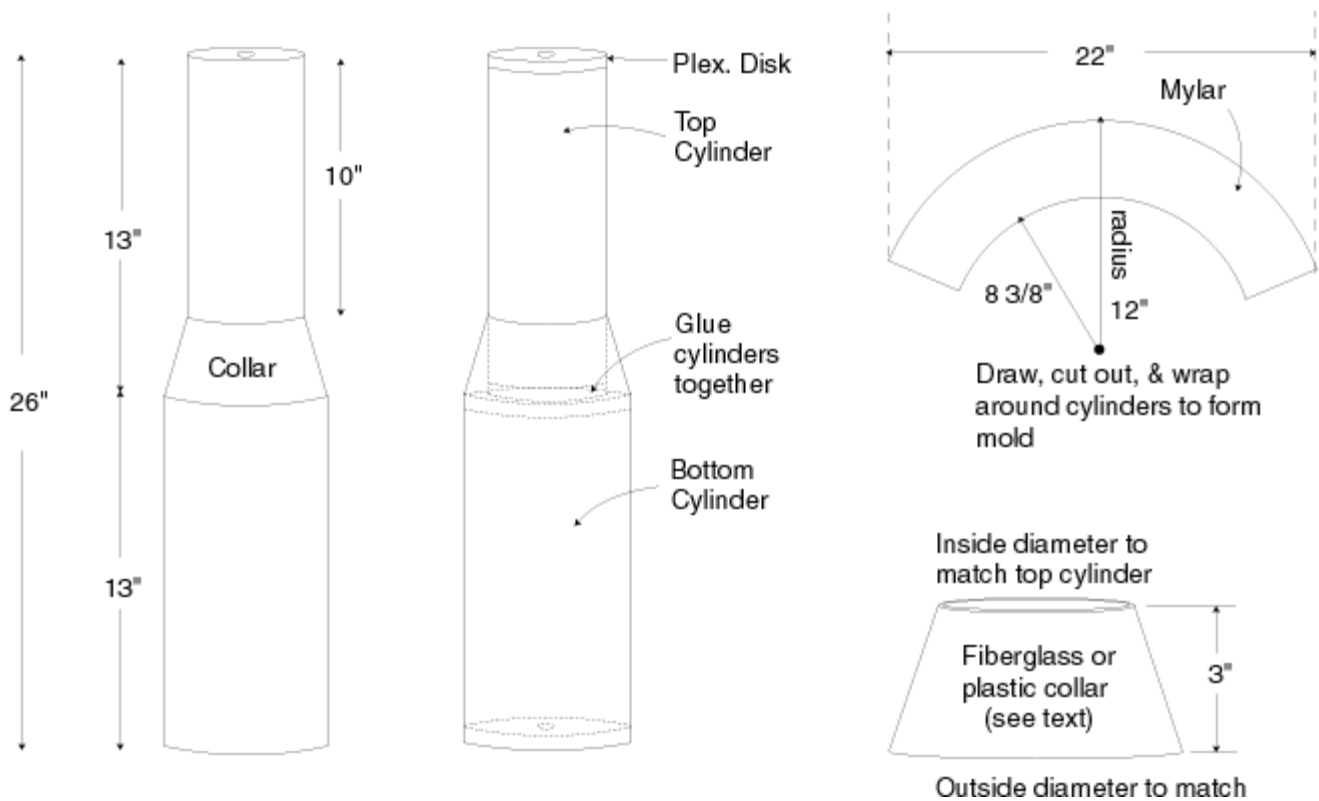
**NO. I Secondary Coil Form:** The Secondary Coil Form for No.I consists of a cylinder made from a piece of PVC pipe 13" long and 8" in diameter (Fig. 5).

**Plexiglas or similar plastics are acceptable substitutes. Cardboard or paper cylinders are not recommended, as they tend to hold moisture.**

**Cut a disk of 1/2" or 3/4" plywood to fit flush inside the bottom of the form.**



**Fig. 6 - Top and Bottom Cylinders of No. II Secondary Coil Form**



The top end of the form will require a disk of 1/4" Plexiglas.

Drill a 3/8" diameter hole in the center of each disk to allow a threaded rod to be inserted during the winding process.

Apply a coat or two of polyurethane varnish to the plywood disk and allow to dry.

Use epoxy cement to glue the plywood disk flush with the bottom of the cylinder. To add strength, it can be pinned with three or four 1/4" diameter wooden dowels.

The Plexiglas disk can also be glued in with epoxy. If a Plexiglas cylinder is used instead of PVC, glue the disk in with acrylic adhesive. (The thickened variety is easier to work with.) Make sure the surfaces to be cemented are clean and free from oil or grease. Roughen all mating surfaces with sandpaper before cementing.

**NO. II Secondary Coil Form:** The Secondary Coil Form for No.II is made from two sections of PVC pipe and a connecting "collar" (Figs. 6 & 7).

The bottom section is 13 inches long and approximately six inches in diameter.

The top section is 13 inches long and four inches in diameter.

Plexiglas or similar plastics are acceptable substitutes for PVC as long as they have enough strength to resist warping. Cardboard or paper cylinders are not recommended, as they tend to hold moisture.

Cut disks of 1/2" or 3/4" plywood to fit flush inside the bottom and top of the 6" dia. PVC cylinder and in the bottom of the smaller cylinder.

The top end of the smaller cylinder will require a disk of 1/4" Plexiglas instead of plywood. This is the end that will receive a feedthrough insulator and Discharge Electrode.

Drill a 3/8" diameter hole in the center of each disk to allow a threaded rod to be inserted during the winding process.

Apply a coat or two of polyurethane varnish to the plywood disks and allow to dry. Note: If the Secondary feedthrough insulator requires screws for attachment, drill and tap the Plexiglas disk so the insulator can be attached later using nylon screws (no metal).

Glue the disks into the cylinders with epoxy cement. The disks should fit flush with

ends of the cylinders. To add strength, the plywood disks can also be pinned with three or four 1/4" diameter wooden dowels.

Make sure the surfaces to be cemented are clean and free from oil or grease. Roughen all mating surfaces with sandpaper before cementing.

Drill a 1/8" dia. hole in the top of the smaller cylinder just below the bottom edge of the Plexiglas disk. The top wire of the coil will pass through this hole.

After the cement has cured, center the top cylinder on the bottom cylinder and cement the two together with epoxy.

**Plastic Collar:** The plastic collar connecting the two cylinders is probably the most difficult component to build.

Fiberglass makes the best collar, as it is strong and has excellent dielectric properties. As an alternative, a collar can be fabricated from a plastic funnel (sold in hardware and automotive stores) and glued in place with silicone sealer.

If you decide to make the collar of fiberglass, here are some steps to follow:

- Make a mold form by cutting a collar pattern out of a sheet of mylar (see pattern drawing in Fig. 7) and wrapping the pattern into the correct shape and diameter. Place the mold over the coil form to check the fit. The mold must fit loosely, as the fiberglass will be laid-up inside the mold. Once a proper fit is achieved, tape the pattern ends so the mold holds its shape.

Thin poster board can be used in place of mylar, but the inside of the mold form will have to be covered with a smooth layer of waxed paper to prevent the resin from sticking.

- Cut two strips of fiberglass mat (available at auto parts stores) or fiberglass cloth to match the collar pattern. Cut the strips into two or three inch-long pieces for easy handling.

- Place the mylar mold small-end down in the opening of a coffee can or jar. This will help hold the mold in shape and catch drips from the resin.

- Catalyze a small amount of resin according to manufacturer's directions and, using a 1" brush, thoroughly wet down several of the cut strips of fiberglass mat. Lay the mat in the mold and use the brush to press out bubbles and voids.

Continue laying in wetted-strips of mat until two layers have been built up. It's ok to overlap the mat. Finished thickness should be about 1/16".

Note: Use resin in a well-ventilated area. Acetone can be used to clean brushes and hands, but it is highly flammable. New, non-flammable and non-toxic chemicals for hand-cleaning are available at fiberglass supply outlets. Waxed paper can be used to protect work surfaces from resin.

- After the resin has cured (4-8 hrs.) remove the part from the mold and trim excess fiberglass from the edges with coarse sandpaper. It may be necessary to use a saw to trim an even opening at each end.
- Fit the collar to the cylinders. You'll need to do additional trimming with coarse sandpaper to get a good fit. Once the fit is satisfactory, glue the collar in place with epoxy. Sand the finished piece smooth.
- Large voids in the surface of the collar can be filled with a commercial automotive filler, like Bondo (easiest), or with paste epoxy. After filling, sand the surface smooth.

