MandK - Mutual Inductance Computation Program
Version 3.1 - January 2, 2001

Disclaimer: This program is freeware. You are free to use this program as you wish. The author requests that commercial uses such as publication of results from this program in textbooks, etc., contain an acknowledgment recognizing the contribution of this author. I expect no royalties. As freeware, there are no warranties or guarantees for this program, and the author assumes no responsibility for the use of this software. This program computes the mutual inductance and other properties of two inductively linked tuned circuits. The user is responsible for the safe application of these principles. The construction of tesla coils, or any electrical circuit based on these principles, has many associated hazards. The author assumes NO responsibility for such applications. If you are not properly trained in the safe application of these principles, do not construct potentially lethal devices such as tesla coils!

The program "MandK" computes the mutual inductance "M" and the coefficient of coupling "K" between two coils, along with a few other parameters applicable to the construction of tesla coils. The value of this program is in its ability to simulate a number of possible tesla coil geometries before the actual construction of a coil system. The program is DOS based, and will run properly in an "MS DOS" box under the various flavors of Microsoft Windows. Apologies to UNIX/LINUX and MAC users.

The mutual inductance between two coils is computed using Neumann's double line integral (Reference: Inductance Calculations: Working Formulas and Tables by Frederick Grover, D. Van Nostrand Co., 1946, later reprinted by Dover Books.) This is somewhat different from the method used by Paul Nicholson in his ACMI program, so the two methods are complimentary. In the program MandK, the solution is achieved through a direct numerical integration, so the program may run for several minutes to several hours if many turns of wire are simulated in the computation. Results are printed on the screen and in an ASCII text file (for later review) as the computations proceed.

The primary coil can be a single layer solenoid, flat spiral or inverted cone coil. The secondary must be a single layer solenoid. Of course, the distinction between which coil is the primary and which is the secondary is arbitrary. The wires of each coil are assumed to be infinitely thin for the mutual inductance computation. However, the wire thickness is taken into account for the primary and secondary coil self inductance computations, so you must enter this information. Wire gauges are not used. Make sure you know the wire diameter when

The numerical integration is approximate due to the finite step size used, yielding a mutual inductance value M which is nominally within 1% of the true value. Similarly, K is usually within 5% of the true value, based on experimental data, due to additional uncertainties in the estimation of Lp and Ls. The error in M is due to the finite size of the conductors, proximity and skin effects, and due to the integration step size chosen by the program. Nonetheless, it provides results which are as good as one can measure experimentally.

While the calculation for "M" is highly accurate, the calculation for "Lp" for the inverted cone geometry is approximate, resulting in "K" values which are also approximate. The "M" values are correct, and one can use "M" from this program along with your measured "Lp" and "Ls" values to compute a more accurate value for K (where K=M/sqrt[Lp x Ls]). The "Lp" values for the flat spiral and solenoidal primary are fairly accurate, generally within 3-5% of measured values. Beware of false experimental measurements of Lp, especially if less than all of the turns in a flat spiral are used. Capacitance in the unused primary turns can cause erroneous Lp readings, even with expensive LCR meters!

The program assumes lumped element models in the results presented in the Operating

Characteristics section, although it incorporates distributed capacitance, skin effect and proximity effects based on empirical data from the literature (primarily Medhurst) and experimental data from a number of coil systems.

The program does minimal error checking and is prone to incorrect data inputs, so always check these parameters in the ASCII results file. This version of the program requires dimensional inputs to be in inches. Apologies to those of you who actually get to routinely use SI units in your respective countries. A sample results file called "SAMPLE.DAT" is included. It is an ASCII text file which can be viewed with most word processing programs. A second example is provided later in this document with annotations describing what is being presented.

You install the program by copying the files "MandK.exe" and "MandK.ini" to a folder on your hard disk, or by unZIPping the archive file, as appropriate. Then type "MandK" without the quotes followed by a carriage return while in a DOS box with the directory matching the location of the executable file. Alternatively, you can use the RUN command off the start menu in Windows. The file "mandk.ini" should be placed in the same folder as "mandk.exe". The ASCII results data file will be placed in this folder as well.

