Plate is 14 inches diameter

Archimedes
Spiral

$Dia := 14 \cdot 2.54$ $\qquad$ $Dia = 35.56$

$\Delta := 1$ $\qquad$ gap between turns

$Ro := \frac{Dia}{2} - 1.5$ $\qquad$ Outer radius, cm $\qquad$ $Ro = 16.28$

$Ri := 1$ $\qquad$ Inner Radius, cm

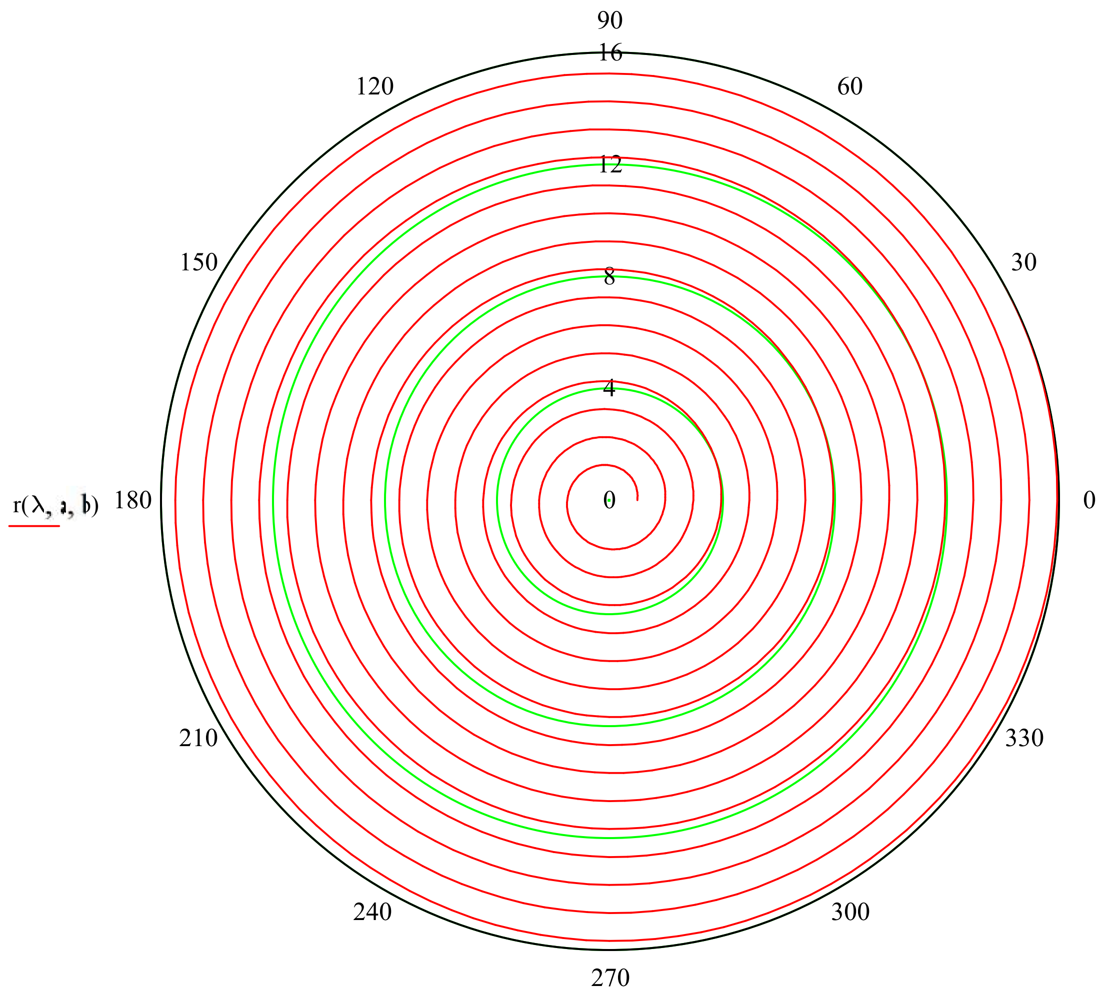
$N := \frac{Ro - Ri}{\Delta}$ $\qquad$ number of turns $\qquad$ $N = 15.28$

