Department LIGO -T020131-00-D

Subject Thermal Transport

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~~X-2063~~
~~X-2128~~ X-2968

National® Brand

Computation Notebook

11 3/4" x 9 1/4", 4 x 4 Quad., 75 Sheets **43-648**

0 73333 43648 8

AVERY DENNISON
Office Products
Chicopee, MA 01022

09/06/02

SPLE_10MICRONS

For the first time, I tried to put the thin part on the system, checking the effects of the changing of section. For that I used the same main geometry, with the width of the 10 microns part at 0.5mm. In order to mesh this geometry, I used the SWEEP function, but tricking a little, as following:

As the usual SWEEP did not work (**Warning** box: error limits) even when it was giving a good mesh, when as on the other hand the SMART MESHING like the MAPPED MESHING gave irregular meshing, I changed the defaults settings by:

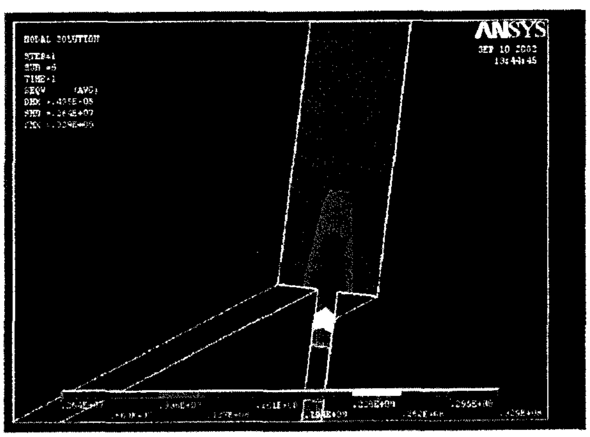
Preprocessor > checking ctrls > toggle checks > Aspect ration test OFF.

This manipulation eliminated the Error message, and I ran the solution in LINEAR. During the resolution, none error were detected, and the results made sense according the previous ones. So far, I will keep this configuration as long as I consider the meshing good enough to make the resolution.

So, the LINEAR SOLUTION settings:

Load applied:
-6.667e6 Pa on the bottom part (equivalency for 1N)

SOLUTION > Sol'n control
Small displacement static
Time at end of loadstep: 1
Number of substeps: 10
Max nber of substeps: 10
Min nber of substeps: 1



Max disp: 0.493e-5m
Stress Max: 0.328e+8 Pa

NOTE: the NON LINEAR resolution gives the same kind of deformation with a light difference in the result.

NON LINEAR resolution:	Max disp=	0.495e-5 m
	Max stress=	0.329e+8 Pa

It makes sense, which shows that so far we can keep this mesh.

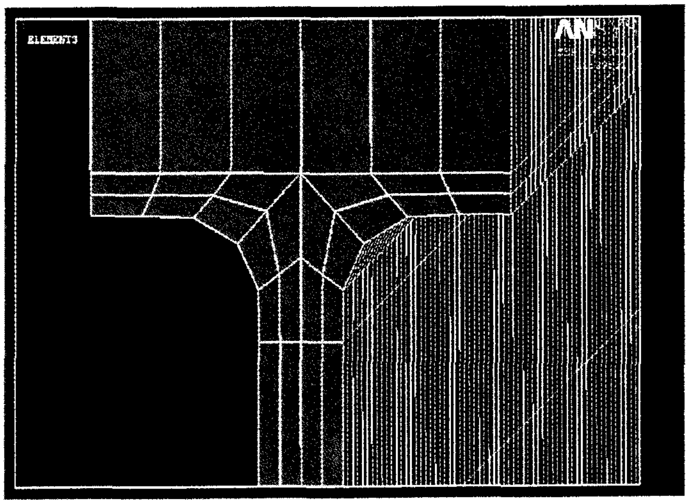
Sample 10 Microns with transition,

In order to have the behavior of the sample according the nature of the transition between the two section, we will try to apply the same efforts than before but different kinds of transition.

First test:

Transition radio: 10e-6 m (fillet),

Mesh: SOLID45 mapped (after concatenation) on the transition parts,
Sweeped on the regular parts,
Negative pressure on the bottom of 6.667e6 Pa



To pull out a result from this simulation, I changed the solution parameters on Sol'n control:

BASIC,
- Large displacement Static
- Time Control: 1
10
10
1

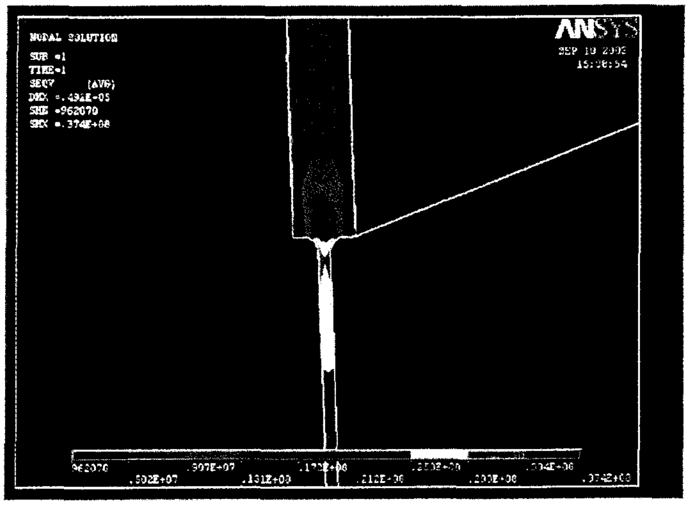
SOL'N OPTIONS
Pre-Condition CG (accuracy)

NONLINEAR
Line search: on
DOF solution predictor: On for all substeps

SOLUTION IS DONE, but with a Warning message

Warning : the calculated reference FORCE CONVERGENCE VALUE = 3.7....E-3 is less than 1E-2 a threshold zero, a value of 1E-2 or specified MINREF is used. Check results carefully.

The result is:



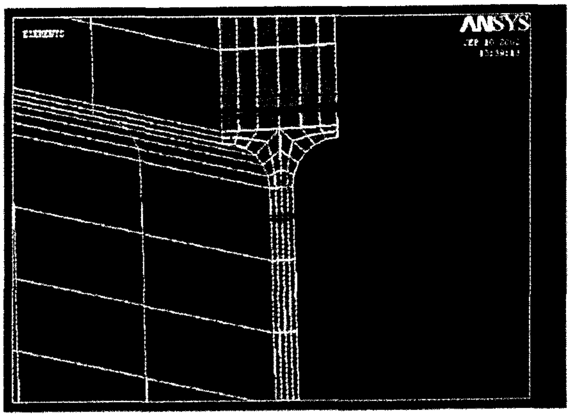
Disp Max: 0.492e-5 m
Stress Max: 0.374e+8 Pa

As we can see on the results, they are similar from the previous ones (without transition), but there is nonsense on the stress result, which means that I will need another test to check this result.

Second test:

Radio transition: 20 Microns

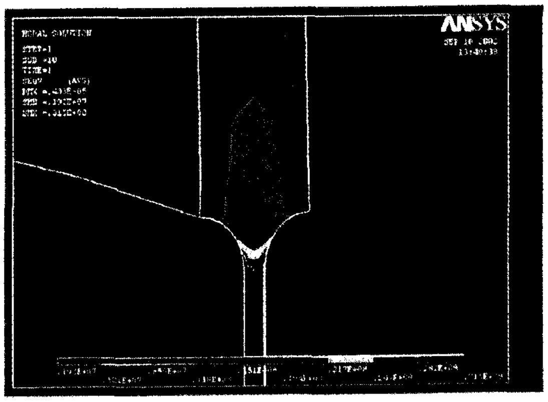
Same conditions.
NOTE: I disabled the Aspect Ratio test
Solution parameters:
BASIC,
Small displacement
1
10
10
1



SOLUTION IS DONE

Disp Max: 0.483e-5 m
Stress Max: 0.315e+8 Pa

The distribution of the stress and the results follow the expected (Less Max stress).
I think more tests are necessary.



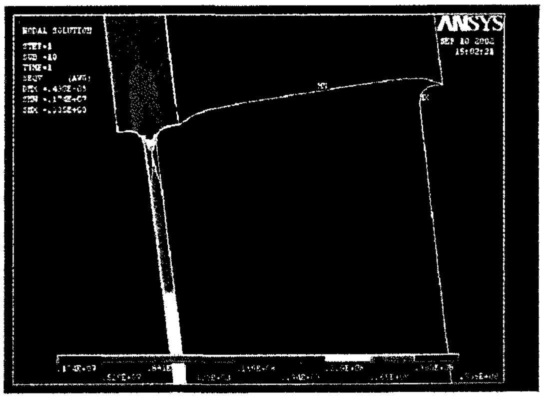
NOTE: the resolution in non-linear gives the same kind of results with just a small difference.
Max Disp: 0.485e-5 m
Max Stress: 0.316e+8 Pa
The shape of the distributions is the same.

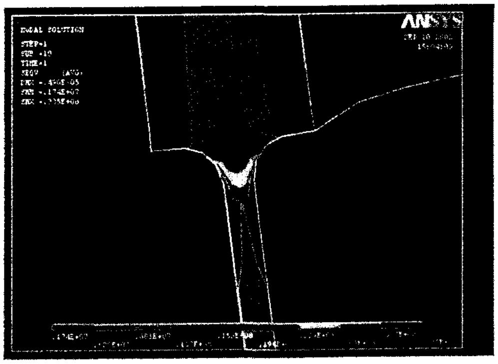
In order to check the previous results, I sent the first mesh of the radio of 10 Microns with the same kind of mesh, i.e. disabling the aspect ration test.
The result I obtained was still above the Max Stress of the sample without transition, but less. During the resolution, a **Warning** message was shown up, saying that a given number of the selected elements have not been performed. Which leads me to think that the result must be considered carefully. However I find this result more acceptable.

Let see the parameters and the comparison between the results of the two meshes:

Aspect ration test Off
Small displacement static
Usual parameters

RESULT

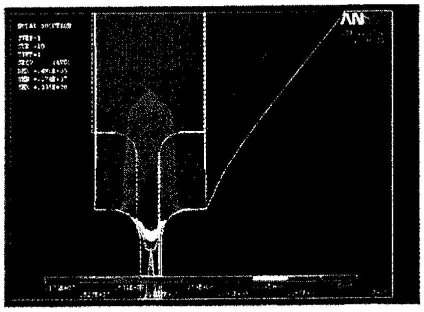




Second mesh
Disp Max: 0.490e-5 m
Stress Max: 0.335e+8 Pa

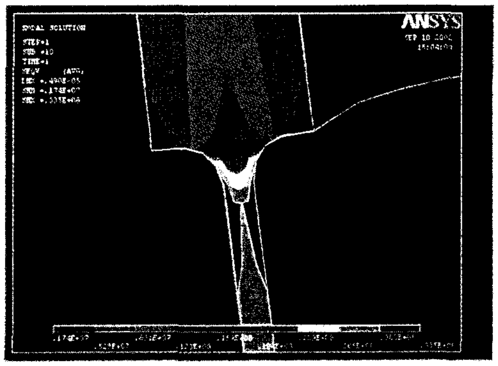
NOTE: exactly the same result with a nonlinear resolution:
Disp Max: 0.490e-5 m
Stress Max: 0.335e+8 Pa

Notice the deformation along the edge. I don't know how far we can trust this picture of the deformation of the sample. Indeed, there is a big difference between this shape and the usual one. However the result keeps giving a good description.

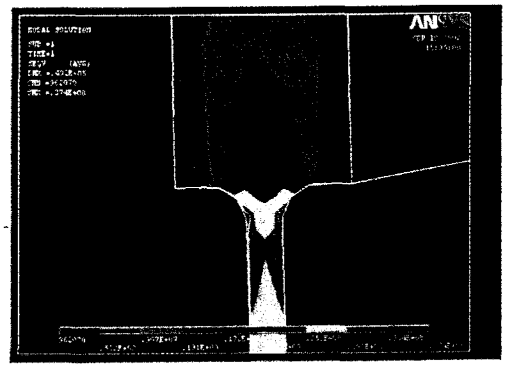


We can see also some kind of concentration of the stress, distinct from the 20Microns radio. This distribution could explain the fact that the stress Max on this configuration is barely greater.

Let see now the comparison for the SAME sample and the same geometry, but with different Mesh, the distribution of the stress:



Mesh2 (without Aspect ratio test, less elements)



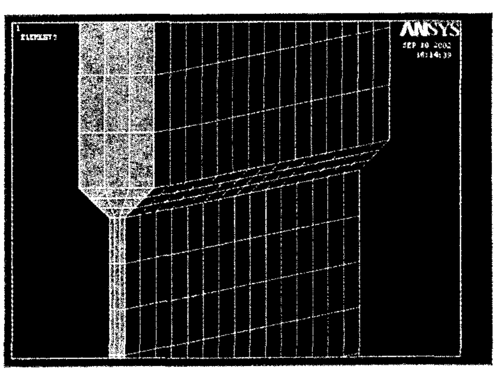
Mesh1 (more elements but **Warning** message on the FORCE CONVERGENCE VALUE)

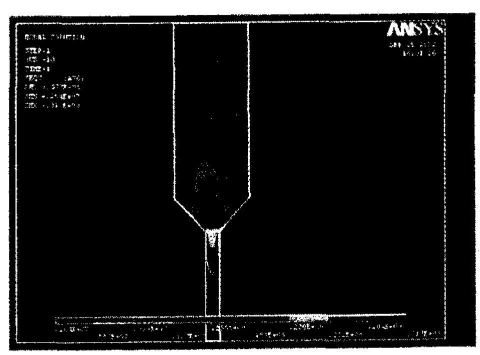
Need more tests.

Next step, I tried with a constant slope in the transition.
For the same reasons, I disabled the Aspect ratio checking. The resolution in Linear is clean and fast while the non linear study never finished (with a wide bunch of parameters). The usual **Warning** message is "Unexpected error (segmentation violation) ...". It can be caused by the tiny deformation of the system under this effort. However, the result makes sense, having an improvement according to the non-transition shape as well for the disp Max and the Stress Max.
We can compare also to the 20 Microns radio, and we can notice that there is less displacement Max for the constant slope shape, but the Stress max of 20 Microns is lower.

Meshing:
SOLID45, mapped
Disabled Aspect ratio

Parameters:
Small displacement
Usual parameters





Max Disp: 0.477e-5 m
Max Stress: 0.317e+8 Pa

We can see that the distribution of the effort is pretty smooth, which can show that the hypothesis of the concentration of stress in the 10Microns could be the explanation of the increasing of the Max Stress.

The result in Non linear resolution gives barely the same result, while the resolution did not give any **Warning** message.

Large displacement:	Max disp:	0.479e-5 m
	Max stress:	0.317e+8 Pa

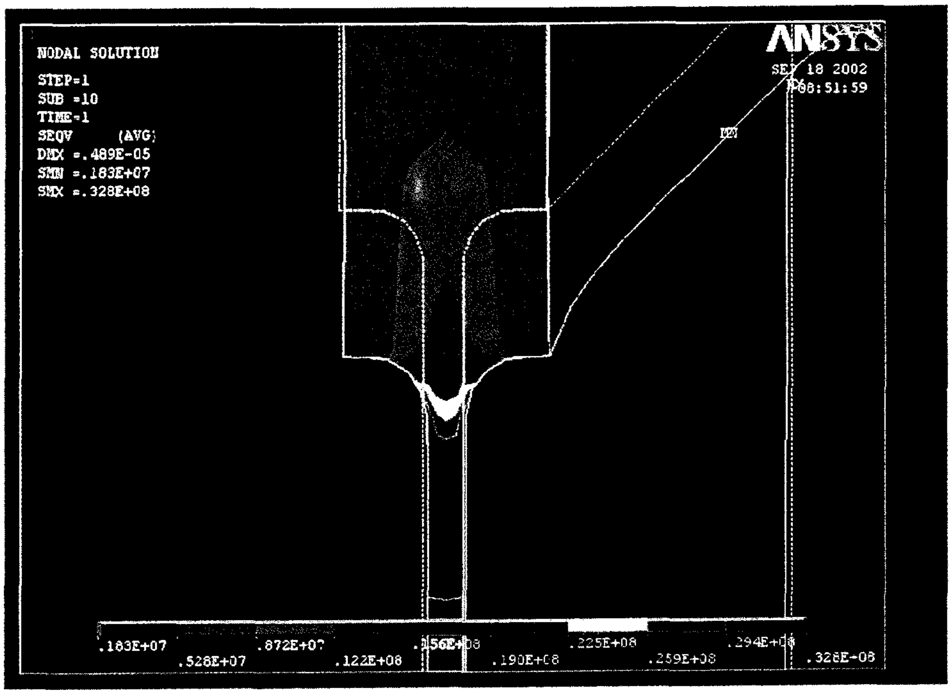
NOTE: there is no great difference between the distributions of the stress.

CONCLUSION:
The simulation seems to be pretty accurate in spite of the incoherency of 10 microns transition, which gives a Max stress greater than the one given WITHOUT transition radio. This result can be explained by a concentration of the stress, but I am still thinking that it is not enough as an explanation. To try to show out the evidence of the truth ness or the false ness of this theory, I will send simulations in a range of radio between 20 Microns and 10 Microns.
We can also pretend that the best shape on the transition between 50 Microns and 10 Microns stands the 20 Microns radio, even though the constant slope transition section gives roughly the same results. However is easier to put a radio transition on a sample than a constant slope, which in machinery operating will cause for sure little gaps and cracks initiating.

TEST 12-18 MICRONS

I realized today that I was using a bad Young Modulus from the beginning. It is not really as long I don't try to do the VERY good simulation. This part will be used to verify if the result with 10 Microns transition is correct. Indeed, the Max Stress in this sample is greater than the one without transition, which is not normal given that smooth transitions in the geometry was supposed to improved the resistance. That is why will be tried a wide range of transition radio (20 to 10 by 2) to check if there is some continuity in this result.

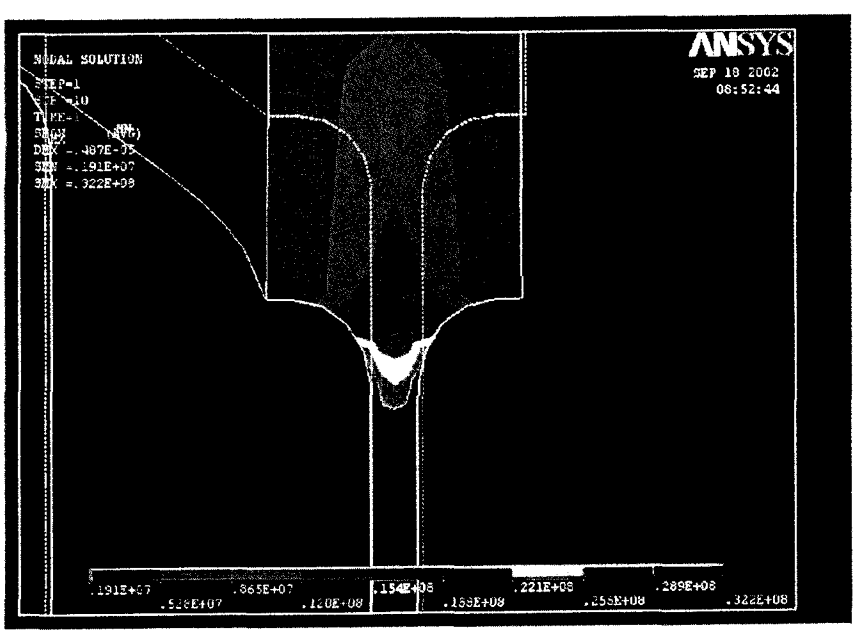
12 Microns



Disp Max:
0.489e-5 m

Stress Max:
0.328e+8 Pa

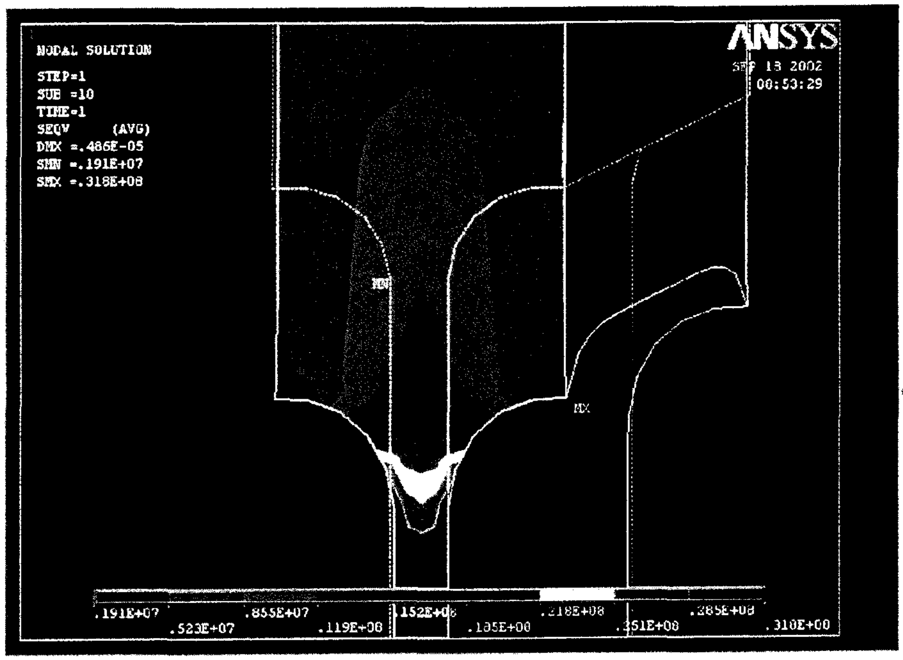
14 Microns



Disp Max:
0.487e-5 m

Stress Max:
0.322e+8 Pa

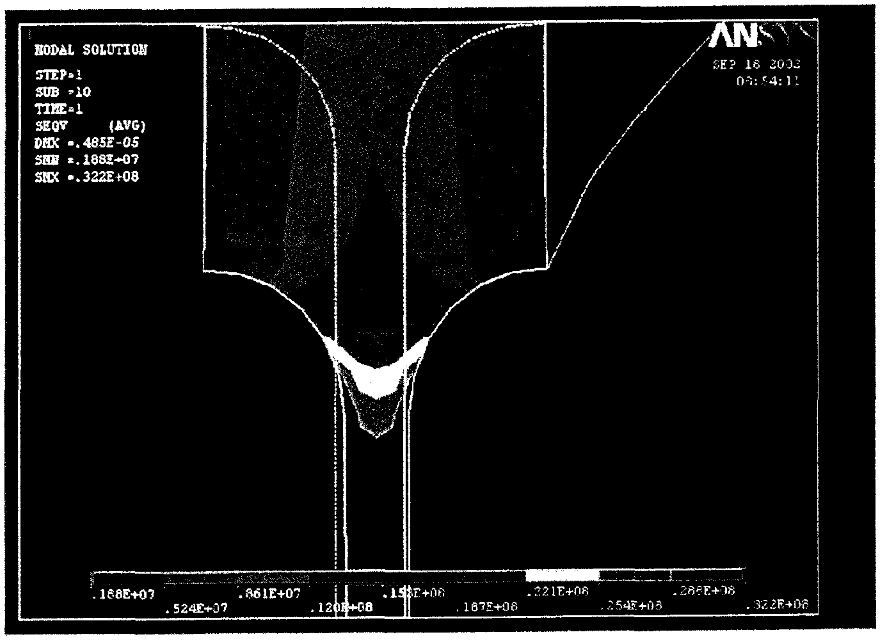
16 Microns



Disp Max:
0.486e-5 m

Stress Max:
0.318e+8 Pa

18 Microns



Disp Max:
0.485e-5 m

Stress Max:
0.322e+8 Pa

Cryostat Fixed — The Cryostat has been functioning properly now for several weeks and the HiVac system finally seems to be operating normally and reliably. Therefore, the remainder of this book will document, as closely as possible, the thermal transport measurements of Glasmet, MoRuB and other glassy metals.

First Measurement: GlasMet

We wanted to get a complete conductivity spectrum for the commercial GlasMet sample before measuring MoRuB. Initially there weren't any acceptable MoRuB samples, and because GlasMet can easily be replaced, mistakes during mounting would not be terrible.

Glasmet Data Sheets

The data sheets are available on the following pages.

Continuous Measurement On Glasmet

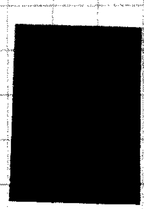
We first attempted a continuous measurement from 2K - 400K, but found this did not work ~~[illegible]~~ between 125K - 250K because the measurement would time out. (See plot 2 pages from now).

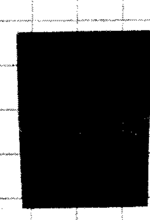
Failed Measurements

For an example of a "timed-out" failed measurement, see the plot 3 pages from now.

Manual Fitting Raw Data

At this point we decided that raw fitting the data ourself might allow us to fill in some data gaps where it had failed. An example of a fitted heated & cooled pulse follows.





Glasmet Sample

Honeywell

metglas SOLUTIONS

www.metglas.com

Magnetic Alloy 2826MB (Iron nickel-based) Technical Bulletin

Applications

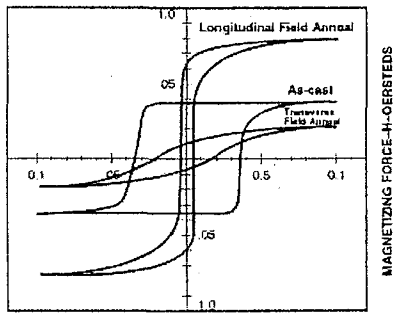
- Field sensors
- Shielding applications
- High frequency cores

Benefits

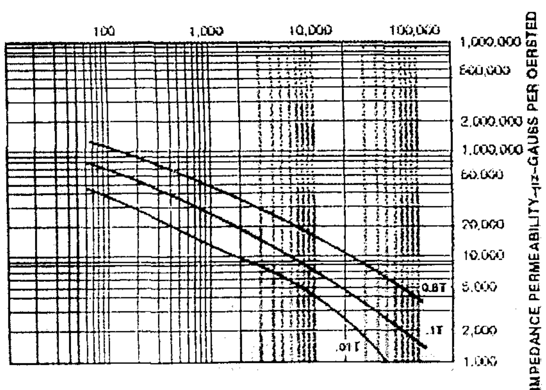
- Medium saturation induction
- Lower magnetostriction
- Higher corrosion resistance
- Can be annealed for very high DC permeability, rounded or square B-H loops

$Fe_{40}Ni_{38}Mo_4B_{18}$

Typical DC Hysteresis Loop



Typical Impedance Permeability Curves, Longitudinal Field Anneal



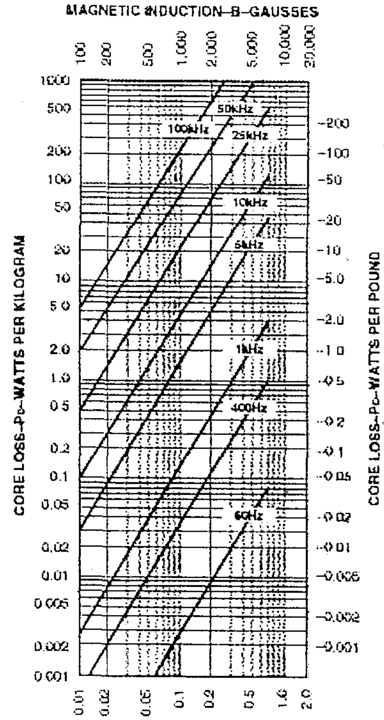
Physical Properties

Density (g/cc)	7.90
Vicker's Hardness (50g load)	740
Tensil Strength (GPa)	1-2
Elastic Modulus (GPa)	100-110
Lamination Factor (%)	>75
Thermal Expansion (ppm/°C)	11 7
Crystallization Temperature (°C)	410
Continuous Service Temp. (°C)	125

Magnetic Properties

Saturation Induction (Tesla)	0.88
Maximum D.C. Permeability (μ):	
Annealed	800,000
As Cast	>50,000
Saturation Magnetostriction (ppm)	12
Electrical Resistivity (μΩ-cm)	138
Curie Temperature (°C)	353

Typical Core Loss Curves, Longitudinal Field Anneal METGLAS Alloy 2826MB



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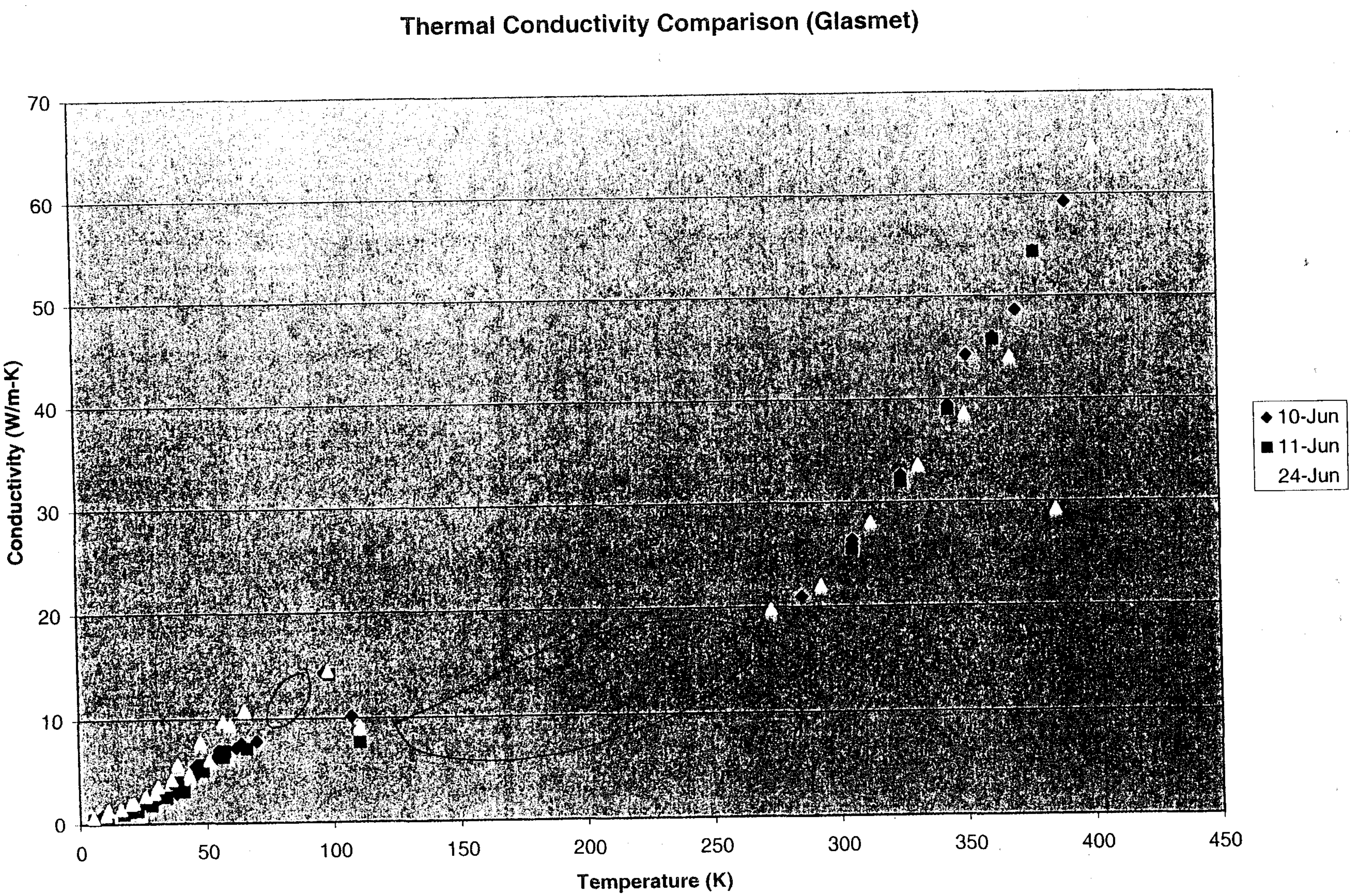
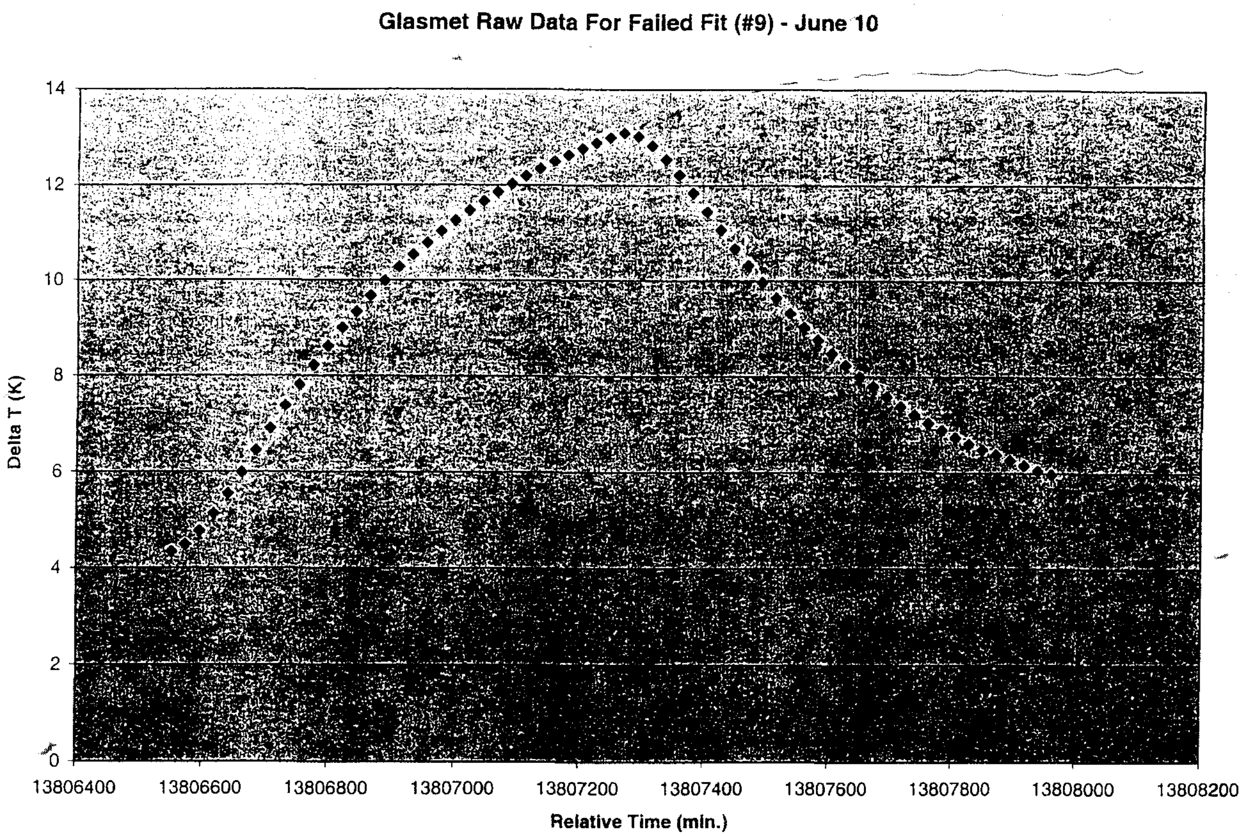
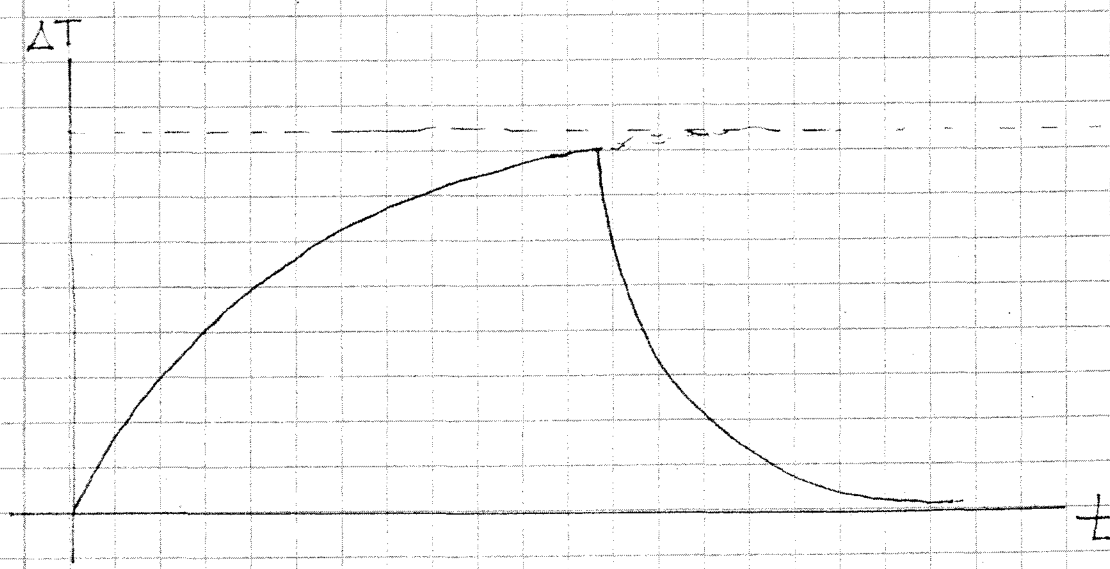


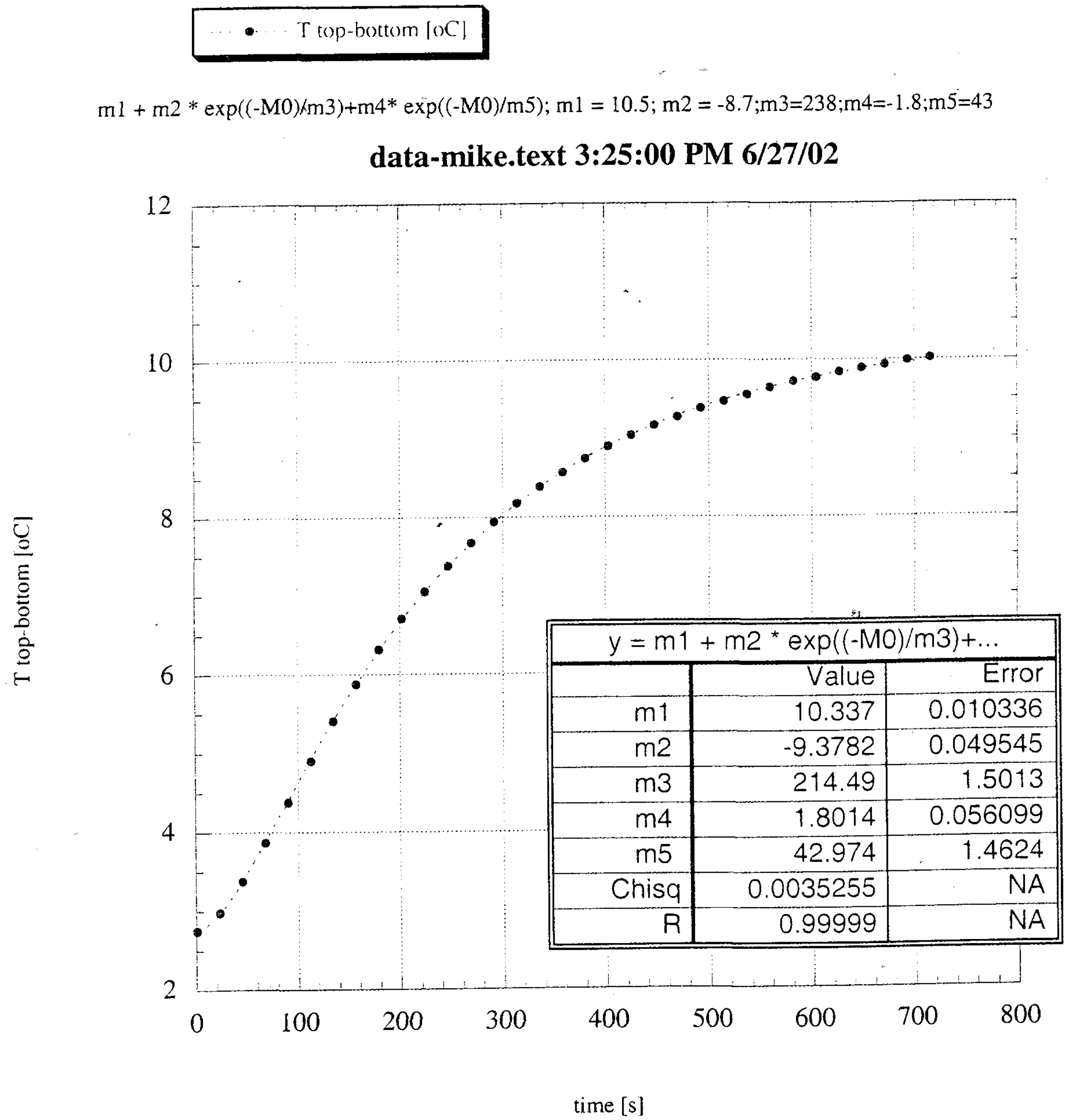
Notice the 2 gaps where data was not collected.