## PRIMARY COILS

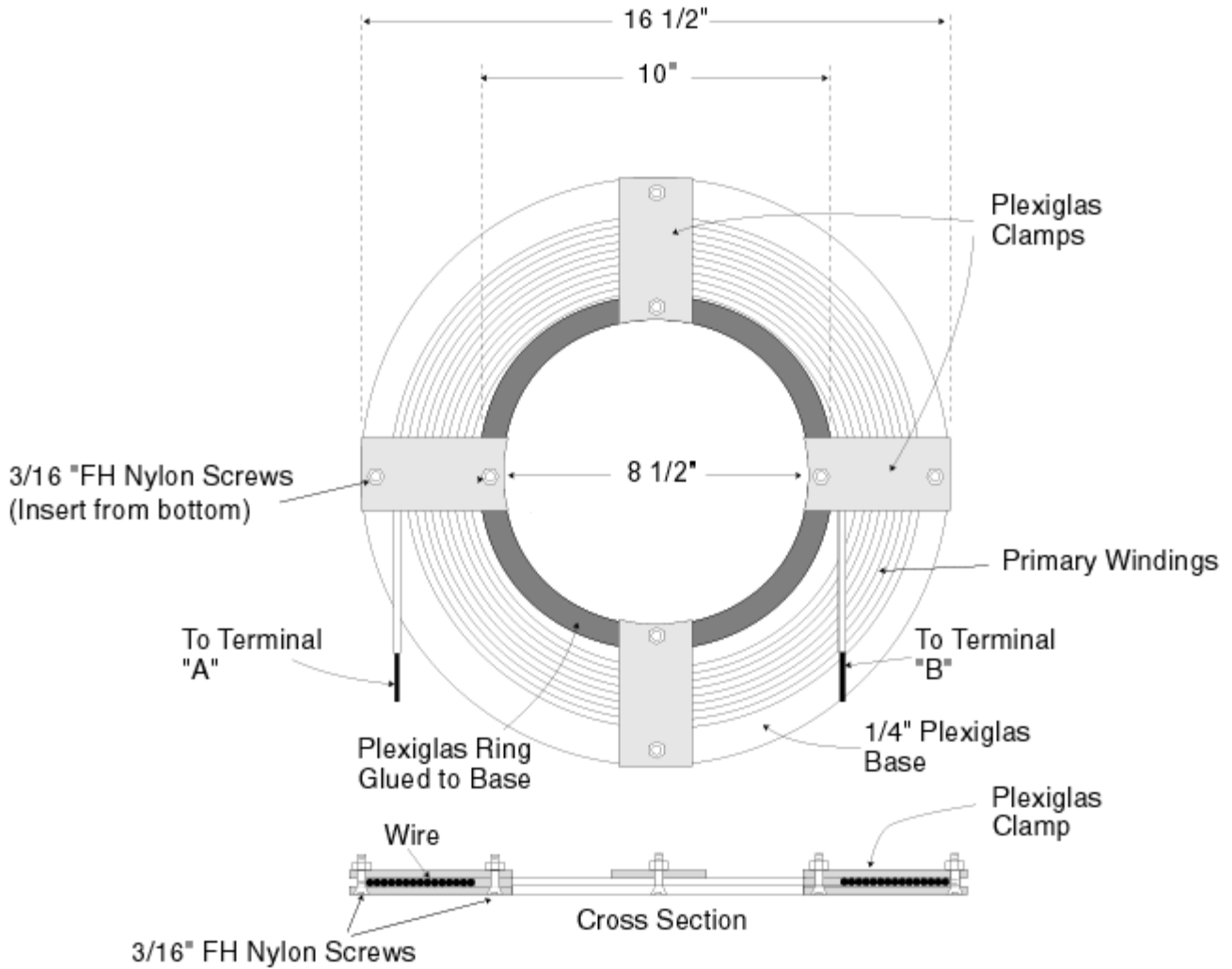
NO. I Primary Coil: The Primary Coil for No.I consists of approximately 15 turns of #10 THHN stranded wire wound in a flat spiral on a 16 1/2" diameter x 1/4" thick Plexiglas base (Fig. 8).

To help hold the turns in place, a ring of 1/4" Plexiglas with an OD of 10" and ID of 8 1/2" is glued to the base.

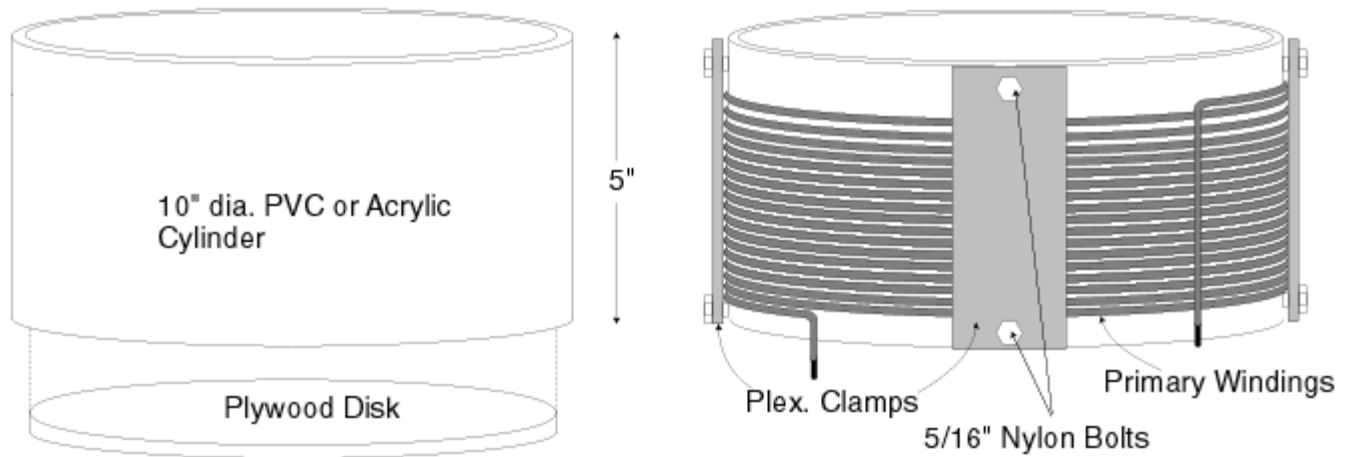
Four pieces of Plexiglas are used as clamps to secure the wire. Use FH nylon bolts to attach the clamps to the base. Countersink the holes in the bottom of the base and insert the bolts from the bottom, so the base will lie flat.

Wind on 18 tight, even turns and leave enough wire free at the center to reach Terminal B on the cabinet. Direction of turns doesn't matter.





**Fig. 8 - Spiral Primary for No. 1 Tesla Coil**



**NO. II Primary Coil:** The Primary Coil form for No. II is simply a cylinder of 10" diameter PVC pipe 5" long (Fig. 9). If Plexiglas or another plastic is used as a substitute, it must be rigid and strong enough to take the primary windings without warping.

Cut a disk of 3/4" plywood to fit flush in the bottom of the cylinder, varnish or paint the disk, and glue in place with epoxy cement. If additional strength is desired, peg the disk with three or four 1/4" dia. wooden dowels.

Four 1/4" x 2" x 5" Plexiglas clamps hold the primary wire in place. Use 1/4" nylon bolts to attach the clamps.

The Primary Coil for No. II will require approximately 15-18 turns of #10 THHN stranded wire. Before buying wire, check that the diameter of the wire is no greater than 0.170", which will yield just under 6 turns per inch. Direction of winding isn't important, but appearance suggests clockwise.

A more compact coil of fewer turns can be made using #8 enameled wire, but this wire is stiff and more difficult to work with. Theoretically, slightly better performance should be obtained if #8 is used, but the author has never made an accurate comparison.

Start winding about 3/4" from the bottom of the form and wind on 20 even, tight turns. Winding will be easier if the first turn is secured with tape.

After final tuning, the clamps will be tightened and the turns further prevented from shifting by adding a turn or two of 2" wide electrical tape at the ends.

