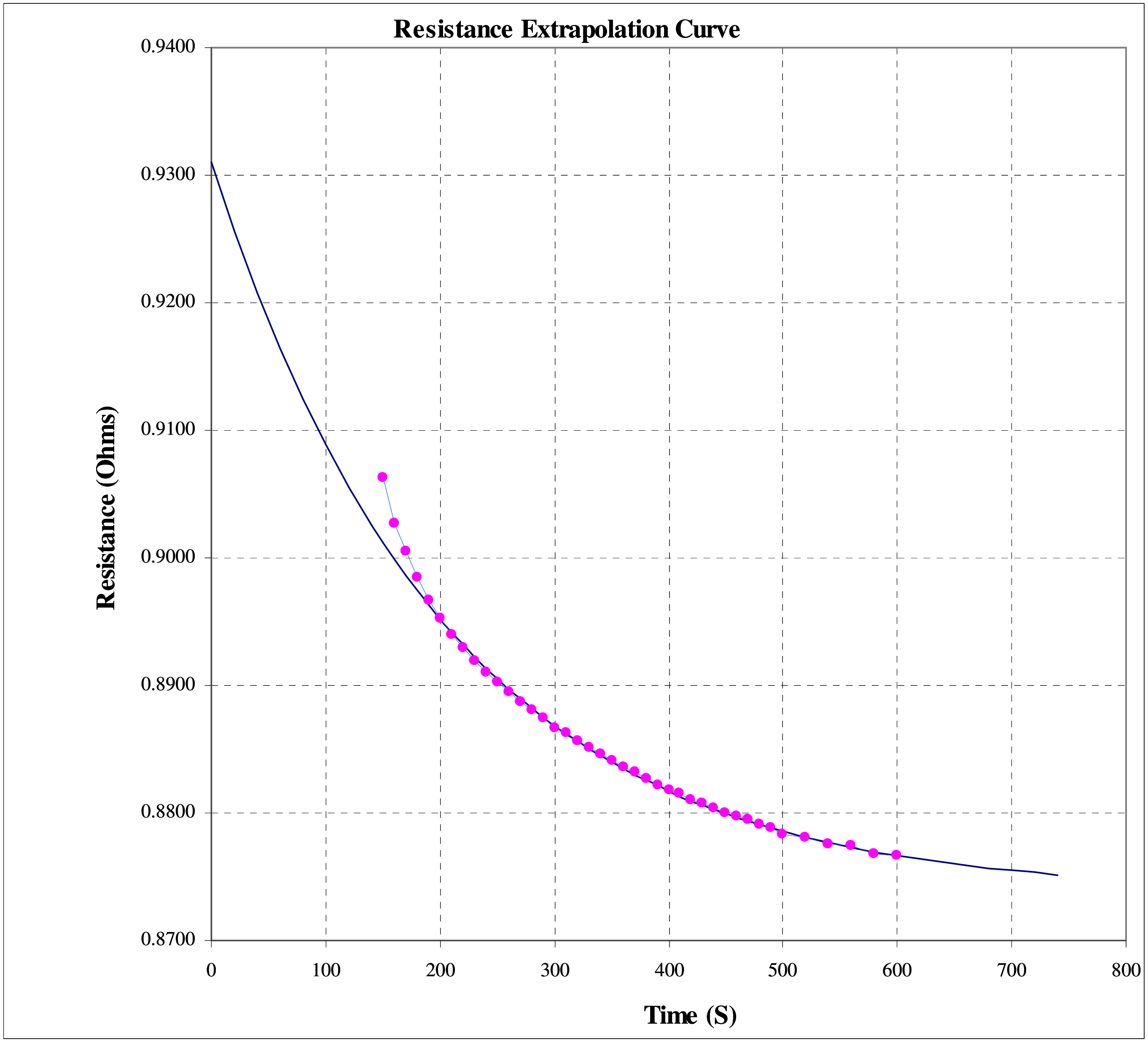
Temperature rise test on power transformers

Numerical Method for Calculating the Average Resistance of a Winding at Shut Down Based on the Cooling Curve Method.