4



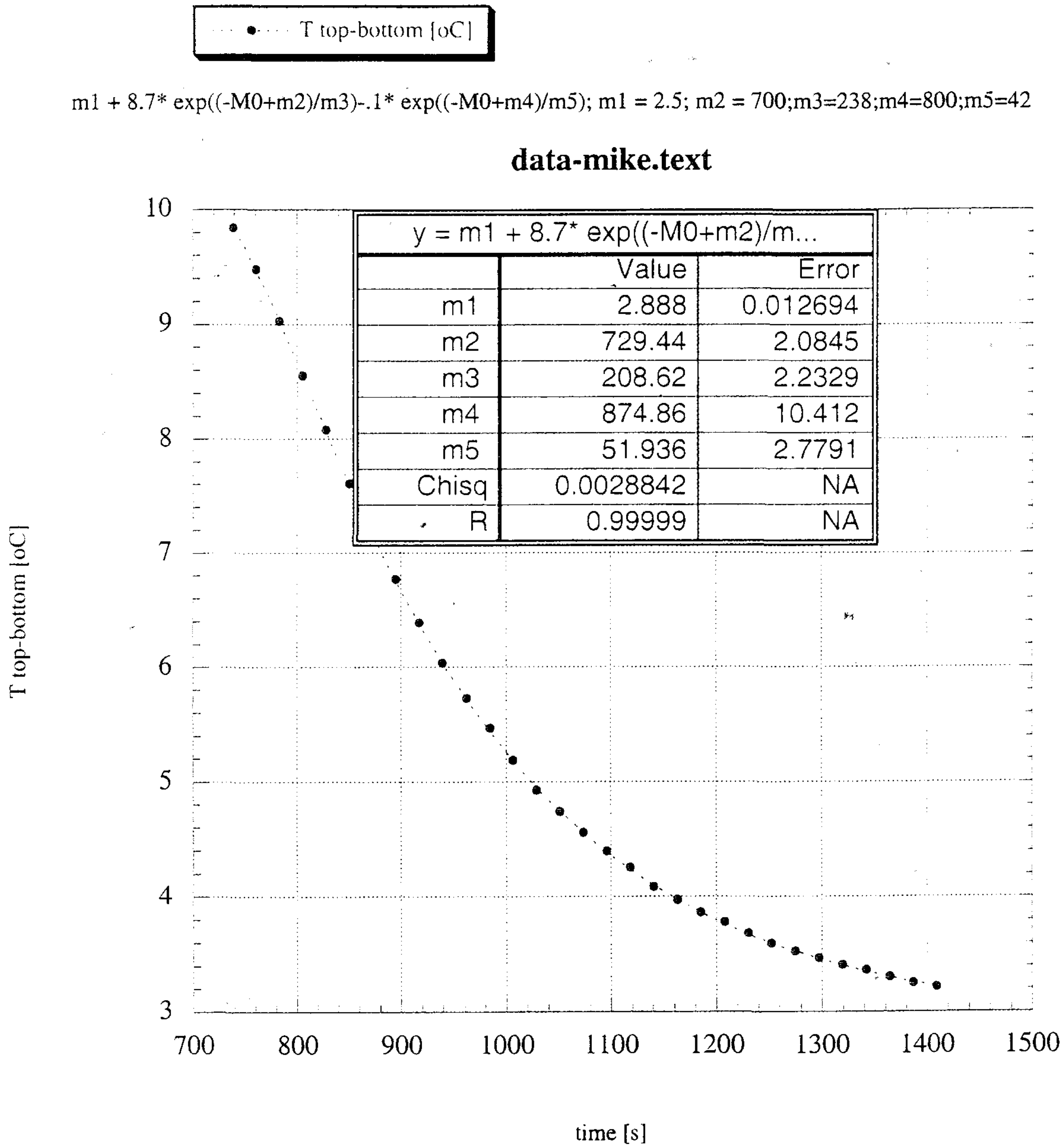
For an ideal fit, the temperature should approach equilibrium:





y = m1 + m2 * exp((-M0)/m3)+...		
	Value	Error
m1	10.337	0.010336
m2	-9.3782	0.049545
m3	214.49	1.5013
m4	1.8014	0.056099
m5	42.974	1.4624
Chisq	0.0035255	NA
R	0.99999	NA

This is one of the first heating fits performed.



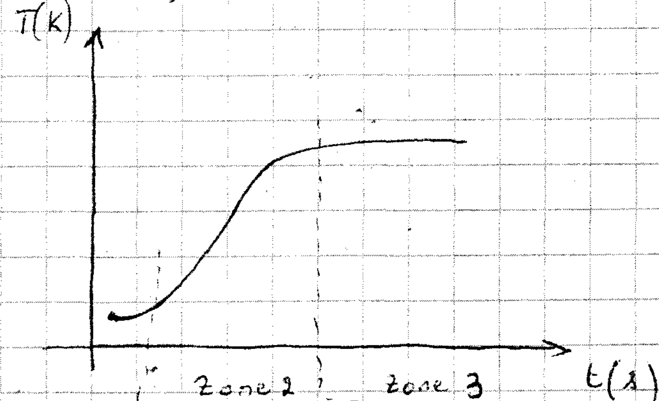
y = m1 + 8.7* exp((-M0+m2)/m...		
	Value	Error
m1	2.888	0.012694
m2	729.44	2.0845
m3	208.62	2.2329
m4	874.86	10.412
m5	51.936	2.7791
Chisq	0.0028842	NA
R	0.99999	NA

This is one of the first cooling fits performed.

TTO Fitting Procedure

To describe the behaviour of the metal, we use the following equation:

$$T(K) = m_1 + m_2 e^{-\frac{t}{m_3}} + m_4 e^{-\frac{t}{m_5}}$$



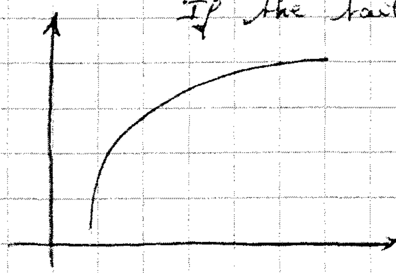
Zone 1: In Addition to the first exponential we have a tail.

Zone 2: The 2nd exponential give us the transitive zone.

Zone 3: The last one comes from the constant part of the expression.

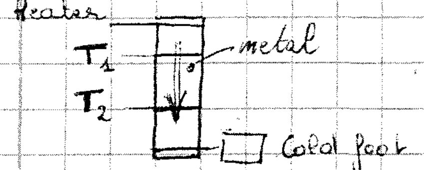
~~Actually, we fit the curve without the tail.~~

If the tail doesn't appear, instead of 5 parameters only 3 are needed.



To find out the parameters we use a program called Kaleida Graph. Trough the fitting of the curve, the parameters are figured out.

CONDUCTANCE : (the distribution of the temperature in the metal according to the power applicated).



$$K = \frac{P}{\Delta T}$$

$\Delta T = T_1 - T_2$
P = Power applicated through the heater
K = conductance

NOTE: we actually want to figure out the "conductivity" wich is just the conductance reported at the dimensions:

$$\kappa = K\left(\frac{l}{A}\right)$$ (l: length, A: Area)

In the experiment, due to the precision we need to find out the value, we do a correction. We substract the values of the Shoes:

$$K = \frac{P - P_{rad}}{\Delta T} - K_{shoes}$$

we use

- $P = I^2 R$ (the only way to measure it)
- P_{rad}: Power radiated by the sample in the chamber
- K_{shoes}: conductance of the different shoes (- Thermometers, - cold foot, - ...)

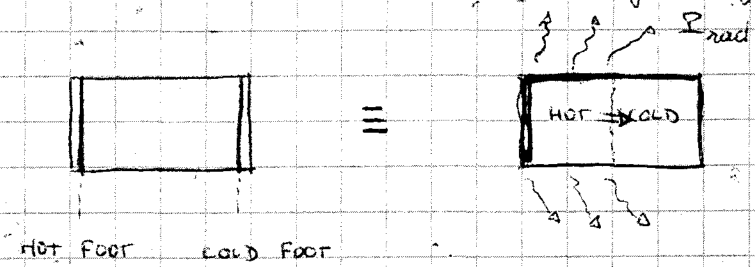
We assume: $K_{shoes} = d\left(aT + bT^2 + cT^3\right)$ ←

NOTE: we follow blindly, but we are going to check the results with an other experiment, using Nickel, which is a well-known metal, and do the transposing.

And $P_{RAD} = \sigma_T \times \left(\frac{S}{2}\right) \times \varepsilon \times \left(T_{HOT}^4 - T_{COLD}^4\right)$

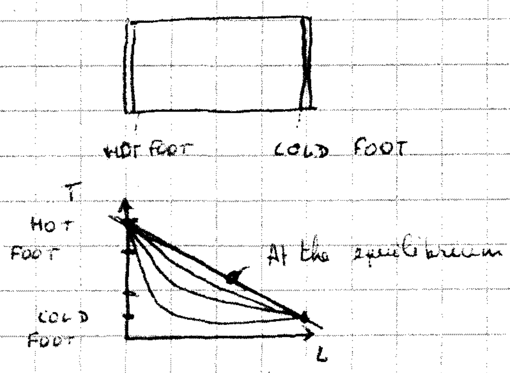
σ_T : Stefan Boltzman constant
ε : emissivity (constante in every metal)
S : Surface area of the sample

To explain ~~the~~ P_{rad}, we assume the following hypothesis:



We assume the radiations are emitted from the first part which has a hot temperature <u>minus</u> what pass through the cold part.

NOTE: To determine T_{HOT} and T_{COLD}, we look out from the <u>profile</u> of the distribution, and we ~~make~~ do the average.



$$\Rightarrow \quad T_{HOT} = \left(T_{HOT\ FOOT} - T_{COLD\ FOOT}\right) \cdot 3/4 + T_{COLD\ FOOT}$$

$$T_{COLD} = \left(T_{HOT\ FOOT} - T_{COLD\ FOOT}\right) \cdot 1/4 + T_{COLD\ FOOT}$$

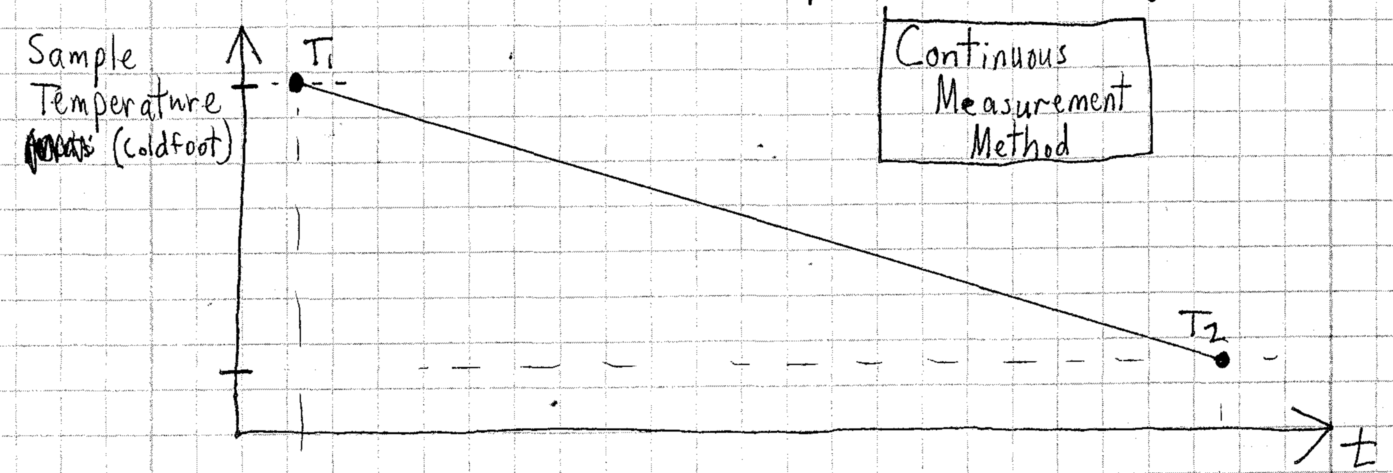
The constants on the right (A,B,C,D) are the parameters used in the equations on the previous page.

```
; TTO for Cal Inst. calibrated 9/01/01
; ====================
;
; Radiation Polynomial Coefficients
;
Rad Loss A = 1.9e-8
Rad Loss B = 9.1e-10
Rad Loss C = 9.6e-12
Rad Loss D = 1.05
;
;
; User config
;
In Use Hot Therm  = therm015
In Use Cold Therm = therm014
In Use Heater     = Heatr020
```

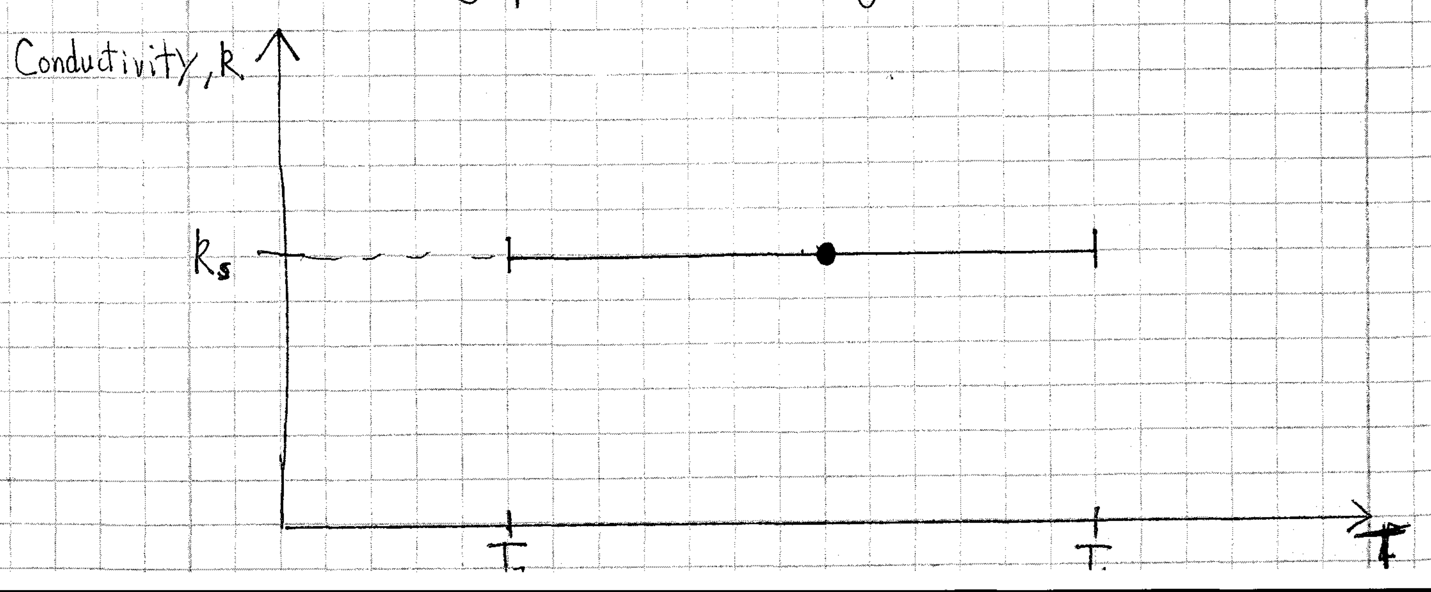
August 1, 2002

Stable Measurements

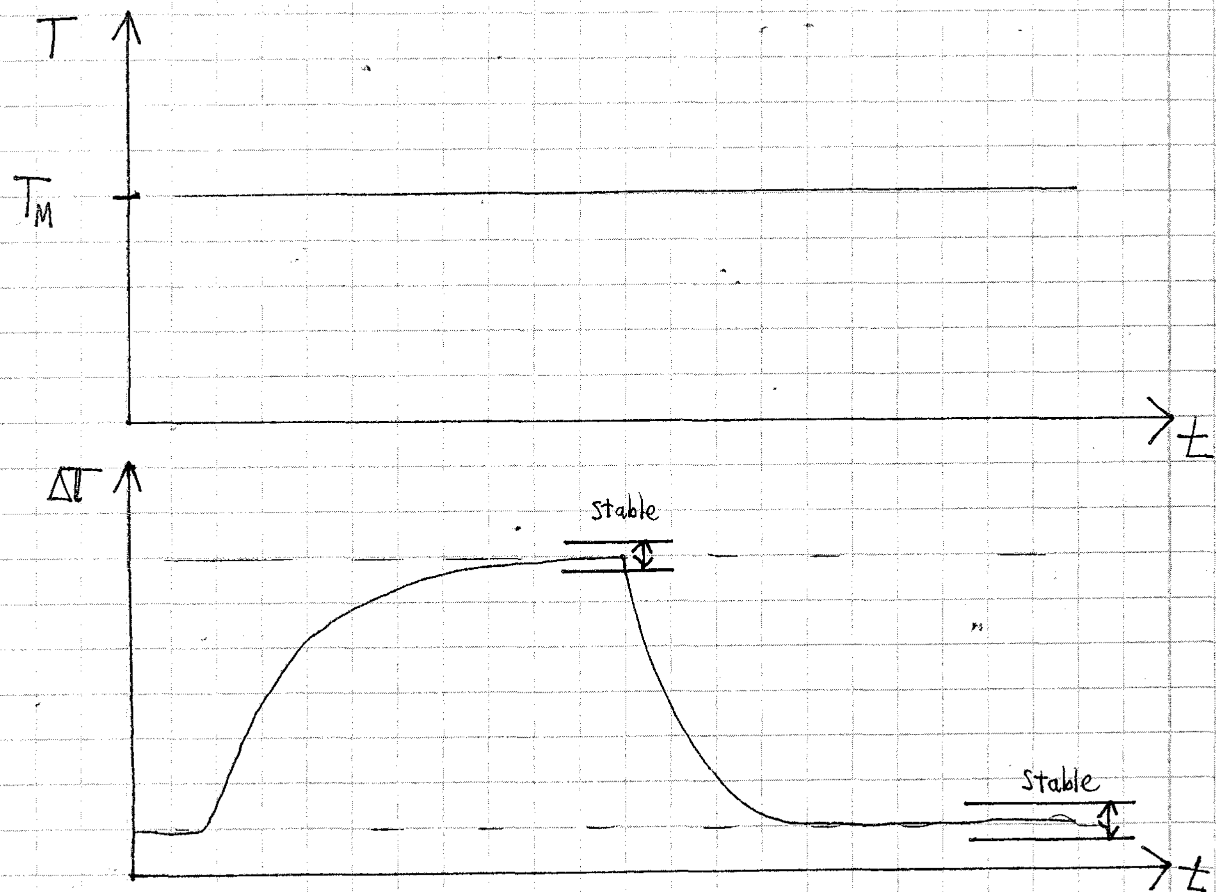
The continuous measurement method is undesirable for our purposes especially because the conductivity of our sample is low. Using this method not only makes QD's fitting algorithm fail, but it places unreasonable error bars on our temperature axis, for the following reasons



During the course of one measurement the temperature has changed by $T_1 - T_2 = \Delta T$, which for our samples is typically very large. So our conductivity plots will have large errors.



However, for a stable measurement:

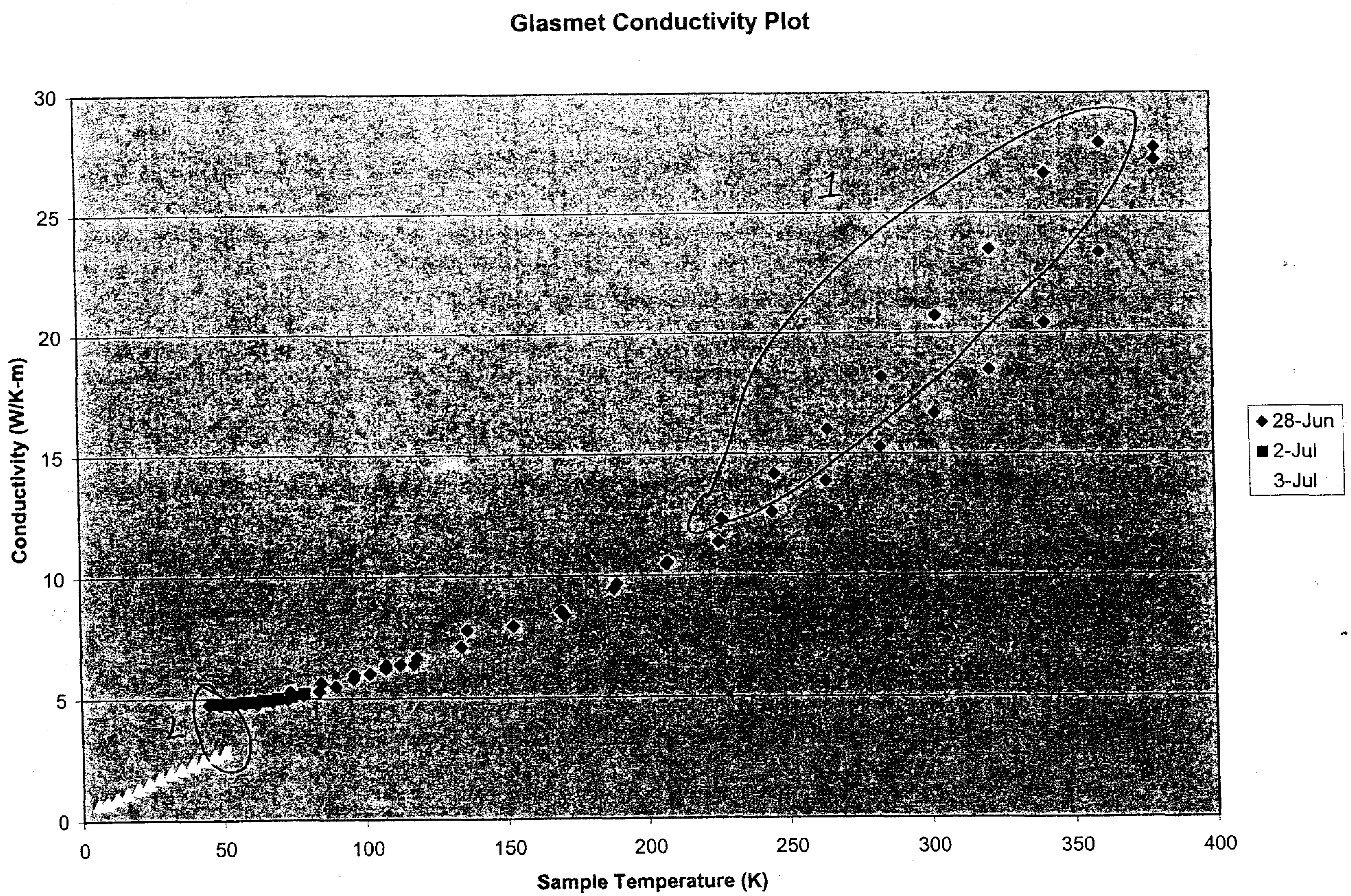


In this case, T remains stable, & our errors are only as large as the inability to keep a stable temperature. In addition, this method waits as long as necessary until the ΔT pulse stabilizes to within a user defined limit (usually 0.1K.)

Whereas the continuous measurement does a fit, the stable method does not.

Stable Measurements on Metglas

The stability measurements are shown on the next page. The area marked "1" diverges because of a Helium refill which unexpectedly (& unexplainedly) forced temperature jumps to occur. The area marked "2" is a concern because it was not repeatable. The July 3rd run was using a different sample & a different heater power which might explain the jump, but in our opinion, it should not be a factor.


Glasmet Conductivity Plot
Conductivity (W/K-m)
Sample Temperature (K)
0
5
10
15
20
25
30
0
50
100
150
200
250
300
350
400
28-Jun
2-Jul
3-Jul
1
2

Conductivity and Heater Power

The conductivity of a sample shouldn't change due to the heater power selected. The conductivity should be a function of temperature only. The power affects the ΔT only and they should obey the following:

$$K = \frac{P}{\Delta T} \quad \text{(Conductivity)}$$

However, the previous plot (as well as some later plots) clearly show a conductivity spread for different power settings. It probably has to do with the imperfect radiation and shoe conductance corrections:

$$K = \frac{(P_{IN} - P_{RAD})}{\Delta T} - (D) K_{SHOES}$$

P_{RAD} changes with increasing power, because the average temperature of T_{HOT} and T_{COLD} change. Large increases in power may even change the sample temperature, which will also change K_{SHOES}. It is possible that we see conductivity spreads only at heater powers which produce unreasonably large values of ΔT. This will soon be tested.

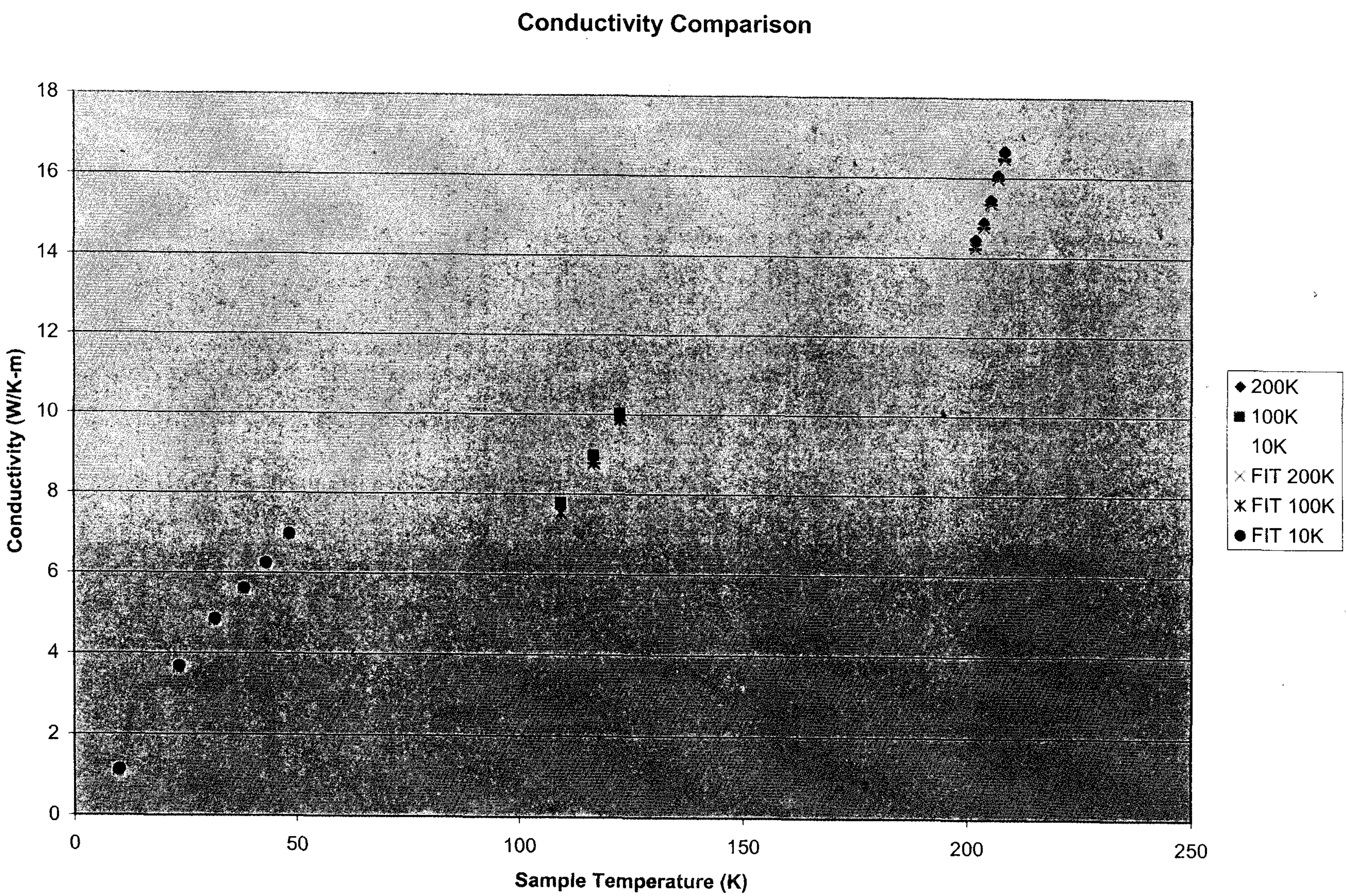
Finding An appropriate Pulse Size and Heater Power

<u>Note:</u> For a detailed account of the measurement, please see the August 1st entry in the "Data Analysis" log book.

A measurement was taken @ 3 different temperatures (200K, 105K, and 10K) and @ 7 different power settings (10mW, 8mW, 6mW, 4mW, 2mW, 10μW, 15μW). The plot of the results (and our corresponding fits) are on the next page.

Amplitude of Noise on ΔT

It was found that the noise in ΔT (due to the noise in both thermometers) is ± 1.8 mK.



Conductivity Comparison
Conductivity (W/K-m)
Sample Temperature (K)
0
2
4
6
8
10
12
14
16
18
0
50
100
150
200
250
200K
100K
10K
FIT 200K
FIT 100K
FIT 10K

What is the ideal pulse size?

For a noise level of 1.8mK, a pulse height of 0.5K yields a SNR of 278, which should be acceptable. Further information gathered by the "power scatter" measurement indicates that non-negligible temperature deviations begin at ≈1.5K. A pulse below 1.5K should have very small error bars.

Also, it has been observed that at ~~no~~ lower powers, the systematic errors fall below ~~that~~ the random errors. The power required for a 0.5K pulse should be well below this level.

August 22, 2002

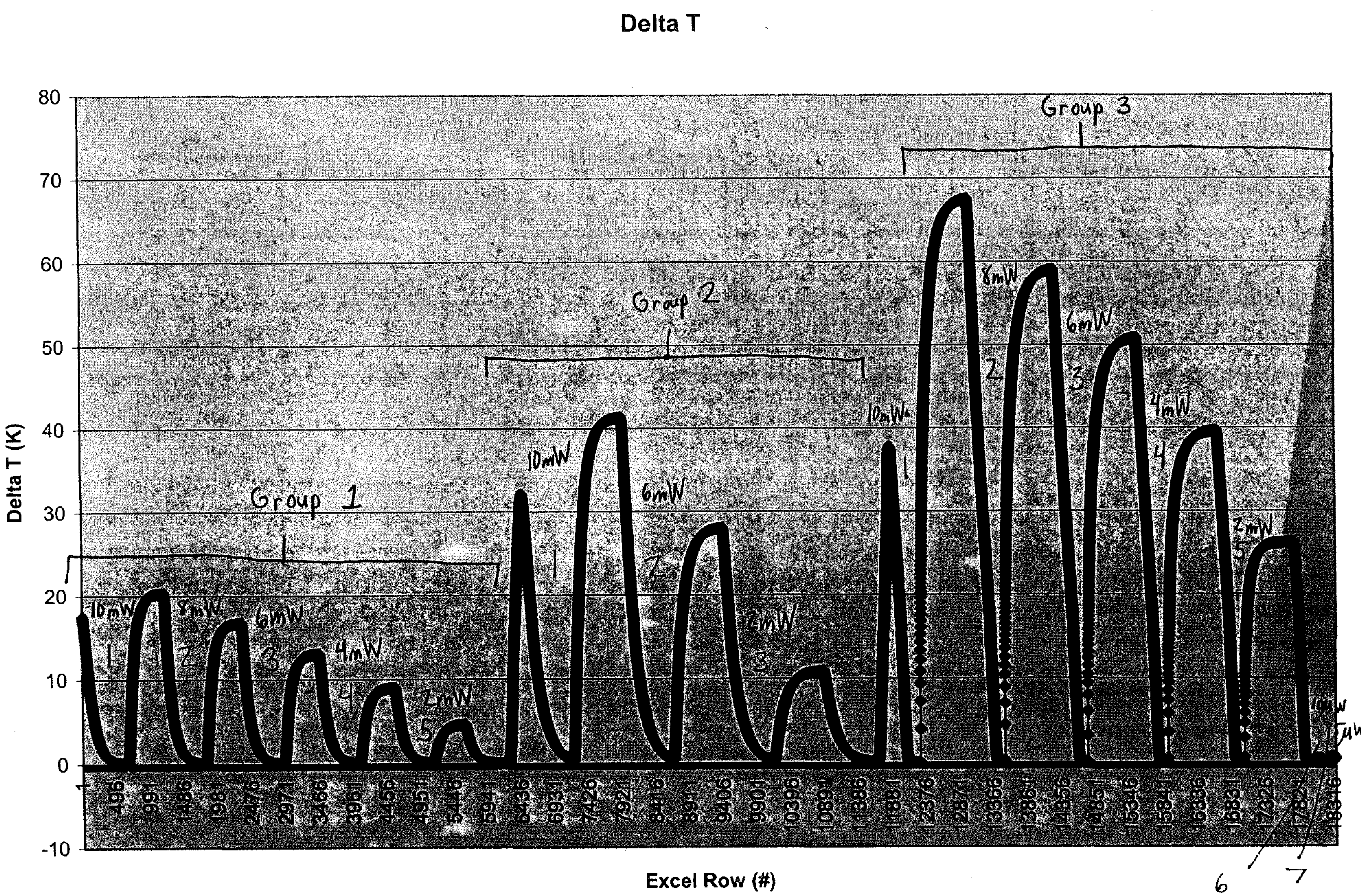
Power Scatter Measurement - Detailed Description

I have decided to eliminate the separate data analysis tool, and therefore will include the power scatter experiment in its entirety.

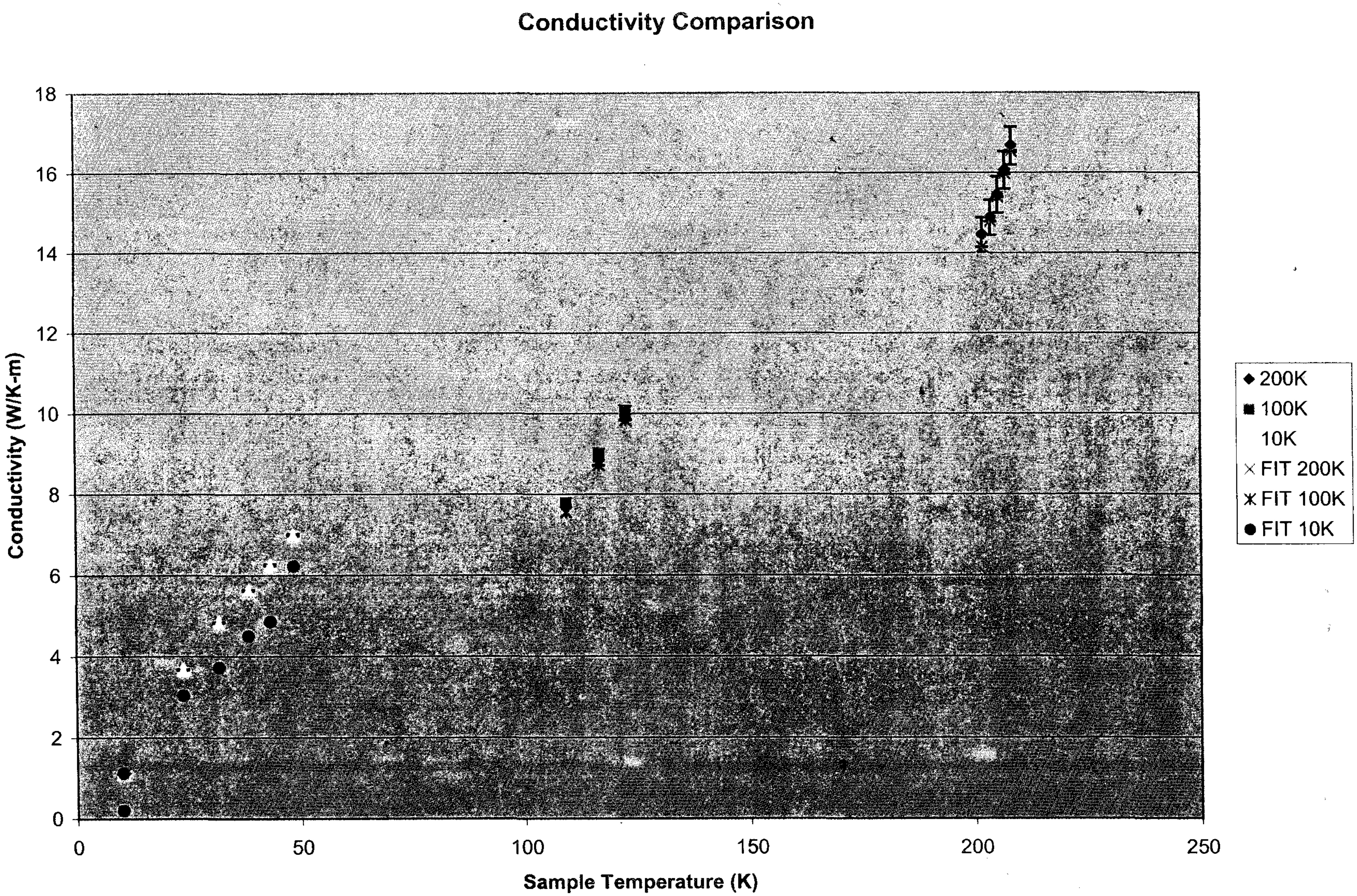
Sequence File: PowerScatter.seq

```
 1:  Set Temperature 200.00K at 20.00K/min. Fast Settle
 2:  Wait For Temperature, Delay 0 secs, No Action
 3:  LogData Start New 5.00 1073741823 1073741823 1073741823 "C:\cryolab\07-19
     -2002\LogPpmsSeq.dat" "Power Scatter from 200K to 10K (10mW - 0.01mW) in
     3 Steps" ""
 4:  Scan Temp from 200.0K to 10.0K at 20.0K/min, in 3 steps, Uniform, Fast
 5:       TTO Single dT Measure K init= 10mW, 300sec max= 50mW, 1430sec, 500uV,
           10mA
 6:       TTO Single dT Measure K init= 10mW, 300sec max= 50mW, 1430sec, 500uV,
           10mA
 7:       TTO Single dT Measure K init= 10mW, 300sec max= 50mW, 1430sec, 500uV,
           10mA
 8:       TTO Single dT Measure K init= 10mW, 300sec max= 50mW, 1430sec, 500uV,
           10mA
 9:       TTO Single dT Measure K init= 10mW, 300sec max= 50mW, 1430sec, 500uV,
           10mA
10:       TTO Single dT Measure K init= 10mW, 300sec max= 50mW, 1430sec, 500uV,
           10mA
11:       TTO Single dT Measure K init= 10mW, 300sec max= 50mW, 1430sec, 500uV,
           10mA
12:  End Scan
13:  LogData Stop ""
14:  Set Temperature 300.00K at 20.00K/min. Fast Settle
15:  Shutdown Temperature Controller
```

The Power Scatter Sequence run on 7/19/02 is listed above.



The above plot is the Delta T for each pulse. (The row # is proportional to the time.)



Here is a comparison of our fits with those of QD. At lower temperatures, a larger difference arises because the large ΔT was difficult to fit. QD was using its "static method".

These 2 pages present the fitting data that was used to generate our conductivity plots.

To the right are the sample parameters of the data taken directly from the cryostat file.