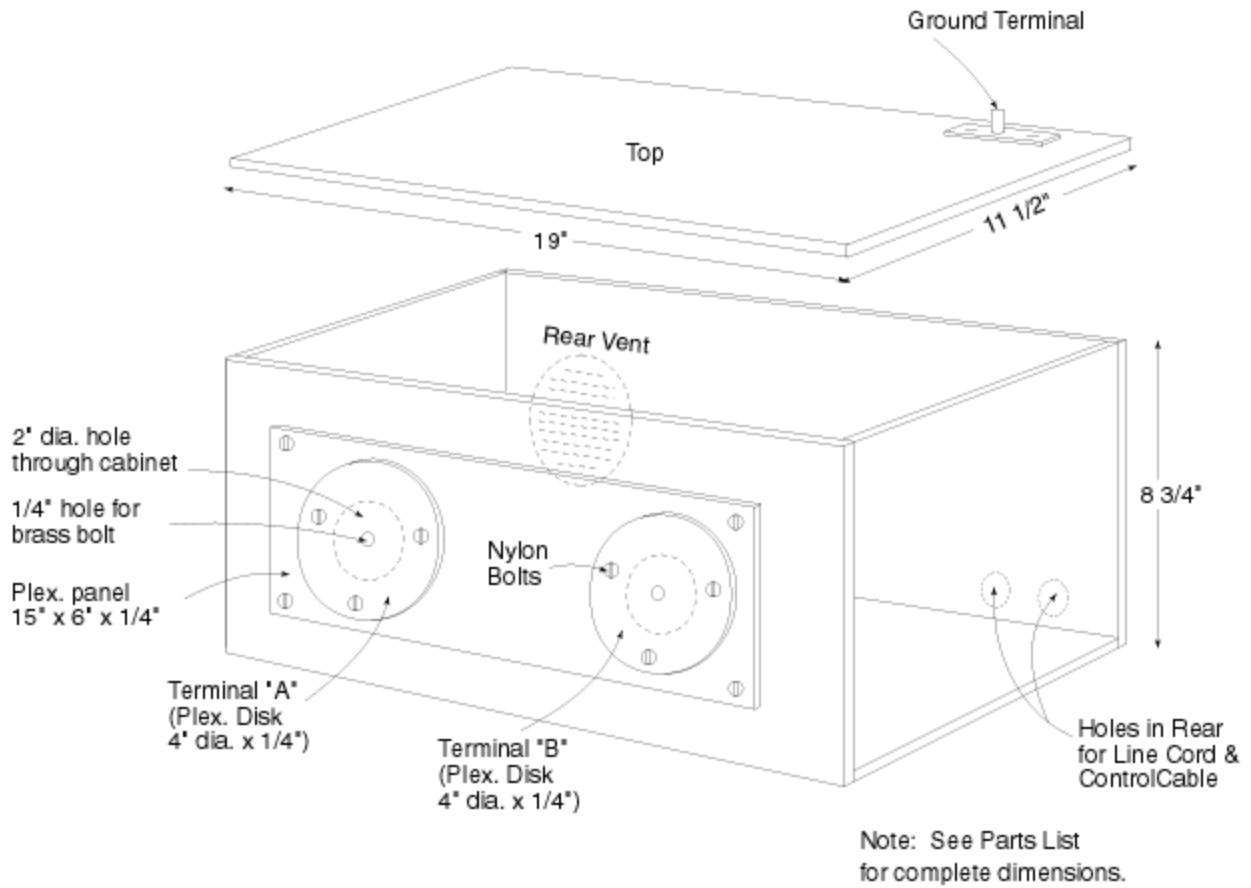
**Cabinet:** The Capacitor, Transformer, and Spark Gap are housed in a cabinet made of plywood, Plexiglas, or Formica-covered plywood (Fig. 10). If wood is used, varnish the interior.

Electrical components can vary in size, so it's a good idea to lay out all parts before deciding on the final cabinet dimensions.

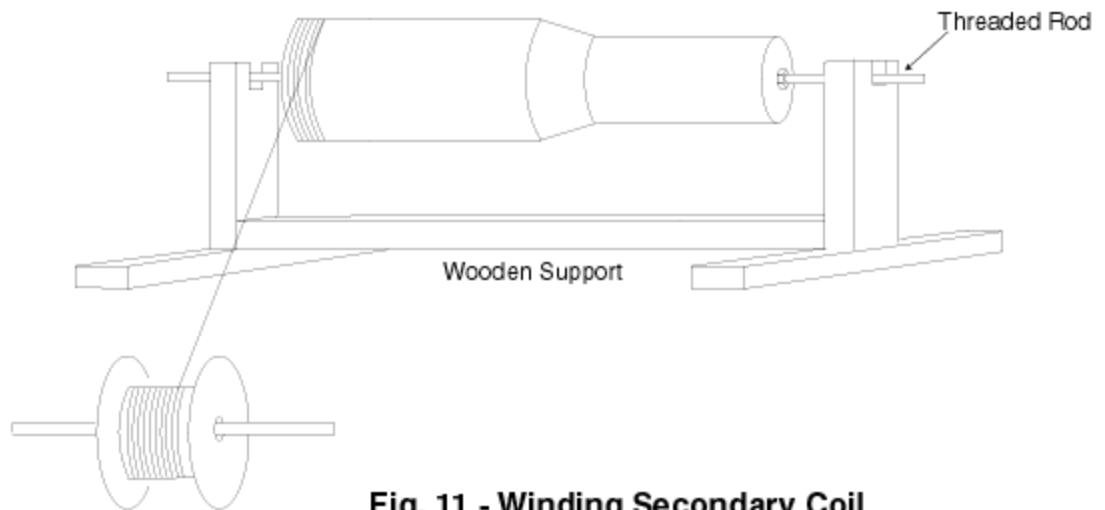
Add one or two vents to the rear of the cabinet to allow heat and corrosive gases from the spark-gap to escape.

Drill 2 holes in the rear corner for the AC line and control cable, and insert plastic grommets for appearance.

The front of the cabinet requires 2 feedthrough insulators. If attractive porcelain insulators of the correct size cannot be found, Plexiglas or phenolic disks or panels can be used instead. The main purpose of the insulators is to keep wiring away



**Fig. 10 - Cabinet**



**Fig. 11 - Winding Secondary Coil**

from the plywood, as wood conducts well enough to bleed off current going to the Primary Coil. It can also char and burn. Drill a 2" dia. hole in the cabinet behind each disk where the wires attach, so they'll be kept away from the wood.

The top of the cabinet should be easily removable for access to components. It can be held in place with a few wood screws, fitted over wooden pegs, or hinged.

Feet or wheels can be added to the bottom if desired. If the unit is to be used on stage, it can be bolted to a rolling cart that can hold accessories for demonstrations.

### **Winding the Secondary Coil**

Winding the Secondary Coil can be accomplished in a few hours and is the same basic procedure for both No. I and No. II.

Insert a piece of 3/8" dia. threaded rod through the Secondary Coil Form and secure the rod with a few nuts and washers.

Place the assembly across a wooden support bracket (Fig. 11). Suspend the wire spool using a similar arrangement.

Start winding at the bottom of the coil form, about 1/4" from the bottom edge. If you're right-handed, winding from left to right will be easiest. Tape the first turn in place with electrical tape, then have a partner rotate the form while you guide the wire.

The Secondary for No. I will require about 550 turns. Number II will take about 1,200 turns. There's no need to count turns, as small differences will be compensated for during the tuning process.

Keep turns tight and as close together as possible. Avoid kinks and don't allow turns to overlap. If a break occurs, solder the ends neatly, avoiding a large junction. Wrap a layer of electrical tape over the soldered area.

Winding the collar used on No. II can be made much easier if double-stick tape is applied across its surface. The tape will help prevent the wire from sliding. Even with tape applied it's almost impossible to make a perfect winding over the collar, so expect wider, slightly uneven spacing.

Stop winding just below the 1/8" dia. hole in the top of the coil form and tape the end windings securely. Leave about 10" of wire free to feed through the hole and attach to the Secondary Feedthrough Insulator.

Spray or brush several coats of clear polyurethane varnish on the windings and allow to dry.

Note: Varnish may dissolve the adhesive on the double-stick tape used on the collar of No. II. Prior to varnishing the collar, apply clear epoxy adhesive to several areas of the collar windings to hold the wire permanently in place. Be sure to smooth the epoxy down to prevent unsightly lumps.

If the Tesla Coil is to be handled frequently, you can protect the windings by adding a layer of electrical tape. Heavy vinyl tape 2" wide can be purchased at electrical parts houses. This tape can be wrapped neatly around the coil for a "gorilla-proof" finish.

Use some ingenuity when taping the collar to avoid wrinkling and bunching. The mylar collar pattern can be used as a guide for cutting tape to fit: lay several sections of tape on a flat surface (a formica table top is perfect) and then lay the pattern over the tape. Cut the tape to fit the pattern and then apply it to the collar. Final blending of edges can be aided with standard electrical tape, which will conform more easily to corners.

### **Discharge Electrode**

The Secondary Coil Feedthrough Insulator is for appearance and to elevate the discharge electrode an inch or two above the Secondary Coil. If a suitable porcelain insulator can't be found, Plexiglas or any similar insulating material can be used.

Note: If the insulator is to be screwed to the top of the Secondary, use nylon screws—no metal.

The No. I Secondary performs well with aluminum toroid or disk electrodes from 8 to 8 1/2" in diameter (Fig. 12). An 8" dia. sphere will have too large a surface area and is not recommended.

If a flat aluminum plate is used as a discharge electrode, it may be attached directly to the top of the secondary coil without a feedthrough insulator.

The No. II Secondary works best with toroid or spherical electrodes around 4" in diameter (Fig. 13). The Tesla Coil will work without a discharge electrode, but streamers will break free from the top winding, eventually burning the insulation.

Best results will be obtained if the Tesla Coil is tuned with the discharge electrode in place. Longer sparks may sometimes be obtained by attaching a sharp point to the discharge electrode.

## ATTACHING PRIMARY AND SECONDARY COILS

The Secondary Coil fits in the center of the Primary Coil. The bottom wire of the Secondary is brought out through a hole in the Primary Coil base and attached to the Ground terminal.

The Secondary can be attached to the Primary base with brass wood screws (Figs. 14-A&B). If the Secondary is to be removed frequently, a wooden peg 2" or 3" long can be used instead.

**Spark Gap:** Many variations of the basic spark gap exist, but the simple design shown in Fig. 15 is adequate for the Table Top coil.