$r(\theta, a, b) := a + b \cdot \theta$ $\qquad$ Archimedes Spiral

$a := Ri$ $\qquad$ Start radius

$b := \frac{\Delta}{2 \cdot \pi}$ $\qquad$ $b = 0.159$

$\lambda := 0, \frac{\pi}{60} .. N \cdot 2 \cdot \pi$



90
16
120
60
12
150
30
8
4
r(λ, a, b)
180
0
0
210
330
240
300
270

λ

Solve for length

$$L(N, a, b) := \int_0^{N \cdot 2 \cdot \pi} \sqrt{(a + b \cdot \theta)^2 + \left[\frac{d}{d\theta}(a + b \cdot \theta)\right]^2}\, d\theta$$

$L(N, a, b) = 829.723$ cm

Solve for the diameter and hence the wires gage

$Watts := 250 \qquad Volts := 23$ Heater requirements

$Rs := \frac{Volts^2}{Watts} \qquad Rs = 2.116$ Required Resistance

$Ni := \frac{1 \cdot 10^{-6}}{.917}$ Ohm − meters Resistivity of Nichome, Adjusted to man data for 80/20 nichrome wire

$A(N, a, b, Rs) := \frac{Ni \cdot \frac{L(N, a, b)}{100}}{Rs}$ Area as a function of N,a,b and resistance

$$D(N, a, b, Rs) := \sqrt{\frac{A(N, a, b, Rs) \cdot 4}{\pi}} \cdot 39.37$$ Inches

Diameter as a function of length and resistance

$$D(N, a, b, Rs) = 0.092$$

$$G(N, a, b, Rs) := \frac{\ln(D(N, a, b, Rs)) + 1.12436}{-.11594}$$

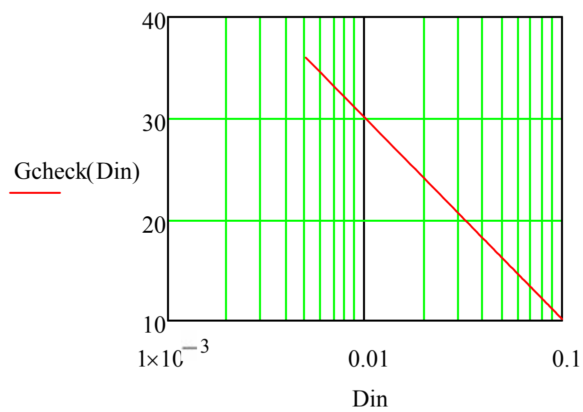
$$G(N, a, b, Rs) = 10.894$$

wire gage eguation, in inches

12 ga wire is a bit big

$$Gcheck(Din) := \frac{\ln(Din) + 1.12436}{-.11594}$$

$$Din := .005, .006 .. .1$$



Solve graphically for a smaller gage

$$ga(\Delta, Ro, Ri, Rs) := \left| \begin{array}{l} N \leftarrow \dfrac{(Ro - Ri)}{\Delta} \\ a \leftarrow Ri \\ b \leftarrow \dfrac{\Delta}{2\cdot\pi} \\ Q \leftarrow G(N, a, b, Rs) \\ Q \end{array} \right.$$