The input data consists of specifying the following parameters for the primary coil: select the type of coil, then: for a solenoid one must enter the diameter, height, number of turns and wire diameter, all in inches; for a flat spiral one must enter the inside and outside diameters, the number of turns and the wire diameter; for an inverted cone one must enter the inside and outside diameters, the vertical height of the outermost turn above the plane of the inside turn, the wire diameter and the number of turns. The primary coil can be specified using a fractional number of turns of wire, like 8.875 turns, if that is your tap point. The outer coil diameter for a flat spiral or inverted cone coil is best determined by measuring the radius from the center of the coil to the tap point, then double the dimension to get the outer diameter. If you do not know the actual number of turns on your secondary you can estimate it using another program like WINTESLA or TESLAC. You might also be able to determine this from the DC wire resistance if you can measure this and you happen to know the wire size of your secondary.

The secondary coil is defined by specifying the diameter, height, number of turns and wire diameter. The secondary axis is assumed to be concentric with the primary coil axis. The primary can be either inside of, or outside of, the secondary. Next, the starting and ending elevation of the bottom of the secondary must be specified, with respect to the bottom turn of the primary. For a conventional tesla coil, typical values are zero inches for the start and perhaps one secondary coil diameter for the ending parameter. Make them the same if you only need M for one position. For a magnifier, you will probably want to position the bottom of the secondary below the bottom turn of the primary, so the number entered must be negative. For a bipolar coil, position the primary in the center of the secondary. In this case, the Operating Characteristics results will be bogus, since they assume one end of the secondary coil is grounded, not the center of the coil as in a magnifier. The computations are made every ½ inch from the starting position to the ending position. This can be varied by editing the initialization file "mandk.ini" if you need values at different spacings. Similarly, the maximum toroid capacitance can be modified in the mandk.ini file if you are building a really large coil system. Change this file using an ASCII text editor such as NOTEPAD.

Here is a copy of contents of the file: "MandK.ini"
0.5
35.0
0
0

   The program only reads the first four lines of this file and expects to find the following information there: first line is the height increment for secondary position M calculations. The default is 0.5 inches. Include a decimal point on this line! Mutual inductance calculations will be made every 0.5 inches from the starting position to the ending position. The second line is the maximum toroid capacitance in pF, used in the Operating Characteristics section (but not required to compute M). A value which is a multiple of seven is convenient (but not required). The default is 35.0 pF. Include a decimal point with this line! Typical values are 35.0 (small coil systems) or 70.0 for large coil systems (higher for Greg Leyh!). The third line is 0 or 1 with no decimal point. Use a value of 1 if you want a toroid capacitance table printed out each time, 0 to omit it. A copy of this table is shown below. It provides general guidance on the approximate capacitance of a toroid of a specified size. The fourth line is 0 or 1 with no decimal point. Use a value of 1 if you want wavelength information included in the printout, 0 to omit it (useful in designing helical resonators, not so useful for tesla coilers). The sample results file provided later in this document is based on an initialization file with the parameters: 1.0, 70.0, 0 and 0. If the program cannot find or cannot read the initialization file, an error message is provided, but the program continues using the default values described above.

   When all coil parameters have been entered into MandK, you are asked to enter a file name. Use something like COIL1.DAT or any other valid DOS file name using seven or fewer letters in the name with a three-letter trailer. The program will write the results to this ASCII text file as well as on the screen as the processing slowly proceeds. It computes Lp, Ls and the distributed capacitance for the secondary coil, and then steps through a series of positions, computing M and K along the way. Finally, some operating characteristics are provided.

   One can speed up the processing at the expense of accuracy by specifying fewer turns for the coils. For example, a 700 turn secondary could be specified as having only 70 turns. Then Ls will be low by a factor of 100, and M will be low by a factor of 10, but the K value will still be correct, except for the inaccuracies due to the slight differences in coil geometries because of fewer terms (end effects).

   A copy of the toroid capacitance table is provided below. It can be generated by the MandK program if the "MandK.ini" file is modified. These values are isotropic capacitance. In an operating tesla coil, the capacitance increases about 1 pF per foot of spark length due to corona that builds up around the toroid. It also depends on the height of the toroid above the top turn of the coil. Read the table by selecting the column based on the torus diameter, then select the row based on the outside diameter of the toroid. For example, a 6" torus with an outside diameter of 30" has a capacitance of 31.66 pF. Don't forget to add a picofarad per foot of anticipated spark length, if you expect to operate the tesla coil with spark breakout.

