Richard G. Aurandt

The Griffith Observatory's Tesla Coil

The Tesla Coil exhibited in the Hall of Science at the Griffith Observatory, was constructed in the 1920's by Earl Ovington. It is reported that Mr. Ovington built the coil for presentations ~~use~~ on the vaudeville stage, a common use for Tesla Coils during that period. The coil as it appears in the 'Hall of Science' is really only half of the original 'Ovington' outfit. That is, the complete unit was two coils butted together at their bases with their axis in a horizontal plane rather than vertically oriented in which case the spark jumped from one end to the other, a spark in excess of eight feet. A double ended ~~coil~~, WITH A MIDPOINT GROUND, is a halfwave coil whereas the single ended ~~resonator~~ variety is a quarter wave.

Mr. Ovington was an associate of Dr. Fredric ~~K.~~ F. Strong, and together they collaborated on the construction and ~~use~~ application of high frequency high potential medical equipment. The coil was given to Dr. Strong by Mr. Ovington who then, in 1937, donated the facility to the Griffith Observatory.

In its halfwave double ended configuration it was to large to be set up in the available space. Thus it was necessary to separate the coil into two quarter wave resonators and set one of them up as a single ended vertical unit; this arrangement sometimes refered to as an Oudin (~~Maurice A. Oudin, M.S.EE.~~) coil or resonator.

The preparation of the coil as it is seen was done under the direction of Mr. Leon Hall, technical director of the observatory at its inception. Mr. Hall with the assistance of Mr. Kenneth Strickfaden, an authority on all types of high frequency high potential equipment, Tesla coils in particular, set the coil up in the observatory basement as two independent quarter wave units looking at one another, again producing a spark over eight feet long. In the arrangement just ~~mentioned~~ described, each coil (~~quarter wave section~~) had its own primary winding. The primaries were so connected as too require only one capacitor bank, spark gap and 60 hertz high voltage transformer. Unfortunatly, as previously stated, the available display location was only large enough for one of the quarter wave cones and its associated primary. Thus the other secondary and its primary were stored away ~~for spares~~ too be used when the demonstration unit was in need of service. This turned out to be a wise decision as at some point between 1937 and 1951 the lower fourinches of the demonstration coils secondary burned out and was replaced with the spare unit. The coil now on display had a similar failure at the top, but was able to be salvaged by the removal of a few top turns.

Again in 1951, the secondary with the damage lower section was borrowed by the Moody Institute of Science. The damaged lower secondary turns were removed, reducing the secondary length from 49" to 45", in the remaining 4" space a six turn primary of rubber covered power line (industrial !) cable having a diameter of one half inch was wound; the winding of the primary and secondary on the same form is a standard configuration in high frequency coil design. The coil was then connected with a 0.2 mfd capacitor, a syncronous rotary spark gap, three of the five primary turns and a 17,200 volt 10.4 KVA transformer. When the coil was first tried it drew over 100 amps at 117 volts but the spark from the coil was well over nine feet in length. While this may seem impossible, a spark over double the coils length, a well designed coil can easily breakdown twice its length if enough power is made available to it. That is, if a coil is correctly tuned, the high potential gradient exists only from end to end, a uniform voltage distribution does not occure from turn to turn but instead follows a sine curve along the total quarter wave length of the secondary wire. It is for this reason that high frequency inductances of the single layer type often have their last 20% stretched out in the case of cylinderical coils or the coils shaped as a cone thus providing more turns per unit length of wire at the ungrounded end.

Tesla, in his early work (1890's) realized the non-linearity of the voltage gradient along the secondary coil and compensated for it by winding the primary and 80% of the secondary on a large cylinderical form and the last 20% on a smaller elevated cylinder.

Mr. Ovington elected to employ the conical (tapered) coil form and constructed them (two) like a wooden barrel, that is, of several wooden disks per cone. Starting at the bottom with one of 36" in diameter and ending at the top with an 18" one. These disks are placed along a wooden dowel 48" long. The disks were then covered with wooden strips 49" (hypotenuse) long by 1/8" thick, tapering from 4" at one end to 2" at the other. The top and bottom of the cones was then provided with a turn of ½ round wooden moulding for winding termination and cosmetic appearance.

The winding itself consists of 400 turns of 18 gauge rubber covered stranded wire. Since the outside diameter of the insulation is approximately ~~is~~ an 1/8 of an inch, the winding is not space wound as is typically done when enameled wire is used. The winding, for physically protective reasons, was then covered with a layer of 3/16" twine, much like a small rope. This surface was then given a coat of red glyptol, a finish frequently used for electrical equipment where high voltage insulation is important. Befor leaving the secondary winding it would be well to point out that the frequency of the coil will be in wave length, four times the actual secondary wire (not cone or coil) length in meters — that is, to say, the secondary winding is a ¼ wave antenna coiled up.

