Tank Capacitor

The capacitor in the tank circuit has a very hard life indeed! Not only does it have to withstand high voltages (more than double the supply voltage!) but it has to cope with extremely high currents at high frequency (approx 100kHz to 300kHz).

Commercially available capacitors, capable of surviving Tesla coil use, are not off-the-shelf items. A common approach to aquiring a suitable capacitor is to build it yourself! This can work out a lot cheaper than buying a new one but can involve embarking on a whole new project of its own!

For your very first coil, you could make one of the cheapest high voltage capacitors available - a saltwater cap. All you need are some empty glass bottles (beer bottles are a favorite choice!), salt, water, some buckets and some wire! The performance is not great but they're certainly cheap to make, and easy. I decided not to use this type of cap. Initially, I planned to make a poly plate cap but half way through construction I changed my mind and built anMMC instead (Multi Mini Cap). It was quicker and easier to build but I still intend to finish the poly plate cap.

The Poly Plate Capacitor:

The poly plate cap consists of an alternating stack of metal plates and polyethylene dielectric sheets, with electrical connections made to the metal sheets, giving you the two capacitor terminals. The whole stack is placed in a suitable container and submerged in insulating oil (transformer oil), to improve insulation and eliminate/reduce corona losses.

Design Considerations:

The type of work a capacitor does determines what materials it can be made of. A small value of capacitance leads to a physically small capacitor. If you increase the voltage it is required to handle, it will need to be physically larger.

The speed at which energy is required to move in and out of the capacitor determines the type of dielectric material you can use. The higher the operating frequency, the more careful your choice of dielectric needs to be.

Voltage Rating:

Insulation: The two plates of a capacitor have to be sufficiently insulated from each other so that, at the operating voltage, a spark cannot jump the gap and generate a short. The dielectric between the plates provides this insulation. Different materials have different insulating ability, or **dielectric strength**s. A guide figure of 160V(RMS)* worth of insulation for every mil (0.001 inch) of poly used will give a longlife to your cap. This value applies to a dielectric built up from multiple sheets of thin polyethene (e.g. using 6mil sheeting).

Example: A single cap on a 10kV(RMS) NST will require a dielectric 62.5 mil thick.

As you increase the dielectric thickness, to a value where its insulation properties meet your voltage requirements, the value of capacitance will decrease accordingly (both properties are dependant on the dielectric thickness). To regain the lost capacitance you must increase the size of the plates.

Corona Trouble: As well as straight-forward failure due to insufficient insulation, corona dammage must be considered. Any high voltage conductor can generate corona. It appears as a hazy purple glow on the conductors surface. Placing the conductors in oil will reduce corona formation considerably but there is a limit to the oils ability. Corona can form in air bubbles between plates and cause localised heating. This can melt the polyethene and short out the cap, with explosive results! Corona can also eat away at the dielectric, weakening it.

A limit of 5kV(RMS)* per capacitor is advisable, to reduce the chance of cap failure.

*RMS is used to denote the average AC voltage of the power supply (the label rating) but the actual voltage can peak at 1.4 x VRMS

It is unlikely that you will be using a supply voltage for your coil as low as 5kV(RMS) so in order to limit the voltage accross any one capacitor, you can wire 2 or more in series. This has the effect of sharing the voltage equally between the caps, but only if all the series wired caps are identical in construction. Series wiring of different caps can give uneven voltage sharing and you may unexpectedly over-stress one of them (N.B. a short in one series cap will immediately overload the remaining ones!).

The Dielectric:

Our dielectric of choice is LDPE (low density polyethylene).

The most important component of any capacitor is the dielectric layer. For Tesla Coil use there are three specific requirements to be aware of. Firstly, we are dealing with very high voltages, so the **dielectric strength** needs to be adequate (see 'Voltage Rating' section above). The second, and less obvious, property to be aware of is the materials **dissipation factor**. The last property to consider is the **dielectric constant**.

Dissipation Factor: DF is a measure of how good the dielectric is at doing its job without absorbing energy by heating up. It is given as a value at a particular operating frequency. At the peak power levels (megawatts) and operating frequencies (100kHz to 300kHz) found in Tesla Coil tank circuits, heating up is a big problem and can destroy a cap by melting it! As the dielectric melts an arc can jump between the plates and discharge all the stored energy. With a poor DF rating, even if the cap does not fail, due to you only running it for short periods of time, it will still rob your system of energy and decrease your output. Bummer!

Dielectric Constant: The DC of a material indicates how good it will be for storing energy. The higher the DC value, the higher the capacitance value, for the same thickness of dielectric. The DC of a vacuum is 1, LDPE is about 2 and glass can be 5 to 10 (see the 'Material Properties' table in the 'Data Lists' section). Although a high DC value will make for a physically smaller capacitor, a low DF is what you should look for, then live with its DC value. Glass can give you 3 to 5 times more capacitance (for a given thickness) than LDPE, but its energy loss (at typical TC frequencies) could be 65 to 200 times worse than LDPE!

(The term 'dielectric constant' is more correctly refered to as 'relative permittivity', its value being relative to the permittivity of a vacuum).

Capacitor Calculations:

So far, I have not talked about capacitance or voltage rating, but now we will see how to determine their values.