$$r(\theta, a, b) := a + \theta\cdot b$$

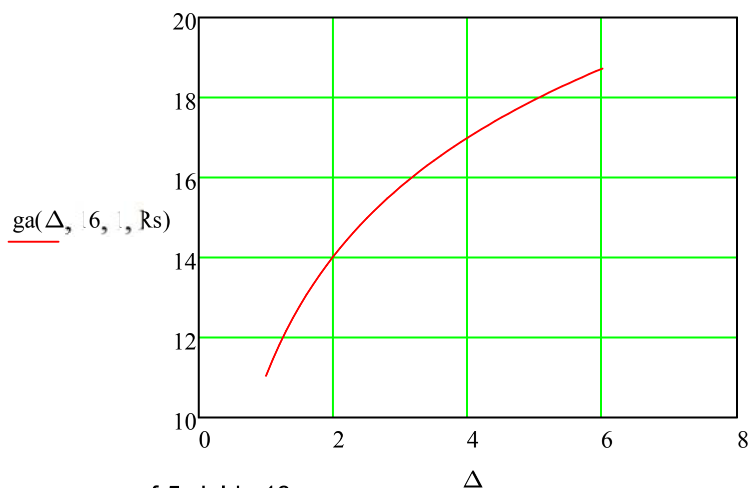
$$\lambda := 0, \frac{\pi}{100} .. 6\cdot 2\cdot\pi$$

more than enough radians

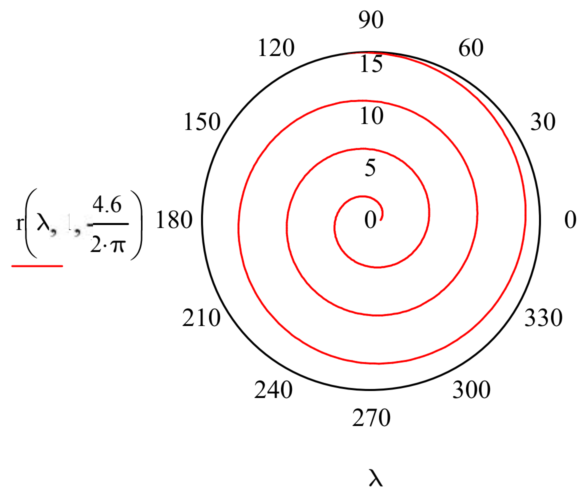
$$L\left(\frac{Ro - Ri}{5}, Ri, \frac{5}{2\cdot\pi}\right) = 166.983$$