by Bertrand Poulin, October 2009

Time	Res.
150.0	0.90625200
160.0	0.90268100
170.0	0.90052800
180.0	0.89842100
190.0	0.89669500
200.0	0.89523200
210.0	0.89401400
220.0	0.89291800
230.0	0.89196600
240.0	0.89108200
250.0	0.89025800
260.0	0.88946100
270.0	0.88875400
280.0	0.88807200
290.0	0.88740500
300.0	0.88670600
310.0	0.88622600
320.0	0.88563700
330.0	0.88509500
340.0	0.88457500
350.0	0.88405300
360.0	0.88360400
370.0	0.88315500
380.0	0.88269800
390.0	0.88219600
400.0	0.88182300
410.0	0.88149100
420.0	0.88108100
430.0	0.88072200
440.0	0.88035500
450.0	0.88000100
460.0	0.87978800
470.0	0.87943600
480.0	0.87915400
490.0	0.87889700
500.0	0.87833200
520.0	0.87807400
540.0	0.87758000
560.0	0.87747800
580.0	0.87677800
600.0	0.87665900



R_o = **Resistance at shut down**

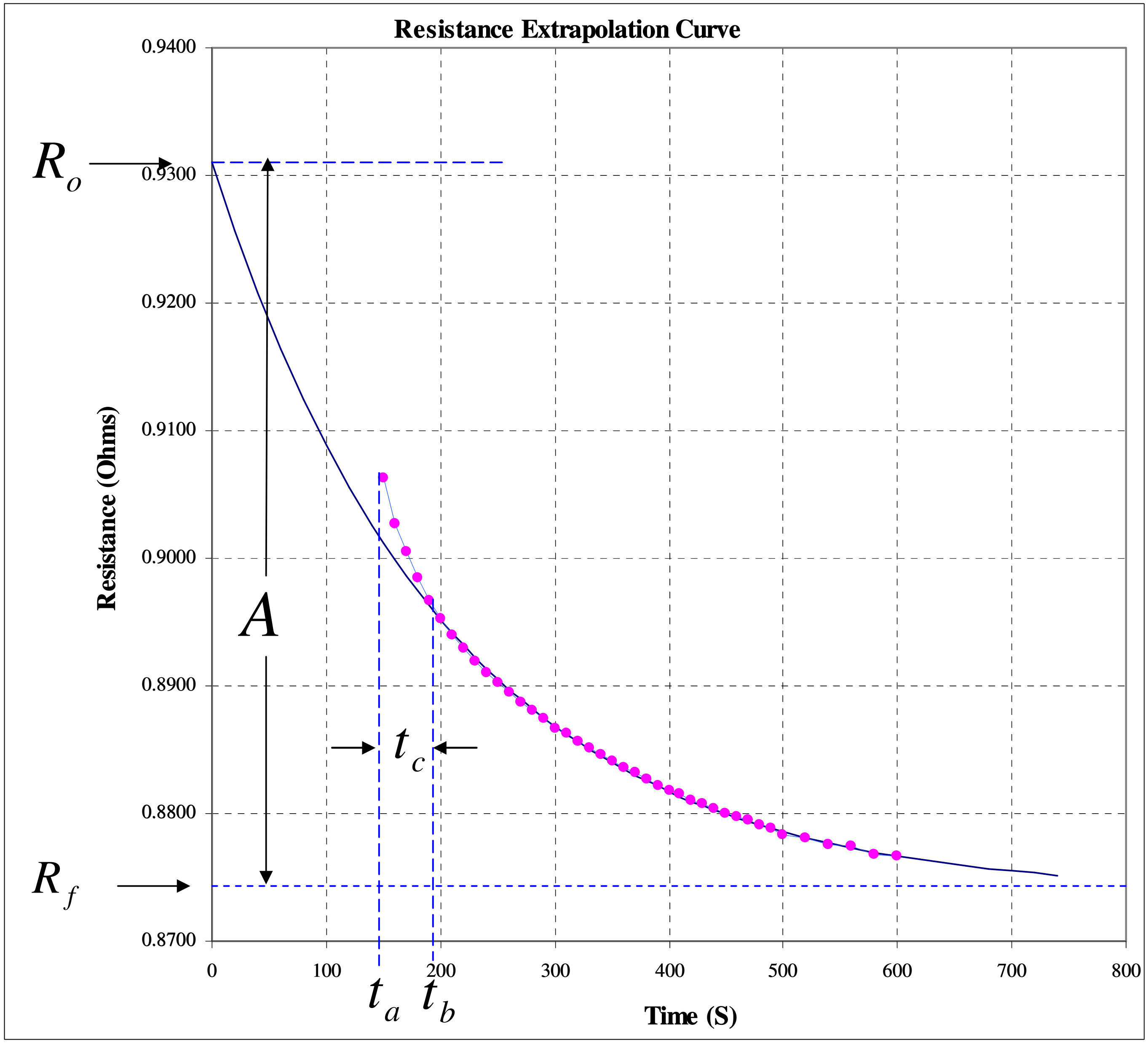