Table of Toroid Capacitance in picofarads (pF)
Reference: Australian Journal of Physics, V7 1953, pp 347-350
### 1st Column Is Toroid Outside Diameter In Inches

Torus Circle Diameter in Inches

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
4.	4.34	4.93	5.51	6.10	6.68	7.26	7.85	8.43	9.02	9.60	10.19	10.77
6.	6.20	6.81	7.39	7.98	8.56	9.14	9.73	10.31	10.90	11.48	12.06	12.65
8.	7.95	8.69	9.27	9.86	10.44	11.02	11.61	12.19	12.78	13.36	13.94	14.53
10.	9.62	10.55	11.15	11.73	12.32	12.90	13.49	14.07	14.66	15.24	15.82	16.41
12.	11.23	12.39	13.03	13.61	14.20	14.78	15.37	15.95	16.54	17.12	17.70	18.29
14.	12.80	14.17	14.88	15.49	16.08	16.66	17.25	17.83	18.41	19.00	19.58	20.17
16.	14.32	15.90	16.76	17.37	17.96	18.54	19.13	19.71	20.29	20.88	21.46	22.05
18.	15.82	17.59	18.59	19.21	19.84	20.42	21.01	21.59	22.17	22.76	23.34	23.93
20.	17.29	19.24	20.38	21.11	21.72	22.30	22.89	23.47	24.05	24.64	25.22	25.81
22.	18.74	20.87	22.13	22.97	23.53	24.18	24.76	25.35	25.93	26.52	27.10	27.69
24.	20.16	22.47	23.85	24.79	25.44	26.06	26.64	27.23	27.81	28.40	28.98	29.57
26.	21.57	24.04	25.55	26.58	27.32	27.85	28.52	29.11	29.69	30.28	30.86	31.45
28.	22.97	25.59	27.22	28.34	29.17	29.77	30.40	30.99	31.57	32.16	32.74	33.32
30.	24.34	27.13	28.86	30.08	30.99	31.66	32.17	32.87	33.45	34.04	34.62	35.20
32.	25.71	28.65	30.49	31.80	32.78	33.52	34.09	34.75	35.33	35.92	36.50	37.08
34.	27.06	30.15	32.10	33.50	34.55	35.36	36.00	36.49	37.21	37.80	38.38	38.96
36.	28.40	31.64	33.70	35.18	36.30	37.18	37.87	38.42	39.09	39.67	40.26	40.84
38.	29.73	33.12	35.28	36.84	38.04	38.98	39.73	40.33	40.80	41.55	42.14	42.72
40.	31.05	34.58	36.84	38.49	39.75	40.76	41.56	42.21	42.74	43.43	44.02	44.60
42.	32.36	36.03	38.39	40.12	41.45	42.52	43.38	44.08	44.65	45.12	45.90	46.48
44.	33.66	37.48	39.93	41.73	43.14	44.26	45.18	45.93	46.55	47.06	47.78	48.36
46.	34.95	38.91	41.46	43.34	44.81	45.99	46.96	47.76	48.43	48.98	49.44	50.24
48.	36.24	40.33	42.97	44.93	46.46	47.70	48.73	49.58	50.29	50.88	51.38	52.12
50.	37.52	41.74	44.48	46.51	48.11	49.40	50.48	51.38	52.13	52.77	53.30	53.75
52.	38.79	43.15	45.98	48.08	49.74	51.09	52.22	53.16	53.96	54.64	55.21	55.70
54.	40.05	44.54	47.46	49.64	51.36	52.77	53.94	54.93	55.77	56.49	57.10	57.63
56.	41.31	45.93	48.94	51.19	52.97	54.43	55.65	56.69	57.57	58.33	58.98	59.54
58.	42.57	47.31	50.41	52.73	54.57	56.09	57.36	58.44	59.36	60.16	60.84	61.44
60.	43.81	48.69	51.87	54.26	56.16	57.73	59.05	60.17	61.14	61.97	62.69	63.32
62.	45.05	50.05	53.33	55.78	57.74	59.36	60.73	61.89	62.90	63.77	64.53	65.19
64.	46.29	51.41	54.77	57.30	59.32	60.99	62.40	63.60	64.65	65.56	66.35	67.05
66.	47.52	52.77	56.21	58.81	60.88	62.60	64.06	65.31	66.39	67.34	68.17	68.90
68.	48.75	54.12	57.65	60.31	62.44	64.21	65.71	67.00	68.12	69.10	69.97	70.73
70.	49.97	55.46	59.07	61.80	63.99	65.81	67.35	68.68	69.84	70.86	71.76	72.55
72.	51.18	56.80	60.49	63.28	65.53	67.40	68.98	70.36	71.56	72.61	73.54	74.36
74.	52.40	58.13	61.91	64.76	67.06	68.98	70.61	72.02	73.26	74.35	75.31	76.17
76.	53.60	59.46	63.32	66.24	68.59	70.55	72.23	73.68	74.95	76.07	77.07	77.96
78.	54.81	60.78	64.72	67.70	70.11	72.12	73.84	75.33	76.64	77.79	78.82	79.74
80.	56.01	62.10	66.12	69.16	71.62	73.68	75.44	76.97	78.32	79.51	80.57	81.51
82.	57.20	63.41	67.51	70.62	73.13	75.24	77.04	78.61	79.99	81.21	82.30	83.28
84.	58.40	64.72	68.90	72.07	74.63	76.78	78.63	80.23	81.65	82.90	84.03	85.03
86.	59.59	66.02	70.28	73.51	76.13	78.33	80.21	81.85	83.30	84.59	85.75	86.78
88.	60.77	67.32	71.66	74.95	77.62	79.86	81.79	83.47	84.95	86.27	87.46	88.52
90.	61.95	68.62	73.03	76.39	79.11	81.39	83.36	85.08	86.59	87.95	89.16	90.25
92.	63.13	69.91	74.40	77.81	80.59	82.92	84.92	86.68	88.23	89.61	90.86	91.98
94.	64.31	71.19	75.76	79.24	82.06	84.44	86.48	88.27	89.86	91.27	92.55	93.70
96.	65.48	72.48	77.12	80.66	83.53	85.95	88.03	89.86	91.48	92.93	94.23	95.41
98.	66.65	73.76	78.48	82.07	84.99	87.46	89.58	91.44	93.10	94.57	95.91	97.11
100.	67.81	75.04	79.83	83.48	86.46	88.96	91.12	93.02	94.71	96.22	97.58	98.81