cm of 18 ga

$$\Delta := 1, 1.1 .. 6$$



a gap of 5 yields 18 ga



a 5 cm gap may be too big for even heating of glass, especially

Consider nested sprials

$$ga(1, 16, 1, Rs) = 11.045$$

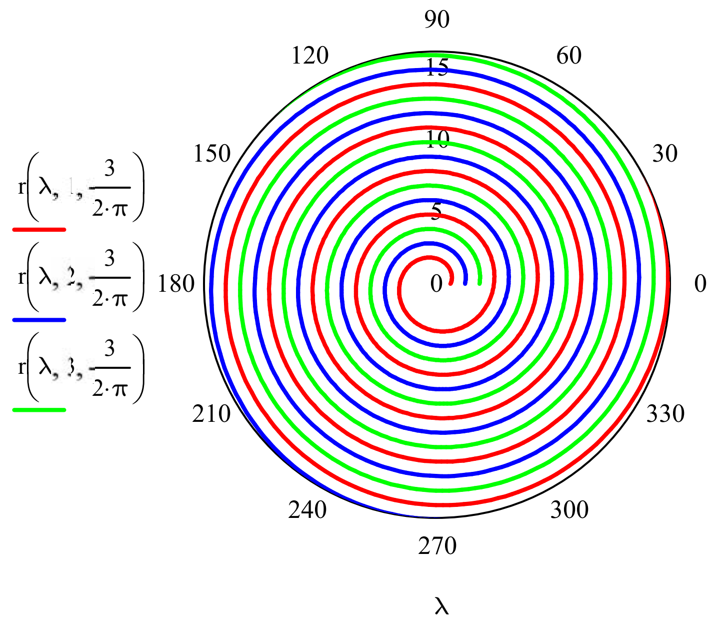
$$ga(3, 16, 1, Rs \cdot 3) = 20.511$$

$$ga(3, 16, 2, Rs \cdot 3) = 20.564$$ three sprials of about 21 gage

$$ga(3, 16, 3, Rs \cdot 3) = 20.652$$

Three spirals

Plot clipped at 16 cm radius



$$L\left(\frac{16-3}{3}, 1, \frac{3}{2\cdot\pi}\right) = 204.827$$

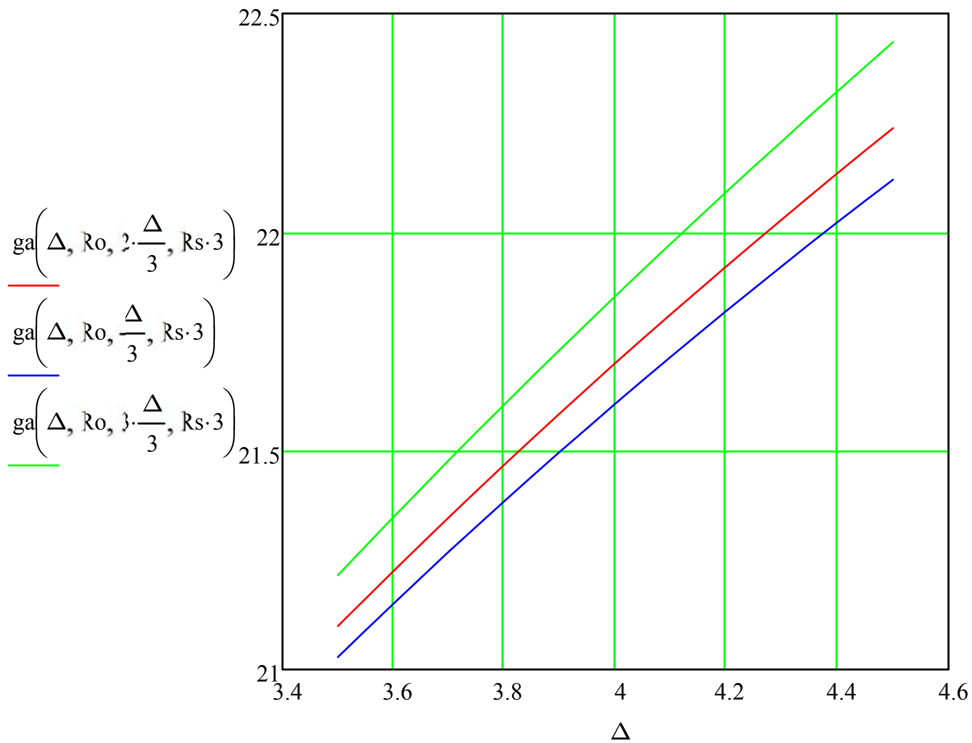
$$L\left(\frac{16-2}{3}, 2, \frac{3}{2\cdot\pi}\right) = 264.389$$

$$L\left(\frac{16-1}{3}, 3, \frac{3}{2\cdot\pi}\right) = 330.294$$

This soultion will use three spirals of different length, in parallel.

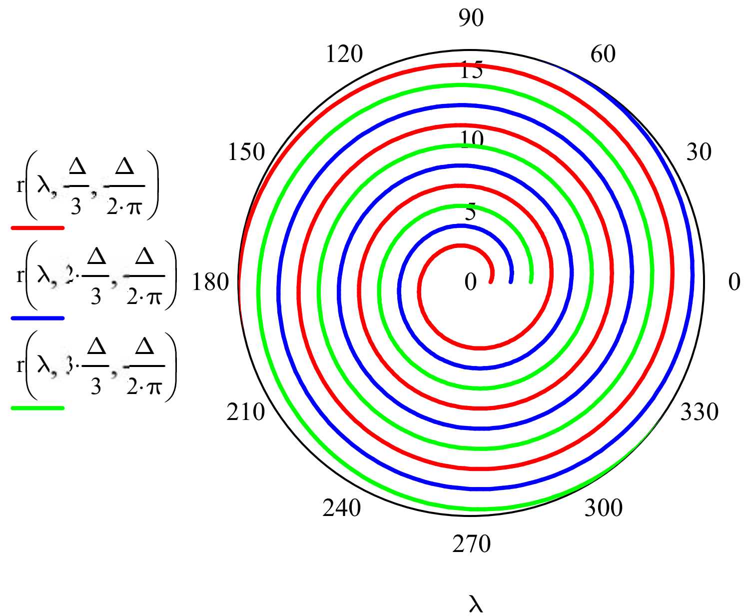
$\Delta := 3.5, 3.55 .. 4.5$

A gap of 4.3 yields 22 ga for the middle sprial



$$\Delta := 4.25$$

Plot clipped at Ro cm radius



$$L\left(\frac{Ro - 3\cdot\frac{\Delta}{3}}{\Delta}, \Delta, \frac{\Delta}{2\cdot\pi}\right) = 183.017$$