R_f = **Asymptote to the curve**

$A = R_0 - R_f$

t_a = **time to first reading**

t_b = **time to first valid reading**

t_c = **time for current to build**



$$R = (R_0 - R_f) \bullet e^{-t/\tau} + R_f$$

$$A = R_0 - R_f \qquad m = 1/\tau$$

$$\boxed{R = A \bullet e^{-mt} + R_f}$$

$$R - R_f = A \bullet e^{-mt}$$

$$\boxed{\ln(R - R_f) = \ln A - mt}$$

$$\frac{\partial R}{\partial t} = -m \bullet A \bullet e^{-mt} \qquad R - R_f = A \bullet e^{-mt}$$

$$\frac{\partial R}{\partial t} = -m \bullet (R - R_f)$$

$$\boxed{\frac{\partial R}{\partial t} = -mR + mR_f}$$

$$\boxed{\frac{\Delta R}{\Delta t} = -mR + mR_f}$$

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$$t_i\,,\ R_i \longrightarrow x_j\,,\ y_j$$

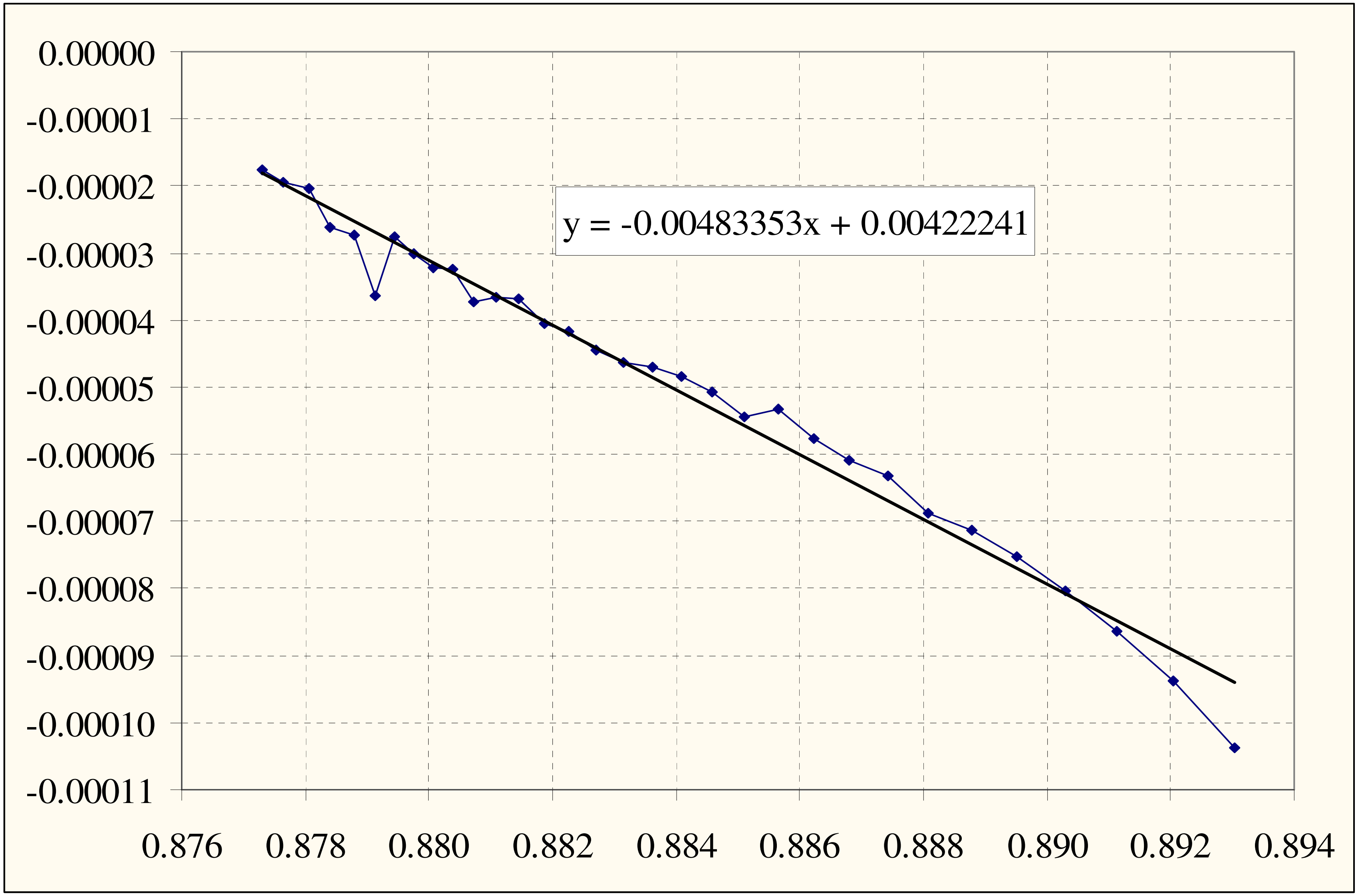
$$x_j = R_{j-2} + R_{j-1} + R_j + R_{j+1} + R_{j+2}$$