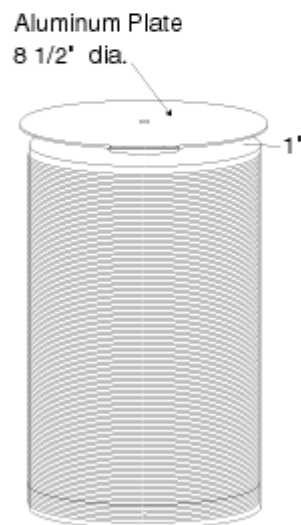
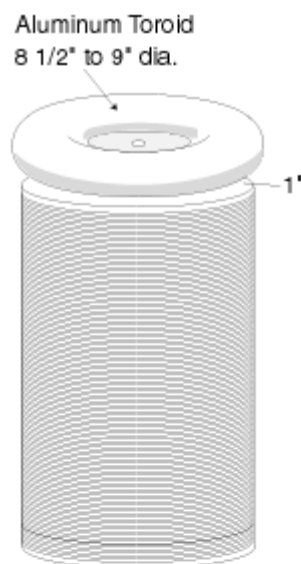
The posts are made from 3/4" x 3/4" solid brass stock. Brass rods comprising the Electrodes are clamped securely in each post by a split-hole arrangement. Tolerances are not terribly critical, but if cutting and drilling the brass is difficult, a machine shop should do the work at a reasonable cost.

The Spark Gap's plastic base is designed to minimize current leakage. As stated earlier, wood can bleed current from the high voltage wiring and can burn.

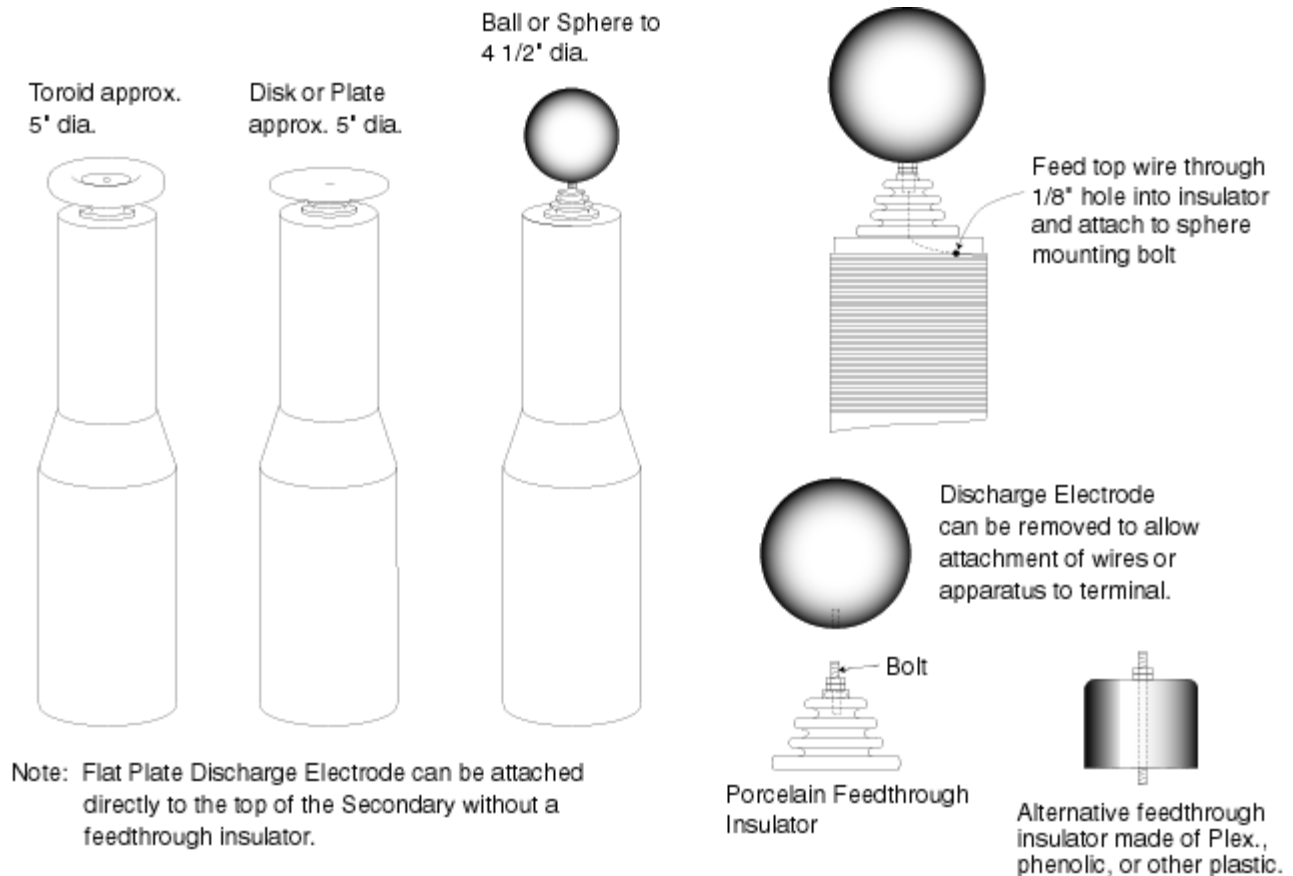
Plug the Tesla Coil into the AC outlet. Stand four feet away and turn the coil "on" for a brief instant. The Spark Gap should fire with a loud buzzing sound. The sparks jumping the gap should be blue-white in appearance. Don't stare at the gap for long periods, as the ultraviolet light produced can injure the eyes.

There should be at least some visible discharge from the top of the Secondary Coil.

If the Spark Gap "flames out" with a sputtering, yellowish spark, it may need to be opened. Do not exceed one inch maximum gap.



**Fig 12 - No. 1 Discharge Electrodes**



**Fig. 13 - No. II Discharge Electrodes**

Mount the Spark Gap using nylon bolts. Use nylon spacers or Plexiglas feet to raise the Spark Gap about 1/2" from the cabinet floor.

**Control Box:** The control box can be made from an inexpensive Bud Minibox or, for a deluxe version, a cast aluminum box.

Two switches are used: An S.P.S.T. toggle switch in series as a safety switch, and a pushbutton switch to activate the relay.

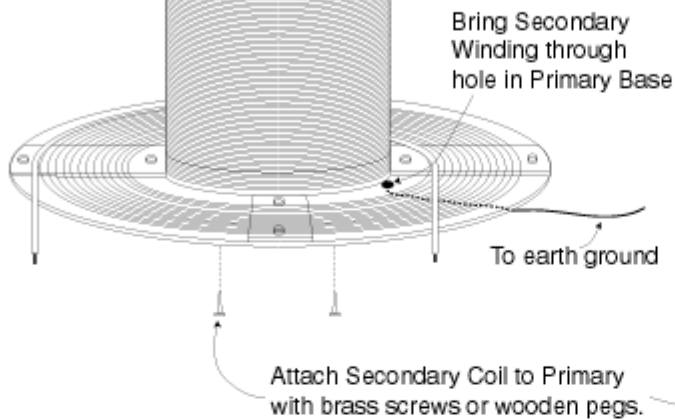
Attach the control-cable ground wire to the box with a solderless terminal and screw.

The aluminum boxes look excellent when sprayed with gray hammertone paint. If you paint, make sure to sand the boxes with 120- or 200-grit sandpaper and clean well with a compatible solvent. The paint manufacturer may recommend that an aluminum primer be used as well.

Several different types of strain reliefs are available for the control cable. You can go a step further and use a military-style connector.

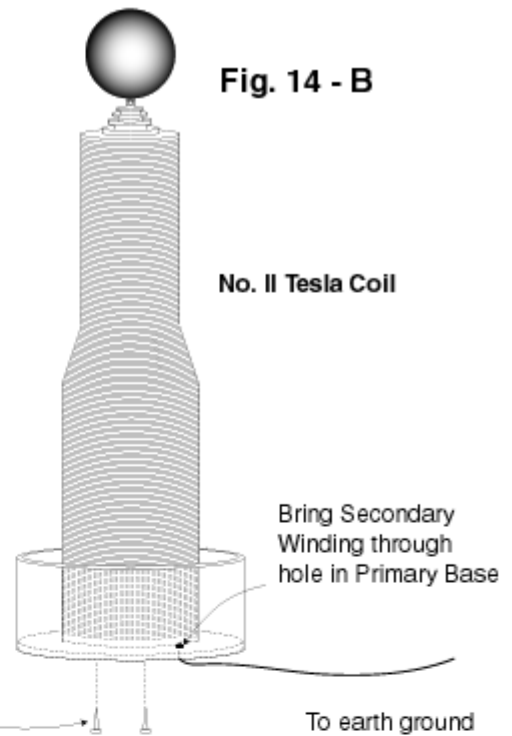
**Fig. 14 - A**

**No. I Tesla Coil**

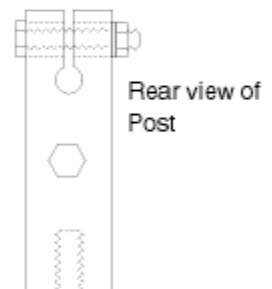
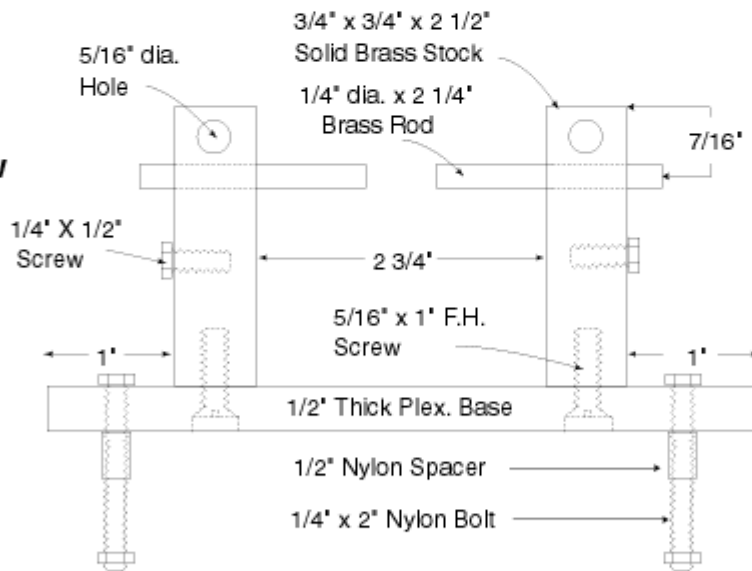