A sample ASCII results file from the MandK program is provided below. The output of the program is highlighted in bold text, with added annotations in regular text.

```
Mutual Inductance Program V3.1
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Inverted Cone Primary Coil Geometry
Primary coil inside diameter (inches)=      18.000
Primary coil outside diameter (inches)=      45.500
Number of primary coil turns =     11.000
Last turn elevation in inches =      8.000
Wire diameter (inches)=        .6250
```

In this example the primary coil is of the inverted cone geometry, an example of which is shown here. In this case, one must specify the elevation of the outermost turn as well as the inside and outside diameters. This is a large primary coil.
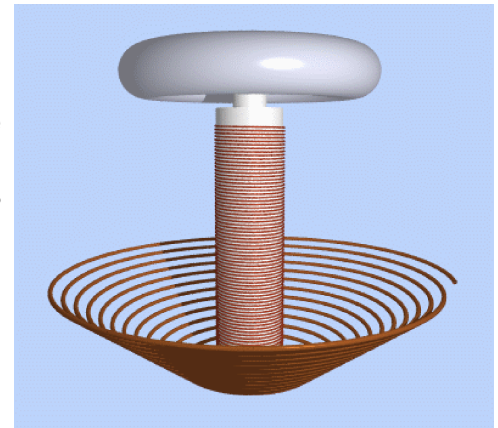
```
Solenoidal Secondary Coil Geometry
Secondary coil diameter (inches)=      14.000
Secondary coil height (inches)=      46.000
Number of secondary coil turns =   1085.000
Secondary coil wire diameter (inches)=        .0402
```

The secondary coil is also large, wound with 18 AWG wire. This program always assumes the secondary coil is cylindrical in shape. One can extract wire diameter information from the handy table below. You can also use this table to estimate how many pounds of wire you need to wind your next best tesla coil system. It can also be used to estimate the number of turns by comparing the DC resistance of the coil to the ohms per 1000 feet of wire of a particular size.