$$L\left(\frac{Ro - 2\cdot\frac{\Delta}{3}}{\Delta}, 2\cdot\frac{\Delta}{3}, \frac{\Delta}{2\cdot\pi}\right) = 190.571$$

$$L\left(\frac{Ro - \frac{\Delta}{3}}{\Delta}, \frac{\Delta}{3}, \frac{\Delta}{2\cdot\pi}\right) = 195.249$$

This soultion will use three spirals of different length, in parallel, of 22 ga.

$$\frac{Ni\cdot\dfrac{L\left(\dfrac{Ro-3\cdot\dfrac{\Delta}{3}}{\Delta},\Delta,\dfrac{\Delta}{2\cdot\pi}\right)}{100}}{\dfrac{.326}{10^{6}}}=6.122$$

$$\frac{190\cdot 3}{2.54\cdot 12}=18.701 \qquad \text{feet}$$

$$\frac{1}{\dfrac{1}{\dfrac{Ni\cdot\dfrac{L\left(\dfrac{Rc-\Delta}{\Delta},\Delta,\dfrac{\Delta}{2\cdot\pi}\right)}{100}}{\dfrac{.326}{10^{6}}}}+\dfrac{1}{\dfrac{Ni\cdot\dfrac{L\left(\dfrac{Rc-2\cdot\dfrac{\Delta}{3}}{\Delta},\dfrac{\Delta\cdot 2}{3},\dfrac{\Delta}{2\cdot\pi}\right)}{100}}{\dfrac{.326}{10^{6}}}}+\dfrac{1}{\dfrac{Ni\cdot\dfrac{L\left(\dfrac{Rc-\dfrac{\Delta}{3}}{\Delta},\dfrac{\Delta}{3},\dfrac{\Delta}{2\cdot\pi}\right)}{100}}{\dfrac{.326}{10^{6}}}}}=2.113$$

Check on resistivity

$$Ni = 1.091 \times 10^{-6}$$

$$A(N, a, b, Rs) := \frac{Ni \cdot \frac{L(N, a, b)}{100}}{Rs}$$

Expresion to find the required area(m^2) from length(cm) and resistance

$$Acheck(L, Rs) := \frac{Ni \cdot L}{100 \cdot Rs}$$

$$\frac{Acheck(100, 138.8) \cdot 10^{6}}{.007845} = 1.001 \qquad mm^{2}$$

Close to man data

$$\frac{Acheck(100, 6.835) \cdot 10^{6}}{.1590} = 1.003 \qquad mm^{2}$$

Close to man data

$$Acheck(100, .1542) \cdot 10^{6} = 7.072$$

$$\frac{Acheck(100, .1542) \cdot 10^{6}}{7.089} = 0.998$$

$$Acheck(265, 2.1) \cdot 10^{6} = 1.376$$

Serpentine
path

Assume a serpentine path. The long runs are chords of the circle, the first run is a distance away from the perimeter termed the versine or sagitta (S). Each of N runs after that are evenly gapped by G. The last run is again S from the perimeter. The chords end a distance away from the perimeter defined by the chord and an intersection of a smaller circle of radius R. The runs are then ful chords of the smaller circle R. The connectors will be treated as straight lines connecting the runs.