**Fig. 14 - B**

**No. II Tesla Coil**

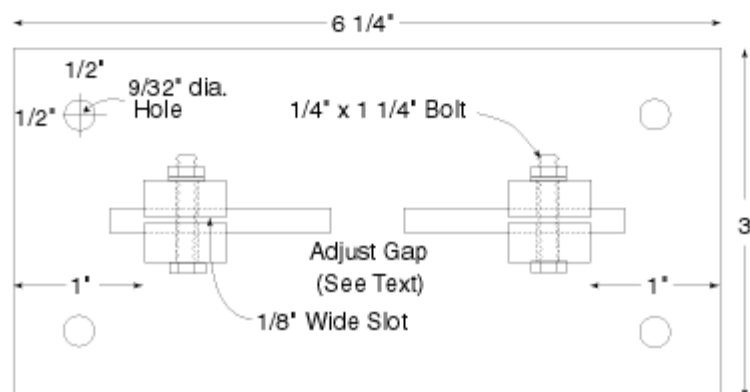


**Side View**



**Fig. 15 - Spark Gap Assembly**

**Top**





**Transformer:** A neon sign transformer rated at 15,000 Volts, 30 milliamps supplies power. Actown, Jefferson, or Franceformer are recommended. Specify an “outdoor” style, as this is the most economical. Transformers without ground-fault interrupters are preferred. (Author’s note: since this was written, neon sign transformers without ground-fault interrupters are almost impossible to find. Research online: maybe someone has figured out an easy way to bypass the GFI unit.

**Capacitor:** The capacitor must be able to withstand more than 15,000 Volts at a frequency of around 200 kHz. One supplier is Plastic Capacitors, Inc. When ordering, specify that the capacitor is to be used in a Tesla Coil Circuit. The commercial units are expensive, so prepare for sticker shock!

### Component Installation and Wiring

Lay out all components as shown in Fig. 16 and check clearances.

Bolt the Transformer, Capacitor, Spark Gap, Relay, and Fuse Holder to the cabinet floor according to the drawing.

Bring the AC line and control cable through holes in the rear of the cabinet and secure with nylon cable clamps.

Attach the AC and control cable ground wires to the Transformer ground lug.

Connect the Relay switch contacts to the Transformer with #12 or #14 stranded wire. Transformer polarity is not important.

Wire the Relay field coil with #18 or #20 hookup wire.

Use 15,000-volt neon sign wire between the Transformer high voltage terminals and the Capacitor. All wiring carrying high voltage must be kept away from the transformer case and other wires. Avoid running any wiring near the top of the cabinet in close proximity to the Primary Coil.

Wiring from the Capacitor to the Spark Gap, from the Spark Gap to Terminal A, and from the Capacitor to Terminal B should be #10 stranded. Attach wires to the Spark Gap with the 1/4" screws on each post. Use lock washers, but be careful not to strip the threads.

Solderless terminals can be used for all connections, but it’s a good idea to solder the #10 terminals to the wires for maximum conductivity.

Use good wiring practice, keeping wires short and neat. Route all wiring clear of high voltage areas. Bundle low voltage wiring with nylon wire ties and attach to the cabinet at appropriate intervals with nylon cable clamps.

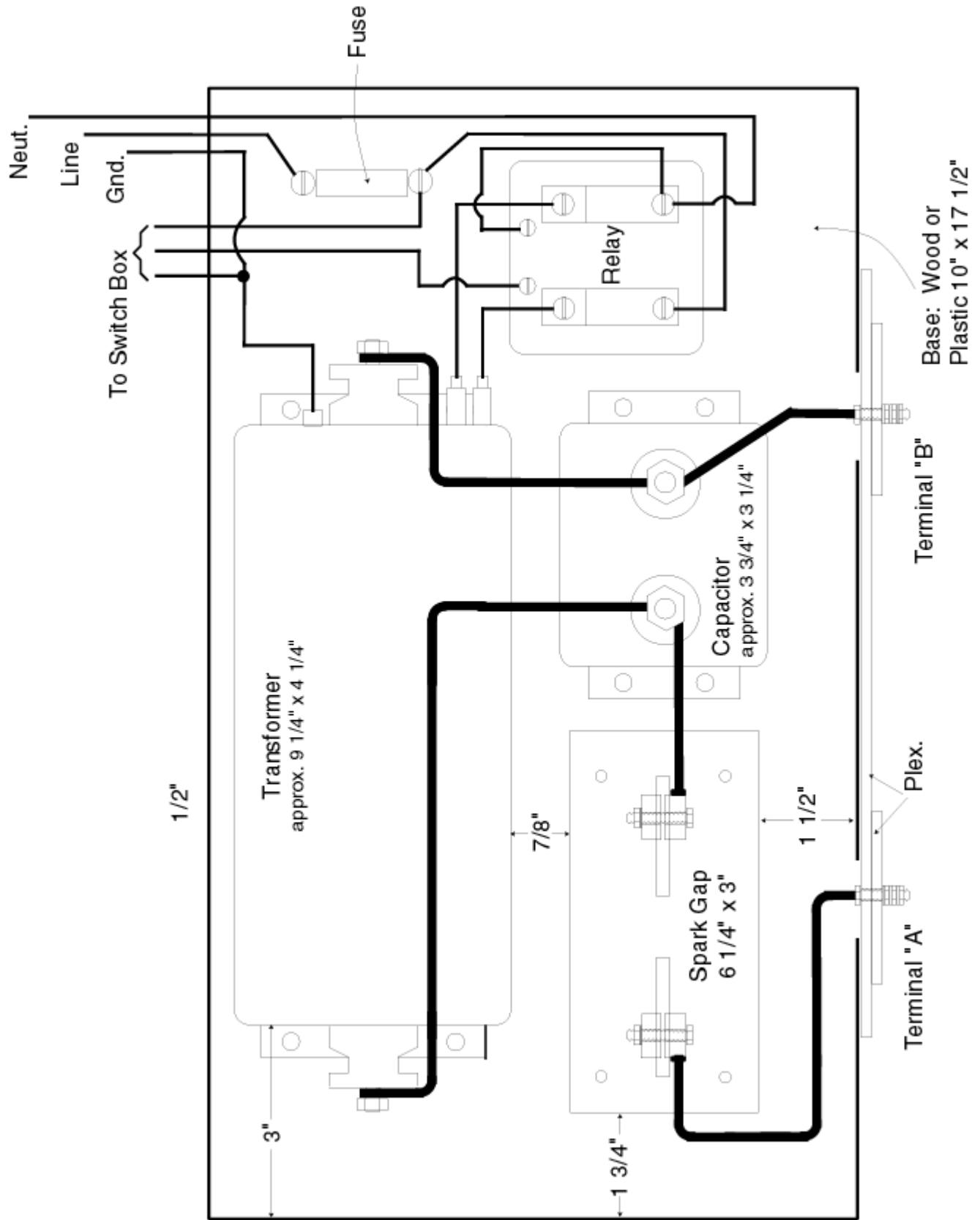


Fig 16 - Parts Layout

Wiring and components should be sufficiently secure that they cannot accidentally make contact with the Transformer high voltage terminals, Capacitor, Spark Gap, or associated high voltage wiring—damaging short circuits and fire can result.

### **Testing and Tuning**

After completing the internal wiring, adjust the Spark-Gap to about 3/4" separation, clamping the electrodes securely with the bolts at the top of each post.

Place the Tesla Coil at least four feet from metal objects. Keep it away from computers and other sensitive electronic apparatus (see section on Safety & Interference).

You'll want to observe the Spark Gap during testing and watch the other components for short-circuits. Instead of using the cabinet top piece, temporarily lay two short pieces of 2 x 2s or 2 x 4s across the cabinet top and place the Tesla Coil Primary/Secondary assembly on top.