Below are the fitting results for the cooling portion.

sigma_T:	5.67E-08	Rad Loss A:	0.000000019
Sample Properties		Rad Loss B:	9.1E-10
Surface Area:	36.1916	Rad Loss C:	9.6E-12
Length:	6.92	Rad Loss D:	1.05
CrossSection:	0.14121		
Emmisivity:	0.3		

Fit #	Temperature	Avg. Cold	Avg. Hot	Heater Power
1	208.2939038	199.9822693	226.7397308	0.009965554
2	206.8183907	199.9837189	222.0238495	0.007974004
3	205.2663229	199.9843903	217.058136	0.005998767
4	203.6046597	199.9828339	211.7086334	0.003998828
5	201.8336618	199.9826202	205.9885864	0.001998749
1	122.6366997	104.8594055	160.8986511	0.009970868
2	116.6720731	104.8692017	142.2724152	0.005997643
3	109.2679628	104.8185883	119.037384	0.001998746
1	48.44920301	10.0144215	120.6443481	0.009961674
2	43.27157417	10.0045223	106.0666351	0.007763731
3	38.40353791	10.0037146	92.25457	0.005996897
4	31.83781047	10.0044765	73.509407	0.003999098
5	23.77258506	10.0045452	50.6388245	0.001999189
6	10.18115854	10.004591	10.5699968	0.00001
7	10.26398725	10.0040903	10.8391409	1.4994E-05

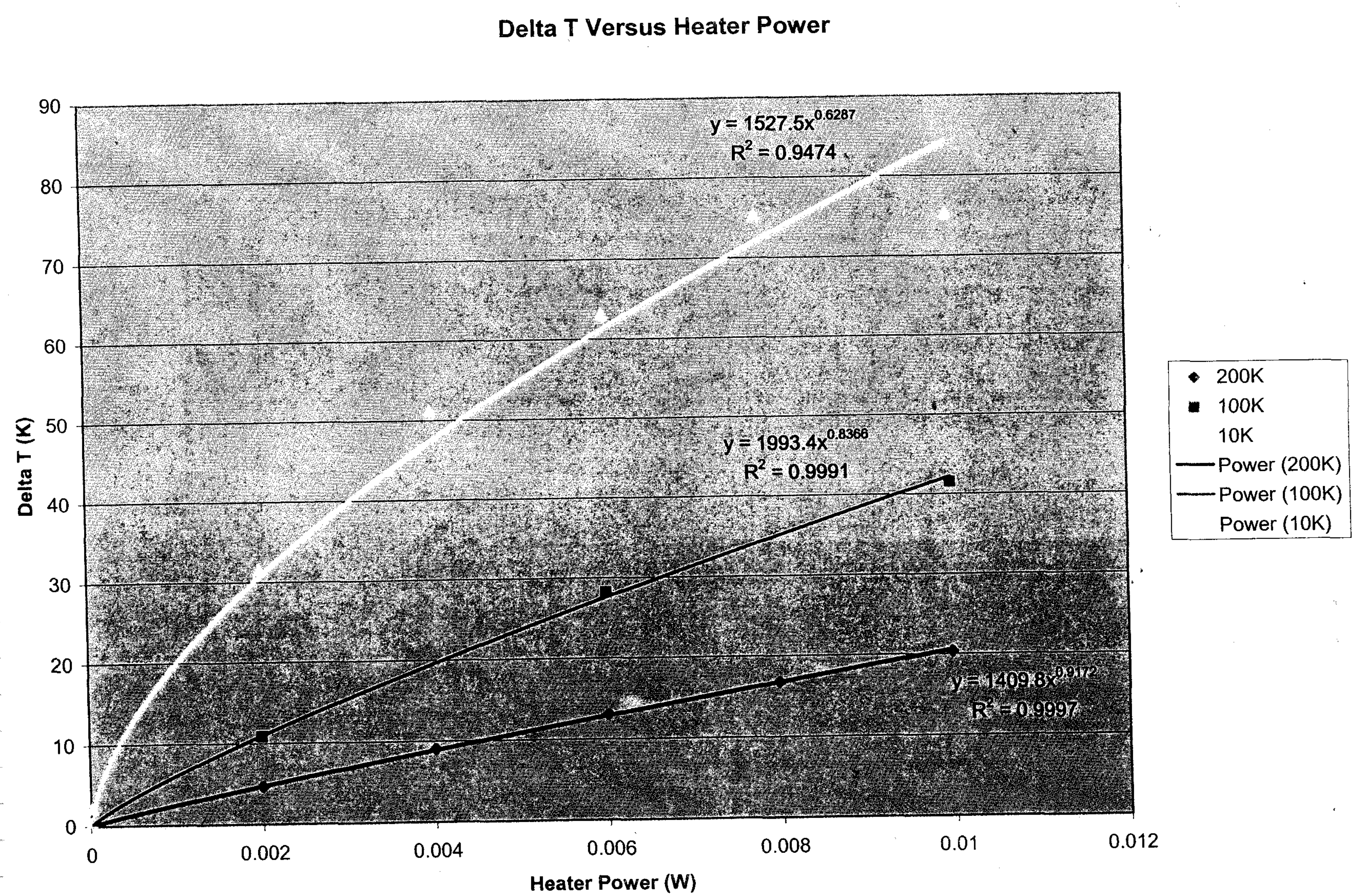
m1	m1 err	m2	m2 err	m3	m3 err	m4	m4 err	m5	m5 err	Chi Sq	R
0.049148	0.0075316	148.32	263.94	391.87	35.281	-130.46	263.93	353.71	37.266	3.3046	0.9999
-0.0025551	0.0024013	25.098	0.020317	476.1	0.43089	-5.146	0.02423	60.597	0.56343	0.7342	0.99998
0.01814	0.0037137	23.896	0.055982	469.08	0.93386	-8.4673	0.17632	77.012	1.8404	1.6848	0.99993
0.007735	0.0028769	18.146	0.0424	471.09	0.93235	-5.361	0.11077	80.982	2.0974	0.78353	0.99994
-0.020591	0.00066737	10.819	4.85E-03	483.34	0.25535	-1.8894	5.75E-03	61.928	0.37126	0.035846	0.99999
-0.1533	0.0032082	41.394	0.039434	824.32	0.66813	-8.8929	0.035659	199.73	1.0971	0.51683	1
-0.17879	0.0030673	44.782	9.80E-03	820.87	0.31954	-3.3767	2.00E-02	56.959	0.65554	0.87979	1
0.030778	0.013584	34.44	5.07E-01	749.96	5.6713	-5.5862	5.04E-01	289.73	15.212	7.1496	0.99992
-7.8137	2.1509	239.93	1.90E+03	478.23	468.44	-195.8	1.91E+03	379.97	405.32	689.8	0.99413
-16.317	4.6236	265.7	1594.6	907.91	887.87	-182.41	1598.8	680.51	790.44	1812.2	0.99629
-12.186	3.2098	549.07	1.75E+04	707.99	1413.2	-478.8	1.75E+04	627.34	1343.8	1706.5	0.99538
-11.658	3.3345	1060.6	1.71E+05	617.85	2860.5	-999.31	1.71E+05	583.73	2815.7	1259.7	0.99497
-5.4543	1.2222	290.32	2.29E+03	452.66	364.81	-247.37	2.29E+03	371.82	330.37	1076.2	0.99291
-1.841	0.37976	258.17	2.26E+03	250.04	173.58	-232.38	2.26E+03	213.59	164.43	399.47	0.99237
-0.0039796	0.0007751	-2.0355	7.18E+01	73.94	99.245	2.6744	7.18E+01	68.415	72.995	0.00073555	0.9996

m1	m1 err	m2	m2 err	m3	m3 err	m4	m4 err	m5	m5 err	Chi Sq	R
20.4	0.010397	-32.7	0.38799	403.5	2.7411	7.42	0.64138	106.35	12.472	6.7787	0.99975
16.777	0.00065702	-20.753	0.0072663	404.47	0.13674	4.0279	0.0073109	69.592	0.21718	0.030526	1
13.054	0.00038932	-15.65	0.0037971	422.59	0.1044	2.6211	0.0039098	68.739	0.18228	0.0098989	1
9.0053	0.00038144	-11.045	0.0034456	442.85	0.14576	2.0852	0.0036256	68.708	0.21837	0.0098652	1
4.6525	0.00028137	-5.5359	0.0018545	464.29	0.18725	0.90005	0.0020392	66.703	0.28067	0.0030093	1
41.381	0.0019663	-45.844	0.013178	565.32	0.20445	4.9483	0.019225	56.151	0.43779	0.67915	1
28.061	0.0021059	-30.798	0.011316	627.96	0.32006	3.2262	0.018511	55.038	0.62869	0.66388	0.99999
10.951	0.00070452	-11.902	0.0032282	704.81	0.28294	1.2178	0.0051905	63.012	0.53707	0.056871	1
67.479	0.0093825	-51.061	0.070153	592.27	0.9586	-14.616	0.15577	65.187	1.132	14.001	0.99993
58.998	0.013348	-41.766	0.069511	611.25	1.4432	-14.326	0.12617	48.127	0.83182	28.52	0.99983
50.908	0.011401	-32.523	0.068916	643.37	1.7652	-12.889	0.094235	69.078	1.0151	17.8	0.99984
39.492	0.01238	-29.366	0.12361	550.64	2.4081	-100.78	5.6788	51.176	1.2234	28.377	0.99948
26.139	0.0061764	-13.593	0.060157	436.47	2.1212	-10.62	0.080251	48.674	0.73701	9.3946	0.99948
0.42981	0.00031222	-0.57909	20088	46.712	3147.3	0.13577	20088	46.87	9993	0.00034286	0.99978
0.63557	0.00028423	-3.2005	9779.9	43.466	751.77	2.5768	9779.9	42.955	1007.5	0.00020182	0.99993

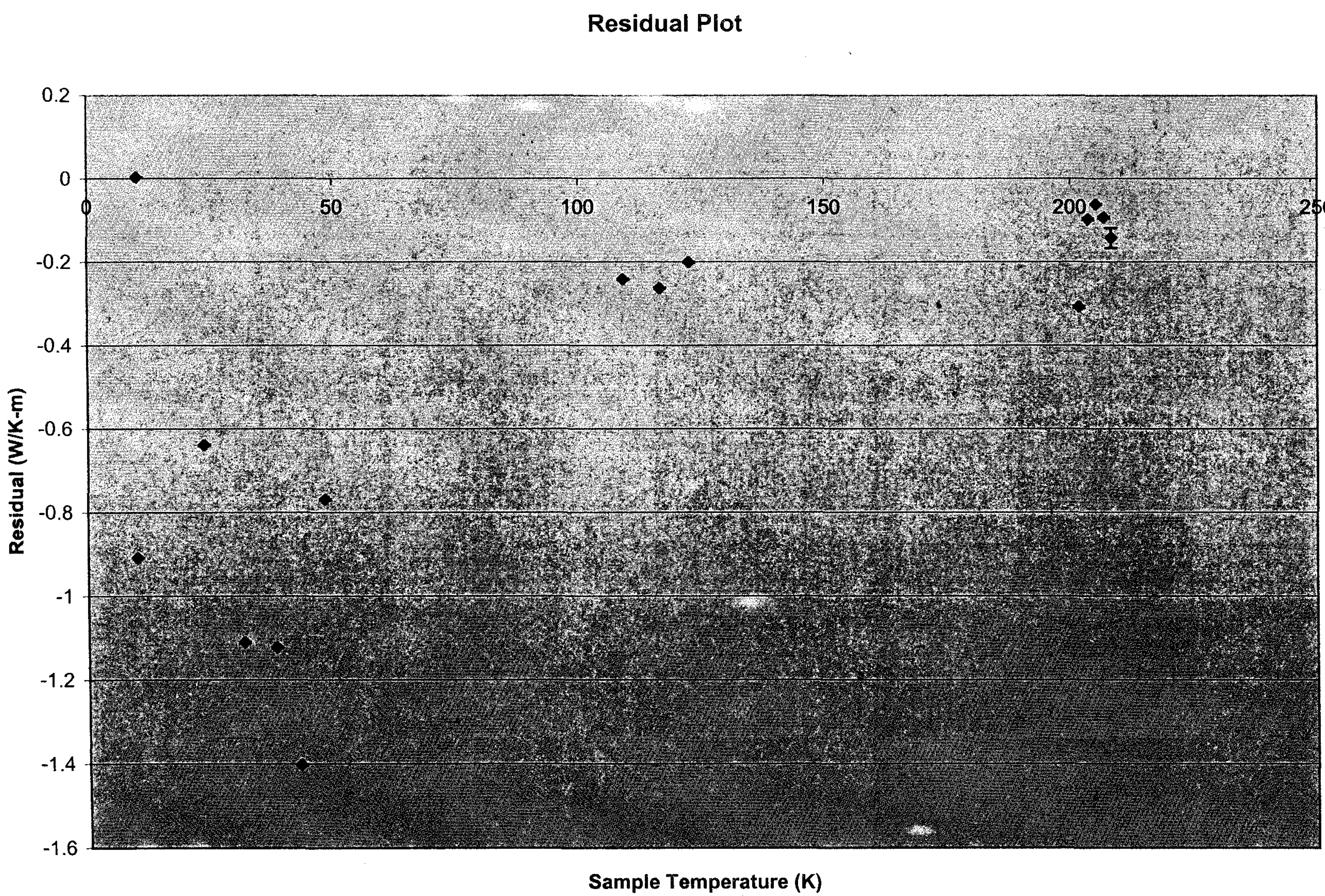
Above are the fitting results for the heating portions.

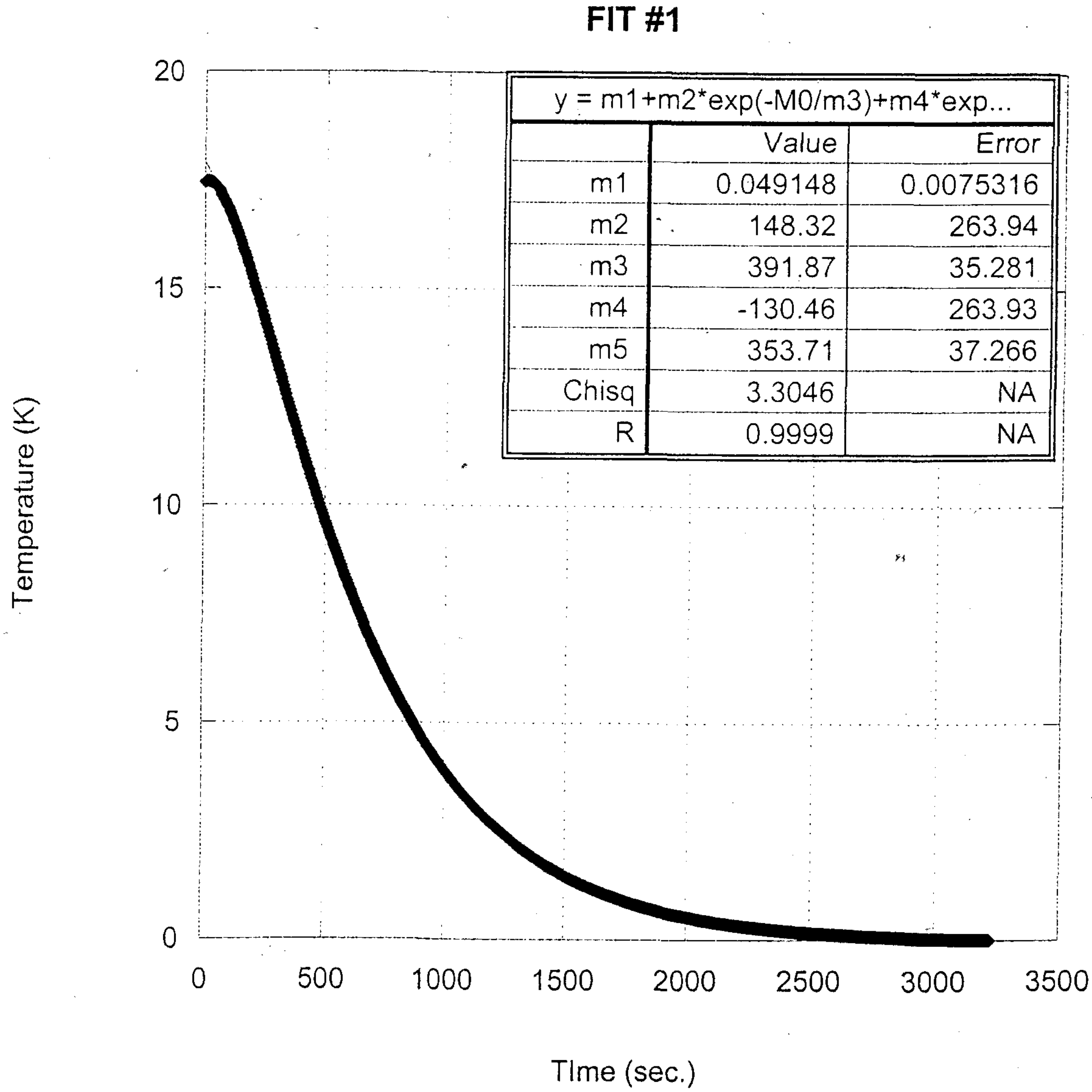
Delta K	Raw Conductance	P_rad (W)	K_shoes	Conductance	[redacted]	Residual	Delta K Err	Conductivity Err
20.350852	0.000489687	0.000321245	0.000130195	0.000337197	[redacted]	-0.142042	0.010397	0.029720289
16.7795551	0.000475221	0.000255629	0.000127779	0.000325819	[redacted]	-0.093752	0.00065702	0.001765299
13.03586	0.000460174	0.000190919	0.00012527	0.000313995	[redacted]	-0.062131	0.00038932	0.001304107
8.997565	0.000444435	0.000126027	0.00012262	0.000301676	[redacted]	-0.097777	0.00038144	0.001788491
4.673091	0.000427715	6.18608E-05	0.000119837	0.000288648	[redacted]	-0.307606	0.00028137	0.002445933
41.5343	0.000240063	0.000169082	3.37228E-05	0.000200584	[redacted]	-0.200911	0.0019663	0.001094994
28.23979	0.000212383	8.88861E-05	2.98506E-05	0.000177892	[redacted]	-0.26322	0.0021059	0.001529261
10.920222	0.000183032	2.46473E-05	2.54652E-05	0.000154036	[redacted]	-0.24182	0.00070452	0.001143063
75.2927	0.000132306	6.52063E-05	4.14837E-06	0.000127084	[redacted]	-0.769633	0.0093825	0.001605328
75.315	0.000103083	3.8955E-05	3.30389E-06	9.90971E-05	[redacted]	-1.402331	0.013348	0.001781698
63.094	9.5047E-05	2.22933E-05	2.6155E-06	9.19474E-05	[redacted]	-1.123283	0.011401	0.001677052
51.15	7.81837E-05	8.98472E-06	1.83715E-06	7.60791E-05	[redacted]	-1.110993	0.01238	0.001850484
31.5933	6.32789E-05	2.02094E-06	1.09493E-06	6.20652E-05	[redacted]	-0.638824	0.0061764	0.001211241
2.27081	4.40371E-06	7.58462E-10	2.979E-07	4.09059E-06	[redacted]	-0.909464	0.00031222	5.93885E-05
0.6395496	2.34447E-05	1.16562E-09	3.01264E-07	2.31265E-05	[redacted]	0.0026609	0.00028423	0.001021121

Above are the calculations of derived conductivities / residuals.



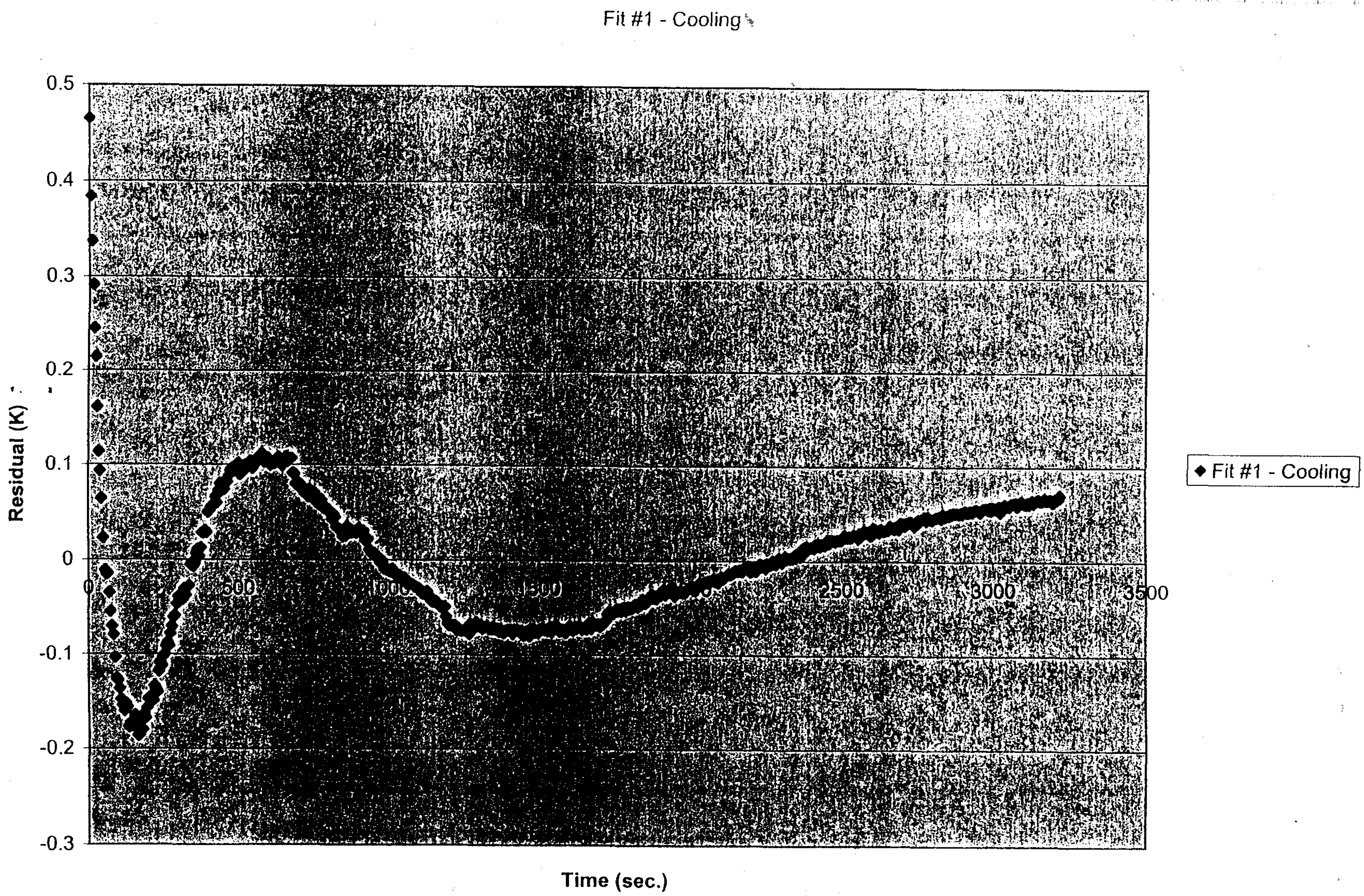
above is the relationship of the Delta T versus heater power for 3 different temperatures, Below is the residual plot of our fits minus the computer fit. Again @ lower temperatures, the residuals are large because of large ΔT.





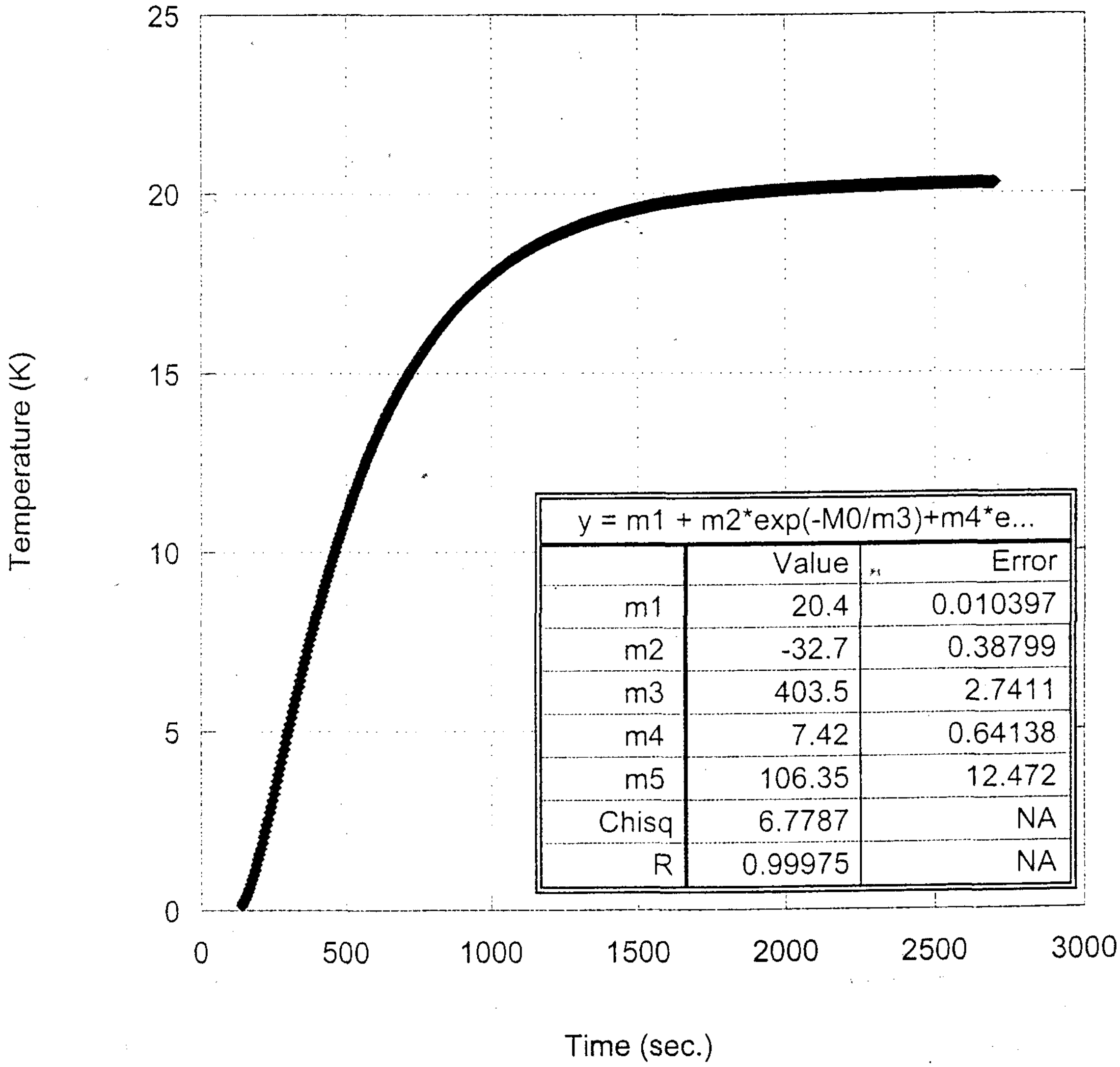
The equation used to fit both the heating & the cooling portion is:

$$y = m_1 + m_2 e^{\frac{-t}{m_3}} + m_4 e^{\frac{-t}{m_5}}$$



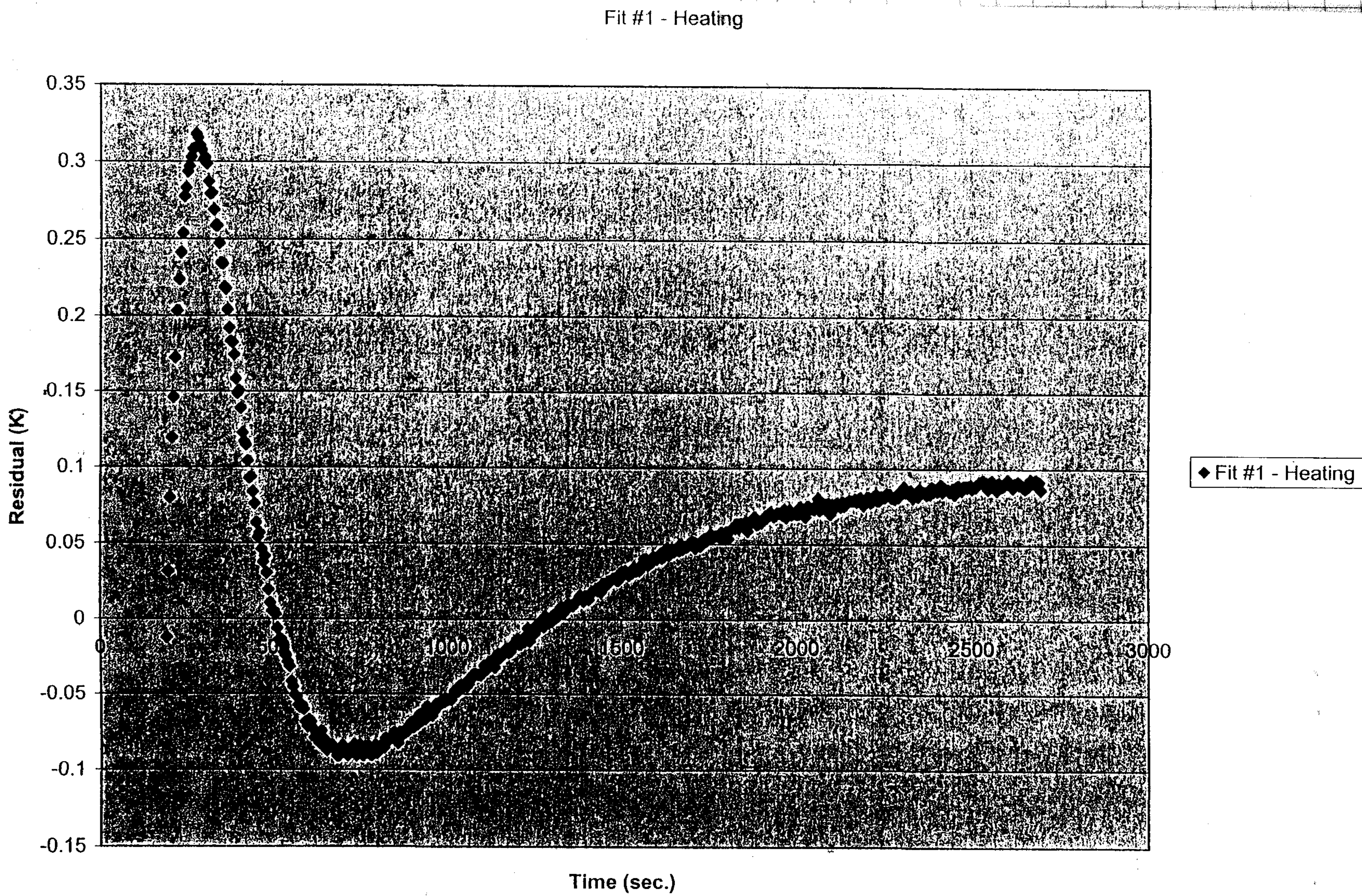
The residual plot above shows us our systematic errors. These errors decrease with decreased heater power.

FIT #1

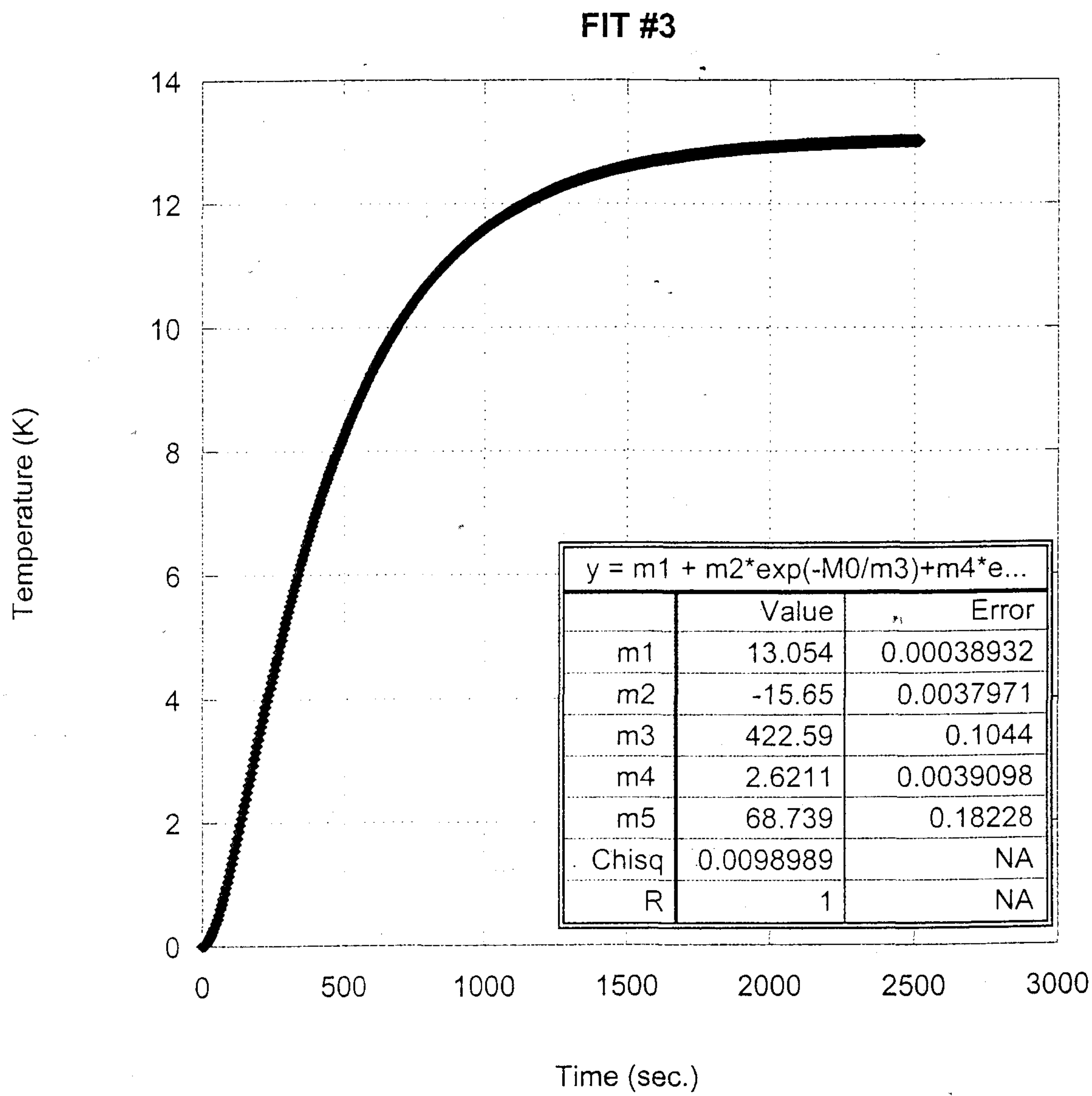


y = m1 + m2*exp(-M0/m3)+m4*e...		
	Value	Error
m1	20.4	0.010397
m2	-32.7	0.38799
m3	403.5	2.7411
m4	7.42	0.64138
m5	106.35	12.472
Chisq	6.7787	NA
R	0.99975	NA

$$y = m_1 + m_2 e^{\frac{-t}{m_3}} + m_4 e^{\frac{-t}{m_5}}$$

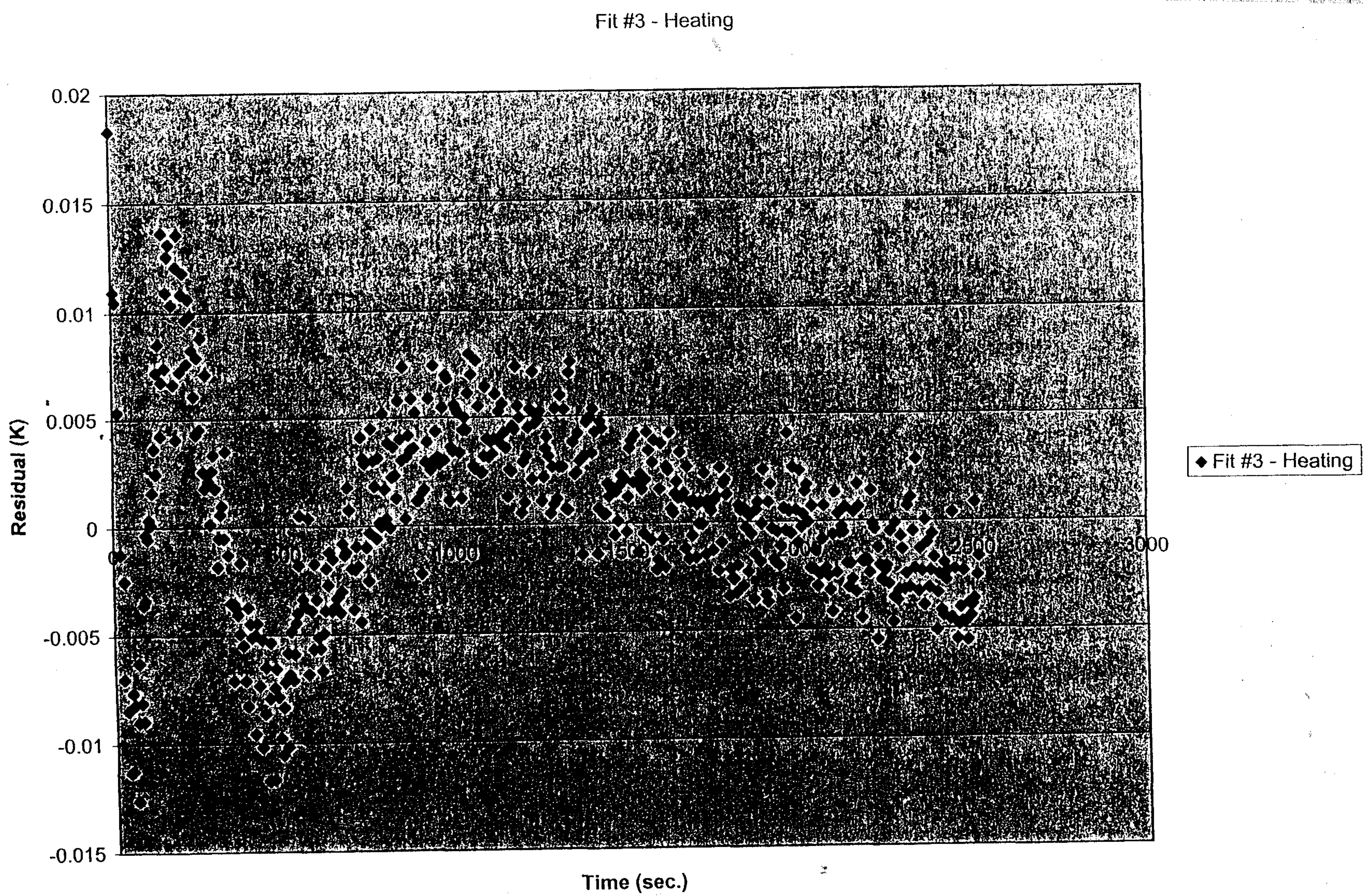


The systematic error for the heating portion @ 10mW is ≈ 0.35K. Notice the decrease to ≈ 0.015 K for a power of 6mW.

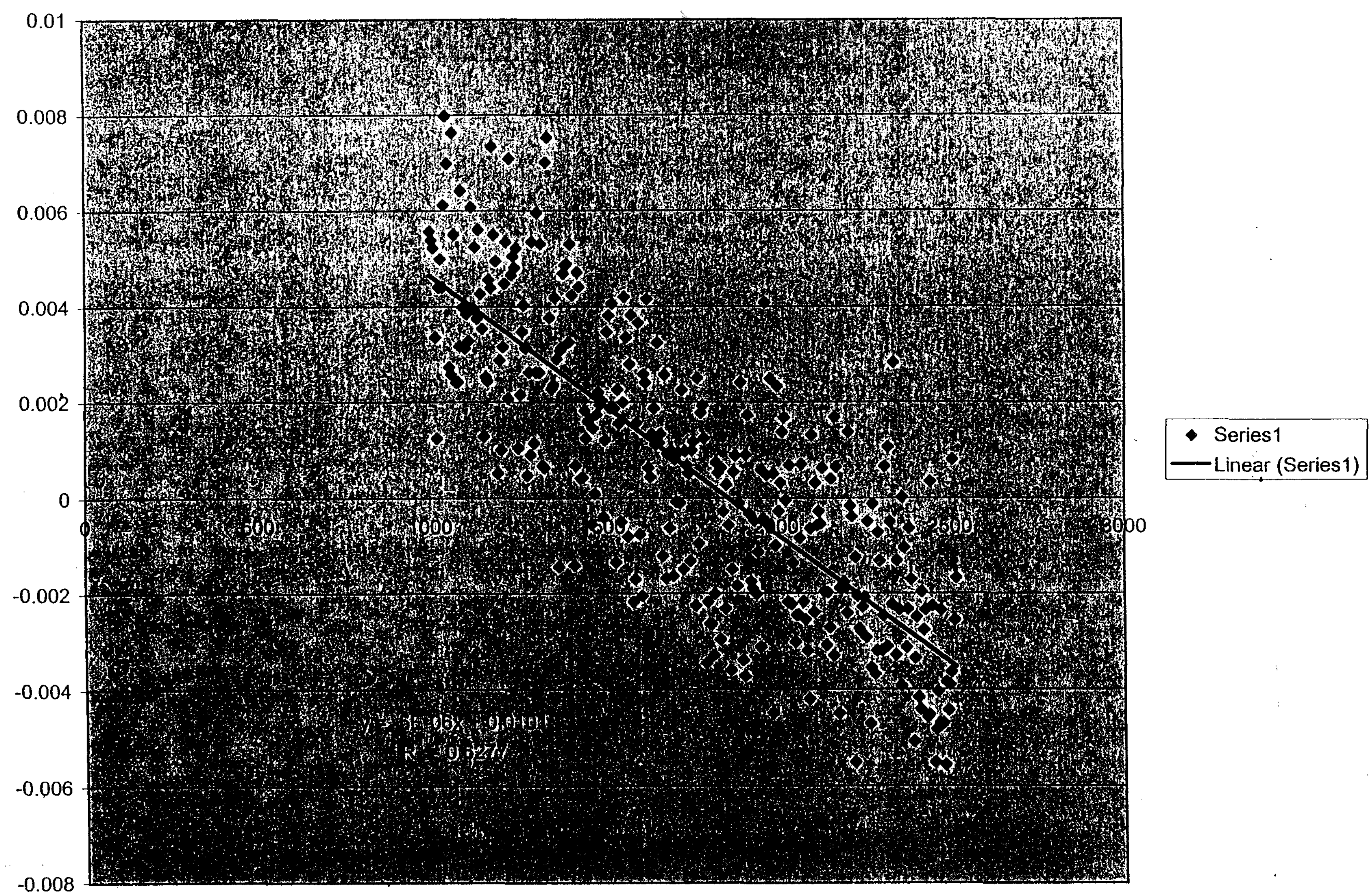


y = m1 + m2*exp(-M0/m3)+m4*e...		
	Value	Error
m1	13.054	0.00038932
m2	-15.65	0.0037971
m3	422.59	0.1044
m4	2.6211	0.0039098
m5	68.739	0.18228
Chisq	0.0098989	NA
R	1	NA

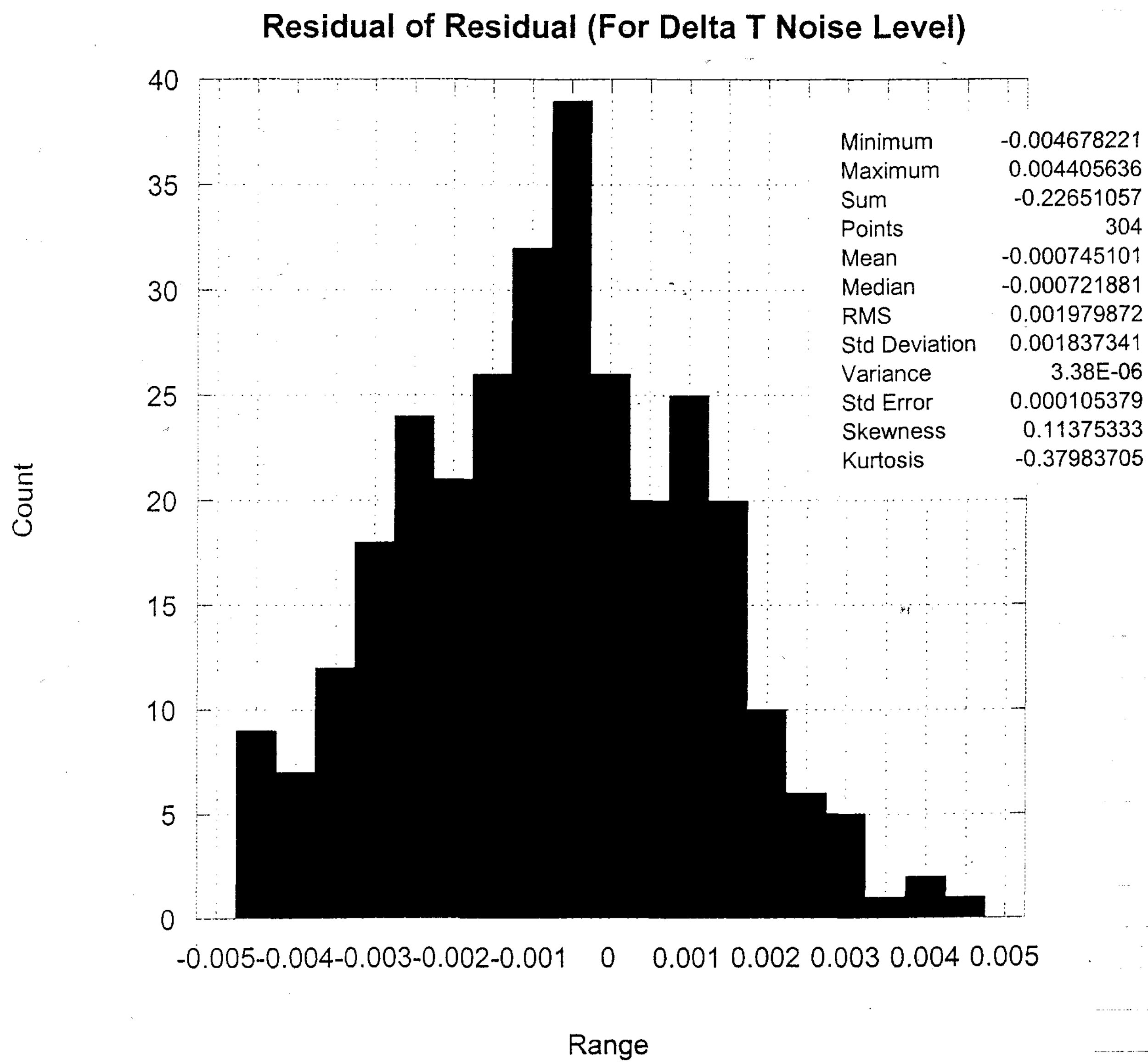
We used the following fit sequence to estimate our errors on ΔT.