A.W.G.	Ohms/1000 ft	Area (mils)	Diameter (inches)	Pounds/1000 ft
1	.13	84060.27	.2894	274.877
2	.16	66661.59	.2577	217.983
3	.20	52864.07	.2295	172.865
4	.25	41922.34	.2043	137.086
5	.32	33245.31	.1820	108.712
6	.40	26364.24	.1620	86.211
7	.51	20907.41	.1443	68.367
8	.64	16580.02	.1285	54.217
9	.81	13148.31	.1144	42.995
10	1.02	10426.89	.1019	34.096
11	1.28	8268.75	.0907	27.039
12	1.62	6557.29	.0808	21.442
13	2.04	5200.07	.0719	17.004
14	2.57	4123.77	.0641	13.485
15	3.24	3270.24	.0570	10.694
16	4.09	2593.37	.0508	8.480
17	5.16	2056.60	.0452	6.725
18	6.50	1630.93	.0403	5.333
19	8.20	1293.36	.0359	4.229
20	10.34	1025.66	.0319	3.354

```
A.W.G.   Ohms/1000 ft    Area (mils)    Diameter (inches)    Pounds/1000 ft
  21        13.04          813.37             .0284               2.660
  22        16.44          645.02             .0253               2.109
  23        20.74          511.52             .0226               1.673
  24        26.15          405.64             .0201               1.326
  25        32.97          321.68             .0179               1.052
  26        41.58          255.10             .0159                .834
  27        52.44          202.30             .0142                .662
  28        66.12          160.43             .0126                .525
  29        83.38          127.22             .0112                .416
  30       105.15          100.89             .0100                .330
  31       132.60           80.01             .0089                .262
  32       167.21           63.45             .0079                .207
  33       210.86           50.32             .0071                .165
  34       265.90           39.90             .0063                .130
  35       335.30           31.64             .0056                .103
  36       422.83           25.09             .0050                .082
  37       533.20           19.90             .0044                .065
  38       672.39           15.78             .0040                .052
  39       847.90           12.51             .0035                .041
  40      1069.23            9.92             .0031                .032
```

Calculational Results
Primary coil inductance in microhenries: Lp =   120.28
Secondary coil inductance in microhenries: Ls =   110942.00
Figure of Merit (square root of Ls/Lp) =   30.37
Primary coil wire length in feet =   91.31
Secondary coil wire length in feet =   3976.73
DC secondary resistance in ohms: 25.86
Secondary coil distributed capacitance in picofarads: 22.91
 (Medhurst formula, assumes one end of secondary is grounded)

The results above show the primary to have 120 uH of inductance and the secondary to have 111 mH of inductance (a rather large coil system). Ls is computed using Lundin's formula, and Lp is calculated using formulas from Grover (interpolated, in the case of an inverted cone geometry). The figure of merit is an estimate of the voltage rise expected for this coil system: expect the peak output voltage to be about 30 times the peak input voltage. Losses may reduce this substantially, and resonant rise in the primary may cause this to be higher than expected if the primary peak voltage is enhanced due to resonance effect in the charging circuit. The wire length provides guidance on how many feet of tubing to buy. Plan on 25 or 50 foot increments if purchasing copper tubing, and wind more than you expect to need (since the tendency is to increase toroid size for maximum spark length). The secondary wire length provides an indication of how much wire to buy. The DC resistance along with the wire length and number of turns can be compared with the wire chart above to see if they match. The distributed capacitance is based on the Medhurst formula, which assumes one end of the secondary is grounded (not true in the case of a magnifier).

```
Mutual Inductance Results
Position is the secondary coil bottom wire position in inches
above the bottom wire of the primary coil.
A negative value means the bottom wire of the
secondary is below the bottom wire of the primary.
A positive value means that the bottom wire of the
secondary is above the bottom wire of the primary coil.
M = Mutual Inductance in microhenries
K = Coefficient of Coupling: K =  M / square root ( Lp x Ls )

        Position            M                 K
        -2.000           822.105            .2251
        -1.000           784.268            .2147
          .000           742.904            .2034
         1.000           699.100            .1914
         2.000           654.372            .1791
         3.000           610.024            .1670
         4.000           566.933            .1552
         5.000           525.643            .1439
         6.000           486.476            .1332
```

In this example, the coil was operated with the bottom turn of the secondary positioned in the same plane as the bottom turn of the primary, resulting in a coupling coefficient of 0.20, (position 0.0 in the printout above). This is very tight coupling compared to the 0.10 to 0.15 typically used in non-magnifier tesla coil systems. One could raise the secondary so it is 4" above the bottom turn to drop the coupling to 15.5%. Note the relative position specification here is the opposite of that used in the ACMI program. The calculation of M was made every 1" in this example. The file "MandK.ini" was modified in this case from its nominal 0.5" spacing (See comments above about the "Mandk.ini" file).