Connect #10 wires from Terminals A and B to the Primary Coil leads.

Run the bottom wire of the Secondary to the ground terminal on the top of the cabinet, then run a length of #12 wire to the nearest earth ground. If the ground is more than 100 feet away, use #10 wire.

Coil performance will suffer if the ground connection is poor or a great distance away.

Sparking between the Secondary Coil and the Primary and to other components will occur if the ground connection is broken. This can damage the components and create a fire hazard.

Note: Acceptable earth grounds include metal cold water pipes, electric company grounds at the utility box, and lightning rod grounds. On occasion, steel building foundation supports will work. It is not advisable to use the ground wire supplied at the AC outlet.

Some buildings have "floating grounds," where conduit and utility boxes may not have normal ground connections.

If there is any doubt about a ground, test it by connecting a 100-watt lamp between the ground and the AC line. If the lamp glows at less than full brilliancy, find a better ground. Make sure that the ground wire does not touch either the Primary or Secondary.

If sparks jump along the Secondary Coil windings or between the Secondary and Primary Coils, increase the separation between the two coils before proceeding. This is most easily accomplished by raising the Secondary Coil a couple of inches using wood blocks or other insulating material. The sparking should cease when the coil is properly tuned.

Assuming the Spark Gap is working within reason and that a visible discharge is discernable from the top of the Coil, the tuning process can begin. Tuning consists mostly of adding and subtracting turns of wire on the Primary Coil until the precise number is found.

Unplug the Tesla Coil and remove one winding from the Primary Coil. (Instead of removing a turn, you can tap into the next turn by removing some insulation and attaching the wire temporarily with an alligator clip.) If you're using the Spiral Primary, remove or add turns at the outside of the spiral. If you're using the No. II Primary, remove or add turns at the top of the primary.

After tapping down one turn, turn the coil on again and watch the Secondary discharge. If it is longer, you're headed in the right direction. If the discharge is smaller, add a turn of wire.

Once the discharge is up to around 18"-20," fine-tune the coil by tapping in at shorter intervals and by varying the spacing between the last 2 or 3 turns of the Primary Coil.

The No. II Tesla Coil is capable of 24" discharges in free air and will strike a grounded metal rod at 18" to 20". The No. I Coil will produce somewhat brighter sparks about 18" long. Bright, heavy arcs can be drawn from the discharge terminal at short distances.

Once the final number of primary turns and wire spacing are determined, tighten the Plexiglas clamps to hold the windings firmly. Further stabilize the turns with 2"-wide electrical tape.

### **Trouble Shooting**

**Spark Gap Doesn't Fire:** Check that the Spark Gap is no wider than 1". Check wiring to make sure the transformer output leads aren't shorted.

If the gap still doesn't fire, disconnect the high voltage leads from the Transformer. The output from the Transformer will bridge a gap about 3/4" wide from pole to

pole and about 1/2" wide from either pole to ground. If the output is conspicuously weak, the Transformer may be defective.

Search for short or open circuits. When the transformer is activated, you should be able to hear the current hissing in the high voltage section if there is no short circuit.

If the Transformer is ok, check the Capacitor for a short or open circuit. A sensitive voltmeter can usually tell if there's a short, but a capacitor checker will probably be required to check further.

**Spark Gap Fires Intermittently:** If the gap is too wide, the spark will be intermittent or non-existent.

If Transformer is weak, the spark will decrease.

Check the Capacitor. A partial short-circuit in the Capacitor will reduce voltage across the gap.

Check high voltage wiring.

**Spark Gap "Flames-Out":** A yellowish, flaming spark across the gap can be caused by a narrow gap, by an open circuit in the Capacitor, or by partially-shortened Capacitor.

**Sparking Between Primary and Secondary:** Absence of an earth ground connection to the bottom wire of the Secondary will cause sparking between Primary and Secondary.

Poor tuning or a Primary Coil too close to the Secondary can also cause sparking. Make sure the Primary wires are no higher than 5" from the bottom of the Secondary Coil for the No. II design.

Low output from the Secondary Coil indicates that the tuning is off. Keep tuning until output from the Discharge Electrode is at maximum. The sparking between Primary and Secondary should disappear as the tuning is improved. If the sparking persists, try raising the Secondary Coil several inches above the bottom of the Primary (this should rarely be necessary).

**Leakage from Secondary Top Turn:** A discharge electrode smaller in diameter than the Secondary diameter will allow corona or discharge from the top turn of the Secondary.

Although a heavy application of electrical tape to the top turns will sometimes stop the corona, the best solution is to use a discharge electrode a fraction of an inch larger in diameter than the Secondary.

Note: If you experiment with different discharge electrodes, be sure to re-tune the coil for each change in surface area. A larger electrode will require more inductance in the Primary Coil, and vice versa.

## Experiments

Note: The Capacitor and Transformer are placed under considerable stress when the Coil is operated. Although the instrument has been designed to be rugged and dependable, leaving the Coil “on” for long periods will reduce the life of the components.

If the Coil is to be used for long periods, as in a museum display, a good duty cycle would be three seconds “on” with 10-15 seconds “off.” The coil can be switched “on” for 5-6 seconds several times in close succession if it is allowed a minute or two “off.”

**Free-Air Discharge:** The simple free-air discharge is probably the most spectacular phenomena. The high voltage appearing at the Discharge Electrode ionizes the air molecules and forms lightning-like channels through which the current passes.

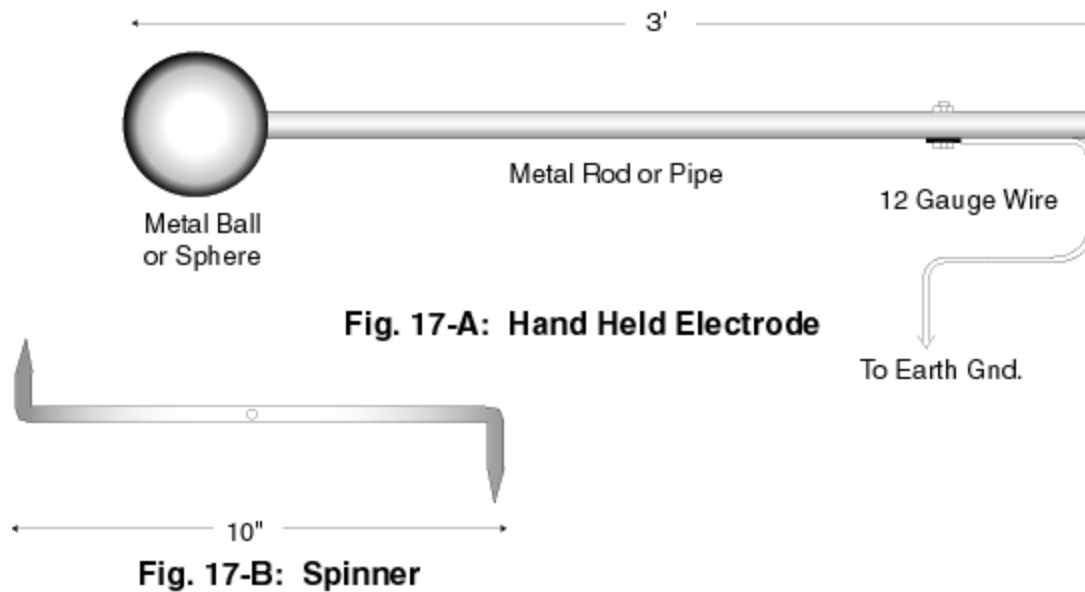
The violet glow is a result of electrons agitating air molecules and causing a release of photons. The buzzing sound emitted by the discharge is caused by rapid expansion of air as the electricity tears a path.

**Discharge to a Grounded Electrode:** A heavy, waving discharge can be drawn to an aluminum rod held in the bare hand. **Use a rod about 3 feet long and attach a ground lead of #12 wire between the rod and the coil’s earth ground (Fig. 17-A).**

Have an assistant turn the coil “on” and bring the rod close to the Discharge Electrode. No sensation will be felt as deadly-appearing streamers crackle to the rod.

Note: Never allow discharges to be drawn directly from the windings. This will burn the insulation and eventually ruin the coil.

**Electric Spinner:** A metal pinwheel rotor will spin at a moderate speed when attached to the Discharge Terminal. A lightweight rotor can be made from sheet



aluminum (See Fig. 17-B) and balanced atop a short wire attached to the Discharge Electrode. The popular explanation is that ionized molecules of air are repelled from the end of the rotor, causing it to spin.