The actual wavelength is slightly longer than the wire length as a result of the capacity introduced in the secondary by its being wound into a coil but using the wire length as a 1/4 wave measure, very close estimates can be derived regarding the primary inductance and capacitance.

The balance of the circuit consists of a primary coil, a primary capacitor, spark gap, transformer, and line filter.

The primary coil consists of 10 turns of 3/16 x 3/4" copper ribbon spirally wound radiating out from the base of the secondary cone; roughly three turns of this winding are used to obtain resonance with the secondary. Ten turns were wound as it was not absolutly certain the value of the original capacitor and too many turns was safer than too few.

The capacitors provided with the coil were large Leyden jars, approximatly 8" in diameter by 18" tall. Eight of these jars gave a capacity of around .125 ufd which was a fairly good match for the power available. These jars were supported in a wooden frame similar to a "GIANT" test tube rack. The coil came with extra jars as apparently Mr. Ovington new what was to come when he designed the outfit. As suggested, over the years, the Leyden jars broke down (punctured) and were one by one, consumed.

Hence the capacitor is now a glass plate stack of 60 copper plates, 14" by 15", separated by 3/16" window glass. As to the electrical quality of the window glass as compared with what may have been "quartz" in the leyden jars, a standard dielectric used in commercial Leyden jars used for spark radio transmitting equipment and other high frequency high voltage applications at the start of the century, there is some uncertainty. The capacity of the glass stack is approximately .117 uf and since 3/16" glass plates (.187") are employed at 200-250 volts per mil the ~~can~~ dielectric should stand ~~approximately~~ 37.4→46.8 KV's, an adaquit safty margin since it is charged with only 10,000 volts ~~rms~~. (14 KV P.P).

The spark gap used with the Griffith coil is a non syncronous (does not rotate in step with the 60 hertz supply line frequency), Marconi type, that is, a revolving disk with axiallly oriented electrodes placed around its periphery rotates between two stationary electrodes, thus as the disk revolves ~~each~~ electrode on the disk comes inbetween the two stationary electrodes providing two small spark gaps wich then can be broken down by the transformer voltage. Their are 14 electrodes equally spaced on a 12" bakelite disk. The rotary as well as the stationary electrodes are 3/8" in deameter and

Tungsten tiped. When a moving electrode is in line with the stationary electrodes a total of 1/8" spacing exists.

It is frequently though that in some way the rotary gap is envolved with the frequency (wavelength) at which the coil operates, this is not exactcly true. The frequency of oscillation is dictated by the L/C (Inductance/Capacitance) ratio as needed to resonate with the secondary winding, the rotary, or for that mater, whatever type of spark is used does, indeed, influence the wave shape produced by the oscillator. winding. The wave shape has a significantioeffect on the appearance and sound of the spark. If the primary circuit is charged with a D.C. rather than an A.C. (60 hertz) source, the rate at which the rotary gap interrupts the primary current will be the only audible frequency ~~sound~~ in the spark.

The rotary gaps greatest advantage over other types is its self cleaning and cooling qualities, desirable chairitics where high power and frequsint operation is called for.

The transformer is a 10,000 volt 2 KVA (KVA - Kilovoltamp - is a term used in AC + circuits where inductances are involved as ats KW - kilowatt is used for AC + DC circuits having only resistance) unit manuf actured by the Reinhartd Transformer Co, it is of the high reactance type, for spark oscillator service, It was originally manufactured as a 20,000 volt unit with a midpoint ground but had been internally reconnected for 10,000 volts at twice the current (200 milamps) with one end grounded.

Because ~~the~~ a transformer being used to excite a spark gap oscillator is subjected to short circuit conditions each time the spark gap breaks down or when the capacitor is completely discharged it must either be a high reactance (self limiting) type or have its input or output limited by chokes or resistancesses, the chokes being preferable.

The capacity of the primary transformer is 2KVA as a good "rule of thumb" in Tesla Coil design is to use 500 VA (.5KVA) for every foot of spark needed. The location in the Hall of Science provides for a four foot spark, approximately one million volts, thus 2KVA is adaquit. The .5KVA/foot ratio is based on how bright the spark (current) against how long the spark (potential) and the ratio indicated produces a "good looking" spark for what ever length is chosen. This number only applies to well designed coils where good electrical considerations as well as good construction materials are employed.

The bottom line is electrical 'Q' (quality factor); all phases of the circuit, especially the high frequency circuitary must have the highest 'Q' possible.