Here is the residual for the fit. The random error can be readily seen.



Above is a fit of the linear residual region.



Above is a histogram of the residual of the residual. A Gaussian fit reveals:

$\sigma = 1.8\,mK$.

Thus, for a SNR > 200, a pulse of only $\approx 0.5\,K$ is required.

SNR: Signal to Noise Raise $\left(\frac{S}{\sigma}\right)$

Conclusion → Power Scatter Measurement

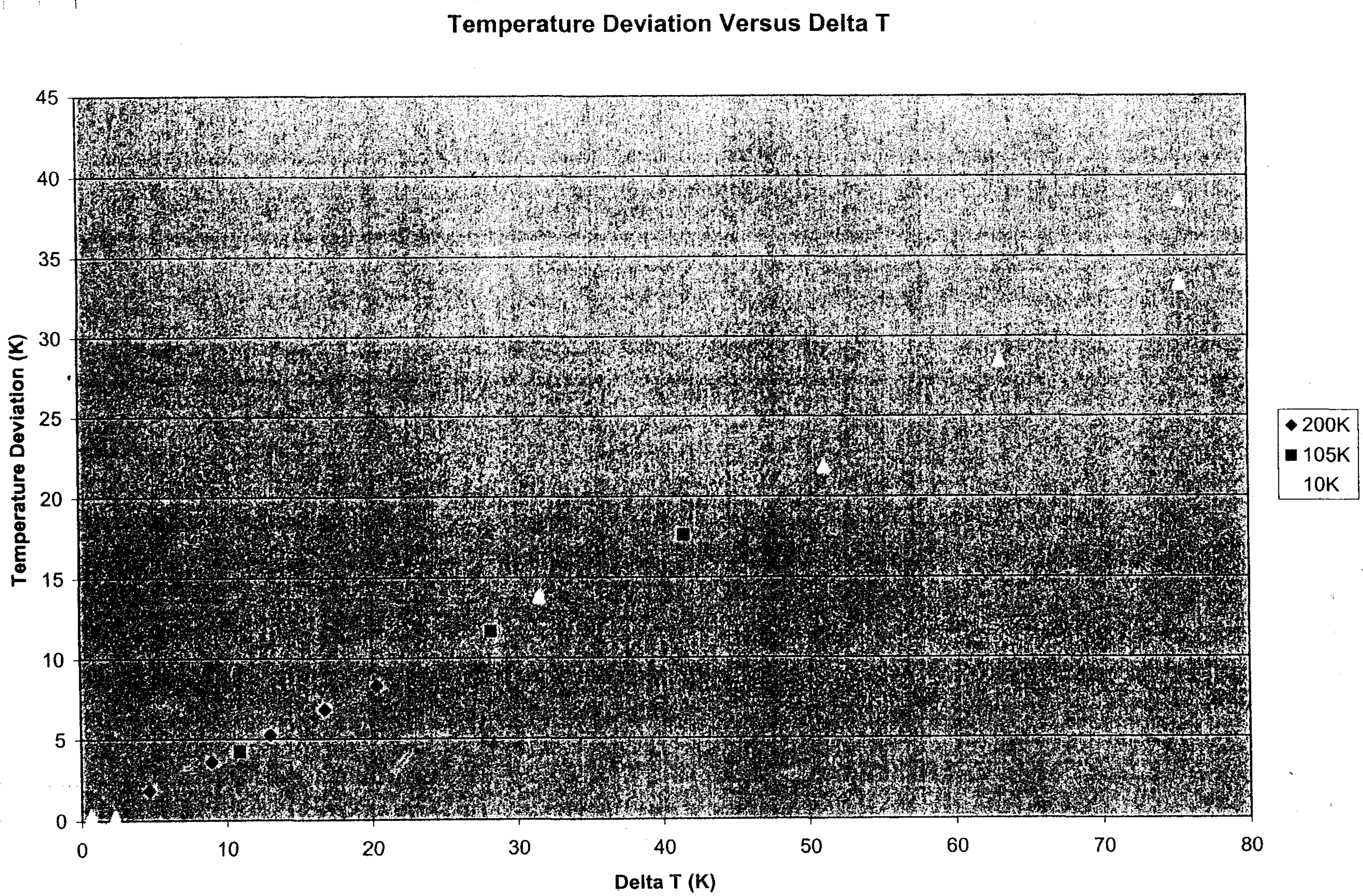
1. A pulse of 0.5K would yield a SNR of 278.

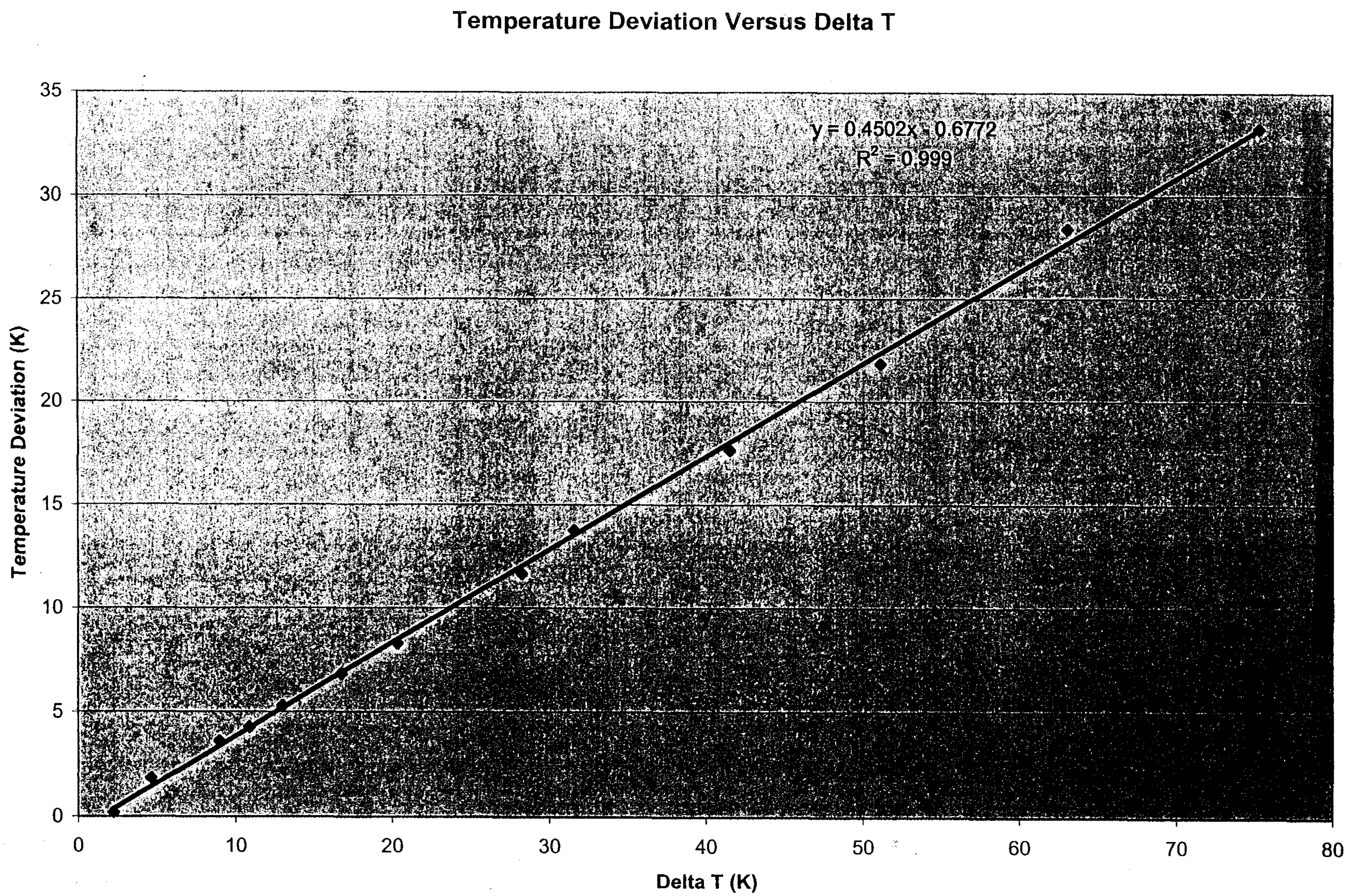
2. The systematic error will not be a concern once it can be pushed down on the order of the random error. It has been observed that a decrease in the power from 10mW to 6mW @ 200K (40% decrease) had decreased the systematic error from 0.35K to 0.015K (95% decrease). However, to achieve a pulse of only 0.5K, the power must decrease even further. This is very likely to decrease the systematic error even further, possibly even to below the random error.

3. A basic ΔT vs. P plot has been constructed. Estimates can be made from this plot as to which power must be used to attain pulses of 0.5K! It may be useful to build a better plot using more data.

4. The small differences in temperature arise because of the large ΔT involved. The smaller the ΔT, the smaller the deviation from the requested temperature.

A plot of this relationship is on the next page.


Temperature Deviation Versus Delta T
Temperature Deviation (K)
Delta T (K)
0
5
10
15
20
25
30
35
40
45
0
10
20
30
40
50
60
70
80
200K
105K
10K



This fit gives us a good estimate of our temperature deviation for different values of ΔT. It appears that the deviation will be negligible @ $\Delta T \approx 0.5K$.

Why does the conductivity vary?

On August 8, I talked with both Neil and Dinesh at QD. Both of them agreed that for low conductance samples, the P_{RAD} and K_{SHOES} corrections are large & may introduce an apparent input power dependence.

As of now, the exact origin and reasoning behind how these equations shift the conductivity is not understood. However, we have some ideas:

Since P_{RAD} depends on both T_H and T_C, it has some ΔT dependence:

$$P_{RAD} = \sigma \left(\frac{S}{2}\right) \varepsilon \left(T_H^4 - T_c^4\right)$$

where:

$$T_H = T_c + \Delta \qquad (\Delta = \Delta T)$$

$$C = \sigma \left(\frac{S}{2}\right) \varepsilon$$

$$P_{RAD} = C\left[(T_c + \Delta)^4 - T_c^4\right]$$

$$P_{RAD} = C\left[T_c^4 + T_c^3\Delta + T_c^2\Delta^2 + T_c\Delta^3 + \Delta^4 - T_c^4\right]$$

$$\boxed{P_{RAD} = C\left[4T_c^3\Delta + 6T_c^2\Delta^2 + 4T_c\Delta^3 + \Delta^4\right]}$$

Above we see the explicit dependence of P_{RAD} on ΔT. So, larger heater powers will create larger ΔT, thus changing P_{RAD}. Since P_{RAD} is only a close approximation, some errors will remain (and are some function of heater power)

The conductance of the shoes:

$$K_{SHOES} = aT^3 + bT^2 + cT$$

If the temperature deviates due to large ΔT, so too will the conductance of the shoes.

Reducing Correction Errors

From the boxed equation for P_{RAD}, it can be seen that the correction from P_{RAD} decreases as ΔT decreases. Therefore, it is advantageous to make ΔT as small as possible.

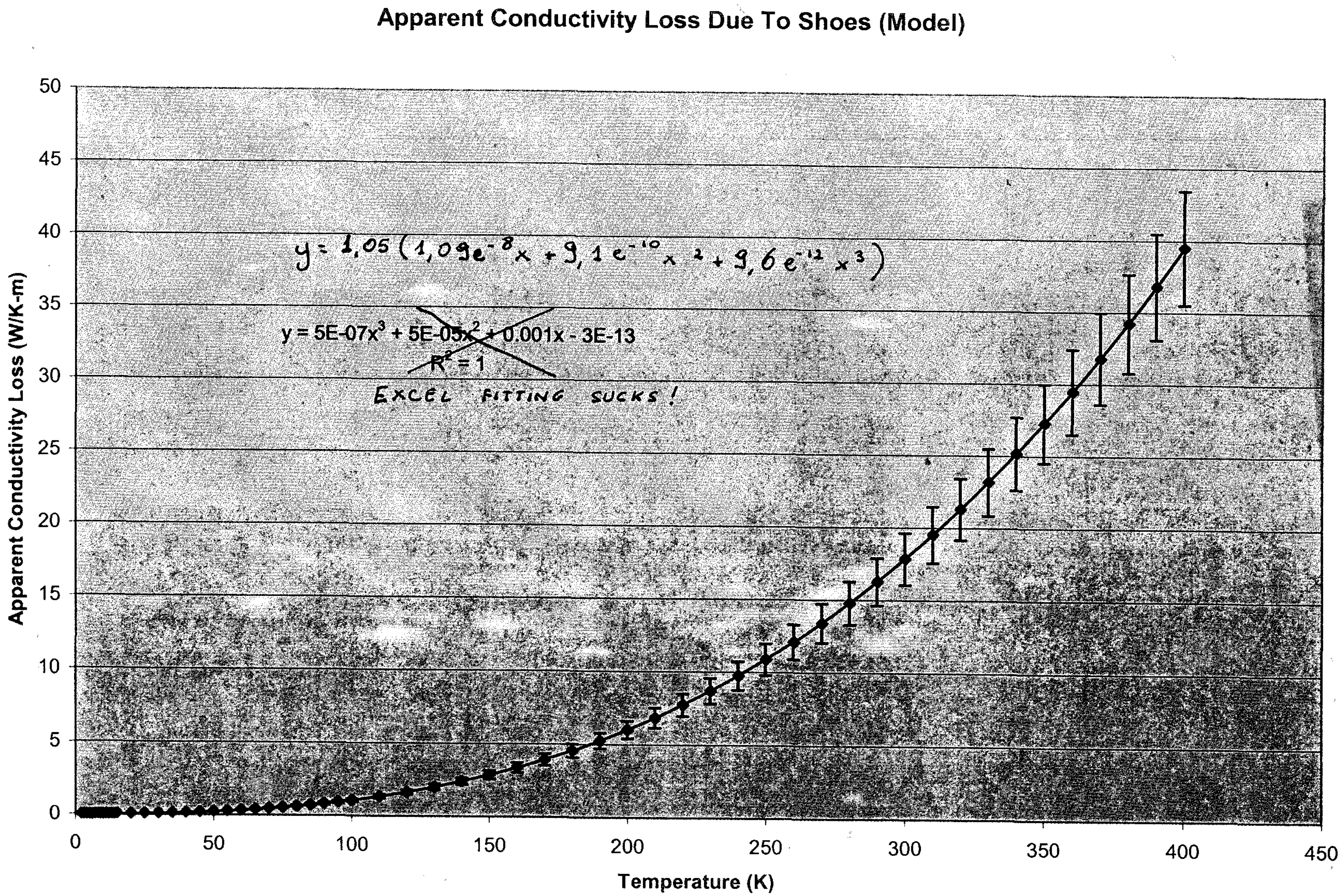
Similarly for K_{SHOES} ... if ΔT is small, then the deviation in T is also small. Thus, it seems likely that there will be less variation in K_{SHOES}. However, the fact remains that K_{SHOES} is inaccurate from the beginning. QD admits to K_{SHOES} errors of $\pm 10\%$. Since K_{SHOES} can sometimes make a 50% correction for our sample, this 10% error is large. It seems as though the best method is to measure the conductance of the shoes directly and subtract it out ourselves.

To illustrate how large a correction K_{SHOES} is, see the following two plots. The next page shows the apparent conductivity correction due to K_{SHOES}:

$$K = K_{SHOES}\left(\frac{L}{A}\right)$$

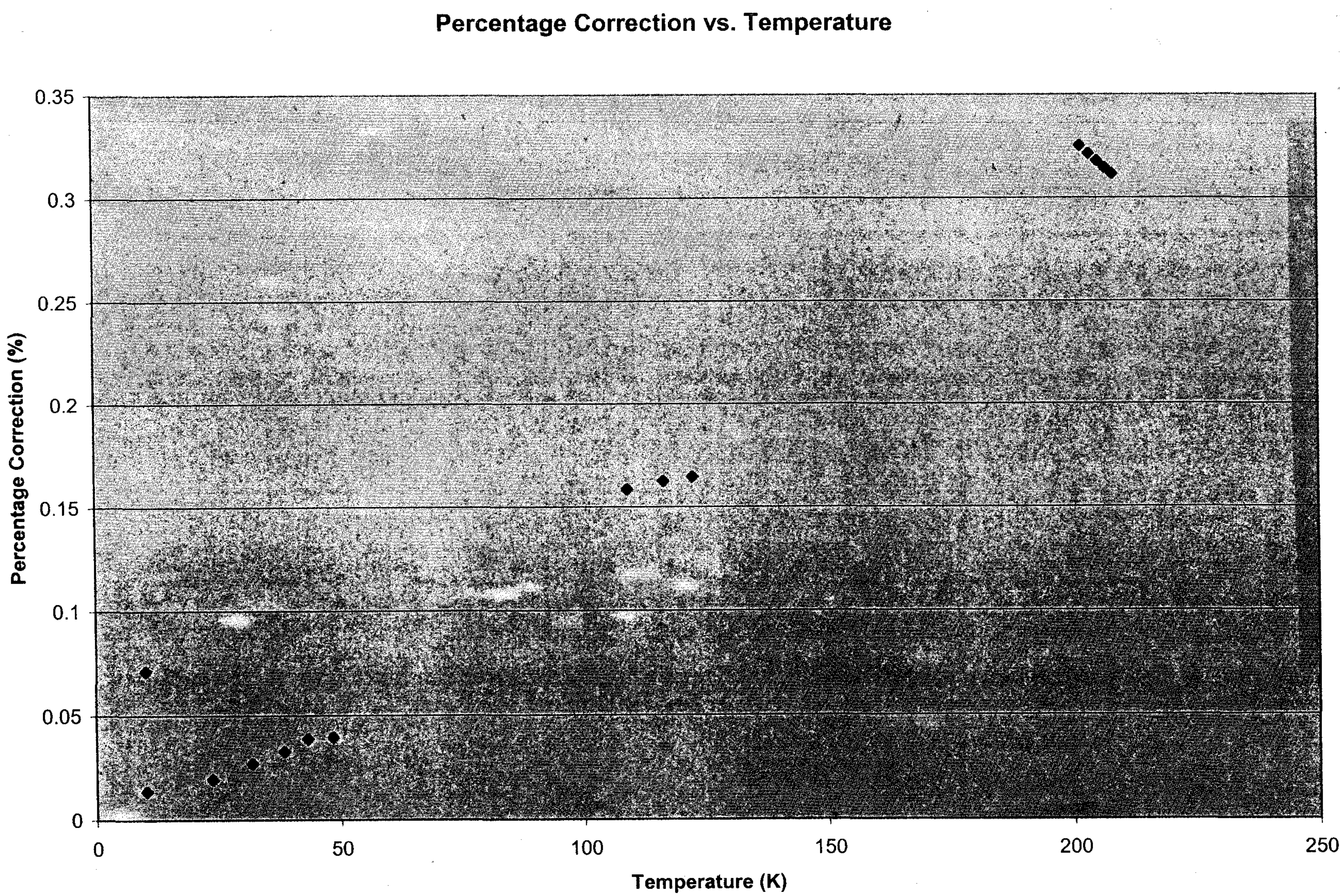
↑ sample parameters

The plot after that shows the correction percentage as a function of temperature. Notice the sharp increase as temperatures rise. This gives a great uncertainty in large temperature measurements.



This plot is the QD estimate for K_{SHOES} along w/ its stated 10% error bars.
(Note that this is the APPARENT correction to conductivity after multiplying by (L/A).

$$K_{SHOES} = d(aT + bT^2 + cT^3)$$



Percentage correction vs. temperature.

August 23, 2002

Which powers will produce $\Delta T = 0.5K$ for all temperatures?

As a result of our Power scatter measurement, I realized that it is not possible to construct a plot of the heater power versus T (to attain $\Delta T = 0.5K$) for all samples. The power is actually a function of the conductance, as can be seen below.

$$K = \frac{P}{\Delta T} \qquad \text{(Conductance)}$$

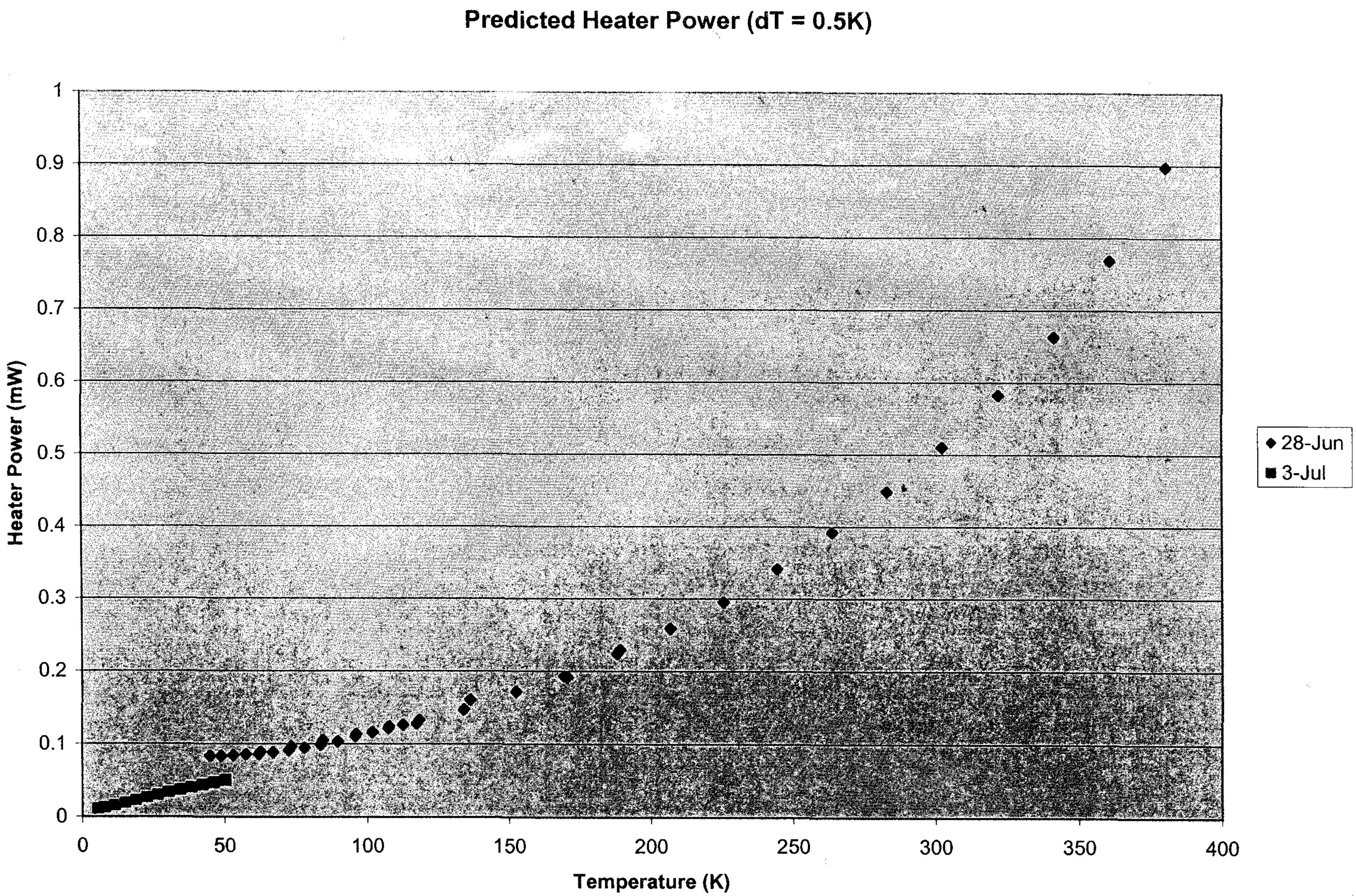
$$\boxed{P = (\Delta T)\, K}$$

This presents a clear problem because to measure the conductance properly, the power is needed to create a $\Delta T = 0.5K$. However the ideal power setting is a function of conductance. For $\Delta T = 0.5K$:

$$P = (0.5)\, K$$

I decided to use the stable TTO measurement as an estimate for K. This would give a decent (although imperfect) estimate for P.

The plot on the following page was used to predict the powers needed to make $\Delta T = 0.5K$.



Power prediction to keep $\Delta T = 0.5K$.

Keeping the ΔT pulse at 0.5K.

The plot on the left was used to predict the powers required to keep $\Delta T = 0.5K$. The TTO run information follows:

TTO Run Initiated: 8/6/02 @ 9:50am

Purpose: To collect the conductivity spectrum of Glasmet with the new predicted power settings.

Sample Parameters:

length: 6.92 mm   Surface Area: 36.1916 mm^2
Cross-Section: 0.14121 mm^2 Emmissivity: 0.3

Temperature Range (K)	Power Selected (μW)
400-350	800
350-300	600
300-250	450
250-200	300
200-150	200
150-100	125
100-50	100
50-25	50
25-5	20
5-2	10

A copy of the sequence follows:

```
1:  Set Temperature 400.00K at 20.00K/min. Fast Settle
2:  Wait For Temperature, Delay 0 secs, No Action
3:  Chamber Vent then Seal
4:  Wait For Chamber, Delay 0 secs, No Action
5:  Chamber Purge then Seal
6:  Wait For Chamber, Delay 0 secs, No Action
7:  Chamber High Vacuum
8:  Wait For Chamber, Delay 1800 secs, No Action
9:  LogData Start New 2.00 6815995 2094067 7 "C:\cryolab\08-05-2002\LogPpmsSe
    q.dat" "" ""
10: Scan Temp from 400.0K to 350.0K at 12.0K/min, in 6 steps, Uniform, Fast
11:     TTO Single dT Measure K init= 10mW, 300sec max= 50mW, 1430sec, 500uV,
        10mA
12: End Scan
13: Scan Temp from 350.0K to 300.0K at 12.0K/min, in 6 steps, Uniform, Fast
14:     TTO Single dT Measure K init= 10mW, 300sec max= 50mW, 1430sec, 500uV,
        10mA
15: End Scan
16: Scan Temp from 300.0K to 250.0K at 12.0K/min, in 6 steps, Uniform, Fast
17:     TTO Single dT Measure K init= 10mW, 300sec max= 50mW, 1430sec, 500uV,
        10mA
18: End Scan
19: Scan Temp from 250.0K to 200.0K at 12.0K/min, in 6 steps, Uniform, Fast
20:     TTO Single dT Measure K init= 10mW, 300sec max= 50mW, 1430sec, 500uV,
        10mA
21: End Scan
```

```
22:  Scan Temp from 200.0K to 150.0K at 12.0K/min, in 6 steps, Uniform, Fast
23:       TTO Single dT Measure K init= 10mW, 300sec max= 50mW, 1430sec, 500uV,
           10mA
24:  End Scan
25:  Scan Temp from 150.0K to 100.0K at 12.0K/min, in 6 steps, Uniform, Fast
26:       TTO Single dT Measure K init= 10mW, 300sec max= 50mW, 1430sec, 500uV,
           10mA
27:  End Scan
28:  Scan Temp from 100.0K to 50.0K at 12.0K/min, in 6 steps, Uniform, Fast
29:       TTO Single dT Measure K init= 10mW, 300sec max= 50mW, 1430sec, 500uV,
           10mA
30:  End Scan
31:  Scan Temp from 50.0K to 25.0K at 12.0K/min, in 6 steps, Uniform, Fast
32:       TTO Single dT Measure K init= 10mW, 300sec max= 50mW, 1430sec, 500uV,
           10mA
33:  End Scan
34:  Scan Temp from 25.0K to 5.0K at 12.0K/min, in 5 steps, Uniform, Fast
35:       TTO Single dT Measure K init= 10mW, 300sec max= 50mW, 1430sec, 500uV,
           10mA
36:  End Scan
37:  Scan Temp from 5.0K to 2.0K at 12.0K/min, in 4 steps, Uniform, Fast
38:       TTO Single dT Measure K init= 10mW, 300sec max= 50mW, 1430sec, 500uV,
           10mA
39:  End Scan
40:  Scan Temp from 2.0K to 5.0K at 12.0K/min, in 4 steps, Uniform, Fast
41:       TTO Single dT Measure K init= 10mW, 300sec max= 50mW, 1430sec, 500uV,
           10mA
```

Sequence File: PowerPredictionOnGlasmet.seq

```
43:  Scan Temp from 5.0K to 25.0K at 12.0K/min, in 5 steps, Uniform, Fast
44:       TTO Single dT Measure K init= 10mW, 300sec max= 50mW, 1430sec, 500uV,
           10mA
45:  End Scan
46:  Scan Temp from 25.0K to 50.0K at 12.0K/min, in 6 steps, Uniform, Fast
47:       TTO Single dT Measure K init= 10mW, 300sec max= 50mW, 1430sec, 500uV,
           10mA
48:  End Scan
49:  Scan Temp from 50.0K to 100.0K at 12.0K/min, in 6 steps, Uniform, Fast
50:       TTO Single dT Measure K init= 10mW, 300sec max= 50mW, 1430sec, 500uV,
           10mA
51:  End Scan
52:  Scan Temp from 100.0K to 150.0K at 12.0K/min, in 6 steps, Uniform, Fast
53:       TTO Single dT Measure K init= 10mW, 300sec max= 50mW, 1430sec, 500uV,
           10mA
54:  End Scan
55:  Scan Temp from 150.0K to 200.0K at 12.0K/min, in 6 steps, Uniform, Fast
56:       TTO Single dT Measure K init= 10mW, 300sec max= 50mW, 1430sec, 500uV,
           10mA
57:  End Scan
58:  Scan Temp from 200.0K to 250.0K at 12.0K/min, in 6 steps, Uniform, Fast
59:       TTO Single dT Measure K init= 10mW, 300sec max= 50mW, 1430sec, 500uV,
           10mA
60:  End Scan
61:  Scan Temp from 250.0K to 300.0K at 12.0K/min, in 6 steps, Uniform, Fast
62:       TTO Single dT Measure K init= 10mW, 300sec max= 50mW, 1430sec, 500uV,
           10mA
63:  End Scan
64:  Scan Temp from 300.0K to 350.0K at 12.0K/min, in 6 steps, Uniform, Fast
65:       TTO Single dT Measure K init= 10mW, 300sec max= 50mW, 1430sec, 500uV,
           10mA
66:  End Scan
67:  Scan Temp from 350.0K to 400.0K at 12.0K/min, in 6 steps, Uniform, Fast
68:       TTO Single dT Measure K init= 10mW, 300sec max= 50mW, 1430sec, 500uV,
           10mA
69:  End Scan
```

Results of the $\Delta T = 0.5$ K sequence

September 4, 2002

sigma_T:	5.67E-08	Rad Loss A:	0.000000019
Sample Properties		Rad Loss B:	9.1E-10
Surface Area:	36.1916	Rad Loss C:	9.6E-12
Length:	6.92	Rad Loss D:	1.05
CrossSection:	0.14121		
Emmisivity:	0.3		

Fit #	Temperature	Avg. Cold	Avg. Hot	Heater Power
1	394.7517495	394.1156921	395.5664368	0.000798931
2	384.6340446	384.0250549	385.4328003	0.000798833
3	374.518686	373.9456787	375.2955017	0.000799922
4	364.4487455	363.9025574	365.2229614	0.000799802
5	354.4176281	353.8811646	355.2000427	0.000799689
6	354.4181392	353.9268494	355.0879517	0.00059906
7	344.346643	343.8577271	345.0398254	0.00059899
8	334.2966607	333.7938538	335.0180359	0.000599967
9	324.2362478	323.7405701	324.9672546	0.000599911
10	314.1902075	313.6835938	314.9593506	0.000599866
11	304.1377678	303.618103	304.9390259	0.000599834
12	304.090409	303.6315002	304.7494202	0.0004494
13	294.0070951	293.5310364	294.7070923	0.000449385
14	283.9747419	283.4763489	284.7113037	0.000449377
15	273.9390078	273.3890381	274.7476196	0.000449376
16	263.8883388	263.3033752	264.7550049	0.000449383
17	253.8088933	253.2012787	254.7287445	0.000449401
18	253.7230834	253.2052917	254.4376526	0.000299701
19	243.6810814	243.1419067	244.4390564	0.000299722
20	233.6405927	233.0656281	234.4537354	0.000299755
21	223.6251014	223.018158	224.4974365	0.000299796
22	213.608556	212.9309998	214.5850372	0.000299845
23	203.5840309	202.8611603	204.6313171	0.000299904
24	203.4843372	202.8515167	204.3206787	0.000199669
25	193.4850352	192.8096771	194.3830261	0.000199714
26	183.4570562	182.7254333	184.4361877	0.000199764
27	173.4129792	172.6224976	174.4798279	0.000199824
28	163.3801793	162.5342255	164.5352783	0.000199897
29	153.3539852	152.4301758	154.6223602	0.000199984
30	153.2439233	152.4305115	154.2540894	0.000124644
31	143.2130316	142.309494	144.3428497	0.000124708
32	133.1731577	132.1886902	134.4001465	0.000124786
33	123.1547993	122.0951996	124.4837646	0.000124878
34	113.1069368	111.9913864	114.5289841	0.000124983
35	101.2899757	98.5361176	104.3902054	0.000124626
36	101.2230394	98.5297623	104.1957626	9.98371E-05
37	91.96297956	89.4000702	94.8385849	9.99445E-05
38	80.81935006	80.3682861	81.6165085	9.96379E-05
39	70.68341368	70.3943481	71.3577042	9.97782E-05
40	60.66662535	60.2873611	61.3832474	9.99397E-05
41	50.72713918	50.3030319	51.5704308	9.96789E-05
42	50.53373778	50.302597	50.9258194	4.99884E-05
43	45.55439937	45.305233	45.9934006	4.99725E-05
44	40.56964118	40.3051453	41.0721359	4.99938E-05
45	35.59501427	35.3109932	36.1764793	4.99954E-05
46	30.63108201	30.3132439	31.3015842	4.99728E-05
47	25.68755006	25.323288	26.4848309	4.99862E-05
48	25.48014978	25.32197	25.7919693	1.99835E-05
49	20.49590131	20.3092575	20.899971	1.99991E-05
50	15.54761878	15.3161945	16.0904179	1.9985E-05
51	10.62862136	10.2802973	11.4294147	1.99862E-05
52	5.708814665	5.010839	7.3122802	2E-05
53	5.344947765	5.010788	6.0805573	0.00001
54	4.415773416	4.0143571	5.3024487	0.00001
55	3.523168707	3.0232294	4.6212835	0.00001
56	2.700016756	2.0358982	4.1003127	0.00001

The following pages present the raw data and calculations.