Equation for the length of a chord

Solve for the
chord

$$r = \frac{c^2}{8s} + \frac{s}{2}$$ the radius of a circles that just encloses a chord of length C with sagitta S

$$c(r, s) := 2\cdot\sqrt{s}\cdot\sqrt{2\cdot r - s}$$ the length of a chord of a circle r with sagitta s

$$N(D, \Delta, s) := \frac{D - 2\cdot s}{\Delta} + 1$$ Number of runs in a circle of diameter D, sagitta s and gap Δ

$$
\mathrm{Ls}(d, r, s, N) :=
\begin{array}{|l}
\Delta \leftarrow \dfrac{d - 2\cdot s}{N - 1} \\
k \leftarrow 0 \\
L \leftarrow 0 \\
pl \leftarrow 0 \\
\text{for } n \in 0..N-1 \\
\quad \begin{array}{|l}
pc \leftarrow c\left[r, s - \left(\dfrac{d}{2} - r\right) + n\cdot\Delta\right] \\
Q_{k,0} \leftarrow pc \\
L \leftarrow L + pc \\
\text{if } n > 0 \\
\quad \begin{array}{|l}
gl \leftarrow \sqrt{\Delta^2 + \left(\dfrac{pc - pl}{2}\right)^2} \\
Q_{k,1} \leftarrow gl \\
L \leftarrow L + gl
\end{array} \\
pl \leftarrow pc \\
k \leftarrow k + 1
\end{array} \\
Q_{k,0} \leftarrow L \\
Q
\end{array}
$$

$\mathrm{Ls}(32, 15, 1.5, 10) =$

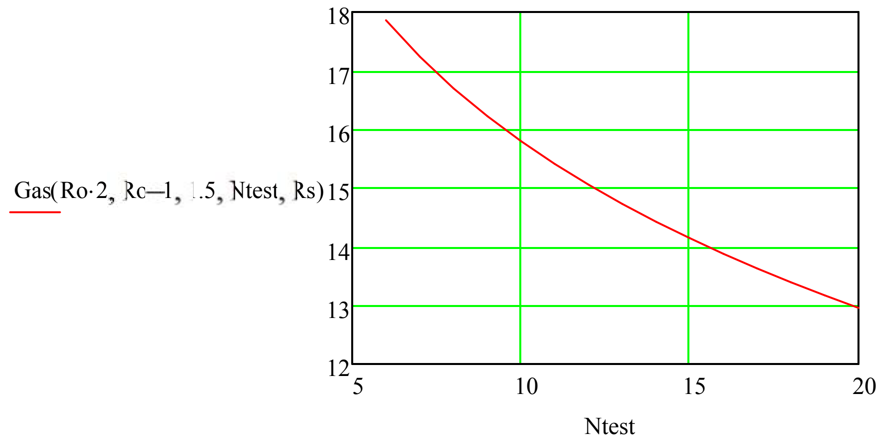
	0	1
0	7.681	0
1	19.78	6.854
2	25.307	4.245
3	28.4	3.574
4	29.826	3.3
5	29.826	3.222
6	28.4	3.3
7	25.307	3.574
8	19.78	4.245
9	7.681	6.854
10	261.157	0

10	201.157	0

$$
\mathrm{Gas}(d, l, s, N, Rs) := \left|
\begin{array}{l}
\mathrm{Lall} \leftarrow \mathrm{Ls}(d, l, s, N) \\
\mathrm{Lser} \leftarrow \mathrm{Lall}_{N,\,0} \\
\mathrm{Aser} \leftarrow \mathrm{Acheck}(\mathrm{Lser}, Rs) \\
\mathrm{Dser} \leftarrow \sqrt{\dfrac{\mathrm{Aser}\cdot 4}{\pi}}\cdot 39.37 \\
\mathrm{Gser} \leftarrow \mathrm{Gcheck}(\mathrm{Dser}) \\
\mathrm{Gser}
\end{array}
\right.
$$

$$\mathrm{Gas}(32, 15, 1.5, 10, 2.1) = 15.847$$

$$\mathrm{Ntest} := 6, 7 .. 20$$



$Gap(N) := \frac{Ro \cdot 2}{N}$ $\qquad$ $Gap(10) = 3.256$ $\qquad$ Aproximate gap