$$Y_j = \left(\frac{\Delta R}{\Delta t}\right)_j = \frac{R_{j+2} - R_{j-2}}{t_{j+2} - t_{j-2}}$$

j = 3, 4, … n-2

0.89205	-0.0000939
0.89114	-0.0000864
0.89030	-0.0000803
0.88953	-0.0000753
0.88879	-0.0000713
0.88808	-0.0000689
0.88743	-0.0000632
0.88681	-0.0000609
0.88621	-0.0000578
0.88565	-0.0000533
0.88512	-0.0000543
0.88459	-0.0000508
0.88410	-0.0000485
0.88362	-0.0000469
0.88314	-0.0000464
0.88270	-0.0000445
0.88227	-0.0000416
0.88186	-0.0000404
0.88146	-0.0000368
0.88109	-0.0000367
0.88073	-0.0000372
0.88039	-0.0000323
0.88006	-0.0000322
0.87975	-0.0000300
0.87946	-0.0000276
0.87912	-0.0000364
0.87878	-0.0000272
0.87841	-0.0000262
0.87807	-0.0000203
0.87765	-0.0000194
0.87731	-0.0000177

$$R_f = -\frac{b}{m} \qquad R_f = \frac{0.00422241}{.00483353} = 0.87356$$



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600.0	0.87665900

$$t_i \, , \, R_i \longrightarrow x_i \, , \, y_i$$

$$x_i = t_i$$

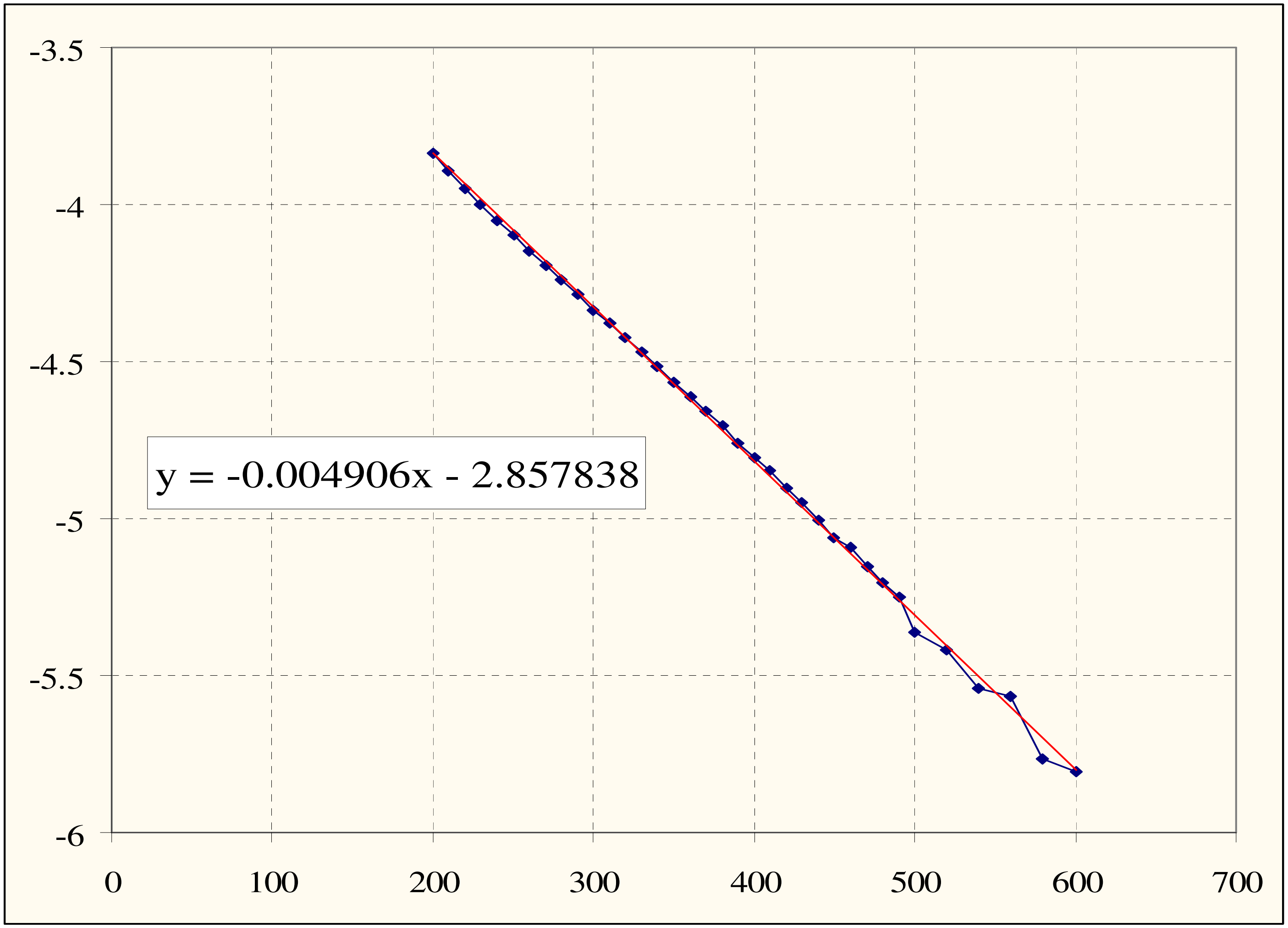
$$y_i = \ln(R_i - R_f)$$

i = 1, 2, … n

200	-3.83586
210	-3.89395
220	-3.94927
230	-3.99994
240	-4.0494
250	-4.09782
260	-4.147
270	-4.19274
280	-4.23894
290	-4.28629
300	-4.33844
310	-4.3759
320	-4.42386
330	-4.47013
340	-4.51663
350	-4.56558
360	-4.6097
370	-4.65585
380	-4.70512
390	-4.7622
400	-4.80682
410	-4.84828
420	-4.90198
430	-4.9515
440	-5.00478
450	-5.05901
460	-5.09312
470	-5.15217
480	-5.20213
490	-5.24994
500	-5.36385
520	-5.42053
540	-5.53891
560	-5.5652
580	-5.7671
600	-5.80587

$$A = e^{b} = e^{-2.857838} = 0.057393$$

$$R_0 = A + R_f = 0.057393 + 0.87356 = 0.93095$$



A conventional graphical extrapolation procedure for the same purpose uses a manually smoothed plot. Intercepts are made at equal intervals of time, starting from the instant of shutdown. The resistance differences should form a geometric series, if the decay curve is exponential. A sloping line in the graph is fitted, as shown in figure C.3. This line tends to the intersection corresponding to parameter A_o (figure C.3) and, at the other end, permits a graphical estimate of R_o as well.