[redacted]	2.700076422	2.0360932	4.1002131	0.00001
58	3.517528846	3.0140166	4.6170583	0.00001
59	4.411828114	4.0084224	5.2984419	0.00001
60	5.340117635	5.0027165	6.0764542	0.00001
61	5.704845479	5.0054164	7.3076301	2E-05
62	10.48974782	10.0210257	11.4095306	1.99862E-05
63	15.54747275	15.316123	16.0877171	1.9985E-05
64	20.50465606	20.3244362	20.9100132	1.9999E-05
65	25.4821899	25.3248138	25.7940464	1.99835E-05
66	25.68804021	25.322588	26.4845047	4.99862E-05
67	30.62875392	30.3059807	31.2981186	4.99728E-05
68	35.59294528	35.3031425	36.1765518	4.99954E-05
69	40.56728143	40.2945442	41.0782089	4.99938E-05
70	45.55303714	45.2864418	46.0052185	4.99725E-05
71	50.53070911	50.2767944	50.9368744	4.99883E-05
72	50.7360813	50.3068199	51.5907326	9.96789E-05
73	60.66256564	60.2480431	61.4073944	9.99397E-05
74	70.66896141	70.3259659	71.3886948	9.97782E-05
75	80.79010815	80.3398361	81.6437683	9.96378E-05
76	90.04620494	89.3685837	91.0902481	9.99445E-05
77	99.35355783	98.5030365	100.5389404	9.98371E-05
78	99.45392489	98.5324936	100.7439804	0.000124626
79	111.3804548	108.5667496	114.5732803	0.000124983
80	123.1062706	122.0489655	124.4942474	0.000124878
81	133.1587007	132.1719513	134.4502411	0.000124786
82	143.201926	142.2942963	144.3823242	0.000124708
83	153.2280294	152.3918915	154.3083344	0.000124644
84	153.3744682	152.4187317	154.6803894	0.000199984
85	163.3670282	162.5177307	164.5784149	0.000199897
86	173.4124742	172.6257935	174.5350952	0.000199824
87	183.4420692	182.6955109	184.4915771	0.000199764
88	193.4566462	192.7764282	194.4053192	0.000199714
89	203.464623	202.8479309	204.3308868	0.000199669
90	203.6027501	202.8829193	204.6522064	0.000299904
91	213.5866861	212.9024963	214.616394	0.000299845
92	223.5993223	222.9772797	224.5317993	0.000299796
93	233.6120306	233.0390167	234.4699097	0.000299755
94	243.6748694	243.1384735	244.4761047	0.000299722
95	253.7210543	253.1994781	254.4831696	0.000299701
96	253.8491954	253.2409668	254.7750092	0.000449401
97	263.8706982	263.2872925	264.7812195	0.000449383
98	273.90838	273.3510437	274.7647705	0.000449376
99	283.9655435	283.4494019	284.7628784	0.000449377
100	294.0137577	293.5173645	294.7702332	0.000449385
101	304.0632198	303.6020508	304.7496643	0.0004494
102	304.1549845	303.6359863	304.9432068	0.000599834
103	314.195462	313.7086182	314.962677	0.000599866
104	324.2804644	323.7922058	325.021698	0.000599911
105	334.3256648	333.828949	335.0646973	0.000599967
106	344.3795345	343.8783875	345.1029358	0.00059899
107	354.447278	353.9421387	355.1498718	0.00059906
108	354.5241568	353.9749756	355.3159485	0.000799689
109	364.5321403	363.9643555	365.344696	0.000799802
110	374.5804169	374.013855	375.3742676	0.000799922
112	384.6395814	384.0550232	385.429718	0.000798833
113	394.6864548	394.0579224	395.5061035	0.000798931

m1	m1 err	m2	m2 err	m3	m3 err	m4	m4 err	m5	m5 err	Chi Sq	R
0.93517	0.0011797	2.8916	0.057571	244.08	2.2013	-0.68761	0.057523	108.09	4.2562	0.025222	0.99994
0.82216	0.00087678	4.3873	0.020291	275.03	0.81536	-1.8246	0.017631	84.954	0.91105	0.028673	0.99997
0.74556	0.00086514	4.0442	0.014355	290.26	0.76491	-1.3136	0.014081	82.338	0.82215	0.036237	0.99996
0.64949	0.00087268	3.7659	0.011528	307.71	0.7768	-0.91333	0.011304	78.856	1.0355	0.039355	0.99996
0.59454	0.00094695	4.0126	0.011899	320.61	0.79656	-1.0712	0.011726	82.525	0.94164	0.040853	0.99996
0.65566	0.0018799	1.6494	2.1531	122.08	23.554	-1.1656	2.1527	90.957	25.432	0.035335	0.99755
0.56999	0.00074113	4.2057	0.010874	327.75	0.66788	-1.2143	0.010632	87.055	0.77852	0.035955	0.99997
0.57522	0.00083073	4.4331	0.01703	323.12	0.83729	-1.362	0.016732	100.35	1.0177	0.041789	0.99997
0.53664	0.00097902	4.857	0.024233	329.95	1.0113	-1.6435	0.023978	113.2	1.169	0.047874	0.99997
0.53008	0.00077163	5.0453	0.021534	335.66	0.84601	-1.7323	0.021224	117.05	1.0078	0.041209	0.99997
0.52566	0.0011125	5.2722	0.02597	355.79	1.1101	-1.857	0.025617	117.97	1.2181	0.080546	0.99996
0.58482	0.0015427	1.6744	1.393	183.8	22.937	-1.1039	1.3933	137.14	25.588	0.017203	0.99935
0.53887	0.00076396	5.2516	0.015473	374.96	0.75198	-1.7613	0.015161	114.7	0.83788	0.051819	0.99998
0.55616	0.00078374	5.0761	0.014839	394.48	0.79598	-1.4603	0.014654	122.65	0.99821	0.040672	0.99998
0.64015	0.00081214	5.7571	0.026702	394.42	0.99845	-2.0409	0.026451	148.56	1.1958	0.051552	0.99998
0.65528	0.00089083	5.5164	0.016673	427.41	0.89388	-1.6768	0.016487	133.27	1.0545	0.057566	0.99998
0.67536	0.00093457	5.7444	0.027738	439.16	1.2168	-1.7608	0.027409	157.53	1.6447	0.098506	0.99997
0.69836	0.0012087	0.64582	0.0063389	334.94	4.0909	-0.051264	0.0068022	73.129	10.772	0.010987	0.9996
0.68257	0.00075056	5.7848	0.014777	465.48	0.81122	-1.7742	0.014547	144.68	0.97179	0.060157	0.99998
0.71713	0.00081443	5.6782	0.015878	494.98	0.95365	-1.5454	0.015581	150.99	1.2901	0.09112	0.99997
0.73535	0.00065313	5.9599	0.012217	521.18	0.73948	-1.6863	0.012077	162.42	0.93764	0.046063	0.99999
0.83893	0.00079791	5.886	0.014412	537.99	0.93408	-1.5589	0.014174	161.47	1.2619	0.08961	0.99998
0.89804	0.00052134	6.233	0.010285	556.58	0.62863	-1.7501	0.010115	171.33	0.82438	0.045989	0.99999
0.91013	0.00064901	0.78489	0.0015135	480.45	1.8845	-0.094518	0.0018851	65.244	2.2959	0.0065986	0.99988
0.94727	0.00073581	5.953	0.012106	587.29	0.8837	-1.4725	0.011914	169.58	1.2377	0.090058	0.99998
1.0373	0.0049416	6.3209	0.0095245	603.83	0.62857	-1.742	0.009368	184.66	0.83331	0.047188	0.99999
1.1038	0.00051464	6.2326	0.0093775	640	0.68197	-1.5284	0.0092186	191.42	0.99838	0.056566	0.99999
1.1682	0.0003536	6.2684	0.0042252	681.05	0.39993	-1.4841	0.0041233	161.69	0.53166	0.037306	0.99999
1.2593	0.00043145	6.3224	0.0049312	717.25	0.49739	-1.4099	0.0048171	167.08	0.69059	0.059645	0.99999
1.2819	0.00043197	0.84596	0.00088312	636.88	1.4752	-0.11308	0.0011931	74.82	1.5234	0.0060546	0.99993
1.4076	0.00051409	6.0245	0.0066923	740.64	0.68673	-1.1619	0.0065285	184.87	1.1543	0.089797	0.99999

First the fits for the cooling portion...

1.5491	0.00062341	6.4171	0.0080486	746.26	0.78387	-1.4876	0.007853	185.85	1.0928	0.13212	0.99998
1.6443	0.00050217	6.4875	0.0055905	771.55	0.59614	-1.4341	0.0054724	180.31	0.8251	0.083512	0.99999
1.7001	0.00082352	6.6277	0.010428	777.02	1.0118	-1.3771	0.010313	206.66	1.533	0.14551	0.99998
4.905	0.00053692	6.7027	0.0048281	798.99	0.57222	-1.2683	0.004779	168.25	0.84977	0.094039	0.99999
4.9387	0.00024709	0.85301	0.00052321	716.44	0.95606	-0.10337	0.00071505	81.667	1.1045	0.0030328	0.99997
4.6061	0.00047058	6.5057	0.005453	760.59	0.56201	-1.4014	0.0053343	179.81	0.80982	0.076344	0.99999
0.34139	0.00035661	6.6549	0.0055503	718.93	0.46428	-1.4726	0.005393	190.14	0.72679	0.050876	0.99999
-0.032599	0.00031164	7.2081	0.0051435	674.69	0.36878	-1.6328	0.004956	174.17	0.58164	0.049737	0.99999
-0.1285	0.00029062	7.0427	0.0052359	614.48	0.34372	-1.5762	0.0049973	154.65	0.5715	0.057491	0.99999
-0.10538	0.00029558	7.6828	0.009514	508.62	0.37474	-2.1683	0.0091404	160.96	0.59025	0.05741	0.99999
-0.10017	4.00E-05	1.1798	0.0002245	483.59	0.12019	-0.1514	0.00026781	61.769	0.21545	0.00037298	1
-0.097703	0.00014893	3.6797	0.0031464	440.35	0.26571	-0.8865	0.0029994	117.7	0.43314	0.0089492	0.99999
-0.081358	0.00018558	3.8047	0.0044525	375.22	0.29383	-0.96514	0.0042514	105.94	0.47328	0.010614	0.99999
-0.057967	0.00024199	4.0523	0.0083824	308.34	0.37246	-1.1375	0.008031	98.06	0.60469	0.017566	0.99999
-0.051174	0.00022166	4.2023	0.012115	238.79	0.33915	-1.2409	0.01173	88.53	0.58669	0.011229	0.99999
-0.037232	0.0002693	4.772	0.017067	176.47	0.2984	-1.7673	0.016574	67.265	0.42392	0.012041	0.99999
-0.037625	4.55E-05	1.1229	0.00069864	166.21	0.087341	-0.18142	0.00067469	33.105	0.18915	0.00023128	1
-0.018157	0.00036196	5.3687	0.095625	115.46	0.58591	-2.5821	0.094898	63.812	0.81827	0.011972	0.99998
-0.010044	0.0015999	5.1192	0.22446	82.545	1.2445	-2.3112	0.22218	40.959	1.6685	0.065638	0.99983
0.012327	0.00044403	4.216	0.12726	50.598	0.52351	-1.6369	0.12489	23.931	0.8892	0.055821	0.99976
-0.018472	0.0010967	3.8491	5.42E-01	28.517	1.0198	-2.4653	5.39E-01	16.639	1.1408	0.027579	0.99948
-0.014845	0.001047	11.887	47.725	22.29	6.6481	-11.23	47.53	18.897	7.6202	0.015563	0.99893
-0.0097792	5.89E-05	0.65555	0.0019559	24.02	0.053425	-0.15777	0.0018937	4.7638	0.087025	0.00012622	0.99997
0.00048458	5.19E-05	0.62562	0.0024391	22.104	0.056447	-0.13873	0.0023404	5.3305	0.11051	9.97E-05	0.99997
0.0078716	0.00010327	0.66936	0.0078117	23.419	0.19569	-0.18752	0.0075549	4.6895	0.28542	0.0081829	0.99814
0.0057048	5.16E-05	-4.941	0.15165	11.947	0.73782	4.8166	0.39785	20.178	0.27838	0.00013661	0.99996
-0.0042319	5.10E-05	-9.4494	1.0173	19.373	0.33692	223.31	115.1	8.6099	0.72396	0.00018131	0.99964
-0.012726	4.56E-05	-0.28322	0.0011591	23.163	0.085897	0.060141	0.0012712	3.0585	0.12896	0.00015146	0.99981
-0.18318	2.17E-05	-0.31187	0.0005559	25.248	0.037107	0.046979	0.00055903	4.2108	0.088214	1.65E-05	0.99998
-0.016729	4.38E-05	1.9183	0.20748	23.392	0.44265	-1.3565	0.12815	14.143	1.215	9.31E-05	0.99993
0.25289	5.58E-05	-2.6332	0.064465	31.879	0.89326	-0.76972	0.11733	54.671	1.5725	8.20E-05	0.99997
-0.0060394	0.00041407	0.26435	0.010687	5.523	0.44286	-1.9718	0.0057127	75.483	0.24736	0.070804	0.99945

-0.012734	0.00016529	0.23003	0.002677	7.5889	0.1704	-2.2008	0.00013108	111.14	0.083257	0.0041783	0.99998
-0.03552	0.00010401	0.24834	0.0013579	18.17	0.19942	-2.3596	0.0010192	161.77	0.076456	0.0022673	0.99999
-0.038246	3.36E-05	-0.052475	0.00032747	24.609	0.28985	0.43357	0.00030442	165.78	0.12368	7.91E-05	0.99999
-0.051155	5.36E-05	0.31842	0.00059297	29.702	0.1094	-2.2103	0.00050371	227.49	0.05573	0.00066226	1
-0.054564	6.65E-05	0.32008	0.00060927	42.914	0.15466	-2.2576	0.00056232	291.8	0.079195	0.00080277	1
-0.070829	3.47E-05	0.36719	0.0003548	56.002	0.099913	-2.3351	0.00033898	357.67	0.053197	0.00040743	1
-0.094918	3.45E-05	0.39313	0.00033888	70.366	0.10785	-2.4032	0.00033223	424.79	0.059808	0.00043196	1
-0.10255	4.17E-05	0.37783	0.00040284	83.422	0.15449	-2.4201	0.00039913	489.12	0.081807	0.00072699	1
-0.10181	0.0020017	-0.064095	0.00097592	58.417	1.7617	0.58182	0.00077715	484.74	1.0083	0.0039018	0.9999
-0.12079	0.00021846	0.8243	0.002393	105.77	0.50327	-4.9261	0.0024256	577.07	0.27002	0.032708	0.99999
-0.021004	7.18E-05	0.91549	0.00067971	120.16	0.14712	-5.2075	0.00068134	670.94	0.088492	0.0032032	1
0.35054	0.00013872	0.97485	0.0012195	141.51	0.26548	-5.5242	0.0012319	730.86	0.16568	0.0078875	1
0.86506	0.00018027	0.92771	0.0014867	149.96	0.35267	-5.1513	0.0014943	768.09	0.23219	0.011279	1
1.2675	0.00021064	0.95995	0.0017706	161.46	0.41193	-5.1978	0.001783	788.88	0.27705	0.013505	1
1.259	0.00013972	-0.078794	0.00038631	80.212	0.77992	0.68686	0.00027102	736.59	0.66781	0.00093628	0.99999
5.1352	0.00050847	1.1443	0.0037564	174.29	0.69172	-5.6724	0.003594	795.42	0.5564	0.032106	0.99999
1.6659	0.00038065	1.1519	0.0036659	176.97	0.70499	-5.5663	0.0037198	791.77	0.50294	0.042875	0.99999
1.5833	0.00044419	1.0226	0.0037786	162.19	0.82069	-5.4688	0.0038028	787.52	0.55754	0.060306	0.99999
1.4714	0.00058157	1.2268	0.0068825	194.55	1.1718	-5.634	0.0069956	770.89	0.81846	0.087353	0.99998
1.3588	0.00038917	1.0974	0.0042075	174.56	0.80162	-5.4679	0.0042888	749.26	0.52936	0.046908	0.99999
1.3389	0.00095025	-0.050953	0.0019125	81.237	5.3635	0.49415	0.0013379	643.83	4.8918	0.0090941	0.99961
1.2082	0.0004507	1.1328	0.0057657	187.95	0.97223	-5.2791	0.0058509	715.95	0.65367	0.044871	0.99999
1.1324	0.00039515	-5.2749	0.004023	717.15	0.50565	1.1061	0.0039848	169.08	0.70329	0.031317	0.99999
1.0841	0.00043928	-5.2817	0.0054992	676.71	0.59255	1.1515	0.0054099	172.59	0.8588	0.041326	0.99999
1.0084	0.00055185	-5.5066	0.0063671	650.86	0.66101	1.451	0.0062528	157.04	0.77294	0.066424	0.99998
0.9202	0.00069064	-5.4086	0.0089605	601.99	0.82117	1.4191	0.0088408	158.47	0.99672	0.073024	0.99998
0.89763	0.00091875	-0.079089	0.0028148	75.635	4.0744	0.51927	0.0023699	468.46	4.0396	0.0075584	0.99963
0.88469	0.00045924	-5.0386	0.0062014	596.98	0.59161	1.1669	0.0061305	161.86	0.8223	0.029294	0.99999
0.82246	0.00060647	-4.9673	0.0063386	592.73	0.69458	1.1702	0.0062527	138.06	0.87296	0.059664	0.99998
0.76467	0.00044637	-4.9223	0.0058249	556.35	0.54266	1.1644	0.0057326	144.92	0.73473	0.028728	0.99999
0.71361	0.00061304	-4.9872	0.0077188	532.42	0.68709	1.2826	0.0076257	139.06	0.84052	0.042884	0.99998
0.71276	0.00064269	-4.954	0.0083527	517.63	0.72424	1.2885	0.0081984	132.31	0.89406	0.058252	0.99998

0.69682	0.0012267	-0.11371	0.0054018	68.755	3.9064	0.54941	0.0048486	344.01	4.4149	0.0082831	0.99951
0.69428	0.00051059	-4.7257	0.0074244	487.52	0.59934	1.237	0.0073175	133.93	0.75902	0.028584	0.99999
0.6821	0.00069853	-4.5517	0.011149	462.99	0.84477	1.1509	0.011026	134.91	1.1368	0.041998	0.99998
0.62091	0.00044206	-4.3632	0.007281	439.61	0.54655	1.0562	0.007113	124	0.79173	0.021701	0.99999
0.61868	0.00055243	-4.3739	0.0078182	423.15	0.6024	1.1146	0.007683	112.98	0.77987	0.028421	0.99998
0.57716	0.0004245	-4.4715	0.0071656	402.4	0.47778	1.3086	0.0070078	113.01	0.57573	0.019371	0.99999

0.58374	0.00093134	-0.14437	0.0092962	62.833	3.5976	0.55455	0.0090623	232.38	3.4484	0.0057219	0.99955
0.5463	0.00065085	-4.0782	0.012183	384.25	0.79976	1.05	0.012025	117.7	1.1172	0.029537	0.99998
0.56892	0.00050896	-4.0869	0.0084198	369.14	0.57207	1.0781	0.0082136	100.89	0.76213	0.026942	0.99998
0.61674	0.00055188	-3.9156	0.0072687	355.44	0.54748	0.9942	0.0071174	89.509	0.69773	0.023641	0.99998
0.64841	0.00055111	-3.8233	0.0081038	340.91	0.57285	0.96526	0.0079037	88.639	0.76658	0.025464	0.99998
0.69189	0.00046274	-3.9009	0.0074768	325.46	0.48099	1.1169	0.0072352	84.103	0.59215	0.023755	0.99998

0.69396	0.0011647	-0.089102	0.010551	46.225	5.5303	0.45242	0.01034	186.06	4.093	0.0079945	0.99897
0.74221	0.00058997	-3.578	0.0079915	317.52	0.58447	0.9111	0.0077967	79.223	0.75369	0.025311	0.99997
0.77141	0.0006024	-3.4177	0.0086487	309.01	0.62697	0.8298	0.0084409	79.412	0.86439	0.025026	0.99997
0.82956	0.00051803	-3.3834	0.0081178	292.03	0.54927	0.85118	0.0078487	73.719	0.7624	0.025283	0.99997
0.91974	0.00055835	-3.3686	0.010315	273.98	0.60262	0.88133	0.010051	77.819	0.84131	0.019699	0.99997

	m1 err	m2	m2 err	m3	m3 err	m4	m4 err	m5	m5 err	Chi Sq	R
1.3286	0.0015312	-0.66622	0.012382	174.37	3.3701	7.4689	7.2593	18.037	3.6316	0.016072	0.99742
1.2577	0.0014816	-0.52667	0.0093217	168.88	3.4652	0.15464	0.015815	29.688	4.8941	0.0091688	0.99871
1.2003	0.0017455	-0.5294	0.015544	159.19	4.5439	0.11586	0.015692	37.735	5.6247	0.018338	0.99802
1.1584	0.00094096	-0.54855	0.0043667	195.03	2.1724	0.084613	0.0048352	28.785	2.9299	0.011653	0.99915
1.1455	0.00096265	-0.61191	0.0063866	193.71	2.314	0.11513	0.0065214	37.378	3.0007	0.010631	0.99934
1.0421	0.0016978	-0.45417	0.013128	181.05	5.2987	0.082323	0.013654	45.953	7.2137	0.0081183	0.99884
1.0355	0.0010974	-0.55006	0.0063453	209.15	2.9559	0.13207	0.0065792	38.538	2.8236	0.01317	0.99899
1.0742	0.001289	-0.53892	0.0050599	225.02	3.1574	0.088771	0.0055568	37.941	3.6327	0.0098195	0.99923
1.0797	0.0014544	-0.58202	0.005053	237.18	3.2955	0.098906	0.0056744	38.404	3.4654	0.011667	0.99923
1.1106	0.0010027	-0.69877	0.006284	245.44	2.5779	0.16155	0.0064948	48.64	2.6136	0.013543	0.99945
1.1619	0.00098408	-0.59963	0.0040269	257.61	2.5328	0.055165	0.0043852	43.207	5.3573	0.0086922	0.99956
1.019	0.001588	-0.53634	0.0083211	243.14	4.6703	0.1075	0.0089519	54.556	4.8486	0.00806	0.99931
1.0588	0.0010859	-0.59919	0.0056498	270.99	3.2372	0.12689	0.0059665	54.59	3.2704	0.0093287	0.99948
1.1209	0.0011791	-0.59149	0.0037208	293.47	3.1223	0.087581	0.0042567	46.019	3.6029	0.010236	0.99946
1.2367	0.0013139	-0.70734	0.0060655	297.03	3.4041	0.15267	0.006568	61.398	3.1378	0.0093835	0.99962
1.32	0.0010093	-0.72406	0.0044113	322.28	2.7491	0.12631	0.0047464	58.866	3.1375	0.011356	0.99965
1.3827	0.0011162	-0.85266	0.0052199	333.66	2.7303	0.19066	0.0049665	63.174	2.9495	0.010215	0.99974
1.1604	0.0017476	-0.49094	0.0036132	349.67	5.5591	0.061762	0.0045985	56.45	5.9213	0.008295	0.99934
1.207	0.0012219	-0.5946	0.0035045	364.97	3.8024	0.13027	0.00376	58.607	3.4985	0.007358	0.9996
1.2992	0.0013608	-0.57509	0.002772	402.74	4.2462	0.05816	0.003507	62.22	5.684	0.0078572	0.99962
1.373	0.00094619	-0.64791	0.0026304	413.5	3.0298	0.083561	0.00308	68.56	3.7244	0.0068434	0.99977
1.5363	0.00072987	-0.68061	0.00146	454.63	2.1904	0.059777	0.0019566	54.699	3.3765	0.007768	0.9998
1.6474	0.00073661	-0.84138	0.002042	465.87	2.0597	0.15142	0.0024041	71.619	1.8215	0.0076479	0.99987
1.3933	0.0011579	-0.52587	0.002914	453.54	4.7643	0.082296	0.0035553	81.808	4.45	0.0057852	0.99968
1.4941	0.00079063	-0.61171	0.001936	493.07	3.0531	0.13462	0.0023456	71.599	2.6231	0.0060109	0.99977
1.6318	0.00083002	-0.6581	0.0017801	529.83	3.0393	0.1204	0.0021171	77.41	2.7652	0.005596	0.99983
1.7602	0.00065577	-0.70737	0.0011131	574.46	2.2455	0.10241	0.0015186	71.824	1.9363	0.0056974	0.99988
1.8884	0.0006286	-0.77246	0.0012736	593.92	2.1732	0.10766	0.0016443	76.653	2.2133	0.0074879	0.99987
2.0601	0.00046111	-0.82823	0.00093245	627.5	1.5752	0.093774	0.0012398	76.394	1.9083	0.005785	0.99993
1.7712	0.00074267	-0.47913	0.0070004	643.34	3.4622	0.037678	0.0012203	61.955	4	0.0049032	0.99977
1.9643	0.00066721	-0.54664	0.00091589	660.25	3.1616	0.052312	0.0013382	78.135	3.7084	0.0055521	0.99982

Secondly, the data for the heating portion ...

2.1459	0.00069698	-0.60278	0.00082551	683.24	2.9553	0.067314	0.0012922	74.224	2.7486	0.0059918	0.99984
2.3096	0.00057003	-0.64961	0.00073175	706.34	2.3804	0.060106	0.001154	73.082	2.7807	0.0059851	0.99987
2.4378	0.00041344	-0.90511	0.0012105	705.38	1.6701	0.49771	0.018746	78.627	1.796	0.0053339	0.99992
5.7274	0.00026971	-0.81368	0.00050894	714.98	1.0468	0.083119	0.00075224	74.088	1.3406	0.0035495	0.99996
5.5717	0.00031383	-0.66365	0.00048523	715.56	1.386	0.071047	0.00072718	75.901	1.533	0.0027434	0.99995
5.329	0.00026998	-0.76893	0.00057297	703.81	1.141	0.11412	0.00079807	77.865	1.0775	0.0038142	0.99995
1.1125	8.81E-05	-0.79843	0.00021656	686.74	0.37327	0.07849	0.00031275	71.116	0.57069	0.0006868	0.99999
0.80187	6.67E-05	-0.8972	0.00019095	640.07	0.25068	0.10189	0.00026639	68.418	0.35962	0.0004681	1
0.79514	5.68E-05	-1.0081	0.00018929	579.11	0.18538	0.11092	0.00027594	58.618	0.29435	0.00048158	1
0.93683	6.14E-05	-1.1788	0.00028	482.14	0.16808	0.15751	0.00041442	48.15	0.25473	0.00095724	0.99999
0.42245	5.60E-05	-0.5785	0.0001828	477.26	0.25924	0.066447	0.00025817	50.113	0.39254	0.00027286	0.99999
0.47371	4.27E-05	-0.66391	0.00019054	420.52	0.1773	0.11551	0.00044328	42.999	0.27125	0.00024928	0.99999
0.54659	0.00010193	-0.71902	0.00051464	363.15	0.3666	0.10815	0.00080541	34.611	0.51361	0.0022176	0.99996
0.65017	0.00028882	-0.9811	0.0019954	298.37	0.72989	1.5391	0.48614	21.07	1.8765	0.012873	0.99977
0.75213	6.21E-05	-0.91094	0.00037064	230.58	0.12478	0.1183	0.00059859	20.547	0.20701	0.00063793	0.99999
0.90053	7.78E-05	-1.6178	0.0012417	170.1	0.11211	28.298	3.1366	13.389	0.25579	0.0010419	0.99998
0.34426	3.52E-05	-0.42114	0.00019501	164.97	0.10433	0.041768	0.00030539	14.974	0.2205	8.08E-05	0.99999
0.45	0.00053102	-0.53776	29469	112.46	88911	-0.51715	29469	112.46	92456	0.009216	0.99913
0.62566	0.00076026	-1.5683	0.50926	93.01	7.1244	-2.3909	0.21822	48.032	8.7939	0.0097749	0.99927
0.92287	0.00043945	-0.062101	0.050521	86.059	23.609	-0.85854	0.050389	45.011	0.96032	0.0010055	0.99994
1.4921	0.014371	-1.9867	1.301	32.089	7.2264	-1.9796	1.1258	16.045	5.3478	0.0013743	0.99991
0.81747	7.84E-05	-0.42619	0.059803	31.639	0.97887	-0.37357	0.059553	19.82	0.84184	0.00018465	0.99998
0.98012	6.80E-05	-0.63733	0.027265	27.428	0.33606	-0.31759	0.026997	14.804	0.47106	0.00017792	0.99998
1.1968	8.31E-05	-0.73913	0.020319	25.369	0.24174	-0.39956	0.019989	11.967	0.28933	0.0002877	0.99998
1.478	6.21E-05	-0.88993	0.0083127	23.257	0.095514	-0.4662	0.0080689	8.924	0.10479	0.00017384	0.99999
1.4781	0.0001202	-0.61884	0.021303	10.347	0.20434	-0.82682	0.021801	24.213	0.24932	0.00063993	0.99996
1.1959	6.37E-05	-0.69889	0.022835	25.953	0.27085	-0.46998	0.022512	12.948	0.27226	0.00032827	0.99998
0.9787	8.11E-05	-0.5365	0.045783	28.588	0.61892	-0.41486	0.045465	16.596	0.58302	0.00025989	0.99997
0.81571	0.00013197	-0.61152	0.079324	29.525	0.94333	-0.23244	0.078802	17.426	1.8261	0.0006588	0.99992
1.5036	0.00024258	-0.85826	5.85E-02	35.593	0.78883	-0.67978	0.057768	17.761	0.65137	0.0020879	0.99993
1.1547	0.00023836	-0.42977	0.16263	59.914	4.8478	-0.49023	0.16203	38.255	3.1913	0.0024529	0.99986
0.62244	0.00014602	-0.7349	0.029493	70.456	0.94219	0.097984	0.029047	34.665	4.5927	0.0017521	0.99987

0.45709	0.00032226	-0.49142	0.0038232	111.39	0.8373	0.014376	0.0039985	17.416	8.9487	0.0064094	0.99938
0.34407	3.97E-05	-0.40094	0.00022536	162.57	0.12342	0.027544	0.0003566	14.933	0.38562	0.0001038	0.99999
0.8989	6.34E-05	-1.0022	0.00039297	170.07	0.090266	0.072016	0.00085479	11.291	0.25319	0.00069559	0.99999
0.74742	5.24E-05	-0.85683	0.00028968	230.39	0.10807	0.062339	0.00055018	17.854	0.30491	0.00047294	0.99999
0.6481	7.65E-05	27.572	2.249	36.019	0.51329	-1.6261	0.0018491	292.03	0.22612	0.00088158	0.99998
0.55876	4.45E-05	0.060048	0.00029996	33.971	0.33986	-0.69105	0.00019095	361.38	0.15148	0.00027369	0.99999
0.48136	5.08E-05	0.061738	0.00029621	41.266	0.39922	-0.64354	0.00019833	425.55	0.20754	0.00035871	0.99999
0.4286	5.72E-05	0.052699	0.00026679	48.126	0.49251	-0.59046	0.00017902	484.56	0.25896	0.00030147	0.99999
0.94985	4.35E-05	0.1058	0.00029138	44.911	0.24797	-1.1432	0.00018401	489.25	0.12056	0.00049066	1
0.80862	5.84E-05	0.34556	0.0031738	56.127	0.37125	-1.1687	0.00027148	587.76	0.19473	0.00070808	1
0.82714	6.98E-05	0.069721	0.000286	65.028	0.53908	-0.93564	0.00019181	657.42	0.25462	0.0005962	1
1.1343	9.38E-05	0.15046	0.00044533	73.762	0.42786	-0.97029	0.00026285	708.64	0.35683	0.0010137	0.99999
1.5733	0.00014168	0.034543	0.00041985	90.96	2.0776	-0.75727	0.00032724	725.43	0.64453	0.00093554	0.99999
1.9037	0.00013485	0.037329	0.00037705	90.982	1.7064	-0.70949	0.00029168	719.52	0.63202	0.00067998	0.99999
2.0651	0.00011183	0.091234	0.00035685	80.742	0.62766	-0.8632	0.00025843	729.42	0.45193	0.00087936	0.99999
5.8514	0.0009453	2.7206	0.5366	115.94	7.3254	-1.6	0.0094191	732.27	3.9346	0.034632	0.9997
2.2959	0.00096478	0.084574	0.0058054	178.2	10.365	-0.77282	0.0052776	694.89	5.5938	0.0095752	0.99986
2.1609	0.00085361	0.018228	0.0016757	72.293	13.099	-0.61117	0.0010609	692.26	3.6735	0.011622	0.99972
1.9886	0.00060539	0.09007	0.0014522	86.444	2.4395	-0.67647	0.0010953	655.56	2.5261	0.0061132	0.99987
1.8351	0.00094927	0.077828	0.0019174	78.561	3.471	-0.61411	0.0013342	637.41	3.8928	0.0096682	0.99973
2.1234	0.00062775	0.074818	0.0016468	72.247	3.083	-0.81138	0.0011835	634.61	2.1607	0.011462	0.99985
1.9155	0.00058586	0.068381	0.0014147	67.065	2.7134	-0.82698	0.00097586	610.84	1.8197	0.0075608	0.9999
1.7615	0.00054672	0.083329	0.0016412	77.484	2.706	-0.78729	0.0013261	571.59	1.9139	0.0074492	0.99989
1.6588	0.00075633	0.10592	0.0023131	71.54	2.9935	-0.73843	0.0017667	538.55	2.6167	0.010785	0.99978
1.5186	0.0008961	0.079369	0.0022519	65.613	3.3436	-0.64928	0.001705	511.18	3.0995	0.010316	0.99972
1.3864	0.0011516	0.056567	0.0024217	61.667	4.7489	-0.59307	0.0017185	491.9	3.8487	0.009113	0.99966
1.6387	0.00082064	0.089746	0.0023217	68.267	3.0112	-0.79483	0.0018675	486.76	2.3552	0.0089136	0.99983
1.5417	0.000678	0.10761	0.0024406	68.411	2.5975	-0.82597	0.0021323	447.2	1.9606	0.0086116	0.99985
1.4103	0.00085644	0.077075	0.0028904	68.054	3.9254	-0.715	0.0025031	418.51	2.5752	0.0072902	0.99981
1.3102	0.0010307	0.06117	0.0028423	61.877	4.3315	-0.65019	0.002286	398	2.9036	0.0055178	0.9998
1.2079	0.0011127	0.073367	0.0038171	62.76	4.6925	-0.61986	0.0032747	373.62	3.4456	0.0087726	0.99965
1.1595	0.00096324	0.039609	0.0028057	46.846	6.0075	-0.52118	0.0022199	358.57	3.1367	0.009113	0.99951

1.3937	0.0010373	0.15965	0.0048776	64.87	2.6507	-0.82891	0.0044918	344.31	2.6134	0.011401	0.99974
1.3162	0.00087066	0.15058	0.0049032	62.512	2.7085	-0.81989	0.0046577	320.5	2.2902	0.01131	0.99974
1.2536	0.0011932	0.088347	0.0055763	61.578	4.749	-0.70374	0.0050803	308.94	3.1233	0.0082221	0.99971
1.146	0.0028984	0.14157	0.006689	53.66	2.8984	-0.70308	0.0048287	293.39	4.9446	0.0037285	0.99975
1.0925	0.00087203	0.14794	0.0060001	55.128	2.8246	-0.67025	0.0058291	265.24	2.5965	0.011252	0.99954
1.016	0.0011816	0.089388	0.0064278	54.068	4.4817	-0.5574	0.0060291	251.15	3.4315	0.005686	0.99959
1.1684	0.0010179	0.14346	0.0053759	51.076	2.3339	-0.7141	0.0050071	250.72	2.2842	0.0055512	0.99976
1.0847	0.00151	0.13586	0.013991	63.427	5.5345	-0.70595	0.013458	231.32	4.1292	0.009474	0.99955
1.0707	0.0014087	0.085927	0.0090127	50.774	5.9705	-0.59978	0.0085731	229.18	3.7948	0.010576	0.99935
1.0751	0.0012562	0.13434	0.021062	67.263	7.1824	-0.6152	0.020775	202.01	4.7898	0.0084679	0.99942
1.0712	0.00081924	0.070494	0.0038354	27.181	2.7704	-0.50733	0.0032536	206.18	2.0204	0.0096194	0.99923
1.0763	0.0014142	0.0772	0.0073296	36.675	4.6132	-0.47418	0.0068763	189.16	3.6126	0.0077741	0.99905
1.2108	0.0016857	0.14024	0.0081628	33.139	2.8259	-0.65085	0.0075606	188.13	3.0384	0.014454	0.99906
1.2137	0.0014726	0.12007	0.011877	42.655	4.3792	-0.6113	0.011612	175.06	3.3706	0.0081877	0.99934
1.2065	0.00095104	0.14005	0.0082445	39.603	2.5723	-0.59714	0.0081189	169.01	2.2785	0.0058104	0.99952
1.2308	0.0012991	0.11538	0.012914	39.043	4.4643	-0.52122	0.012766	156.46	3.543	0.009867	0.99889
1.2852	0.00093709	0.096714	0.0094525	35.702	3.8577	-0.4682	0.0094453	149.21	2.7853	0.0067963	0.99907

Delta T	Raw Conductance	P_rad (W)	K_shoes	Conductance	[redacted]	Residual	Delta K Err	Conductivity Err
0.39343	0.002030681	0.000109952	0.000739837	0.000974383	[redacted]	-8.914034	0.0015312	0.668005953
0.43554	0.00183412	9.87034E-05	0.000688215	0.000884871	[redacted]	-11.24231	0.0014816	0.535955501
0.45474	0.001759076	8.73766E-05	0.000639059	0.000895917	[redacted]	-9.414709	0.0017455	0.589499092
0.50891	0.001571598	7.87712E-05	0.000592502	0.000794687	[redacted]	-8.241397	0.00094096	0.256752715
0.55096	0.001451447	7.23679E-05	0.000548424	0.000744254	[redacted]	-8.899966	0.00096265	0.22606151
0.38644	0.001550201	6.36927E-05	0.000548426	0.000809535	[redacted]	-4.832629	0.0016978	0.596558508
0.46551	0.00128674	5.948E-05	0.000506421	0.000627224	[redacted]	-7.890057	0.0010974	0.267780887
0.49898	0.001202387	5.63653E-05	0.000466695	0.000599396	[redacted]	-7.914555	0.001289	0.275829609
0.54306	0.001104687	5.15388E-05	0.00042906	0.00055927	[redacted]	-8.334364	0.0014544	0.265056089
0.58052	0.001033326	4.87791E-05	0.000393549	0.000536073	[redacted]	-5.248946	0.0010027	0.160704863
0.63624	0.000942779	4.5818E-05	0.000360027	0.000492737	[redacted]	-5.947424	0.00098408	0.132002588
0.43418	0.001035056	3.87428E-05	0.000359874	0.000567956	[redacted]	-3.51098	0.001588	0.339052719
0.51993	0.000864318	3.68418E-05	0.000328221	0.000448826	[redacted]	-6.160415	0.0010859	0.162420868
0.56474	0.000795723	3.48643E-05	0.000298621	0.000420436	[redacted]	-6.914511	0.0011791	0.150197877
0.59655	0.000753291	3.44355E-05	0.000270842	0.000411182	[redacted]	-5.491195	0.0013139	0.150150461
0.66472	0.000676048	3.28971E-05	0.000244797	0.000369521	[redacted]	-5.533671	0.0010093	0.093242608
0.70734	0.000635339	3.08063E-05	0.000220405	0.000360362	[redacted]	-3.67091	0.0011162	0.091527311
0.46204	0.000648647	2.48123E-05	0.000220204	0.000363731	[redacted]	-5.175606	0.0017476	0.220554636
0.52443	0.00057152	2.31412E-05	0.000197577	0.000319938	[redacted]	-5.279931	0.0012219	0.120435894
0.58207	0.000514981	2.18312E-05	0.000176552	0.000292095	[redacted]	-5.127585	0.0013608	0.109406276
0.63765	0.000470158	2.04048E-05	0.000157114	0.000273189	[redacted]	-4.425555	0.00094619	0.06372337
0.69737	0.000429966	1.98912E-05	0.000139149	0.000255337	[redacted]	-3.471583	0.00072987	0.04117912
0.74936	0.000400213	1.84345E-05	0.000122588	0.000246896	[redacted]	-2.986362	0.00073661	0.036187526
0.48317	0.000413246	1.52638E-05	0.00012243	0.000253105	[redacted]	-3.87597	0.0011579	0.089643136
0.54683	0.000365221	1.40561E-05	0.00010728	0.000226872	[redacted]	-3.676226	0.00079063	0.048111933
0.5945	0.000336021	1.30323E-05	9.33885E-05	0.000216041	[redacted]	-3.236152	0.00083002	0.042980837
0.6564	0.000304424	1.19544E-05	8.07233E-05	0.000201453	[redacted]	-2.664885	0.00065577	0.028024763
0.7202	0.000277558	1.07757E-05	6.92617E-05	0.000189871	[redacted]	-2.148816	0.0006286	0.022463598
0.8008	0.00024973	9.76763E-06	5.89369E-05	0.000175649	[redacted]	-1.893986	0.00046111	0.013405267
0.4893	0.000254739	8.09595E-06	5.88297E-05	0.000176422	[redacted]	-2.802451	0.00074267	0.035434123
0.5567	0.000224014	7.37146E-06	4.95832E-05	0.00015871	[redacted]	-2.553266	0.00066721	0.024758607

Here are the conductivity calculations -

0.5968	0.000209091	6.44891E-06	4.13429E-05	0.000154875	[illegible]	-2.276249	0.00069698	0.022696194
0.6653	0.000187702	5.51186E-06	3.40739E-05	0.00014364	[illegible]	-2.083046	0.00057003	0.015066636
0.7377	0.000169423	4.53995E-06	2.7682E-05	0.000134202	[illegible]	-1.669026	0.00041344	0.008968218
0.8224	0.000151539	7.53508E-06	2.12371E-05	0.000120078	[illegible]	-1.37047	0.00026971	0.004576408

0.633	0.00015772	7.27098E-06	2.12038E-05	0.00012397	[illegible]	-1.090481	0.00031383	0.007105745
0.7229	0.000138255	5.23905E-06	1.69097E-05	0.000113253	[illegible]	-1.061753	0.00026998	0.004795357
0.77111	0.000129214	8.16568E-07	1.25473E-05	0.00011498	[illegible]	-0.71677	0.000088061	0.001434407
0.834469	0.000119571	4.22325E-07	9.27966E-06	0.000109321	[illegible]	-0.487927	0.000066748	0.00093343
0.92364	0.000108202	3.03815E-07	6.64535E-06	0.000100895	[illegible]	-0.266951	0.000056817	0.000650368
1.04221	9.56419E-05	2.0626E-07	4.55859E-06	9.06575E-05	[illegible]	-0.117919	0.000061351	0.000550663

0.52262	9.56495E-05	9.94991E-08	4.52281E-06	9.07102E-05	[illegible]	-0.211646	0.000056045	0.001003319
0.571413	8.74542E-05	8.06053E-08	3.6615E-06	8.34685E-05	[illegible]	-0.141066	0.0000427	0.000639481
0.627948	7.96146E-05	6.36195E-08	2.90961E-06	7.64582E-05	[illegible]	-0.068869	0.00010193	0.001264995
0.708137	7.06013E-05	4.86705E-08	2.26223E-06	6.81572E-05	[illegible]	-0.052405	0.00028882	0.002819489
0.803304	6.22091E-05	3.55898E-08	1.71171E-06	6.03675E-05	[illegible]	-0.024366	0.00006214	0.00047131
0.937762	5.33037E-05	2.48713E-08	1.25125E-06	5.19634E-05	[illegible]	-0.007736	0.000077752	0.000432943

0.381885	5.23286E-05	9.6606E-09	1.23374E-06	5.10078E-05	[illegible]	-0.020806	0.0000352	0.000472508
0.468157	4.27187E-05	6.36358E-09	8.54352E-07	4.18081E-05	[illegible]	0.0461492	0.00053102	0.004747561
0.635704	3.14376E-05	3.69356E-09	5.51457E-07	3.08527E-05	[illegible]	-0.031297	0.00076026	0.003684234
0.910543	2.19497E-05	1.81465E-09	3.16271E-07	2.16156E-05	[illegible]	-0.00666	0.00043945	0.001038172
1.510572	1.324E-05	6.85967E-10	1.39911E-07	1.30926E-05	[illegible]	0.1160737	0.014371	0.012346089