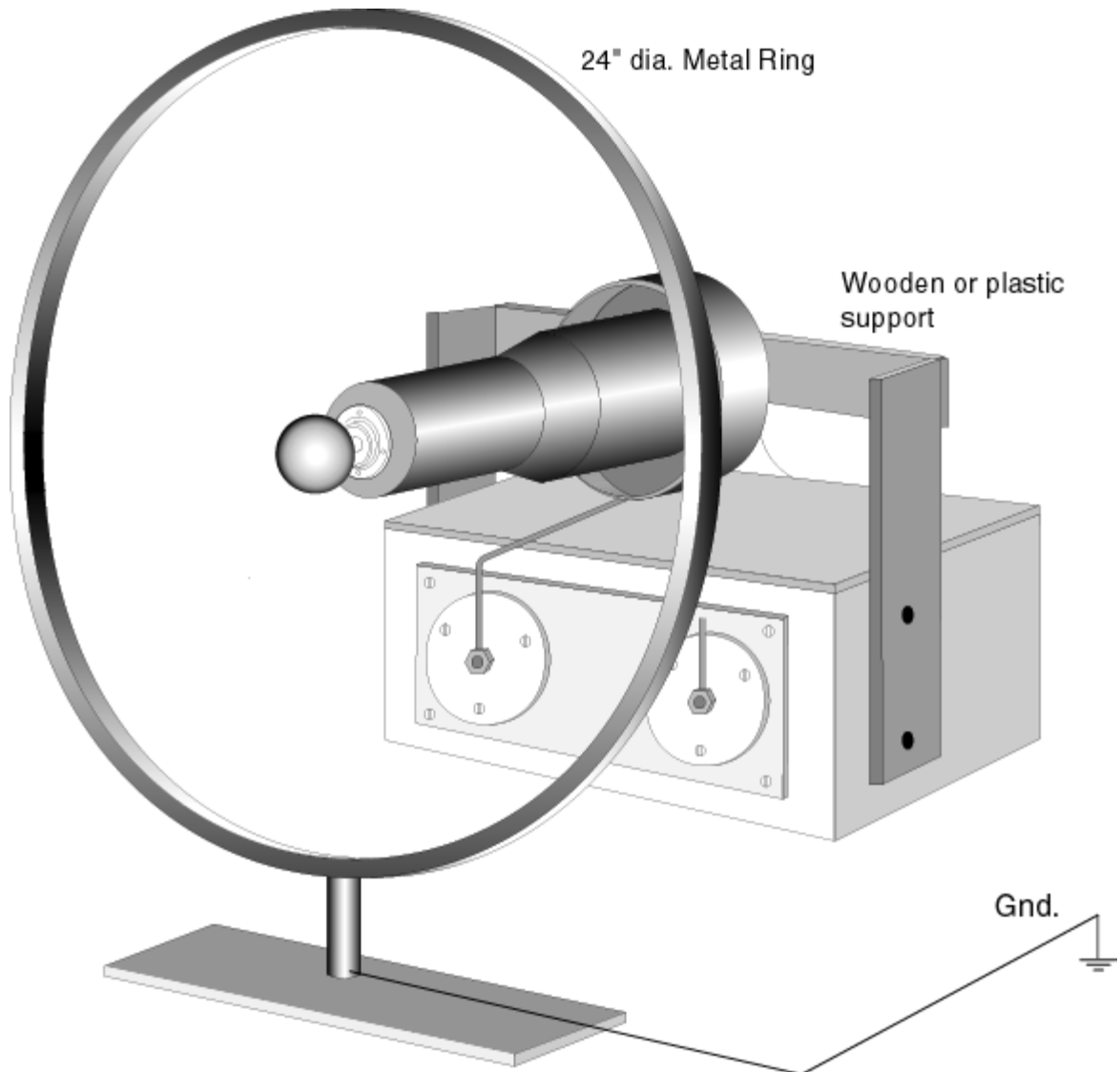
**Balloon Blaster:** Toss a well-inflated balloon at the Discharge Terminal. A streamer striking the balloon will pop it, and sometimes the range of the high-voltage “antiaircraft” is amazing.

**Kindling Paper:** Attach a wad of paper to the hand-held ground electrode and bring the rod close to the terminal. Streamers passing through the paper will set it ablaze in a matter of seconds. Aside from the obvious fire hazard, ash from the paper conducts electricity. Don’t let it collect on Secondary Coil.

**Hot Sparks:** Attach a tuft of fine steel wool to the end of the hand-held ground electrode and bring the rod close to the Discharge Electrode. The steel wool fibers will immediately burst into a shower of hot sparks as the streamers strike them. Exercise the same cautions that you would with burning paper.

**Ring Discharge:** Heavy, crackling streamers create fascinating, random patterns as they jump from the Discharge Electrode to a grounded, vertically-mounted ring 24 to 26 inches in diameter. The Tesla Coil must be mounted horizontally for this effect, as shown in Figure 18.

**Lightning Screen:** A variation of the Ring Discharge. Scintillating electrical discharges radiate outward from the center of a glass disk, appearing to cover most of the surface simultaneously. The Tesla Coil is mounted horizontally and the Discharge Electrode touches the center of a glass disk mounted inside a grounded, conducting ring 24 to 26 inches in diameter. This arrangement is identical to the Ring Discharge except that a disk of glass the same diameter as the ring is mounted inside the ring.



**Fig. 18 - Horizontal Coil with Discharge Ring**

**Conducting Through Glass:** Tape a 6" diameter aluminum disk to the center of both sides of the Lightning Screen. Heavy sparks can be pulled from the outside aluminum disk using the hand-held Ground Electrode.

This demonstrates the ability of a capacitor to pass currents of high frequency. A DC current would be blocked. (If a high voltage DC charge were applied to the disk, a high voltage would appear on the opposite disk by means of electrostatic induction, but no current would flow.)

**“Black Hole” Discharge:** Bend a stiff wire into a circle about 12" in diameter and attach to the Discharge Terminal. Streamers of electricity will radiate outward from the wire loop in a plane at right angles to the axis of the circle. No streamers will



dart to the inside. The appearance is that of a dark “hole” surrounded by luminous threads of electricity.

Like charges repel, so the streamers always radiate to the outside. The action of the electrostatic/electromagnetic fields confines the discharge to virtually one plane.

**Wireless Lights:** Hold neon and fluorescent lamps 5 to 10 feet from the Tesla Coil. They will glow even though no wires are attached. (Tesla once proposed lighting homes in this fashion.)

The rapidly varying electrostatic field from the Tesla Coil agitates the gas molecules inside the lamps, causing them to glow.

**Ozone Collector:** Invert a glass jar over the Discharge Terminal. The discharge will fill the jar with ozone and oxides of nitrogen. If bits of copper wire are placed in the jar and the jar sealed before the ozone escapes, a green scale will form on the wire overnight, showing the powerful oxidizing properties of ozone.

Avoid inhaling the ozone. It is a powerful irritant to the lungs and nasal membranes and can be dangerous in high concentrations. (See section on Safety.)

**Wireless Power Transmission:** Experiment with different wattage incandescent bulbs attached to the Discharge Terminal. Attach one lamp contact to the Discharge Terminal. Attach the other contact to ground, then to a short wire antenna, then to an elevated, insulated metal plate. Which arrangement gives the greatest brightness?

**Faraday Cage:** Make a small cage from metal window screen or chicken wire and ground it. Place a neon lamp inside the cage, and mount the cage where heavy sparks can be drawn to it. The lamp will not light inside the cage. This is because the electrostatic field is screened from the lamp by the conducting cage and current is shunted around the outside to ground.

**Additional Experiments:** Tesla used his powerful Magnifying Transmitter to prove his theory that electrical power could be transmitted around the planet without wires.

The input power of the Table Top Tesla Coil is far too small for true wireless power transmission, but some interesting and revealing experiments can be performed by testing the Coil’s effective energy transmitting range. (See section on Interference.)

Different antenna and tuning configurations can be attached to the Tesla Coil (the Primary tuning will have to be varied if the Tesla Coil is to “load” different antennas or radiating configurations.

A receiver can consist of a large coil (similar to the Tesla Coil Secondary) in conjunction with a capacitor and should be tuned to the Tesla Coil's resonant frequency (around 200 khz) or a harmonic. Different antennas, tuning configurations, and circuit components can be tried.

The receiver can be inductively coupled to a small incandescent light bulb or various meter arrangements.

An interesting goal is to see at how great a distance the lamp will glow, and then relate the power transmitted to the inverse square law regarding radiated energy.

### **Safety**

Potentially lethal currents flow in the primary high-voltage sections of the Table Top Tesla Coil. The particularly dangerous components include the Transformer, Capacitor, Spark Gap, Primary Coil, and associated wiring.

When the Transformer is connected to the Capacitor, the currents flowing throughout the high voltage circuit are especially deadly.

Current in the high voltage wiring can easily puncture the insulation of typical 600 V hookup wires and can sometimes jump more than an inch to a grounded conductor (or hand!). Never bring any part of the body close to the Primary Coil when the Tesla Coil is in operation.

The Capacitor can store a dangerous charge. Although it's shorted through the turns of the Transformer, it's always a good idea to assume that a charge remains. Before working close to the Capacitor, short the terminals with a length of high voltage wire.

High voltage conductors that remain in contact with wood can sometimes burn channels that will slowly increase their conductivity until a heavy current can pass. Always be on the lookout for subtle high voltage leakage.

The discharge from a normally-functioning Table Top Tesla Coil can shock if allowed to directly strike an unprotected hand, but the currents are not generally considered lethal. If a conductor is held in the hand and the person is insulated from ground, a slight tingling is usually felt when sparks are drawn to the conductor from the Discharge Electrode. If the conductor is well grounded and held in the bare hand, no sensation is felt.