Maximum Value of Capacitance:

The limiting factor for the size of capacitor is the power supply (PSU) you intend to use. Maximum power output from your coil requires the PSU to recharge the capacitor, fully, each mains half-cycle. This will occur when the impedance of the PSU matches that of the primary cap (at your line frequency, 50Hz or 60Hz). You can calculate your maximum capacitor value as follows:-

$$Z = \frac{E}{I}$$

PSU:
Z = impedance
E = output voltage
I = output current in amps

$$C = \frac{1}{6.2832 \times Z \times 0.00005}$$

Capacitor:
C = capacitance in uF (micro Farad)
Z = PSU impedance (from above equation)
(N.B. substitute 0.00005 with 0.00006 for 60Hz supply)

Example: For a 10Kv 100mA NST, Z = 100000, therefore C = 0.0318 uF

Series and Parallel wiring of capacitors:

Fig.1

Fig.2

Fig.3

Fig.4

The value of a single capacitor (Fig.1) is $C = C1$ (no surprise there!)

The value of series wired capacitors (Fig.2) is $\frac{1}{C} = \frac{1}{C1} + \frac{1}{C2} + \frac{1}{C3}$ or $C = \frac{1}{\left(\frac{1}{C1} + \frac{1}{C2} + \frac{1}{C3}\right)}$

The value of parallel wired capacitors (Fig.3) is $C = C1 + C2 + C3$

An example of series and parallel wired capacitors (Fig.4) $C = \frac{1}{\left(\frac{1}{C1} + \frac{1}{C2}\right)} + \frac{1}{\left(\frac{1}{C3} + \frac{1}{C4}\right)}$

(N.B. To calculate for more, or less, capacitors in series/parallel, add, or remove, 'Cn' or '1/Cn' terms, where 'n' is an integer).

Physical Capacitor Dimensions:

The value of capacitance of a capacitor is a product of its physical dimensions and the type of dielectric used. The simplest form of capacitor is an arrangement of two plates of area 'A', seperated by a dielectric of thickness 'D' (see Fig.1)

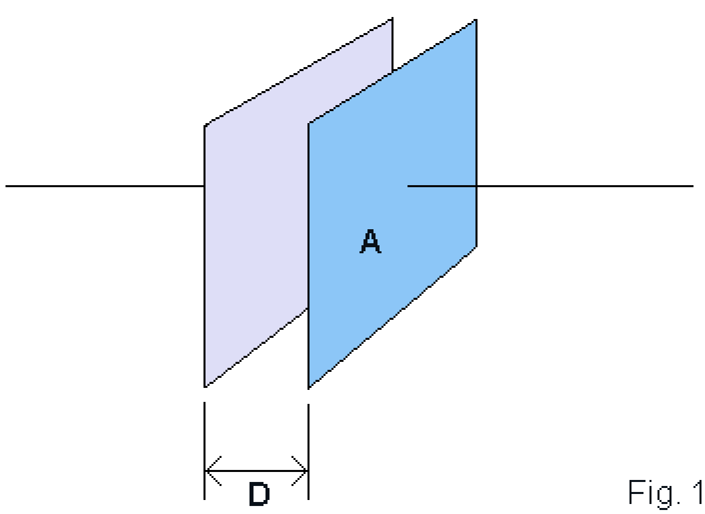


Fig. 1

The capacitance value of a two plate cap is calculated as follows:-

$$C = \frac{8.85\times10^{-12} \times DC \times A}{D}$$

C = capacitance in Farads
DC = dielectric constant
A = overlapping plate area in square metres
D = distance between plates in metres

(Take care to use the correct units when making calculations. A Farad is a million times bigger than a micro Farad).

Unlike the simple capacitor shown in Fig.1, real capacitors have their wire connections at the edges of the plates. Be careful with the area 'A' and include only the overlapping parts of the plates when working out its value (see Fig.2).

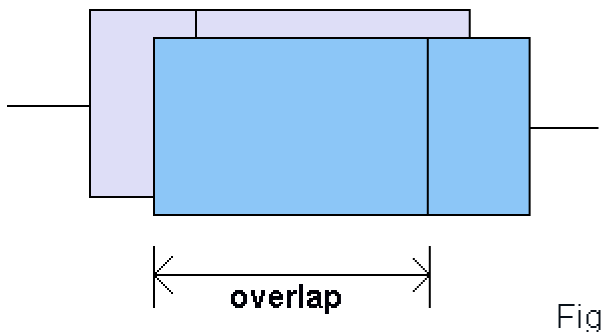


Fig. 2

A real capacitor will stack multiple plates and dielectric together. When this is done, you start to use both sides of all but the end two plates. A three plate cap has twice the capacitance of a two plate one (Fig.2 & Fig.3)

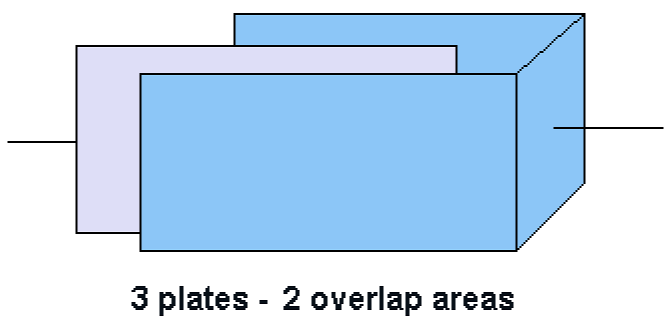
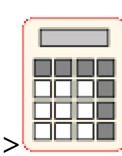


Fig. 3

The equation for calculating the value of a multi-plate cap is :-

$$C = \frac{8.85\times10^{-12} \times DC \times A}{D} \times (N-1)$$

C = capacitance in Farads
DC = dielectric constant
A = overlapping plate area in square metres
D = distance between plates in metres
N = number of plates

Use the capacitance calculator to work out your own parameters - > 

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