0.832315	1.20147E-05	2.26734E-10	1.29017E-07	1.18789E-05	[illegible]	-0.000295	0.000078442	0.000110977
0.9898992	1.0102E-05	1.63389E-10	1.0247E-07	9.99428E-06	[illegible]	-7.23E-05	0.000067984	6.79968E-05
1.19728458	8.35223E-06	1.14675E-10	7.86556E-08	8.26955E-06	[illegible]	-2.38E-05	0.000083084	5.68052E-05
1.4701284	6.80213E-06	8.1718E-11	5.81233E-08	6.74104E-06	[illegible]	0.0006469	0.000062131	2.81751E-05
1.4723952	6.79165E-06	8.17075E-11	5.81247E-08	6.73057E-06	[illegible]	5.867E-05	0.0001202	5.43404E-05
1.2001319	8.33242E-06	1.14474E-10	7.85103E-08	8.24989E-06	[illegible]	-5.56E-05	0.000063746	4.33771E-05
0.991426	1.00865E-05	1.63126E-10	1.02362E-07	9.97884E-06	[illegible]	-0.00022	0.000081109	8.08746E-05
0.99889	1.00111E-05	2.26847E-10	1.28874E-07	9.87557E-06	[illegible]	-0.096602	0.00013197	0.000129629

1.520329	1.3155E-05	6.84569E-10	1.39791E-07	1.30078E-05	[illegible]	0.1120539	0.00024258	0.000205715
0.90181	2.21623E-05	2.11212E-09	3.10518E-07	2.18339E-05	[illegible]	0.00011	0.00023836	0.00057406
0.6284794	5.17989E-05	3.68003E-09	5.61449E-07	3.12141E-05	[illegible]	-0.026977	0.00014602	0.000723977

0.469824	4.25671E-05	6.31981E-09	8.54951E-07	4.16559E-05	[illegible]	0.0076375	0.00032226	0.002860741
0.37959	5.26449E-05	9.64762E-09	1.23391E-06	5.13239E-05	[illegible]	-0.01234	0.000039696	0.000539324

0.937146	5.33388E-05	2.48779E-08	1.25129E-06	5.19984E-05	[illegible]	-0.003636	0.000063378	0.000353369
0.798575	6.25775E-05	3.5708E-08	1.71148E-06	6.07357E-05	[illegible]	0.0021114	0.000052396	0.000402125
0.702664	7.11512E-05	4.91001E-08	2.26198E-06	6.87062E-05	[illegible]	0.00076	0.000076484	0.000758314
0.629589	7.94071E-05	6.4992E-08	2.90928E-06	7.62491E-05	[illegible]	-0.003985	0.000044509	0.000549485
0.576278	8.67159E-05	8.41717E-08	3.66128E-06	8.27255E-05	[illegible]	0.0032461	0.000050846	0.000748621
0.53115	9.41134E-05	1.05338E-07	4.52225E-06	8.91667E-05	[illegible]	-0.023432	0.000057214	0.000991496

1.05166	9.47824E-05	2.09097E-07	4.56024E-06	8.97953E-05	[illegible]	-0.095736	0.000043544	0.00038383
0.92941	0.00010753	3.21293E-07	6.6444E-06	0.000100208	[illegible]	-0.01576	0.000058391	0.000659996
0.848144	0.000117643	4.65525E-07	9.27545E-06	0.000107355	[illegible]	0.0224609	0.000069807	0.000944572
0.78376	0.000127128	8.52999E-07	1.25369E-05	0.000112876	[illegible]	0.1641578	0.000093753	0.001477678
0.70824	0.000141117	1.55731E-06	1.60986E-05	0.000122014	[illegible]	0.2216457	0.00014168	0.002723686
0.6362	0.000156927	2.47109E-06	2.02855E-05	0.000131743	[illegible]	0.3488874	0.00013485	0.003179373

0.8061	0.000154604	2.69375E-06	2.03341E-05	0.000129911	[illegible]	-0.704064	0.00011183	0.002056694
0.7162	0.000174509	1.02783E-05	2.66701E-05	0.000132154	[illegible]	0.3620928	0.0009453	0.020718305
0.63	0.00019822	5.64031E-06	3.40409E-05	0.000153524	[illegible]	0.438371	0.00096478	0.028407559
0.5776	0.000216041	6.64633E-06	4.13317E-05	0.000161136	[illegible]	0.4631732	0.00085361	0.029625839
0.5172	0.000241122	7.57161E-06	4.95735E-05	0.00017443	[illegible]	0.5579444	0.00060539	0.025982615
0.4763	0.000261692	8.50956E-06	5.88142E-05	0.000182071	[illegible]	0.260564	0.00094927	0.047627911

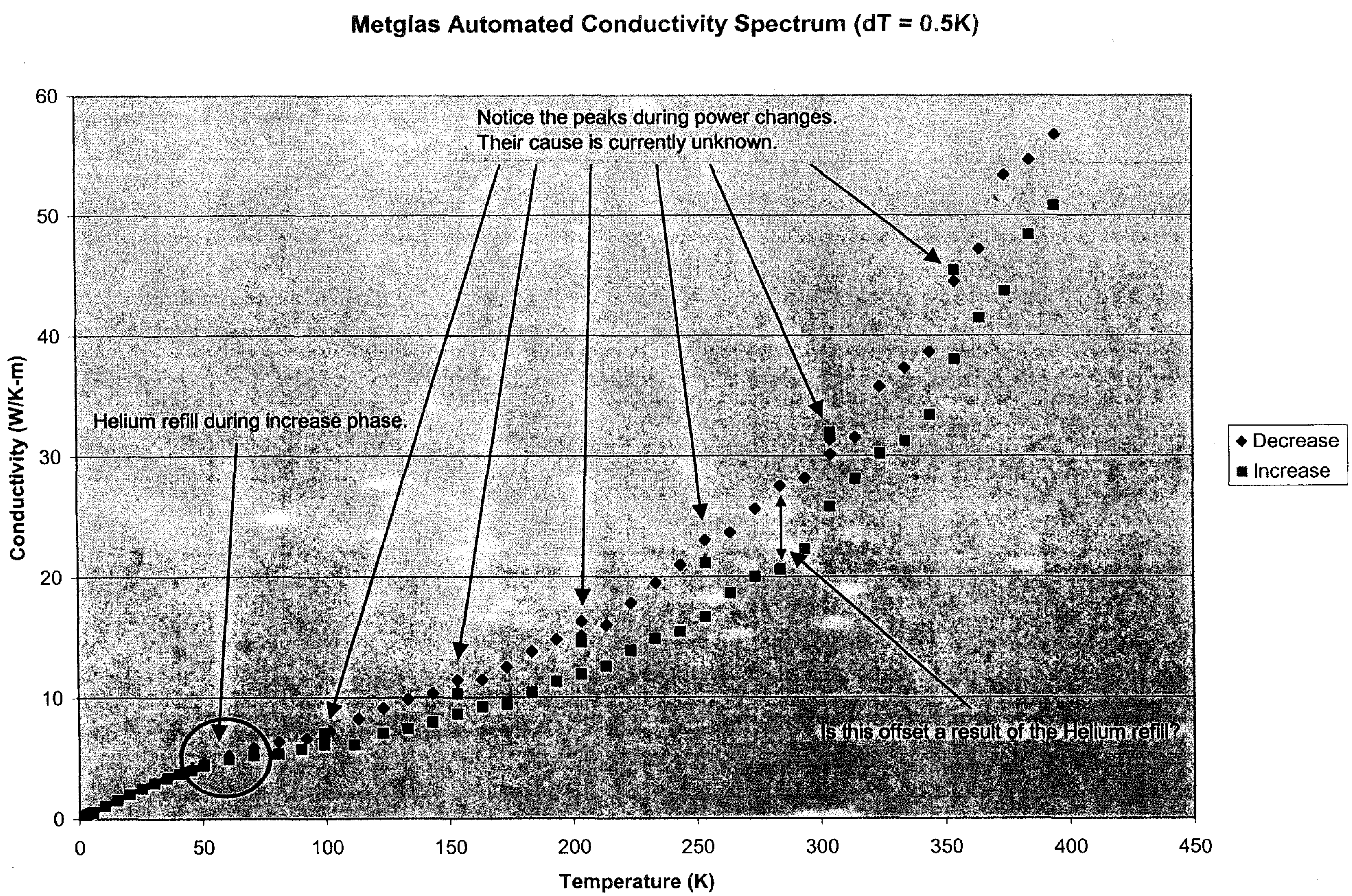
0.7845	0.000254919	1.00818E-05	5.89569E-05	0.000180163	[illegible]	-1.492409	0.00062775	0.018984629
0.7073	0.00028262	1.10996E-05	6.92474E-05	0.000194217	[illegible]	0.2597811	0.00058586	0.021669724
0.6291	0.000317635	1.22951E-05	8.07227E-05	0.000213332	[illegible]	0.9851773	0.00054672	0.025390109
0.5747	0.000347597	1.36851E-05	9.33687E-05	0.000225748	[illegible]	0.6326106	0.00075633	0.041763605
0.5102	0.000391442	1.45511E-05	0.000107239	0.000250321	[illegible]	0.9180674	0.0008961	0.062474209
0.4662	0.00042829	1.54078E-05	0.000122399	0.000266722	[illegible]	1.1330646	0.0011516	0.095689384

0.74107	0.00040469	1.84312E-05	0.000122617	0.000251071	[illegible]	-2.282883	0.00082064	0.041223197
0.65701	0.000456379	2.06115E-05	0.000139111	0.000278941	[illegible]	1.0527764	0.000678	0.042985794
0.58784	0.000509997	2.14417E-05	0.000157066	0.000308602	[illegible]	1.2084006	0.00085644	0.067615911
0.54553	0.000549474	2.25026E-05	0.000176495	0.000322906	[illegible]	0.9465127	0.0010307	0.094111367
0.49429	0.000606369	2.38663E-05	0.000197564	0.000350639	[illegible]	1.7216697	0.0011127	0.123130695
0.44674	0.000670862	2.58519E-05	0.000220199	0.000381784	[illegible]	2.0294361	0.00096324	0.129541349

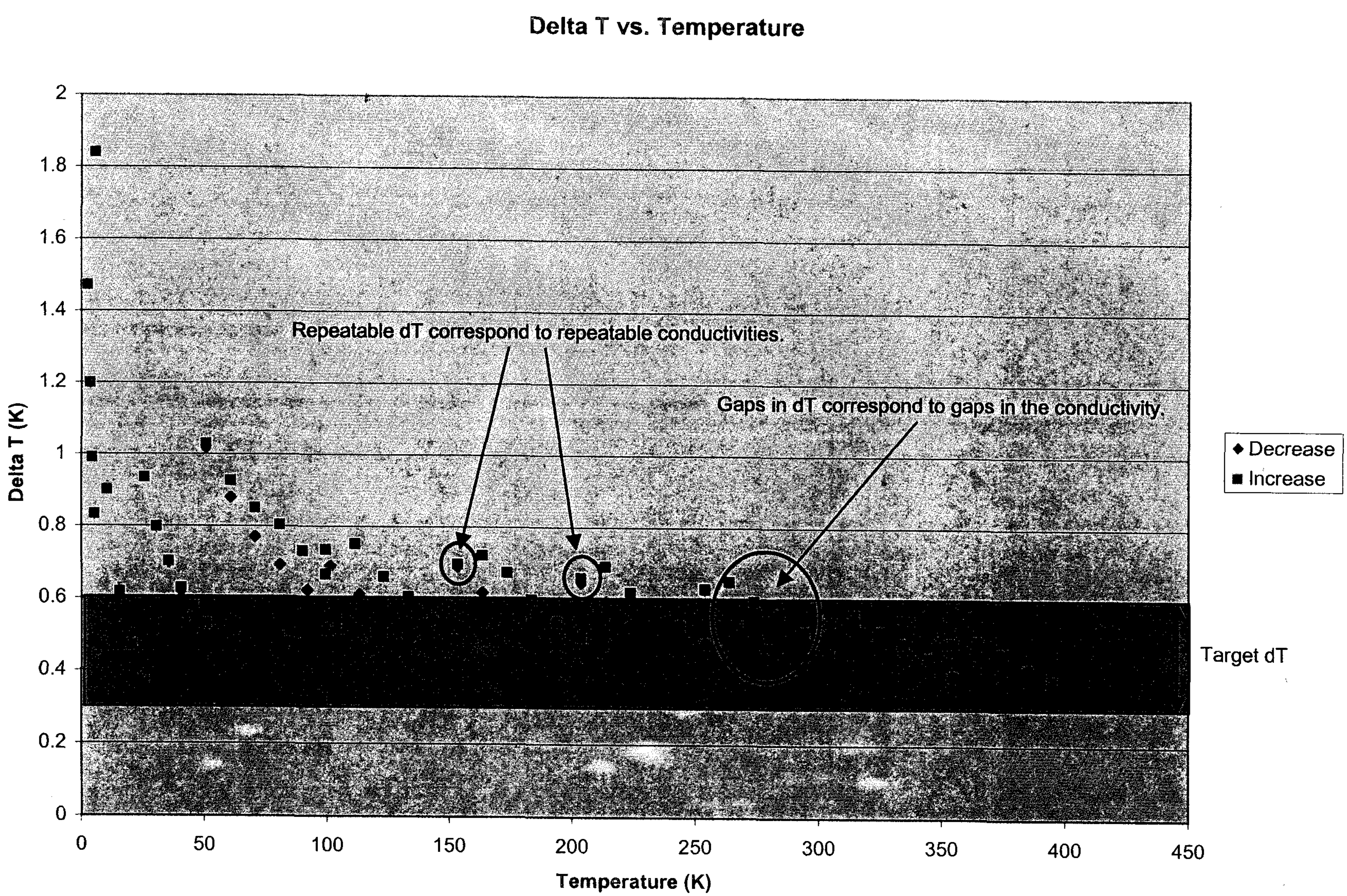
0.69688	0.000644875	3.09546E-05	0.000220499	0.000368933	[illegible]	-3.063404	0.0010373	0.087599057
0.62192	0.000722573	3.38576E-05	0.000244753	0.000411142	[illegible]	1.5005409	0.00087066	0.091674445
0.5715	0.000786309	3.58292E-05	0.00027076	0.000439318	[illegible]	1.5012916	0.0011932	0.148073546
0.52509	0.000855809	3.70859E-05	0.000298595	0.000471657	[illegible]	2.5047187	0.0028984	0.424794149
0.47382	0.000948429	3.9258E-05	0.000328242	0.000520921	[illegible]	3.224558	0.00087203	0.156133069
0.43884	0.001024064	3.97661E-05	0.000359786	0.000555673	[illegible]	1.3967175	0.0011816	0.246336166

0.58466	0.001025953	4.53476E-05	0.000360083	0.000570304	[illegible]	-4.008898	0.0010179	0.161830789
0.5384	0.001114165	4.7956E-05	0.000393567	0.000611849	[illegible]	1.8672344	0.00151	0.281779621
0.50178	0.001195567	5.16821E-05	0.000429221	0.000641887	[illegible]	1.2587428	0.0014087	0.300627152
0.45836	0.001308942	5.69187E-05	0.000466807	0.000694616	[illegible]	2.7878046	0.0012562	0.318242084
0.42279	0.001416756	6.16385E-05	0.000506554	0.000739084	[illegible]	2.7663248	0.00081924	0.241375153
0.38441	0.001558388	6.62723E-05	0.000548551	0.000810009	[illegible]	1.6404501	0.0014142	0.499749079

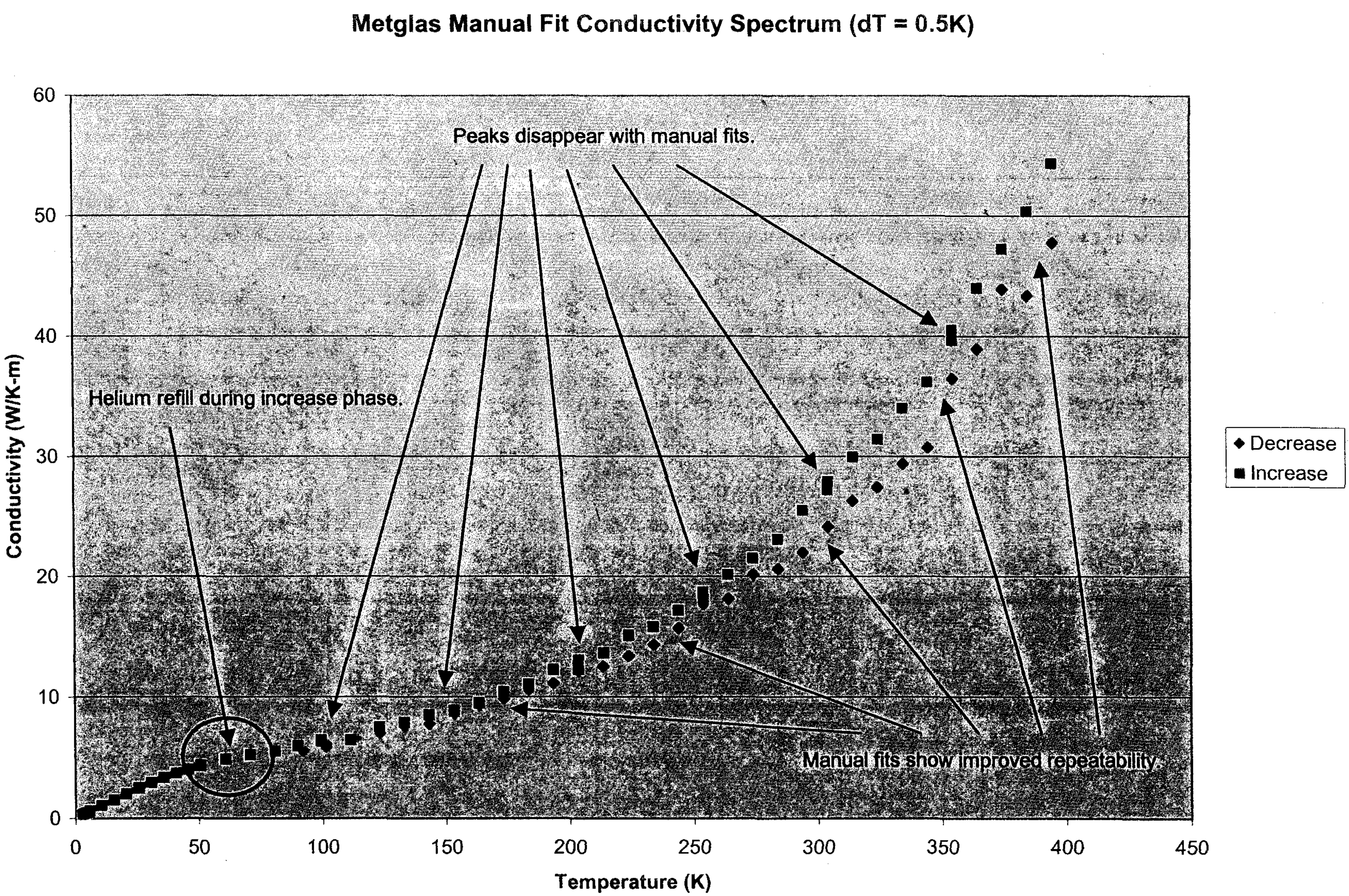
0.51684	0.001547267	7.36456E-05	0.00054888	0.000828451	[illegible]	-4.867676	0.0016857	0.44906173
0.47149	0.001696328	8.2409E-05	0.000592878	0.000899022	[illegible]	2.5682943	0.0014726	0.465770184
0.43509	0.001838521	8.81139E-05	0.000639352	0.000964682	[illegible]	3.5457876	0.00095104	0.350490491
0.40124	0.00199091	9.63962E-05	0.000688243	0.001028009	[illegible]	1.9754405	0.0012991	0.555541393
0.36546	0.002186097	0.000109708	0.000739495	0.001109435	[illegible]	3.5411695	0.00093709	0.473952403



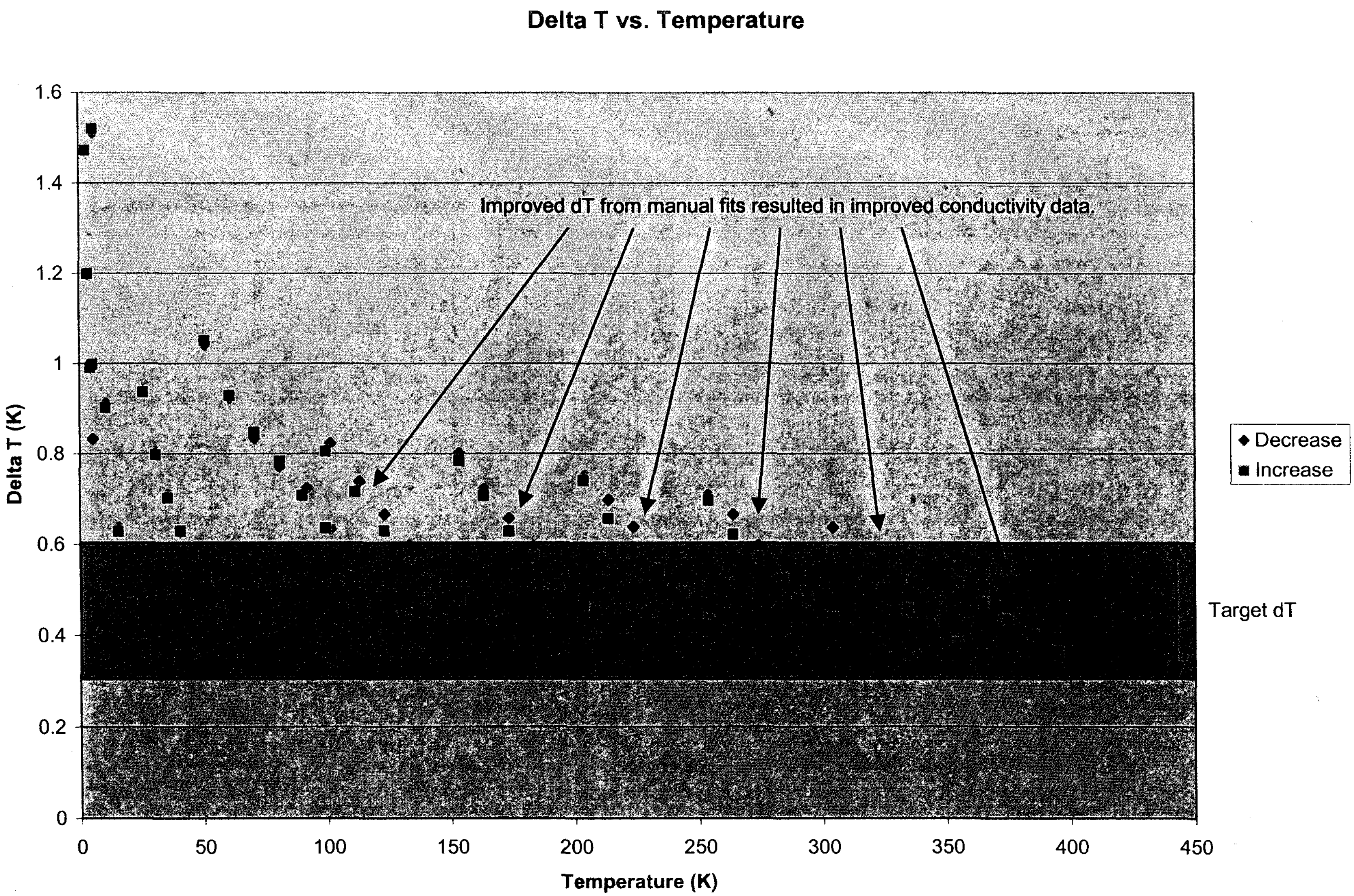
Above is the conductivity spectrum as determined by QD.



Above is the delta T vs T plot determined by QD.



Above is the conductivity spectrum determined by Valerie.



Above is the delta T vs. T plot determined by Valerie.

Conclusions

We believe these results are our best to date. Most errors probably occur at higher temperatures and are most likely due to KSHOES. Any conductivity spreads are most likely due to PRAD.

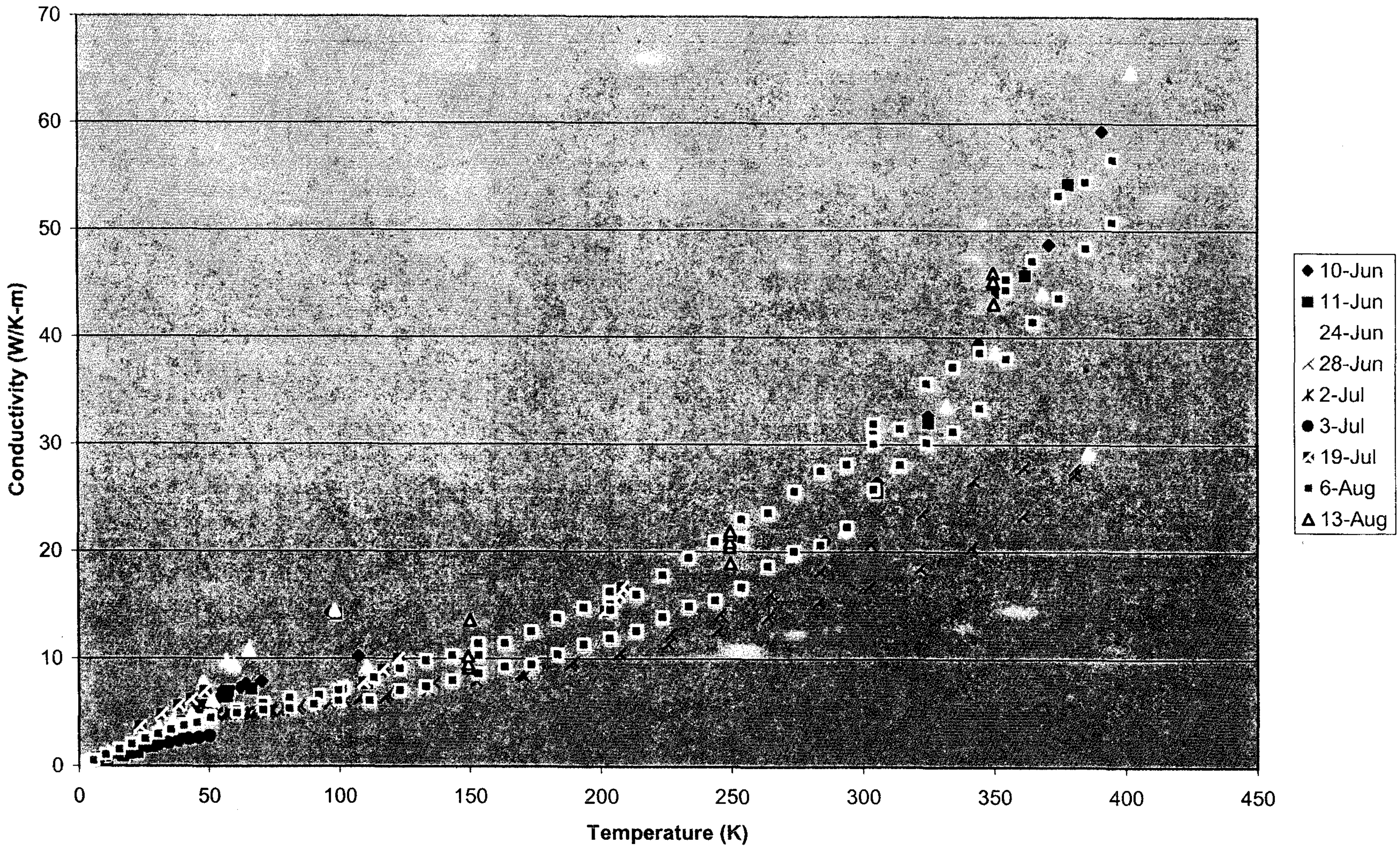
We will use these results as the raw data for our Metglas measurement. We still need to measure KSHOES and PRAD directly. When that is completed, it will be updated.

To keep the ΔT in our target range, its clear that the powers must be reduced at low temperatures. This mistake is due to the imperfect power guesses we used. We can refine our powers for our next measurements.

Where does the real conductivity spectrum lie?

The plot below shows all data on Bismuth Telluride measurements to date. We believe the August 6 measurement is the most accurate so far, and probably correct for low temperatures.

Conductivity Comparison (Quantum Design's Fits)



Power Scatter #2 - Eliminating the Temperature Deviations

The powers were decreased to minimize temperature deviations so we can see if the conductivity spread is also reduced. It may shed some light on whether K_{SHOES} or P_{RAD} is the larger problem.

TTO Run Initiated: 8/13/02

Purpose: To repeat the power scatter measurement at different temperatures, reducing the powers so that the temperature deviations disappear. To estimate the errors due to both K_{SHOES} and P_{RAD}. To extrapolate the "real" conductivities by looking at K vs. P_{RAD} behavior.

Sample Parameters:

length: 6.92 mm — Surface Area: 36.1916 mm^2

Cross-Section: 0.14121 mm^2 — Emmissivity: 0.3

Sequence File: PowerScatter2.seq

```
1:  Chamber High Vacuum
2:  Wait For Chamber, Delay 3600 secs, No Action
3:  Set Temperature 350.00K at 20.00K/min. Fast Settle
4:  Wait For Temperature, Delay 0 secs, No Action
5:  LogData Start New 5.00 1073741823 1073741823 1073741823 "C:\cryolab\08-12
    -2002\LogPpmsSeq.dat" "Second Power Scatter (With Lower Powers & Differen
    t Temperatures)" ""
6:  TTO Single dT Measure K init= 10mW, 300sec max= 50mW, 1430sec, 500uV, 10m
    A
7:  TTO Single dT Measure K init= 10mW, 300sec max= 50mW, 1430sec, 500uV, 10m
    A
8:  TTO Single dT Measure K init= 10mW, 300sec max= 50mW, 1430sec, 500uV, 10m
    A
9:  TTO Single dT Measure K init= 10mW, 300sec max= 50mW, 1430sec, 500uV, 10m
    A
10: TTO Single dT Measure K init= 10mW, 300sec max= 50mW, 1430sec, 500uV, 10m
    A
11: Set Temperature 250.00K at 20.00K/min. Fast Settle
12: Wait For Temperature, Delay 0 secs, No Action
13: TTO Single dT Measure K init= 10mW, 300sec max= 50mW, 1430sec, 500uV, 10m
    A
14: TTO Single dT Measure K init= 10mW, 300sec max= 50mW, 1430sec, 500uV, 10m
    A
15: TTO Single dT Measure K init= 10mW, 300sec max= 50mW, 1430sec, 500uV, 10m
    A
16: TTO Single dT Measure K init= 10mW, 300sec max= 50mW, 1430sec, 500uV, 10m
    A
17: TTO Single dT Measure K init= 10mW, 300sec max= 50mW, 1430sec, 500uV, 10m
    A
18: Set Temperature 150.00K at 20.00K/min. Fast Settle
19: Wait For Temperature, Delay 0 secs, No Action
20: TTO Single dT Measure K init= 10mW, 300sec max= 50mW, 1430sec, 500uV, 10m
    A
21: TTO Single dT Measure K init= 10mW, 300sec max= 50mW, 1430sec, 500uV, 10m
    A
22: TTO Single dT Measure K init= 10mW, 300sec max= 50mW, 1430sec, 500uV, 10m
    A
23: TTO Single dT Measure K init= 10mW, 300sec max= 50mW, 1430sec, 500uV, 10m
    A
24: TTO Single dT Measure K init= 10mW, 300sec max= 50mW, 1430sec, 500uV, 10m
    A
25: LogData Stop ""
26: Set Temperature 300.00K at 20.00K/min. Fast Settle
```

Copy of the sequence used.

sigma_T:	5.67E-08	Rad Loss A:	0.000000019
Sample Properties		Rad Loss B:	9.1E-10
Surface Area:	36.1916	Rad Loss C:	9.6E-12
Length:	6.92	Rad Loss D:	1.05
CrossSection:	0.14121		
Emmisivity:	0.3		

Fit #	Temperature	Avg. Cold	Avg. Hot	Heater Power
1	349.8388107	348.9464111	351.3843079	0.001998282
2	349.6185904	348.9966736	350.5490112	0.000999473
3	349.5913987	348.994873	350.4630127	0.000899984
4	349.5605381	348.9935303	350.3753052	0.000799689
5	349.5351577	348.9944153	350.2889404	0.000699687

This page details the 5 fits that were saved properly. The next page details all the fits as made by Quantum Design.

m1	m1 err	m2	m2 err	m3	m3 err	m4	m4 err	m5	m5 err	Chi Sq	R
0.52159	0.00089881	-1.1406	0.012078	71.58	1.0122	11.514	0.012323	334.64	0.30731	0.029107	0.99999
0.52041	0.0008168	-0.37431	0.0099827	41.599	1.4252	1.6475	0.010137	190.19	1.0302	0.0048457	0.99991
0.54052	0.001977	-0.19476	0.01763	44.217	4.0011	0.80856	0.017073	180.5	3.7273	0.0036161	0.99961
0.56665	0.0021791	-0.24471	0.027016	49.311	4.6398	0.79943	0.026578	174.5	4.7876	0.0046303	0.99943
0.57324	0.0022121	-0.13224	0.013708	37.674	4.9923	0.63331	0.012976	190.39	4.6987	0.0052826	0.99916

m1	m1 err	m2	m2 err	m3	m3 err	m4	m4 err	m5	m5 err	Chi Sq	R
1.808	0.001021	0.38881	0.013631	42.781	1.7612	-1.6426	0.013877	181.43	1.2842	0.0059849	0.99988
1.1742	0.0016669	0.10916	0.0081333	29.349	3.6846	-0.74413	0.0072076	199.36	2.7999	0.0051956	0.99949
1.1338	0.0015608	0.11241	0.011806	38.467	5.142	-0.66321	0.011461	187.7	3.5228	0.0043711	0.99943
1.0843	0.0016106	0.071686	0.0099558	36.207	6.9917	-0.5614	0.0094286	195.47	4.0032	0.0041954	0.99927
1.0233	0.0026902	0.099347	0.012602	34.106	5.5925	-0.51951	0.011342	183.56	5.7082	0.0035827	0.99903

Delta T	Raw Conductance	P_rad (W)	K_shoes	Conductance	[redacted]	Residual	Delta K Err	Conductivity Err
1.28641	0.001553378	0.000128879	0.000529051	0.00089769	[redacted]	0.8552564	0.001021	0.113042214
0.65379	0.001528737	8.17878E-05	0.000528131	0.000849102	[redacted]	-4.453701	0.0016669	0.350752001
0.59328	0.001516963	7.73225E-05	0.000528017	0.000832214	[redacted]	-5.275039	0.0015608	0.357538183
0.51765	0.001544846	7.27461E-05	0.000527888	0.000850031	[redacted]	-3.428835	0.0016106	0.42824531
0.45006	0.001554653	6.81277E-05	0.000527782	0.000849107	[redacted]	-3.667914	0.0026902	0.822136968

Note: There was an error in the data logging, so much of the raw data was not saved. Only the 5 measurements were saved. All rest of the data have been automatically fit by QD.

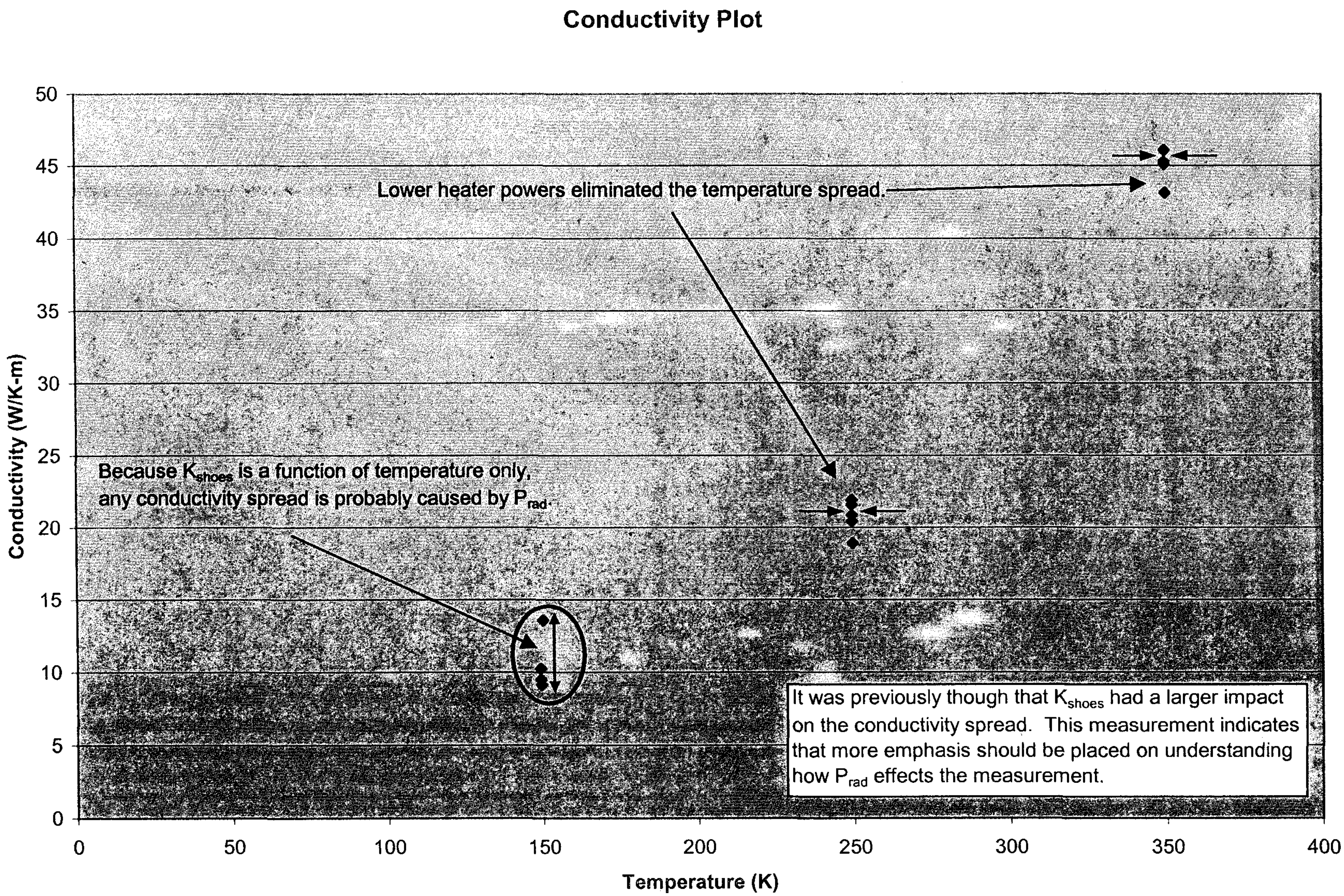
Why are we doing this?

