# Analysis Appendix

**Equation List**

*H = n1(LS)-1Vs* (1)

*B = RC(n2Ac)-1Vs* (2)

*P = AVf (3)*

*V = L \* Area of sample face (4)*

B *=*μ0μrH (5)

μ0= 4π \* 10-7 (6)

flux density = Hμr (7)

**Apparatus Measurements**

n1 = 160 turns

n2 = 150 turns

S = 0.1 +/- 5% Ohms

R = 1e6 +/- 5% Ohms

C = 0.5e-6 +/- 2% F

**Sample Measurements**

Iron Magnetic Length**:** 333 +/- 5mm

Iron Cross Sectional Area: 759.08 +- 0.5 mm2

Carbon Magnetic Length: 78 mm +/- 0.5 mm

Carbon Cross Sectional Area: 844.32 mm2

Table 1 –Series Resistor Voltage and Capacitor Voltage for Iron Sample with C = 0.5e-6 +/- 2% F and S = 0.1 +/- 5% Ohms (Small sample of full dataset with 2000 points)

|  |  |  |
| --- | --- | --- |
| Time [s] | Vc [V] | Vc [V] |
| -2.50E-02 | 3.42E-01 | -3.40E-01 |
| -2.50E-02 | 3.38E-01 | -3.39E-01 |
| -2.50E-02 | 3.34E-01 | -3.39E-01 |
| -2.49E-02 | 3.31E-01 | -3.39E-01 |
| -2.49E-02 | 3.27E-01 | -3.39E-01 |
| -2.49E-02 | 3.22E-01 | -3.38E-01 |
| -2.49E-02 | 3.18E-01 | -3.38E-01 |
| -2.48E-02 | 3.13E-01 | -3.38E-01 |
| -2.48E-02 | 3.09E-01 | -3.38E-01 |
| -2.48E-02 | 3.06E-01 | -3.37E-01 |
| -2.48E-02 | 3.01E-01 | -3.37E-01 |
| -2.47E-02 | 2.96E-01 | -3.36E-01 |
| -2.47E-02 | 2.91E-01 | -3.36E-01 |
|  |  |  |

Table 2 - Series Resistor Voltage and Capacitor Voltage for Carbon Steel Sample with C = 0.5e-6 +/- 2% F and S = 0.1 +/- 5% Ohms (Small sample of full dataset with 2000 points)

|  |  |  |
| --- | --- | --- |
| Time [s] | Vc [V] | Vc [V] |
| -2.50E-02 | 3.58E-01 | 1.78E-01 |
| -2.50E-02 | 3.56E-01 | 1.78E-01 |
| -2.50E-02 | 3.55E-01 | 1.77E-01 |
| -2.49E-02 | 3.53E-01 | 1.78E-01 |
| -2.49E-02 | 3.51E-01 | 1.77E-01 |
| -2.49E-02 | 3.49E-01 | 1.77E-01 |
| -2.49E-02 | 3.46E-01 | 1.76E-01 |
| -2.48E-02 | 3.44E-01 | 1.76E-01 |
| -2.48E-02 | 3.40E-01 | 1.75E-01 |
| -2.48E-02 | 3.39E-01 | 1.75E-01 |
| -2.48E-02 | 3.35E-01 | 1.73E-01 |
| -2.47E-02 | 3.34E-01 | 1.75E-01 |
| -2.47E-02 | 3.30E-01 | 1.72E-01 |

Table 3 - Hysteresis Saturation Point for Iron Sample with

C = 0.5e-6 +/- 2% F and S = 0.1 +/- 5% Ohms

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Variac Voltage [V] | Top-right corner X [mV] | Top-right corner Y [mV] | Error in corner X [mV] | Error in corner Y [mV] |
| 3 | 13.75 | 26.87 | 0.5 | 1 |
| 5 | 18.25 | 43.75 | 0.5 | 2 |
| 7 | 21 | 56.25 | 0.5 | 2 |
| 10 | 25.5 | 72.5 | 0.5 | 2 |
| 13 | 33.5 | 95.3 | 1 | 5 |
| 17 | 42 | 118.8 | 1 | 5 |
| 20 | 50.5 | 139.1 | 1 | 5 |
| 23 | 61.5 | 160.9 | 1 | 5 |
| 25 | 68 | 170.3 | 2 | 5 |
| 30 | 88 | 196.9 | 2 | 10 |
| 35 | 120 | 228.1 | 2 | 10 |
| 40 | 167.5 | 259.4 | 5 | 10 |
| 45 | 227.5 | 284.4 | 5 | 10 |
| 50 | 315 | 303.1 | 10 | 10 |
| 55 | 460 | 318.8 | 10 | 10 |

**Sample Calculations**

H and B Values:

Hi = (n1/(Li\*S)).\*Vsi;

Bi = (R\*C/(n2\*Aci)).\*Vci;

Hs = (n1/(Ls\*S)).\*Vss;

Bs = (R\*C/(n2\*Acs)).\*Vcs;

Remanence and Coercive Forces:

remi = [];

coerci = [];

for i=1:length(Hi)-1

if (Hi(i) >= 0 && Hi(i+1) < 0)

remi(end + 1) = Bi(i);

remi(end + 1) = Bi(i + 1);

end

if (Bi(i) >= 0 && Bi(i+1) < 0)

coerci(end + 1) = Hi(i);

coerci(end + 1) = Hi(i + 1);

end

end

Iron Remanence (mean) = 0.838 +/- 0.003 T

Iron Coercive Force (SEM) = -252 +/- 1 A/m

Steel Remanence (mean) = 0.440 +/- 0.002 T

Steel Coercive Force (SEM) = -3390 +/- 10 A/m

Power Dissipated By Steel Sample:

Ps1 = (2.11e-2 - 1.24e-2)\*2;

Ps2 = (2.11e-2 - 4.49e-3);

fs = 0.5\*((1/Ps1)+(1/Ps2));

Ps\_err = Ps \* (0.002/Ls + Ac\_err/Acs + 2/fs);

P = 100 +/- 6 W

Maximum Relative Permeability and Flux Density:

Uo = 4\*pi\*(10^-7); %http://physics.info/constants/

Ur = Bi4./Hi4./Uo;

Ur\_err = Ur .\* (Bi4\_err./Bi4 + Hi4\_err./Hi4)./2;

Flux = Ur\_max\*Hi4(ind);

Flux\_err = Flux .\* (Ur\_err(ind)./Ur\_max + Hi4\_err(ind)./Hi4(ind))

Relative permeability= 1900 +/- 200 H/m

Calculated as: 333000 +/- 6000 N/(Am)