Resistance is the negative aspect where 'Q' is concerned in inductors — as little as possible is the way to high 'Q' since 'Q' is the ratio of inductive reactance to resistance. A 'Q' of 10 or more is said to be good. The same holds true for the interconnecting cables, although in their case you want as little as possible of both resistance and reactance so a minimum of power will be dissipated in the interconnections. Since high frequencies flow on the surface of conductors, where high currents are involved, as in the primary circuit, large surface areas are desirable to permit the skin effect to handle the power with little resistance. It is for this reason that high power commercial facilities have their ~~interconnections~~ circuitary, ~~where it is exposed to atmosphere~~ silverplated as silver has one of the lowest oxide resistances, and in the case of the capacitors, they are best oil immersed or in some way sealed from the air least they not be equipted with silver plated plates; ~~In the case of the capacitor~~, the air also deposits a film on the exposed insulating surfaces which brings resistance in the form of surface leakage into the circuit.

The kVA rating of the transformer is again a ~~ratio~~ product of its voltage ~~to~~ times its current it is well to point out that you only need enough voltage to breakdown the spark gap and drive as much current as possible through the primary inductance. Since a capacitors volumn goes up by the square of the increase in voltage it is desirable to hold the transformer between 7-10KV and increase the current to increase the KVA for greater spark length.

The line filter ~~for the~~ is placed in the primary of the 60 hertz transformer and is composed of series inductances and shunt capacitances to ground. The function of this filter is to prevent any transients from finding their way back into the building wiring in so doing breaking down insulation and causing serious damage in general.

A frequently asked question concerning the lightning like (appearance only) spark coming from a Tesla Coil is ones ability to allow the spark to jump to him or stand on the coil (bare foot) and have the spark jump from his finger tips. These effects and many more were classic stage show performances starting back at the turn of the century. It must be rembered, that the "skin effect" of high frequency currents is what makes this possible and as the coil gets bigger the wavelength gets longer and so the depth of penetration becomes greater— this permits the current to effect more nerve endings and since the power level in big coils is greater to effect those nerve endings in a more unpleasant fasion. When doing stunts of this sort with big coils the demonstrator should not be grounded or especially when standing on a coil allow the spark to jump to ground as in either of these two cases the circuit is complete and logically greater currents will flow frequently causing ones muscles to react in a violent manner. When experimenting with a coil even as small as a few hundred volt amps lethal conditions may be incountered since although the power available may not electrocute a person it doesn't take much to stop the heart from electric shock. ~~Also when high power outfits (over 1KVA) are.~~ It should also be rembered that if there is a fair amount of current in the spark it is not recommended to receive the spark on the bare skin as this typically results in "Radio Frequency" burns; again the nerve endings are effected and R.F. burns may take a long time to heal. Thimbles on the finger tips ~~or~~ or ~~sets~~ some metal object held in the hand is the way to perform effects of this sort. Also, it is sometimes thought, that ones hair will stand on end, but since you are being charged with alternating current, your body takes on no net charge of ~~any me~~ a magnitude sufficient to cause this effect. To make ones hair stand on end the person must be charged with high voltage direct current obtained from an electro static generator (Van de Graaff) or a d.c. power supply. The Griffith coil is frequently mistaken for a Van de Graaff as it also has a ball on top but for different reasons. The Van de Graaff generator's ball is the capacitance ~~which~~ where the high potential is gradually accumulated where the Tesla Coil's ball is a series capacitance which improves the 'Q' of the secondary winding.

"Stunts" of the type discussed could not be safely done at the observatory due to the physical layout of the coils location, that is to say, ~~that~~ the walls are too close. If the power to the coil was cut down to a level where the spark could not reach the wall it would be feasable to produce these effects safely but much of the specticle would be lost.

At this point I would like to close by thanking those persons, who without their help this article would not have been possible.

In alphabetical order

The Staff of the Griffith Obervatory

Past.

Dr. C. Cleminshaw (Director)

Mr. Leon Hall

Present

Robb Hanson
Kim Johnson
Dr. E.C. Krupp (Director)
John Lofdahl
Wayne Nelson
Bret Paul
John Sepikas

personal associates

Ed Angell and Janice Neymark (Lexington Set Shop)
Lydia Hammond
Dr. Victor Hymowitz
James T. Shaffer
Kenneth Strickfaden

publications

Electricity at High Frequencies and High Potentials
H.L. Transtrom

High Voltage Laboratory Technique
Craggs and Meek

Standard Polyphase Apparatus and Systems
Maurice A. Oudin, M.S.

Richard C. Arnett