Sample Temp. (K)	Conductivity (W/K-m)	Delta Temp. (K)	Conductance (W/K)	Raw Conductance (W/K)	Min. Temp. (K)	Max. Temp. (K)	Heater Power (W)	Rad. Loss (W)
349.8388107	43.13606526	1.302596097	0.000880238	0.001534076	348.9464111	351.3843079	0.001998282	0.000128091
349.6185904	46.06395213	0.61460495	0.000939984	0.001626204	348.9966736	350.5490112	0.000999473	8.09E-05
349.5913987	46.05770754	0.551158897	0.000939857	0.001632893	348.994873	350.4630127	0.000899984	7.64E-05
349.5605381	45.08464299	0.493527438	0.00092	0.001620354	348.9935303	350.3753052	0.000799689	7.21E-05
349.5351577	45.27842159	0.427793509	0.000923955	0.001635572	348.9944153	350.2889404	0.000699687	6.74E-05
249.6764079	18.91218961	1.165189259	0.000385923	0.000643401	248.8681183	251.0671539	0.000749684	4.20E-05
249.5713439	20.42080492	0.733476638	0.000416708	0.000680797	248.9295349	250.5814056	0.000499349	3.15E-05
249.5171852	20.86080352	0.575053206	0.000425687	0.000694774	248.9343262	250.3862305	0.000399532	2.76E-05
249.4742763	21.55787692	0.490329728	0.000439912	0.000712606	248.9300995	250.2652435	0.000349412	2.54E-05
249.44425	21.89700677	0.413789275	0.000446832	0.000724284	248.9306641	250.1650696	0.000299701	2.34E-05
150.0715961	13.57315146	1.150972366	0.000276975	0.000347171	148.7379761	151.9780884	0.000399584	1.34E-05
149.4758722	9.14710658	0.779681675	0.000186656	0.000256495	148.5429535	150.7999725	0.000199984	9.23E-06
149.3834779	9.504200634	0.561787609	0.000193943	0.000266144	148.5400238	150.5091248	0.000149516	8.03E-06
149.2891715	10.24433911	0.348673841	0.000209047	0.000286503	148.5348206	150.217392	9.99E-05	6.85E-06

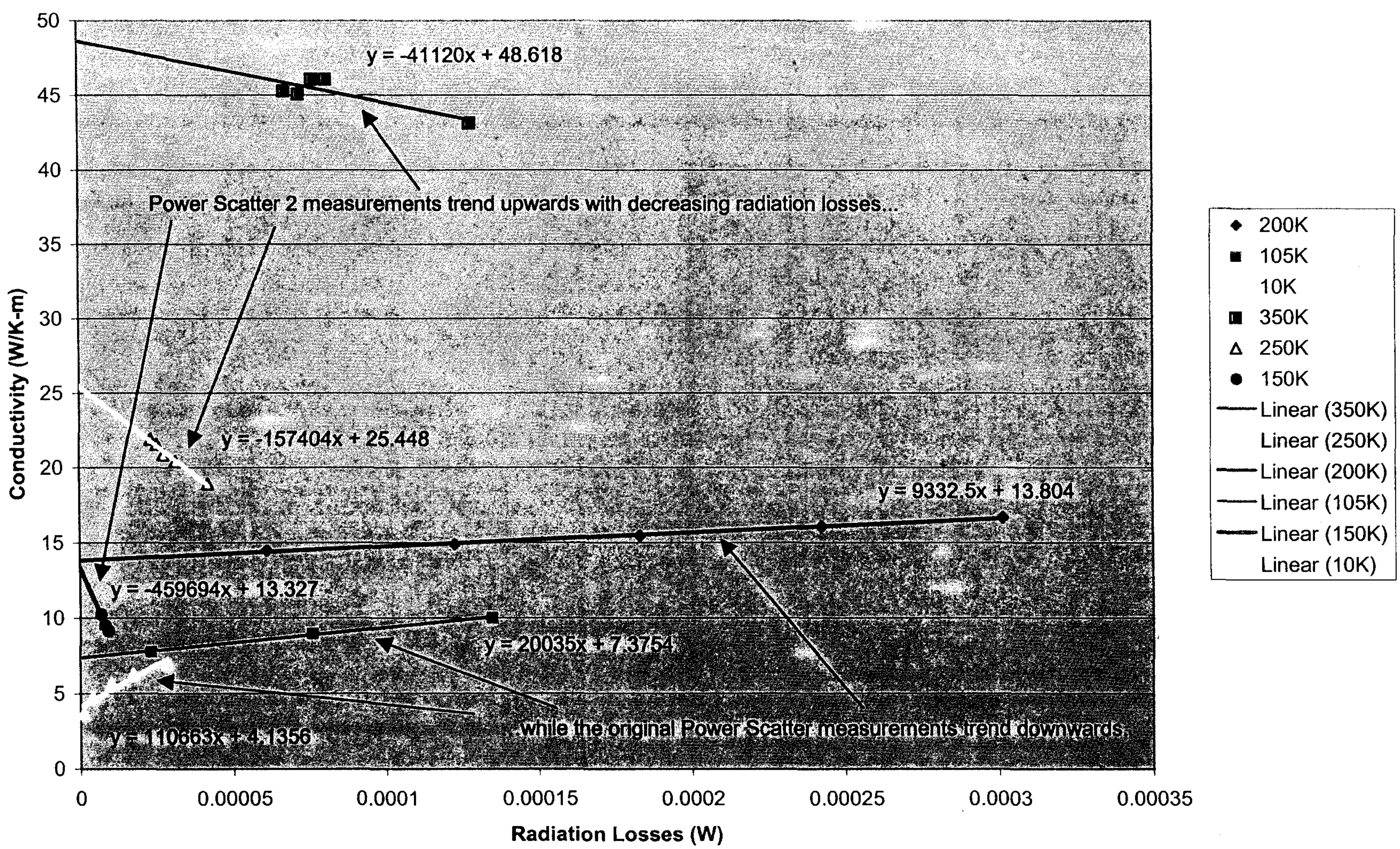
Measurements are fit on previous page.

The primary goal of this measurement was to plot the conductivity as a function of radiation loss for each temperature. The idea was that if the relationship is linear, the "real" value for conductivity will be when the radiation losses are zero, because in that case there are no corrections due to losses, and ~~therefore~~, no possibility of errors.

We had wanted to use the July 19 data as well (Power Scatter 1), but as the following plots will show, that data is useless because of the large temperature deviations.


Conductivity Plot
Lower heater powers eliminated the temperature spread.
Because K shoes is a function of temperature only, any conductivity spread is probably caused by P rad.
It was previously though that K shoes had a larger impact on the conductivity spread. This measurement indicates that more emphasis should be placed on understanding how P rad effects the measurement.
Conductivity (W/K-m)
Temperature (K)
0
5
10
15
20
25
30
35
40
45
50
50
100
150
200
250
300
350
400

Radiation Loss Extrapulation



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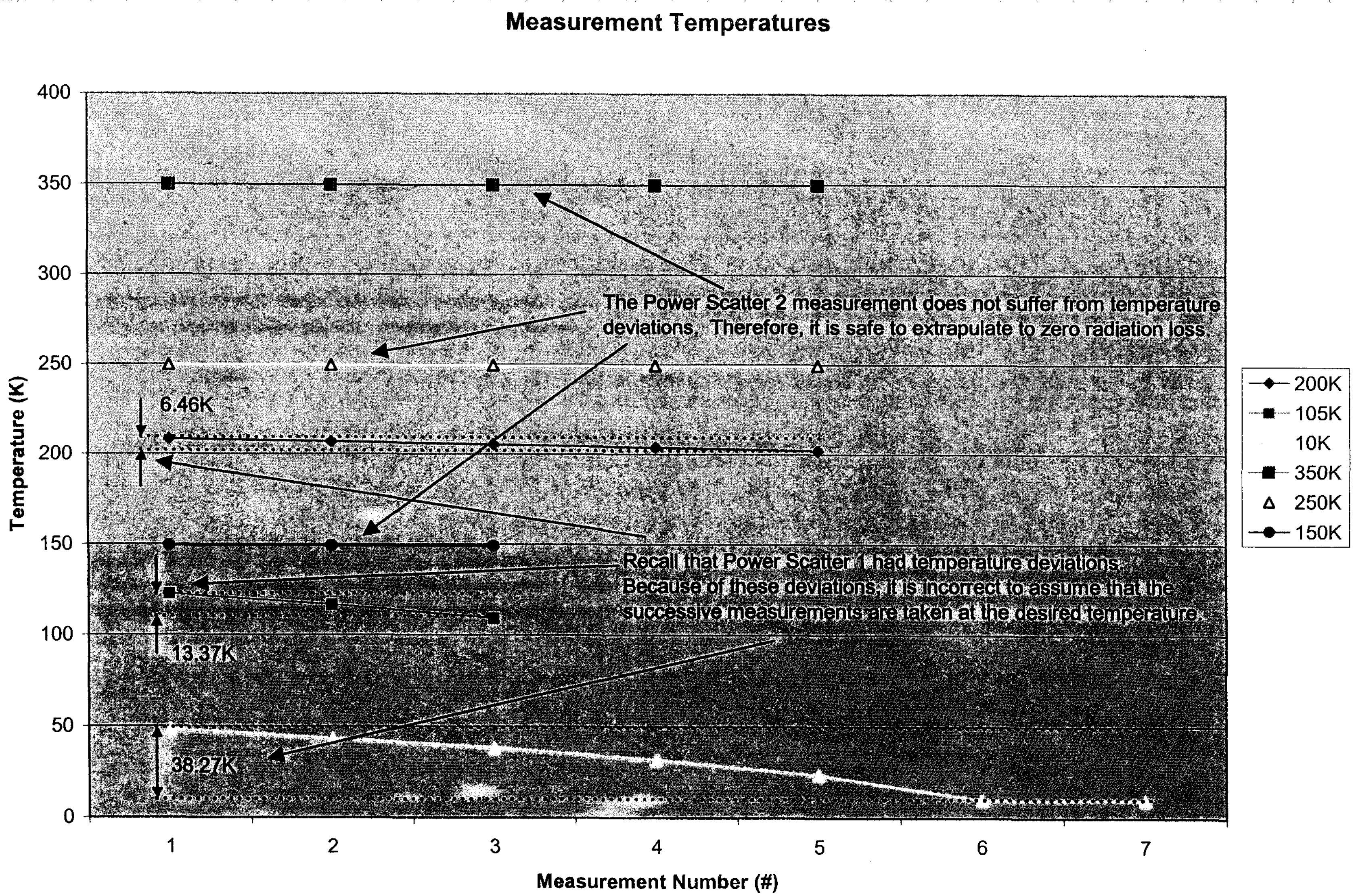
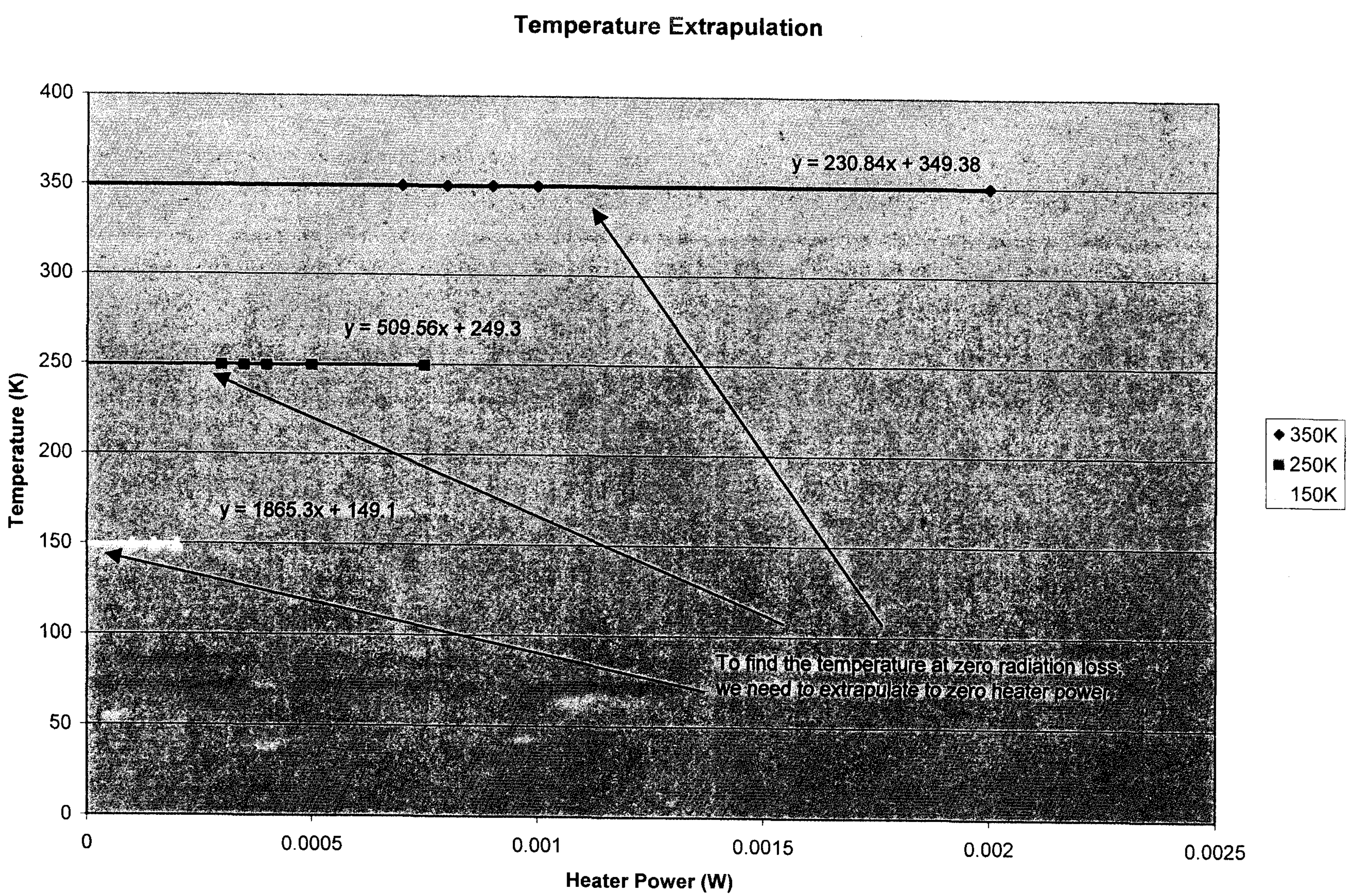
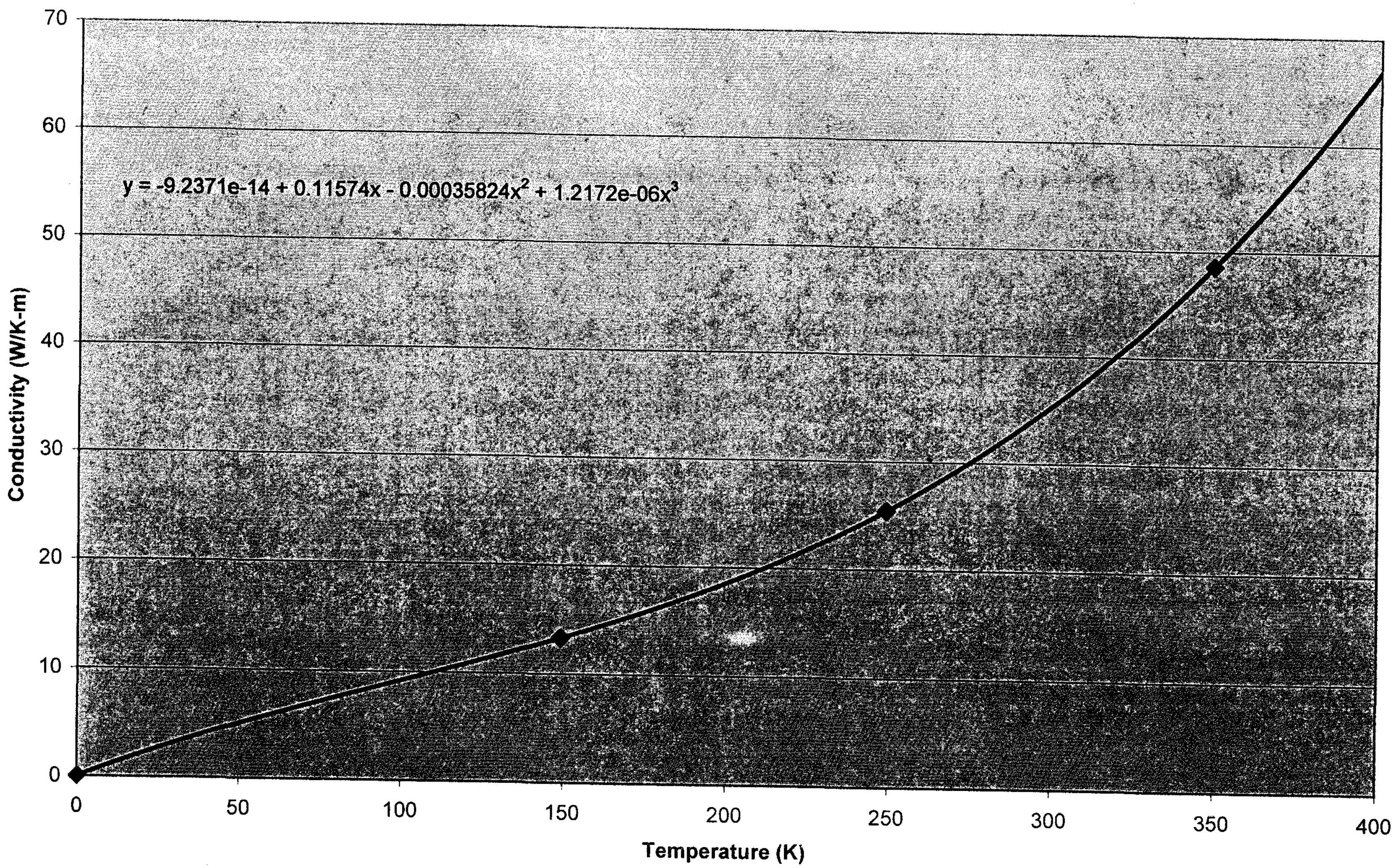

Measurement Temperatures
Temperature (K)
400
350
300
250
200
150
100
50
0
1
2
3
4
5
6
7
Measurement Number (#)
200K
105K
10K
350K
250K
150K
6.46K
13.37K
38.27K
The Power Scatter 2 measurement does not suffer from temperature deviations. Therefore, it is safe to extrapulate to zero radiation loss.
Recall that Power Scatter 1 had temperature deviations. Because of these deviations, it is incorrect to assume that the successive measurements are taken at the desired temperature.



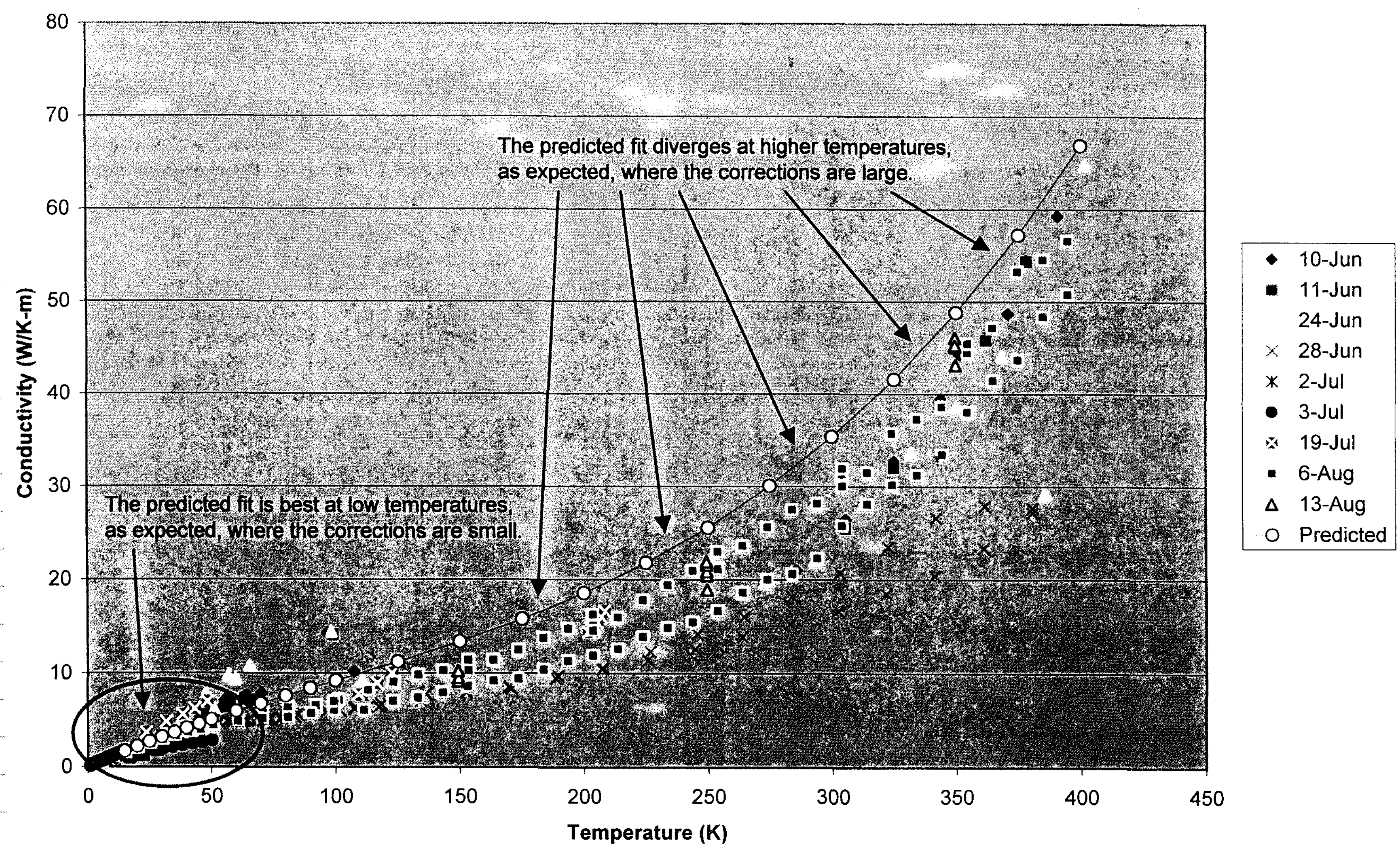
Temperature Extrapulation
y = 230.84x + 349.38
y = 509.56x + 249.3
y = 1865.3x + 149.1
To find the temperature at zero radiation loss,
we need to extrapulate to zero heater power.
Temperature (K)
Heater Power (W)
400
350
300
250
200
150
100
50
0
0
0.0005
0.001
0.0015
0.002
0.0025
350K
250K
150K

67

Predicted Conductivity Spectrum



Conductivity Comparison (Quantum Design's Fits)



Conclusions

(1.) It seems reasonable to say that conductivity spreads are primarily due to PRAD.

(2.) Because radiation losses appear to be linearly related to conductivity, it seems reasonable to say that the "real" conductivity occurs when radiation losses are zero. So, we can extrapolate to find the conductivity and the corresponding ~~temperature~~. The predictions need to be tested by measuring K'SHOES directly and comparing the results. Also, more power scatter measurements should be taken so that an improved prediction can be made.

Future Work

(1.) Measure parasitic conductance & correct the August 6 data. Compare results w/ predictions,

(2.) Make additional power scatter measurements, since it appears to be a good candidate of removing PRAD.

Power Scatter 3 (@ 300K only)

To add another data point to the previous analysis, Power Scatter 3 was done.

TTO Run Initiated: 8/14/02

Purpose: To add another data point to the previous measurement

Sample Parameters:

Length: 6.92 mm
Cross-Section: 0.14121 mm^2
Surface Area: 36.1916 mm^2
Emmissivity: 0.3

The sequence is pasted below:

Sequence File: PowerScatter3.seq

```
 1:  Set Temperature 300.00K at 20.00K/min. Fast Settle
 2:  Wait For Temperature, Delay 0 secs, No Action
 3:  LogData Start New 5.00 1073741823 1073741823 1073741823 "C:\cryolab\08-14
     -2002\LogPpmsSeq.dat" "Third Power Scatter @ 300K (To Fill In Gaps)" "Thi
     s will fill in final power scatter gap..."
 4:  TTO Single dT Measure K init= 10mW, 300sec max= 50mW, 1430sec, 500uV, 10m
     A
 5:  TTO Single dT Measure K init= 10mW, 300sec max= 50mW, 1430sec, 500uV, 10m
     A
 6:  TTO Single dT Measure K init= 10mW, 300sec max= 50mW, 1430sec, 500uV, 10m
     A
 7:  TTO Single dT Measure K init= 10mW, 300sec max= 50mW, 1430sec, 500uV, 10m
     A
 8:  TTO Single dT Measure K init= 10mW, 300sec max= 50mW, 1430sec, 500uV, 10m
     A
 9:  TTO Single dT Measure K init= 10mW, 300sec max= 50mW, 1430sec, 500uV, 10m
     A
10:  TTO Single dT Measure K init= 10mW, 300sec max= 50mW, 1430sec, 500uV, 10m
     A
11:  LogData Stop ""
12:  Set Temperature 300.00K at 20.00K/min. Fast Settle
```

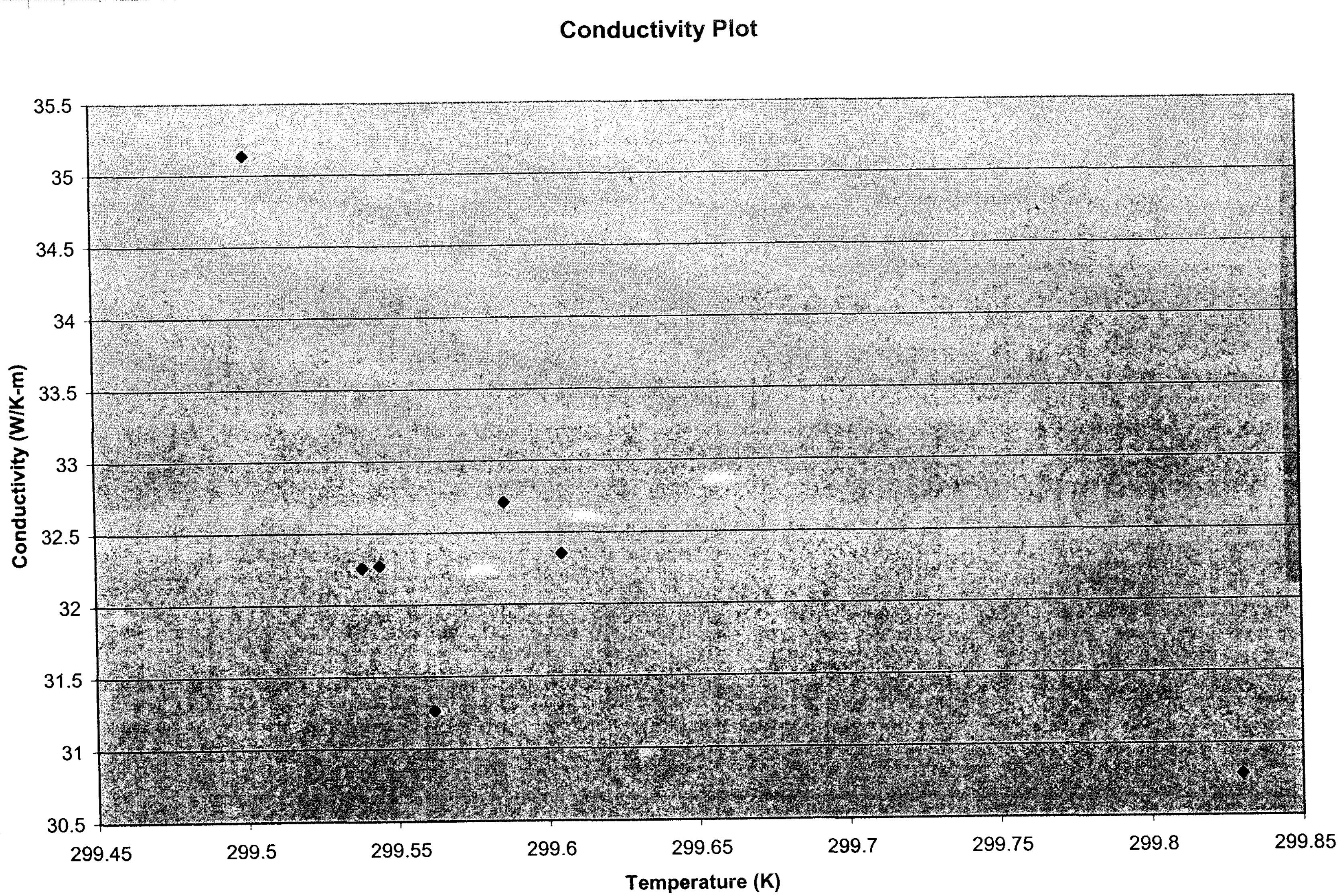
The results are plotted on the following pages. There are no new conclusions to be drawn here. They and fit just as before and this adds another important data point to our prediction of ~~thermal~~ conductivity.

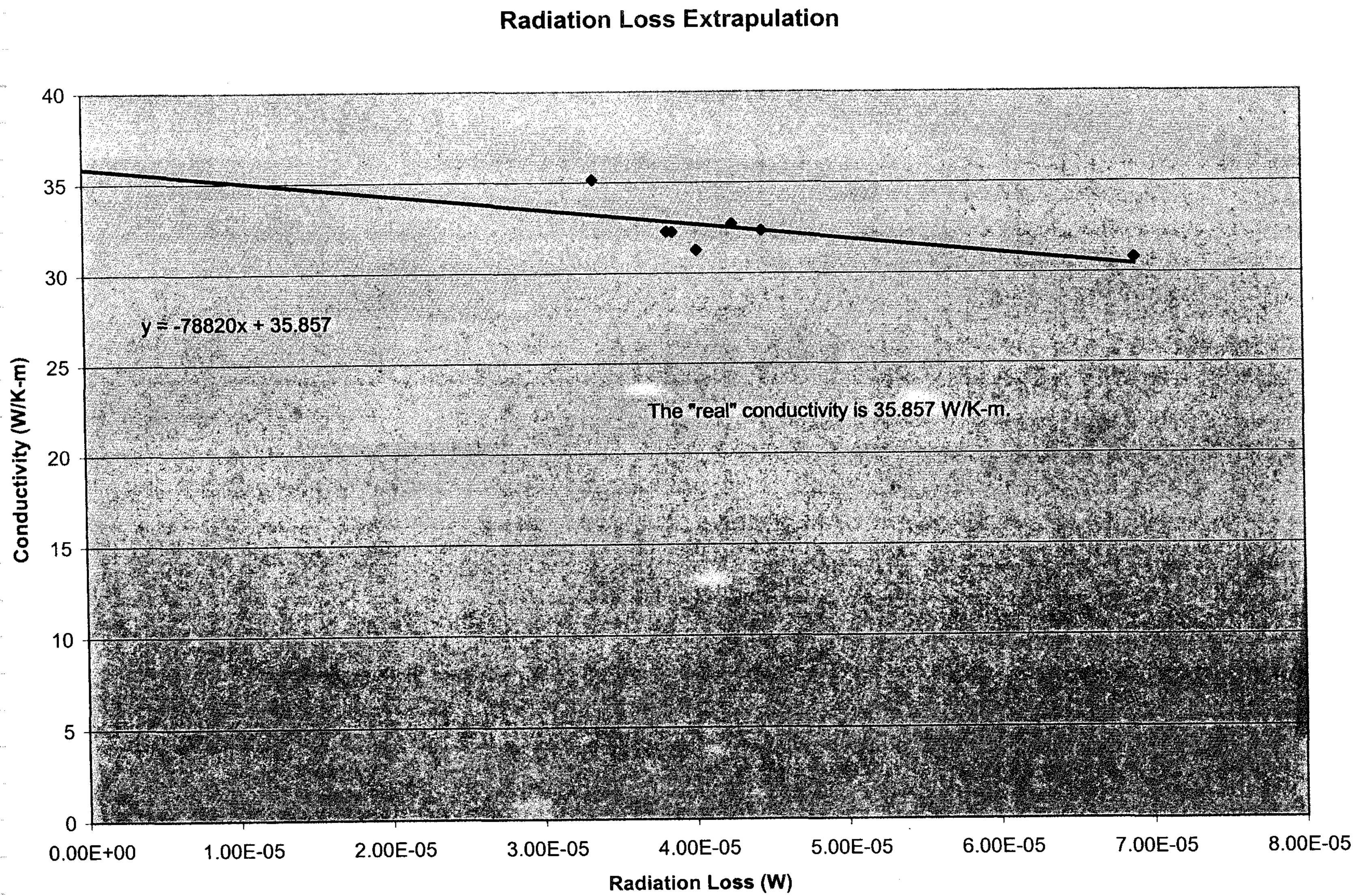
Time Stamp (sec)	Sample Temp. (K)	Conductivity (W/K-m)	Cond. Std.Dev.	Delta Temp. (K)	Conductance (W/K)	Raw Conductance (W/K)
19400280.16	299.8298059	30.78556217	1.125227776	1.139148716	0.000628212	0.001052367
19402374.42	299.6051219	32.35062097	1.173723268	0.591511691	0.000660149	0.001098428
19404314.61	299.5860968	32.71103207	1.192156462	0.540779088	0.000667504	0.001109203
19406256.84	299.5445242	32.27220145	1.201817505	0.451393094	0.000658549	0.001106239
19408204.56	299.5621767	31.2631637	1.168476217	0.509263984	0.000637958	0.00107986
19410152.27	299.5387738	32.25766986	1.200099896	0.451176619	0.000658252	0.00110677
19411801.98	299.5010417	35.13297958	1.280256706	0.339064603	0.000716926	0.001178336

Min. Temp. (K)	Max. Temp. (K)	Temp. Rise (K)	Req. Htr Power (W)	Heater Power (W)	Rad. Loss (W)	Cond. Pwr. (W)	Heater Current (mA)
299.0701904	301.1609802	2.0907898	0.0012	0.001198802	6.90E-05	0.001129795	0.776343008
299.0741272	300.4322815	1.3581543	0.00065	0.000649733	4.46E-05	0.000605106	0.571540864
299.0730591	300.3716736	1.2986145	0.0006	0.000599834	4.27E-05	0.00055715	0.549155514
299.0708923	300.2446289	1.1737366	0.0005	0.000499349	3.84E-05	0.000460954	0.501050825
299.0741272	300.3041382	1.230011	0.00055	0.000549934	4.03E-05	0.000509594	0.525817595
299.0645142	300.2397461	1.1752319	0.0005	0.000499349	3.88E-05	0.000460591	0.501050825
299.0741272	300.0985718	1.0244446	0.0004	0.000399532	3.35E-05	0.000365991	0.448183295

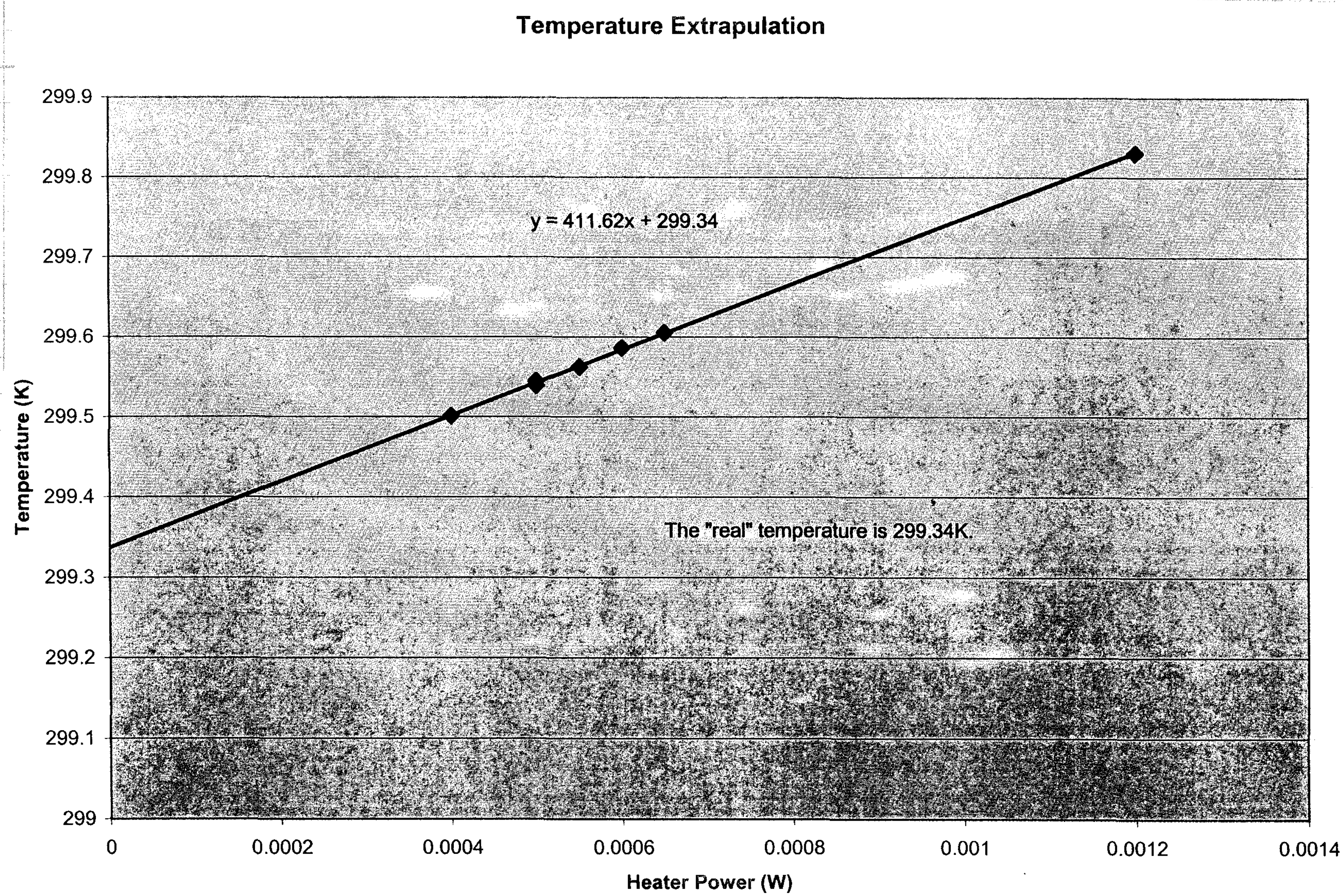
Here is the data presented by QD, to be consistent w/ the previous measurement.

System Temp (K)	Pressure ()	Map 21 ()	Map 22 ()
300.00445	0.00013055	301.1434632	299.4515839
299.99915	0.00014285	300.4230347	299.2672425
300.0071	0.0001387	300.3607026	299.2570954
299.99995	0.0001446	300.2345429	299.221344
300.0018	0.0001338	300.2947236	299.233078
299.9991	0.0001207	300.2326355	299.2213287
299.9973	0.0001171	300.091446	299.1804352


Conductivity Plot
Conductivity (W/K-m)
35.5
35
34.5
34
33.5
33
32.5
32
31.5
31
30.5
299.45
299.5
299.55
299.6
299.65
299.7
299.75
299.8
299.85
Temperature (K)



Radiation Loss Extrapulation
y = -78820x + 35.857
The "real" conductivity is 35.857 W/K-m.
Conductivity (W/K-m)
Radiation Loss (W)
0
5
10
15
20
25
30
35
40
0.00E+00
1.00E-05
2.00E-05
3.00E-05
4.00E-05
5.00E-05
6.00E-05
7.00E-05
8.00E-05



Temperature Extrapulation
y = 411.62x + 299.34
The "real" temperature is 299.34K.
Temperature (K)
299.9
299.8
299.7
299.6
299.5
299.4
299.3
299.2
299.1
299
0
0.0002
0.0004
0.0006
0.0008
0.001
0.0012
0.0014
Heater Power (W)

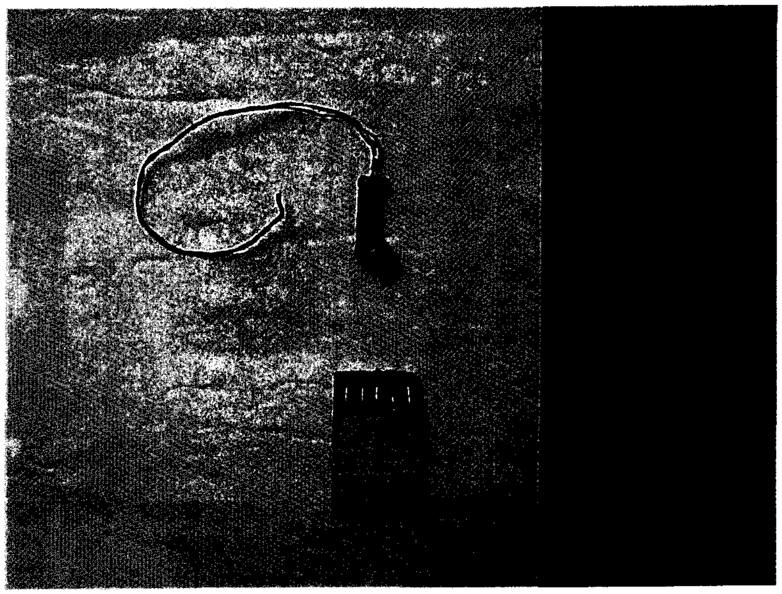
76

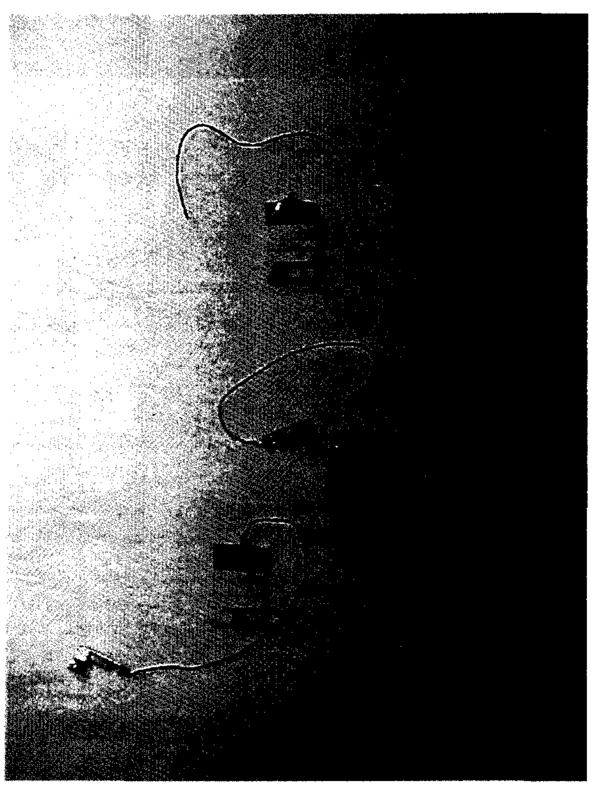
September 6, 2002

Problems with the quality of heaters and thermometers.

Since we began taking TTO measurements, we have had 5 wires break. This includes one heater and 4 thermometers. At least one heater (#20) and one thermometer (#38) broke while in operation inside the Cryostat.

To the right is heater #20. This broke inside the Cryostat and was later completely severed due to checking for problems.





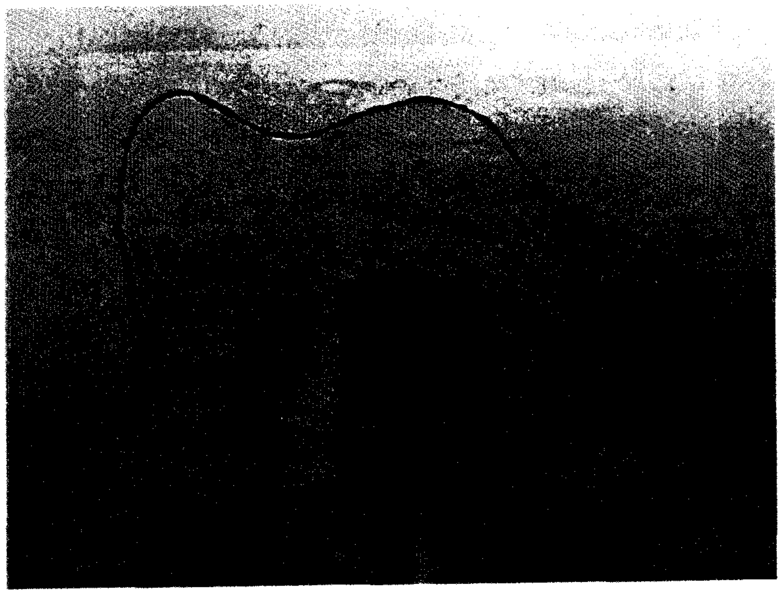
To the left are the three broken thermometers. The top one was severed when mounting & trying not to touch the radiation shield w/ the wires.

