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Constructing a Jacob's Ladder

By Stephen Knubley of Voyage Scientifica, Educational Presentations in St. Louis, MO.

After reading two articles about building a Jacob's Ladder (**Science First** Plan 12-009 - see other page - and another which recommends at least a 10 KV transformer for decent arc length), I located two different **neon transformers** that were take-outs from signs. The **30 MA 12 KV** unit cost me $40, and the **60 MA 15 KV** cost $50. I was told that the largest transformer that I could expect to find reasonably easy would have been a 60 MA 18 KV unit. The sign installer, from whom I bought the larger unit, gave me a few tips for my Jacob's Ladder. I put the switch and fuse in line with the Common (larger) blade of the AC, grounding plug. He recommended using a momentary "on" switch as a safety device placed at a reasonable distance from the Ladder.

Both transformers had their output terminals mounted not on top, side-by-side, but at opposite ends of their oblong case. For appearance sake, since I had planned to demonstrate these units before various grades of Elementary School students, I gave some thought as how to bend the wire "ladders" in a desirable and identical shape. I tried forming a jig on my workbench using 1-1/2" dowels screwed to the bench for forming the bends. That worked for solid rods (like coat hanger), but not for small diameter aluminium, brass or copper tubing, which creased at a certain angle of bend.

I remembered that the sign installer suggested trying **brake line tubing.** The tubing at an auto parts store comes in various lengths. I bought a pair about 45" long, with about 3/16" diameter. While I was there, the salesman suggested that I use a **brake-line tubing bender,** which I purchased for less than $10. Where the bench forming jig worked fine for a solid rod, the bender was a blessing for tubing. It is adjustable for several tubing diameters, and the resulting brake-line tubing "ladders" look great!

To attach the ladders to the transformers, I also purchased two sets of heavy-duty side-post **battery terminals,** which are found at most service stations. A set costs less than $3. These worked very well, easily bolting to the side transformer terminals, with the cable clamps pointing vertically. The ladders simply slide into the cable slot, which is tightened by a pair of nuts and bolts. I replaced the bolts with thumbscrews, since I have to remove the ladders frequently for transporting the units to school presentations.

The ladders were formed so that there was the recommended 1/4" to 3/8" gap to start the arc. Gap adjustment is simple: I loosen one or both cable clamps by their thumbscrews and swivel the ladders for the exact gap desired. I did not want to secure the tops of the ladders to a framework, but to be free standing. For this reason I used the stiffer road and tubing materials aforementioned. However, the arcing induces a vibration which causes the ladders to "sway." This sometimes causes the arc to extinguish prematurely, but almost always guarantees a start to the arc. To keep the arc climbing, and stop the swaying, I slipped a **nylon washer** over the ladders and it dropped to the narrowest gap. I also use small **nylon wire ties.** These help to adjust to the correct gap.

Finally, I mounted the transformers on their own **wood (insulating) base**, with **rubber feet.** The base actually gives me room to attach a pair of carrying handles, since these transformers are heavy and awkward. The height of the ladders is extended by additional tubing slipped over the rodded ladder, or in the tubing ladder. In this way, the arc easily climbs another foot in height. The arcs extinguish when the gap approaches 3" to 4 1/4" for respective units. As a side note, the arcs vary greatly in climb speed, duration and final width. Sometimes the arc climbs to the top and stays lit for a while in an interesting inverted Vee shape.

The school children seem to love the effects of the Jacob's Ladder, including its sound.

They also understand that this device is NOT one to be touched or played with, unlike some Van de Graafs and Tesla Coils.

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More On Jacob's Ladders

By F. B. Lee, teacher, inventor, and founder of **Science First**

This is the name given to a pair of parallel wires between which a spark slowly rises. To construct one, you need a **high voltage transformer** and **wire.**

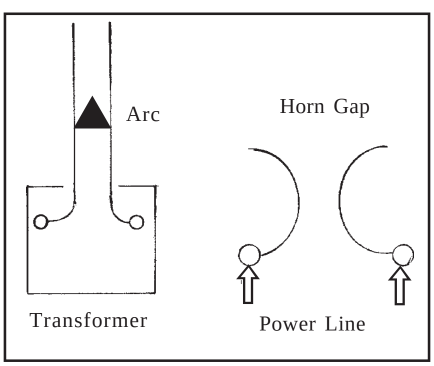
The transformer should be the **high impedance** type used in bug killers, oil burner ignition, or neon signs. There is a good reason you should not use a power type transformer - your fuses will blow or your circuit breaker will go out. As soon as a spark begins, the ionized gases drain all available energy into enlarging the spark and generating heat. High-impedance transformers limit this tendency and maintain a spark or arc of manageable proportions.

To start the arc, the two wires which are the sides of the ladder must be close enough at some point for a spark to jump. For a bug killer transformer, this distance may be about 1/4", for a neon transformer about 3/4". This point must be near the bottom of the ladder since the hot gas in the arc rises. Interestingly, in a zero gravity situation, the arc would not rise and in a windy environment, the arc could actually go down the ladder. Try turning the Jacobs Ladder you make on its side or upside down.

The color of the arc depends on the gases in its makeup. Usually this is a reddish violet from the nitrogen and oxygen of the air. However, the arc also contains metal ions from the wire. This is especially true where here is enough power in the arc to evaporate some metal from the ladder sides. Coating the electrodes with various materials may allow different colors. **Salt** gives a yellow tint; **boric acid** green; **copper chloride** green; **lithium** or **potassium chloride** red.

If the Jacob's Ladder is placed inside a glass tube, you can control the gas atmosphere and thus produce various colors.: **argon** - blue; **hydrogen** -0 blue; **neon** - red; **natural gas** (rich in hydrogen) - blue 0- **helium** - yellow.

there is one practical application of the Jacob's Ladder principle - the **horn gap.** This device is sometime placed across a power line, usually isolated rural areas, where power surges due to lightning or sudden land charges are possible. Where the surge comes, an arc forms which quenches the surge. The arc rises in the gap and quickly blows out. Lights on this power line will flicker briefly when the horn gap operates.



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About **Science First** -

We were founded by Frank Lee who, at age 12, bought his first lathe and equipped his folks' garage with the best machine shop around. Later, as a science teacher, he developed practical devices to use in his own classroom. Our company, now in its second generation of family ownership, designs and makes hands-on labs for physics, physical science, math, technology and electronics.

95 Botsford Place, Buffalo, N.Y. 14216 U.S.A.
1-800-875-3214 • FAX 716-874-9853 • e-mail: info@sciencefirst.com • www.sciencefirst.com