Power Supply Unit:

Specs:
14.4 kV 25 kVA distribution transformer
2.3% impedance at 85°C at max volts

$$Z = \frac{V_o}{I_o} = \frac{14,400}{1.7361} = 8,294.4\ \Omega$$

I'll be overdriving the input voltage to 280 volts

$$V_i = 280\ volts$$

$$V_o = 16,800\ volts\ RMS$$

$$V_p = V_o\sqrt{2} = 16{,}800\sqrt{2} = 23{,}758.8\ volts$$

$$I_i = 50\ amps$$

$$I_o = .833\ amps$$

Inductive Ballast:

Unballasted, the distribution transformer would draw:

$$I_i = \frac{VA}{V_i(\%imped)} = \frac{25{,}000}{240(.023)} = 4{,}528.99\ amps$$

Therefore, we need to design an inductive ballast to limit current to 50 amps:

$$Z = \frac{V_i}{I_i} = \frac{280}{50} = 5.6\ \Omega$$

$$L = \frac{Z}{2\pi f} = \frac{5.6}{2\pi(60)} = 14.85\ mH$$

Tank Capacitor:

Specs:
Maxwell Mini Double-ended (MDE) extended foil plastic case low loss dielectric low inductance high pulse capacitors, 30 nF +/- 10%, 35kV, 20 nH, 25kA peak discharge.

5 strings of 2

$$C_{string} = \frac{1}{\sum_1^n \frac{1}{C_n}} = \frac{1}{\sum_1^2 \frac{1}{30}} = 15\ nF/string$$

$$C_p = NC_{string} = 5(15) = 75\ nF$$

Energy/cap:

$$E_{cap} = .5C_{cap}\left(\frac{V_p}{N}\right)^2 = .5(30\times10^{-9})\left(\frac{23{,}758.8}{2}\right)^2 = 2.117\ Joules/cap$$

Maximum Primary Current:

$$I_{peak} = V_p \sqrt{\frac{C_p}{L_p}} = 23{,}758.8 \sqrt{\frac{(75\times10^{-9})}{(.05\times10^{-3})}} = 920.17\ amps$$

$$Power_{peak} = (I_{peak})^2 R = (920.17)^2 1 = 846.7kW$$

Bang Size:

$$E_p = .5C_pV_p^2 = .5(75\times10^{-9})(23{,}758.8)^2 = 21.168\ Joules/bang$$

Secondary:

Specs:
10 ¾" PVC pipe, close wound with Phelps Dodge AWG 18 Heavy Thermaleze QS Magnet Wire

$$R = 5.375"$$
$$turns/inch = 23.2$$
$$H = height = 54.5"$$
$$N = turns = 23(54.5) = 1{,}253$$
$$wirelength = 10.75\pi(1{,}253) = 42{,}316" = 3{,}526.3'$$

Wheeler Equation:

$$L_s = \frac{(NR)^2}{9R+10H} = \frac{((1{,}253)(5.375))^2}{9(5.375)+10(54)} = 77{,}091\mu H = 77.091\ mH$$

NOTE: JavaTC models this at 71.241 mH.

Medhurst Formula:

$$K = .585 - .25442\left(H/D\right) + .15563\left(H/D\right)^2 - .02777\left(H/D\right)^3 + .00172\left(H/D\right)^4$$

$$= .585 - .25442(5.0698) + .15563(5.0698)^2 - .02777(5.0698)^3 + .00172(5.0698)^4 = .822$$

$$C_s = KD_{cm} = .822(10.75)\,2.54 = 22.446\ pF$$

Topload Specs:
Spun aluminum toroids

$$d_1 = 34"$$
$$d_2 = 8"$$

$$C_{top1} = 2.8\left(1+\left(.2781-\frac{d_2}{d_1}\right)\right)\sqrt{\frac{2\pi^2(d_1-d_2)\left(\frac{d_2}{2}\right)}{4\pi}} = 2.8\left(1+\left(.2781-\frac{8}{34}\right)\right)\sqrt{\frac{2\pi^2(34-8)\left(\frac{8}{2}\right)}{4\pi}} = 37.32\ pF$$

$$d_1 = 24"$$
$$d_2 = 6"$$

$$C_{top2} = 2.8\left(1+\left(.2781-\frac{d_2}{d_1}\right)\right)\sqrt{\frac{2\pi^2\left(d_1-d_2\right)\left(\frac{d_2}{2}\right)}{4\pi}} = 2.8\left(1+\left(.2781-\frac{6}{24}\right)\right)\sqrt{\frac{2\pi^2\left(24-6\right)\left(\frac{6}{2}\right)}{4\pi}} = 26.512\ pF$$

$$C_{top} = C_{top1} + C_{top2} = 37.32 + 26.512 = 63.832\ pF$$

NOTE: JavaTC models this at 40.217 pF.

$$C_{tot} = C_s + C_{top} = 22.446 + 63.832 = 86.278\ pF$$

NOTE: JavaTC models this at 53.514 pF.

Natural Frequency of Secondary with topload:

$$f_o = \frac{1}{2\pi\sqrt{L_s C_{tot}}} = \frac{1}{2\pi\sqrt{\left(77.091\times10^{-3}\right)\left(86.278\times10^{-12}\right)}} = 68,711.81Hz$$

NOTE: JavaTC models this at 81.54 kHz.

Primary:

Specs:
10 turns of 3/8” copper tubing with a wall thickness of .028”, 3/4" center to center, 13.75" average inside diameter, 27.25" average outside diameter.

Skin depth of primary conductor:

$$SD = \frac{2.602}{\sqrt{f}} = \frac{2.602}{\sqrt{81,540}} = .0091"$$

Tubing thickness is adequate.

Primary LC must resonate at same frequency as secondary LC. This is done by means of an adjustable tap on the primary.

$$f_o = \frac{1}{2\pi\sqrt{L_p C_p}} = \frac{1}{2\pi\sqrt{L_p\left(75\times10^{-9}\right)}} = 81,540\ Hz$$

$$L_p = \frac{\left(\frac{1}{2\pi\left(81,540\right)}\right)^2}{\left(75\times10^{-9}\right)} = .05\ mH$$

$$L_1 = helix\ \ factor$$
$$L_2 = spiral\ \ factor$$
$$N = number\ of\ \ turns$$
$$R = average\ radius$$
$$H = effective\ coil\ height$$
$$W = effective\ coil\ width$$

$$L_1 = \frac{(NR)^2}{9R+10H} \quad L_2 = \frac{(NR)^2}{8R+11W}$$

$$L_p = \sqrt{(L_1 \sin\theta)^2 + (L_2 \cos\theta)^2} = .05\ mH$$

Since $\theta = 0$

$$L_p = L_2 = \frac{(NR)^2}{8R + 11W} = .05\ mH$$

Solve for N. (Here's where I turn to my HP programmable calculator.)

Secondary Output Voltage:

$$V_{top} = V_p \sqrt{\frac{C_p}{C_{tot}}} = 23,758.8 \sqrt{\frac{\left(75 \times 10^{-9}\right)}{\left(49.734 \times 10^{-12}\right)}} = 922,631.8\ volts$$