The bottom two broke somewhere in between measurements – possibly when mounting. Microscopes show that at least one tiny wire is severed in each case.

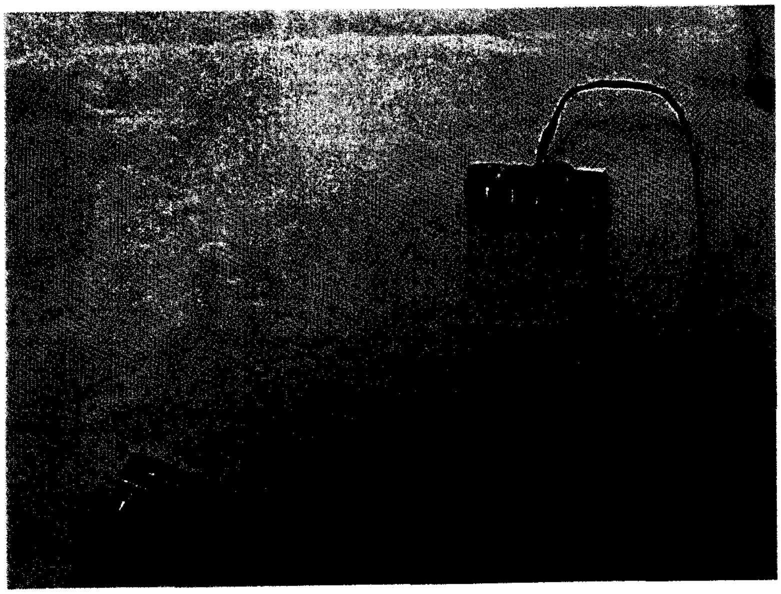
Repairing these devices would be difficult, at best.

One of these thermometers (I don't remember which one now) broke after only ONE TTO measurement!!

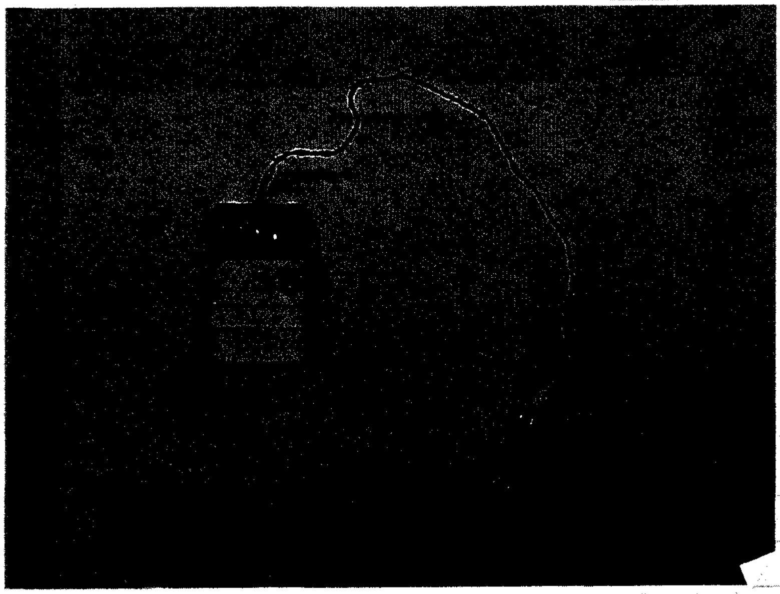
The following 3 pictures serve to show close-ups of the severed wires!

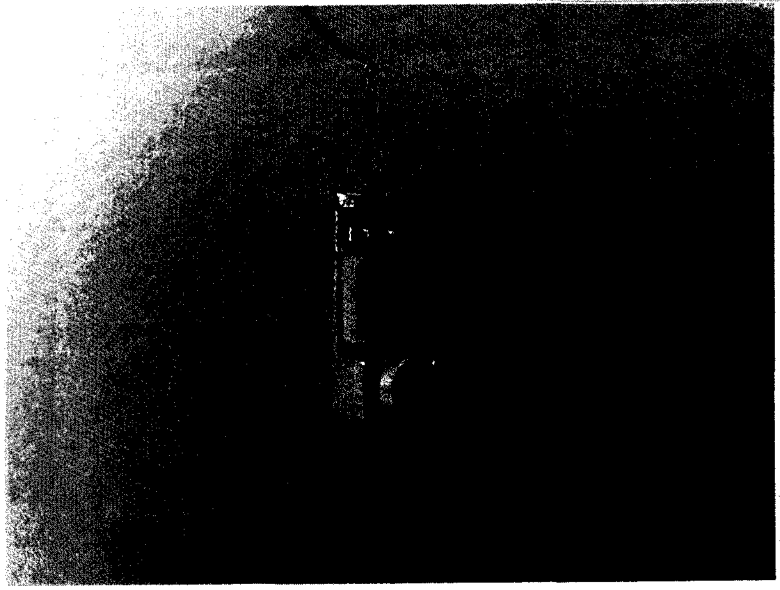


I think that thermometer #14 is the device that failed after only one TTO run!



Thermometer #38 broke on 8/29/02 while in operation, during a calibration procedure. This thermometer was one of our original ones from last October.





A close-up shows where a wire has been severed (and this has been confirmed by optical microscope). Normally, the thermometers sever at the other end. This case seems to be an oddity in that regard.

The first 4 thermometers/heater was sent to the attention of Mark Seebach at Quantum Design on 8/27/02.

Neil Dilly took a look at them, but they could not offer any useful advice. A copy of their e-mail response is on the next page.

We recommended "extreme care", but I had been using tweezers both to mount the shoes and to position the wires away from the radiation shield.

Mark Seebach, 12:06 PM 9/3/02 -0700, Re: ATTN: Mark Seebach

From: Mark Seebach <mark.seebach@qdusa.com>
To: Michael Hall <mhall@ligo.caltech.edu>
Date: Tue, 3 Sep 2002 12:06:10 -0700
Subject: Re: ATTN: Mark Seebach
Priority: normal
X-mailer: Pegasus Mail for Windows (v2.54)

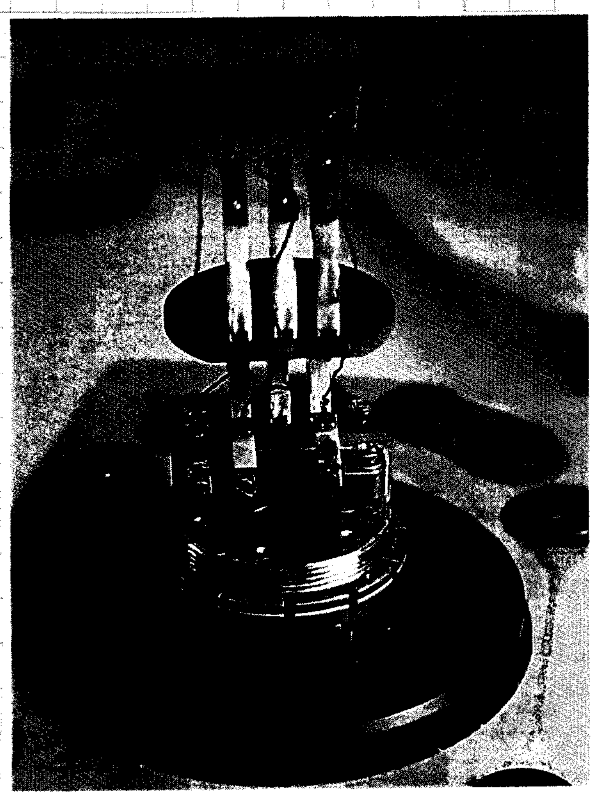
Michael, We did receive the therms./htr. I had Neil Dilley (the physicist who developed TTO) take a look, he was surprised that so many had broken. His first question was how are they being prepped and mounted? This is the first (& only) case we've seen like this, his recommendation, was extreme care, (sorry for the obvious).

Mark.

We believe the wires are too flimsy and easily break because of their lack of an adequate bend relief. We will continue discussion with Quantum Design. A picture below shows the mounting setup after calibration when it was discovered that thermometer #38 was broken.

A few words about calibration...

The Quantum Design manual does a poor job (and sometimes incorrect) at describing the calibration process.



The picture on the right shows the proper calibration setup. All three devices must be mounted, even if they are not all being calibrated.

The calibration fixture must be installed as shown.

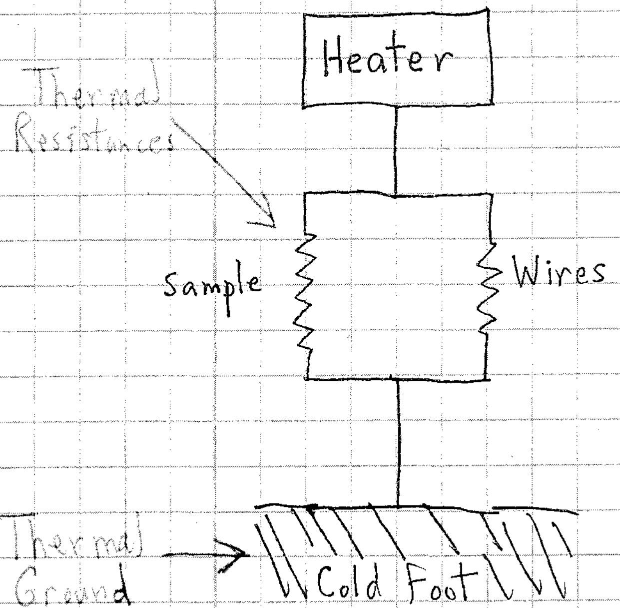
The included copper calibration sample must be used.

Note: The manual completely neglects to mention these crucial details.

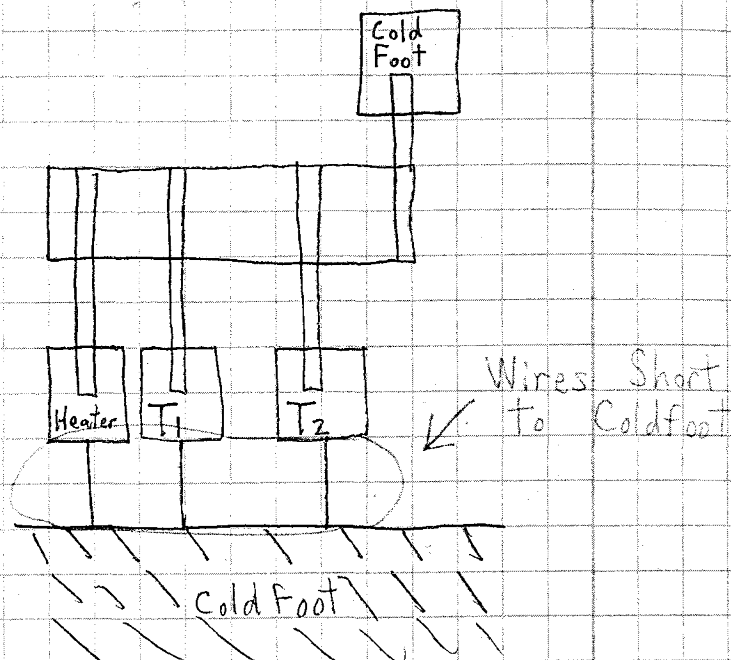
- It typically takes several hours to complete a calibration sequence. (4-6)

How can we measure the conductance of the shoes?

First, let's look at how a normal measurement works...

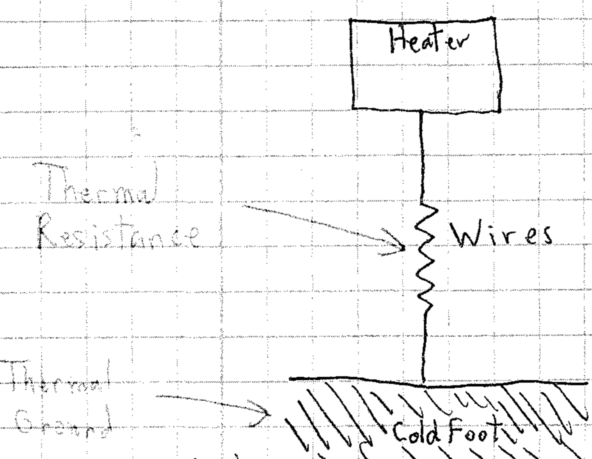


Equivalent Circuit Diagram

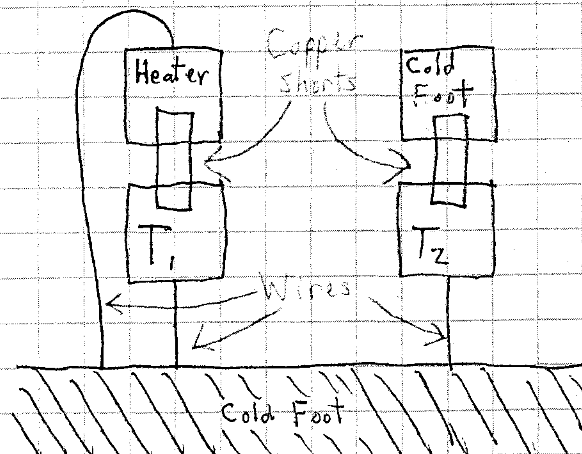


Measurement Setup

So, if we just eliminate the sample, we can measure only the thermal resistance of the wires...



Equivalent Circuit Diagram

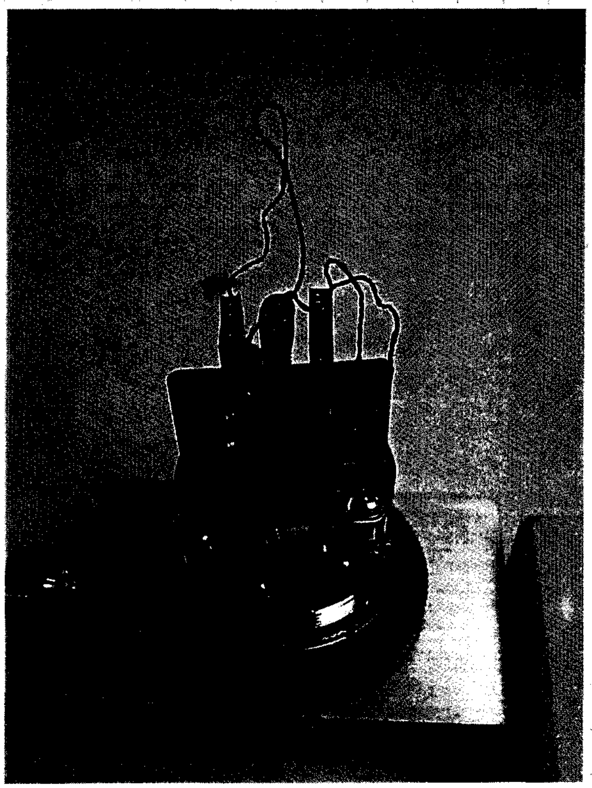


Measurement Setup

So, the setup for measuring the conductance of the wires is relatively straight-forward. It is important to remember that the conductance of the wires must be measured under the same conditions the actual measurement was made at. (example: power settings)

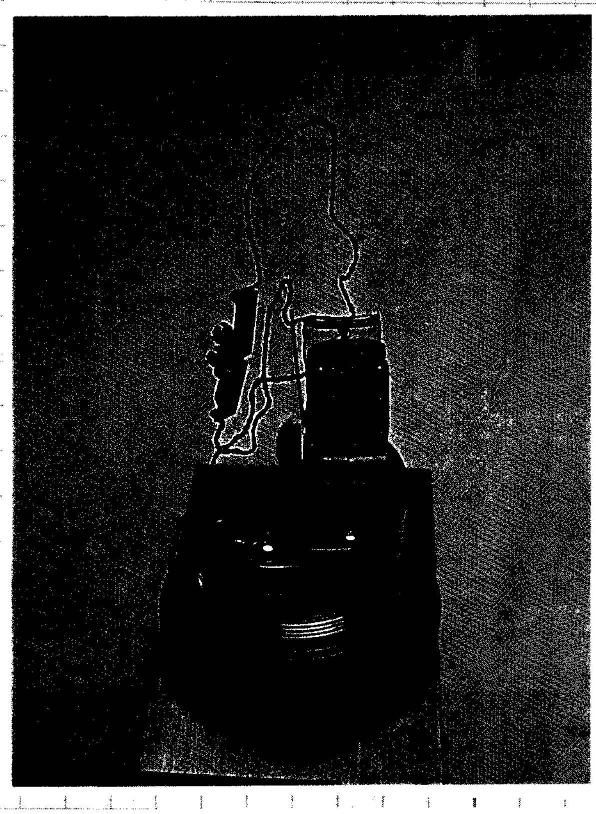
Avoiding wire contacts with the radiation shield

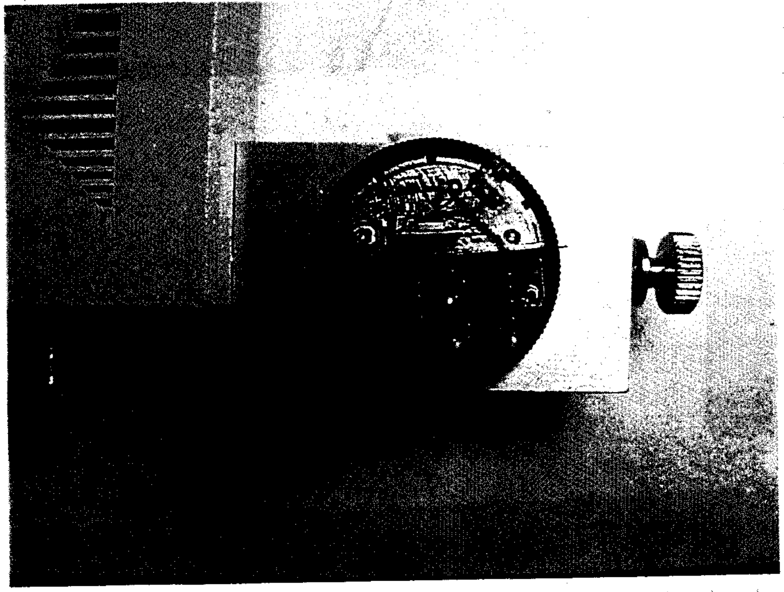
It is absolutely essential that the wires do not make contact with the radiation shield, because this would seriously affect the conductance through the material by altering its apparent length. It is important the measurement be as accurate as possible. To show it is possible, I tested the setup and took pictures. I could not take the measurement, because the red thermometer was broken.



Notice how the copper leads are as small as possible w/out causing the thermometers to touch.

The wires touch absolutely nothing, including the other wires. It is clear from this vantage point.





Before putting on the radiation shield make sure the wires will not be in the way.

Before screwing on the top, ensure that the wires did not move during the addition of the radiation shield. Also, make <u>absolutely sure</u> that the wires do not touch the shield nor will they touch the cup to be added last.

It is very difficult to do, but must be performed with extreme care to ensure reliable results. It very easily can take several minutes or as long as 15-30 minutes, depending upon your luck.

How do we measure the thermal conductivity of MoRuB?

Remember that up until now we have only been measuring MetGlas. We've been using it because we are sure it's completely amorphous, and it is readily available. When we measure MoRuB, we will use all we learned previously and follow the following procedure:

1. "Quick and dirty" measurement of sample using a stable measurement to get an estimate of the sample conductance.
2. Next, use the equation $P_{IN} = K(\Delta T)$, where $\Delta T = 0.5\,K$, to predict which powers will be appropriate at each temperature.
3. Run a power scatter measurement over the full range of temperatures.
4. Extrapolate and remove the P_{RAD} errors.
5. Measure K_{SHOES} under the same conditions used for the power scatter measurement.
6. Manually remove the K_{SHOES} errors.
7. Plot the results!!

September 9, 2002

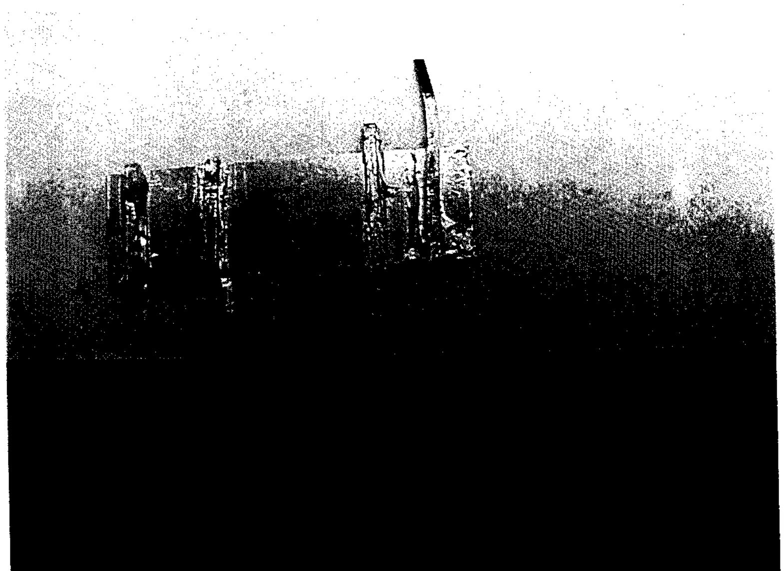
How do we create the sample leads?

We previously had been using epoxy to attach copper leads onto our MetGlas samples, but I have recently pushed to remove these in favor of machining our sample with its own leads.

The pictures below show both sides of a Glasmet sample with copper leads that have been mounted with epoxy.

The extreme difficulty in creating a clean lead mount is seen here, where epoxy residue exists close to the leads, and in some samples, can actually create a thermal short between leads.

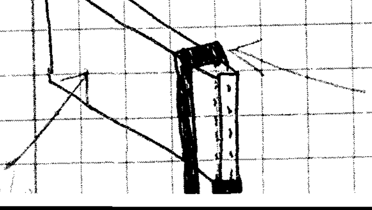
This is very undesirable. After many runs, some leads tend to become brittle and crack off very easily.

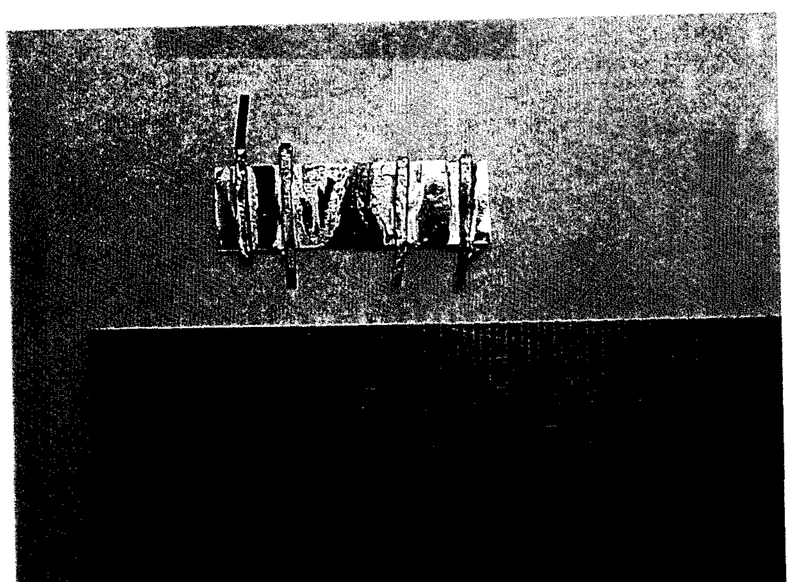


Metglas Front

The back is improved, but it is usually close to impossible to get both sides cleanly mounted, due to current mounting conditions.

Notice the way the copper leads wrap entirely around the sample. This is because when the leads wrap only on one side, they break off almost immediately during the thermometer attachment phase:

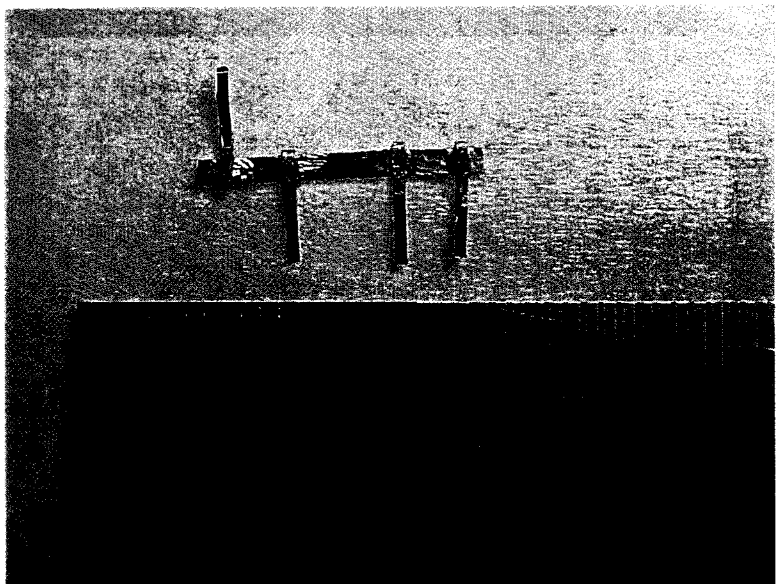




Metglas Back

To the right is a MoRuB sample which was mounted in the same way. This sample was not yet measured.

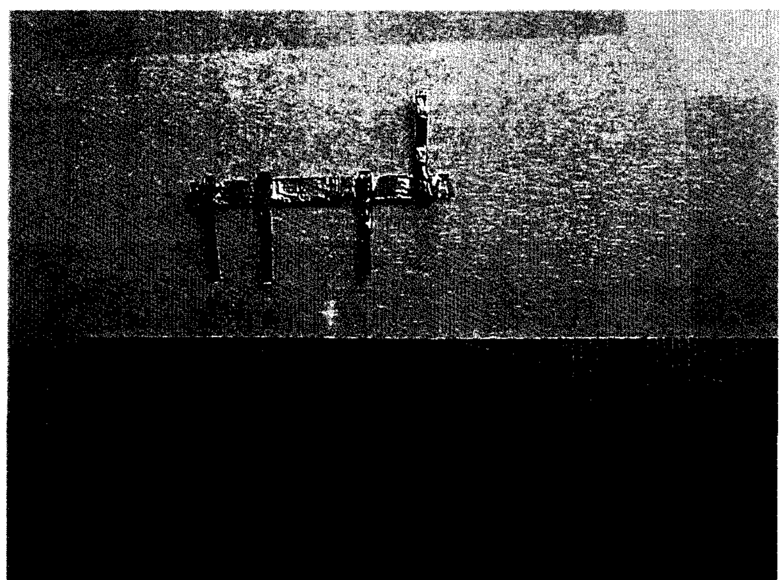
Notice the same epoxy problems which are very hard to reduce and until now, have been impossible to eliminate.



MoRuB Front

This side is even worse. The epoxy almost covers the entire face. Even though the epoxy layer is extremely small, so is the sample – 50 μm.

After mounting approximately 15 samples with no apparent improvements in the mounting techniques, it was starting to become clear that another method was required.

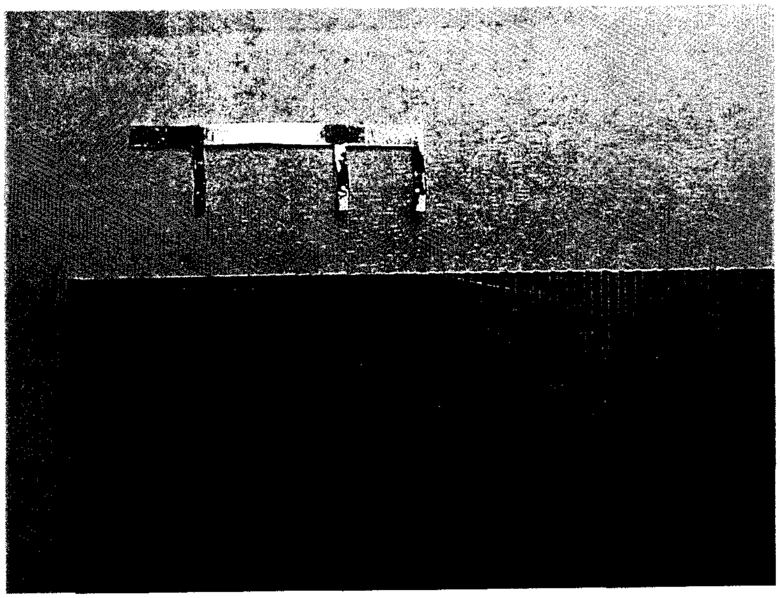


MoRuB Back

Note: Currently, one lead is mounted at a time. First epoxy is applied to a pre-bent lead. This lead is moved onto the sample. The lead is then pressed firmly to the sample & compressed. Next, the sample is heated to 175 °C for 3 minutes to harden the epoxy, before the next lead is attached.

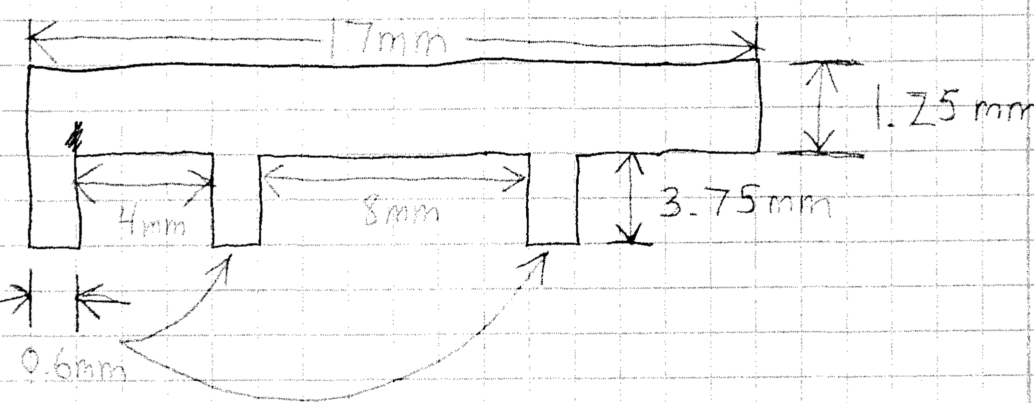
On the right is a copper calibration sample used during new heater and thermometer calibrations.

It's geometry is well-suited for our purposes, and I would like to use EDM or electropolishing to create the same geometries from our MoRuB samples.



There are several advantages to this method. The two greatest advantages are, first, there is no stray epoxy to affect the measurement. Secondly, because the leads do not break, the samples last much longer (and can be used for multiple measurements).

Below are the properties of their sample, which I would like to imitate as closely as possible:

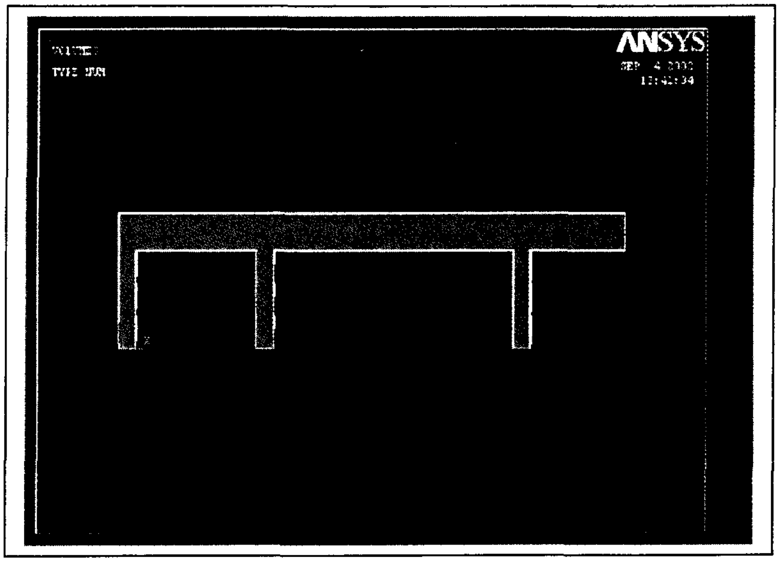


Are there problems with this new geometry?

Riccardo expressed some concerns the replacing the highly conductive copper leads with low conducting MoRuB leads may cause some strange equilibrium temperature behavior around the leads (as opposed to being linear). To explore this problem, Xavier De Lepine analyzed the MoRuB geometry under simulated thermal conditions using ANSYS. His results are presented as follows.

THERMAL ANALYSIS

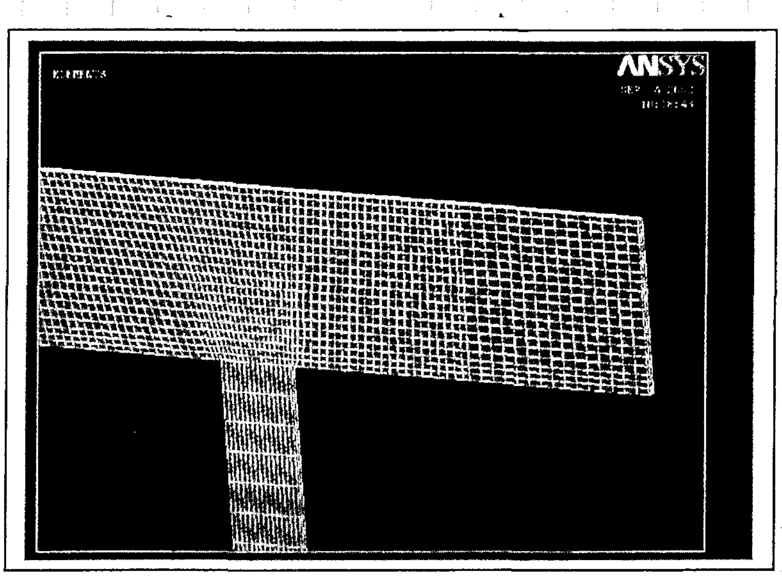
I defined the sample as following, on THERMAL PREFERENCES:



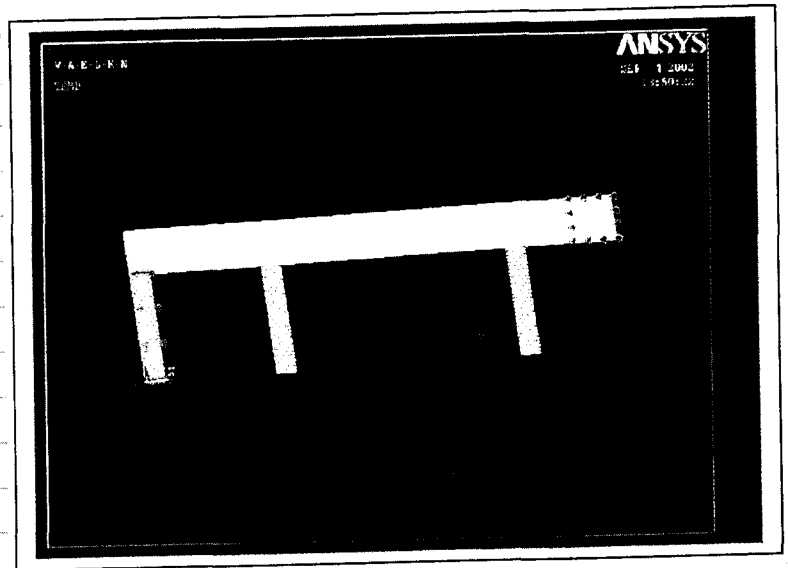
The thickness is 50e-6 meters, and the other parameters follow the specifications.

I used a thin mesh, which allows us to have a very good precision:

- Sweep "simple" SOLID90 for the thin parts.
- Sweep-smart size 1 for the main part



I applied as boundary limits a temperature of 310K on the first arm (HOT FOOT), and 300K on the terminal part (COLD FOOT):



RESOLUTION PARAMETERS:

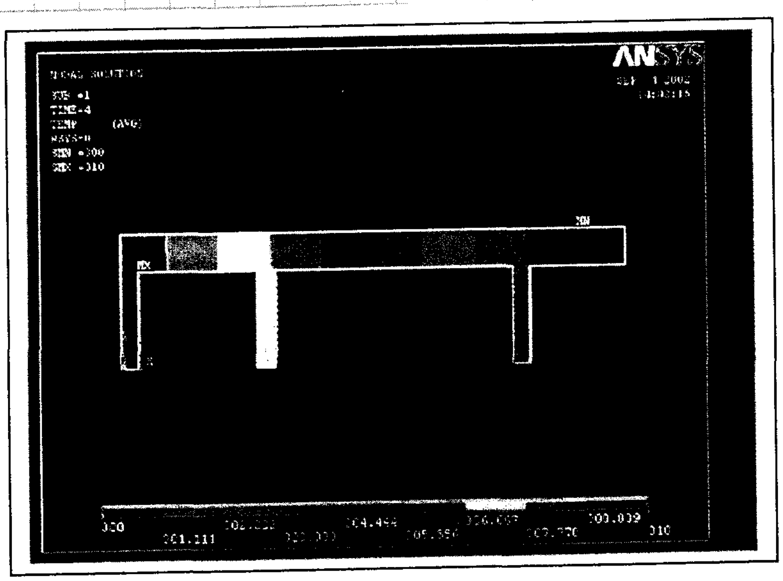
- Solution > new analysis > steady state

- Solution > Time/frequency > Time – Time step …

Time at end of load step:	4
Time step size:	0.01
Minimum time step size:	0.25

SOLUTION:

Notice the linear distribution of temperature in the equilibrium state!



CONLUSION:

We can notice the linear distribution of the temperature within the sample at the equilibrium.

What does this mean?

As Xavier's simulation clearly shows, the temperature distribution is linear at equilibrium.

This eliminates any fears that strange behavior is occurring at the MoRuB leads. Thus, this MoRuB geometry, at this point, presents no problems to our measurement.

Note: For more information about this simulation, contact Xavier DeLepine, or locate the raw data on his computer.

QD Meeting (09/16/2002)

11:00 J. O'BRIEN (meeting people):

communicat° → Steve ~~[illegible]~~ (has done some measurement)
LAUREDSEN

Problems: 1. breaking Thermometers

2. Interpretation of the result: → show up meaningless values →
→ must give the way the fit is done.
→ the power limitation are not easily understandable
→ the automatic settings don't give any kind of warning message when the measurement is screwed up. The variables are not controlled: must be showed up to the USER.

IN GENERAL: – Explanation of the parameters.
– Improve the display.
– " " the manual / help.

⊕ MICHAEL will do the report of the problems

3. Thermal conductivity depending on the involved power (Spread of T°C conduction)

4. Bumps at the Helium refill (Maybe a problem / coincidence)

5 – High vacum reaching

6 – Temperature bumps.

(TTO specialist) Martin DONESH (knows how the the calibration is calibrated):
<80: SERNOX (ceramic oxyd)
80 – 100: mixed
>100: Plautinum

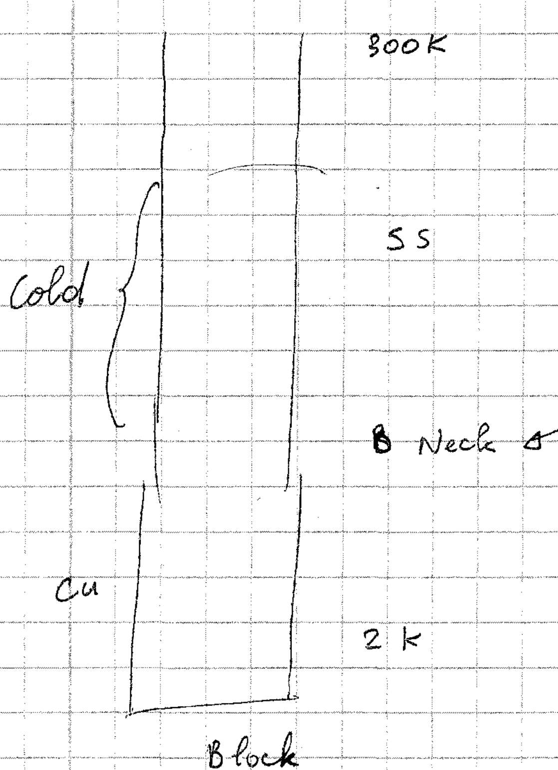
CD BOARD: Re-writer.
copper sample: to make the current go through to the cold [illegible]

6 – Temperature bumps: possible solution: – stop automatic recalibration
– try on "fast mode"

Thick sample measurement Method: 3 Omega technique?

7- Temp. on the chamber.

Takes time in heating up the chamber.



12:45

13:35

8- Heat Capacitance

Different DSP?

⊙ Problem at low Temperature.

→ Heat Capacity – He-3 heat cap. puck. → 2 wire going to 4 wire at puck. (maybe in future for low temp).

!! What will they do?

- power ~~ste~~ scatter : we'll see ourselves.
- breaking thermometers : they'll see. At least, thermometers broken in service won't be pa
- Display and advise on the parameter we hav to check.

CONTACTS
De Nash: Sthing breaks, how to fix it.