This program can be used to perform another useful exercise by calculating how the primary bathes a portion of the coil, specifically, a secondary coil which is only 1" in height. Calculate M from -2" to 45" to see how the primary bathes a small 1" section of the coil (using 24.76 turns). You will find that most of the coupling occurs at the bottom of the coil. It also demonstrates that the toroid should not interfere much with the inductive coupling. One must also recognize from this exercise the importance of coupling between the primary and the floor below the coil, which can act as a shorted turn, sucking energy out of your coil.

```
Operating Characteristics
Ctoroid is the added capacitance of the top terminal.
Fres is the resonant operating frequency in kilohertz.
Cpri is the required primary capacitance in nanofarads.
Zpri is the primary surge impedance in ohms.
Zsec is the secondary surge impedance in ohms.
Qsec is the secondary coil quality factor Q.
Rac is the secondary coil RF resistance in ohms.
```

Ctoroid(pF)	.0	10.0	20.0	30.0	40.0	50.0	60.0	70.0
Fres(kHz)	99.8	83.3	72.9	65.7	60.2	56.0	52.5	49.6
Cpri (nF)	21.13	30.36	39.58	48.80	58.03	67.25	76.47	85.70
Zpri(ohms)	75.4	62.9	55.1	49.6	45.5	42.3	39.7	37.5
Zsec(ohms)	69587.	58060.	50847.	45791.	41994.	39008.	36580.	34555.
Qsec	530.8	477.2	439.3	410.4	386.5	366.9	349.9	335.5
Rac (ohms)	131.1	121.7	115.7	111.6	108.7	106.3	104.5	103.0

The "Operating Characteristics" section was added to assist in evaluating how certain combinations of toploads (toroids) affect the operating characteristics of the coil system. A toroid

capacitance of 0 shows the resonant frequency of the secondary due to distributed capacitance alone (99.8 kHz in this example). Adding a toroid on top then lowers this substantially. This coil was actually fired with a toroid topload around 70 pF, causing the resonant frequency to drop to around 50 kHz. You can look at the toroid chart provided previously, and add about a picofarad per foot of spark length to get a rough idea of the resonant frequency (usually get you within 10%).

Cpri is the primary capacitance in nanofarads required to resonate the primary at the same resonant frequency as the secondary. In this example, 85.7 nF (0.0857 uF) is needed to achieve resonance. In a firing coil system, you provide more inductance than needed in the primary, and move the tap point around to match the primary to the secondary. This program merely shows yu about how many nF you need. This coil was fired with between 50 and 100 nF in the primary circuit.

Zpri is the primary surge impedance. If you know the peak primary voltage Vpri, then the peak primary current is approximately Vpri/Zpri. In this coil system, the primary voltage was about 20 kV peak-peak. The primary current was in excess of 500 amperes! This points out the huge primary currents which often accompany large tesla coil systems. You can reduce this by using larger primary inductance and lower primary capacitance, at the expense of voltage rise in the secondary (square root of Ls/Lp). I try to maintain a primary surge impedance of at least 25-30 ohms, since the spark gap losses add an additional 1-3 ohms, and I don't want spark gap losses to dominate the losses in the circuit. You may also want to consider the rather limited current capability of MMC capacitors, if you happen to use these in your designs.

Zsec is the secondary surge impedance. This is provided for informational purposes only. Some advocate matching Zsec to the spark impedance (nominal 100 kohms). Additional work is needed in this area.

Qsec is the secondary coil quality factor Q. It is a measure of the energy stored divided by the energy dissipated in the secondary, and is an indicator of the relative quality of the coil. When sparks are breaking out, system Q's drop to around 10 or so, so this parameter is perhaps not so useful. It is calculated here using the formula Q= w x Ls / Rac, where w is 2 pi x Fres and Rac is the total resistance of the secondary, inducing DC wire resistance, skin effect and proximity effects. Rac is computed using a combination of empirical data from Medhurst as well as data from Malcolm Watts and others I have gleaned from the Tesla list and my own measurements over the years. Note how Rac drops as the resonant frequency drops (less skin effect). Q also drops slightly since w is decreasing faster than Rac. The optimum Q for a tesla coil is still unknown. I aim for Q's above 100, knowing full well that during spark breakout the secondary will dump its stored energy much faster than it is dissipated.

The author recognizes the crudity of the simple input/output constructs of the program, which was written in Fortran. However, there is little incentive to improve on this since a Windows based Fortran compiler costs around $500. Good luck with the program and please share your results with others. Constructive comments and suggestions for improvement should be sent via E-mail to msr7@po.cwru.edu

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