The hand-held discharge electrode described in this manual is quite safe if correctly grounded and used as described.

The Spark Gap creates heat when the coil is operating. Although the Coil was not designed for continuous operation, if it is used intermittently over a long period of time, heat buildup should be acceptable.

The Spark Gap also creates ultraviolet light that could cause eye damage if viewed for prolonged periods.

Tesla Coil discharges produce ozone in sufficient quantities that good ventilation is required. Ozone is a lung irritant and can be dangerous in large quantities. Always operate the coil in a well-ventilated area.

### **Interference**

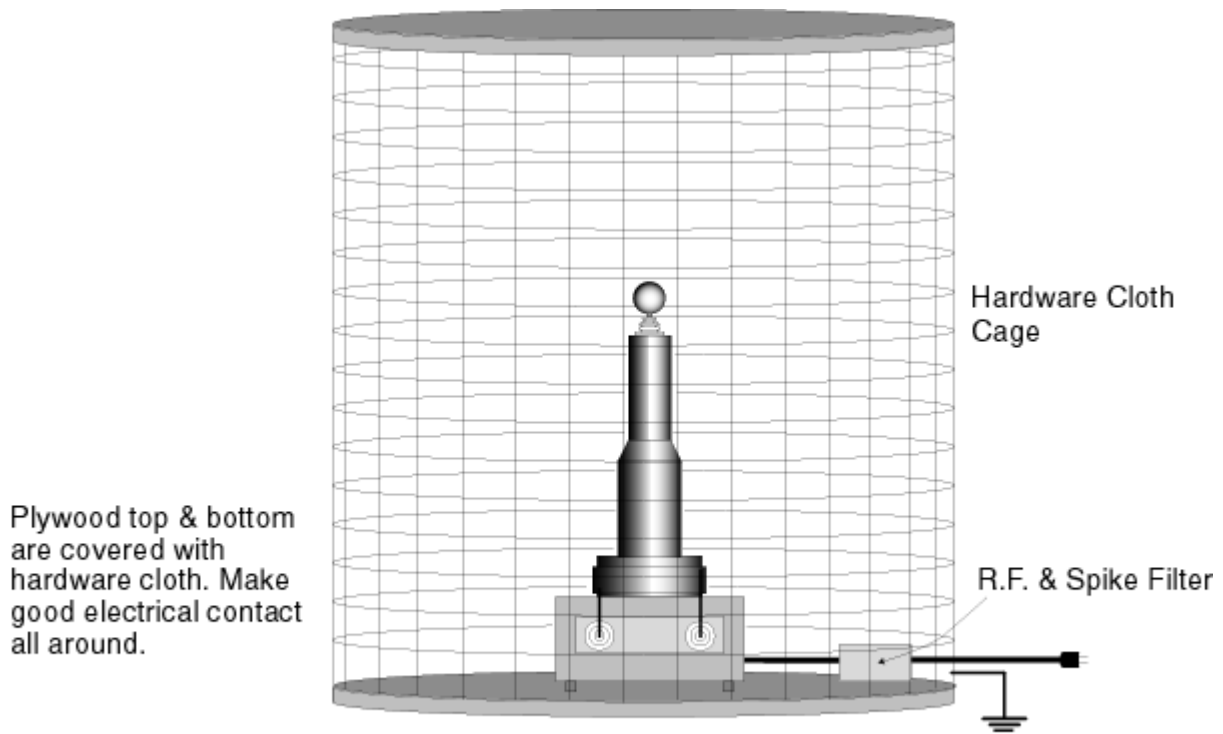
Tesla Coils produce a broad spectrum of electrical noise that can interfere with A.M. radio and television. The effective range of interference is determined by the propagation characteristics of the area in which the coil is used. A Table Top Tesla Coil used in a typical neighborhood might radiate detectable interference several blocks. Hooking the Coil to various antennas will greatly increase interference. It's a good idea to check the Coil's range with a portable radio. Keep operation of the Coil short and be aware of times of the day when interference will be most objectionable.

The interference produced by Tesla Coils is normally propagated through space and through the AC wiring. High voltage "spikes" and radio frequency interference conducted along the AC wiring can sometimes be strong enough to damage sensitive components in computers and other electronic apparatus.

The use of RF line filters and spike protectors in the Tesla Coil AC line may help a little, but it is best to have protection on the AC line feeding the sensitive electronic equipment. The best way to protect a nearby computer or VCR is to make sure they're turned off or unplugged.

In the author's experience, the Table Top Tesla Coil does not produce enough interference to damage a typical PC located more than 50 feet away. However, always assume that such damaging interference is present and make sure that nearby sensitive equipment is turned off.

Persons wearing a heart Pacemaker should keep away. How far? The author is not aware of conclusive tests, but an educated guess is that 100' would ensure safety. No claim is made regarding accuracy of this figure.



**Fig. 19 - Tesla Coil in Faraday Cage**

**An “Interference-Proof” Tesla Coil:** If the Tesla Coil is used in an environment shared by computers and similar apparatus, the Tesla Coil’s interference can be significantly reduced by enclosing it in a Faraday Cage made of hardware cloth or chicken wire (Fig. 19).

Cage wire should make good electrical contact on all sides. Add an RF and spike filter to the AC line to keep transients out of the wiring. Cage should be well grounded and should be large enough to contain discharge without allowing direct sparking to the cage wall.

## PARTS LIST

### SECONDARY COIL FORM FOR DESIGN NO. I:

1. 1 piece sched. 40 PVC pipe (or similar plastic) 8" O.D. x 13"
2. 1 piece 1/2" or 3/4" plywood disk to fit inside 8" dia. pipe
3. 1 piece 1/4" Plexiglas disk to fit inside 8" dia. pipe

### SECONDARY COIL FORM FOR DESIGN NO. II:

1. 1 piece sched. 40 PVC pipe 6" O.D. x 13" long
2. 1 piece sched. 40 PVC pipe 4" O.D. x 13" long
3. 2 pieces 1/2" or 3/4" plywood disks to fit 6" dia. PVC pipe
4. 1 piece 3/4" or 1/2" plywood disk to fit 4" dia. PVC pipe
5. 1 piece 1/4" plastic disk to fit 4" dia. PVC pipe
6. 1 plastic "collar" as per Fig. 7.

### PRIMARY COIL FORM FOR DESIGN NO. I:

1. 1 piece 1/4" Plexiglas Disk 19" dia. (See Fig. 8.)
2. 4 pieces 1/4" Plexiglas approx. 4" x 5 1/4"

### PRIMARY COIL FORM FOR DESIGN NO. II:

1. 1 piece Sched. 40 PVC pipe 10" O.D. x 5" long (Fig. 19.)
2. 1 piece 3/4" plywood disk to fit 10" dia. PVC pipe

### PLYWOOD CABINET

Note: Lay out all components to verify the sizes shown below. (See Fig. 10.)

1. One Bottom piece of 3/4" plywood 17 1/2" x 10"
2. One Top piece of 3/4" plywood 19" x 11 1/2"
3. One Front Piece of 3/4" plywood 19" x 8 3/4"
4. One Back Piece of 3/4" plywood 19" x 8 3/4"
5. Two Side Pieces of 3/4" plywood 10" x 8 3/4"

**COMPONENTS:**

1. One 15,000-volt 30 mA. Neon Sign Transformer
2. One 15,000-volt R.M.S., A.C., .005 mfd. Capacitor
3. One 120 V.A.C., D.P.S.T., 30 A. Relay w/120 V.A.C. coil (Magnecraft # W199AX-9 or equivalent)
4. One 15 A. Fuse Holder & 15 A. fuses
5. One Bud Cast-Aluminum box 4 11/16" x 3 11/16" x 2 7/32
6. One SPST 120 V. toggle switch
7. One 120 V. single-pole, momentary-contact, N.O. Pushbutton
8. Three Feedthrough Insulators (for cabinet and top of Secondary) approx. 2" long with 1/4" to 3/8" dia. center holes for bolts
9. One Aluminum or copper ball, sphere, or toroid for Discharge Electrode (see text)
10. Ground Terminal for top of Cabinet

**SPARK GAP:**

1. 2 pieces solid brass 3/4" x 3/4" x 3"
2. 2 pieces brass rod 1/4" x 2 1/2"
3. 2 pieces Plexiglass or phenolic 1/4" x 3" x 5"
4. 2 hex-head bolts 1/4" x 1 1/4" w/nuts, washers, & lock washers
5. 2 hex-head bolts 1/4" x 1/2" w/lock washers
6. 2 FH machine screws 1/4" x 1"

**WIRE:**

1. #24 enameled magnet wire for winding Secondary Coil. Design No. I will require about 1,200' and Design No.II will require about 1,600'. Allow an extra 10% in each case.
2. 75' #10 THHN stranded wire for winding and tuning the Primary Coil
3. 3' 15,000-volt neon sign wire
4. 3-conductor #12 or #14 Line cord and plug
5. #18 hookup wire
6. #12 or larger stranded wire to connect Coil to earth ground.