AD/RHIC/RD–62

**RHIC PROJECT**

Brookhaven National Laboratory

# Warmup of Dipole 012

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## INTRODUCTION

A performance test of dipole DRE012 was conducted in building 902, during the later part of August '93. At the completion of the test the dipole was warmed to room temperature, using the internal heaters designed for this purpose. During the warmup the temperatures of the magnet iron and the beam tube were monitored and recorded. This data was to be later used to confirm or relieve concerns regarding the possibility of excess stress due to temperature differences between the magnet iron and the beam tube. In addition, the current and voltage of the heaters were monitored and recorded so that the temperature of the heaters could be calculated. Lastly the warmup data was used to compare the actual warmup rate to the calculations that predicted the warmup rate. This calculated warmup rate considered the heat content of the iron and helium, as well as the heat removed by the helium as it was vented.

## DISCUSSION

The warmup data, for warmups 1 and 2 are on computer file. Temperature sensors TI101 and TI102 are located on the outside of the helium vessel, and longitudinally at the magnet center. Temperature sensors TI103 and TI104 are located on the beam tube, longitudinally at the magnet center. During the first(partial) warmup the instrumentation was not entirely functional, and the power applied to the heater was reduced, from its maximum value of 4kW. This was done to simulate the actual warmup rate that will be used in the RHIC ring. The reason for this reduction in power was to allow for a more gradual release of gas in the early part of the warmup. The first warmup was stopped at approximately 190 $^{o}$K, as it was decided to warmup, from a low temperature at a higher rate. The dipole was cooled to approximately 30 $^{o}$K and again heated with the maximum power of 4kW. This condition would provide for the highest rate of warmup of the iron, because its heat capacity is lowest when cold. With the maximum rate of warmup, the condition was established that would yield the best information on any possible temperature gradients.

## CALCULATIONS

Differential temperature:

We assessed the temperature difference, between the magnet and the beam tube, which could cause excess stress on the welded joint that attaches the end volume to the beam tube. As mentioned above, this was accomplished by monitoring these temperatures during a warmup of the highest rate achievable with the warmup heaters. The differential temperature is shown plotted in figure I.

Warmup heater temperature:

The temperature of the 304 SS heaters, was found by measuring the voltage and current during the warmup. From these measurements the heater resistance is calculated and plotted (see figure II). The heater resistance is used with the heater geometry to find the resistivity (see figure III) of the heaters during the warmup. The resistivity is compared with resistivity data[1] for 304 SS at cryogenic temperatures. From this comparison the temperature of the heaters is found. The heater temperature and magnet temperature, comparison, is shown plotted in figure IV.

Warmup calculation verification:

The measured rate of warmup of the dipole was compared with the calculations for the rate of warmup. These are shown plotted in figures V & VI respectively.

## RESULTS

Differential temperature:

The maximum differential temperature, between the magnet and the beam tube was found to be approximately 13 °K. This differential occurred at a magnet temperature of approximately 50 °K. See figure I.

Warmup heater temperature:

From figure IV it is seen that at a magnet temperature of 300 °K the heater will be approximately 50 °K higher.

Warmup calculation verification:

A comparison of the actual warmup and calculated warmup rates, shown in figures V and VI respectively, showed good agreement in the actual and predicted rates.

REFERENCES

1. Brookhaven National Laboratory, Selected Cryogenic Data Handbook, Section X, page Z-4.

**Figure I. Delta Temperature vs. Dipole Temperature- warmup with 4kW**

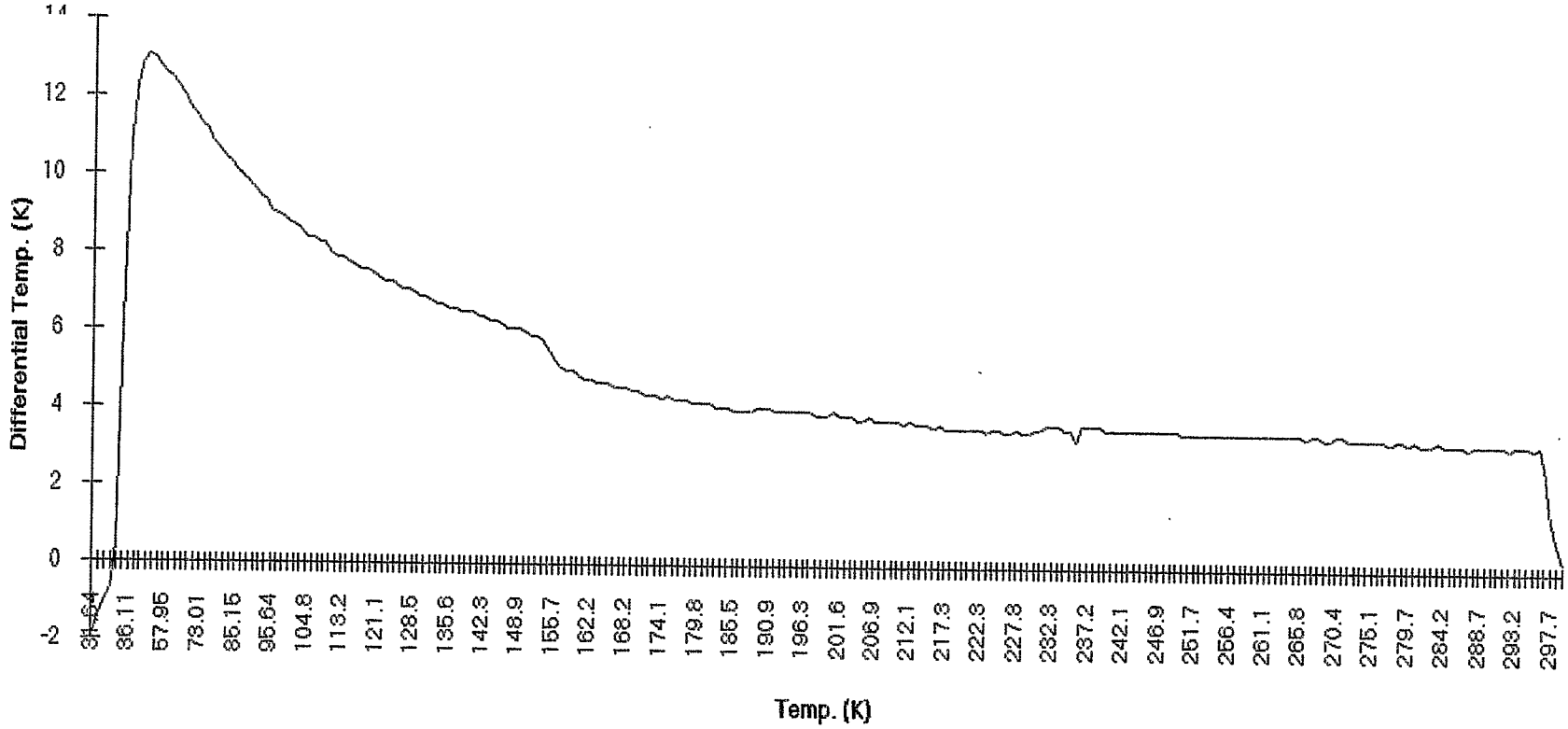

**Figure II. Heater Resistance vs. Dipole Temp.- 4kW**

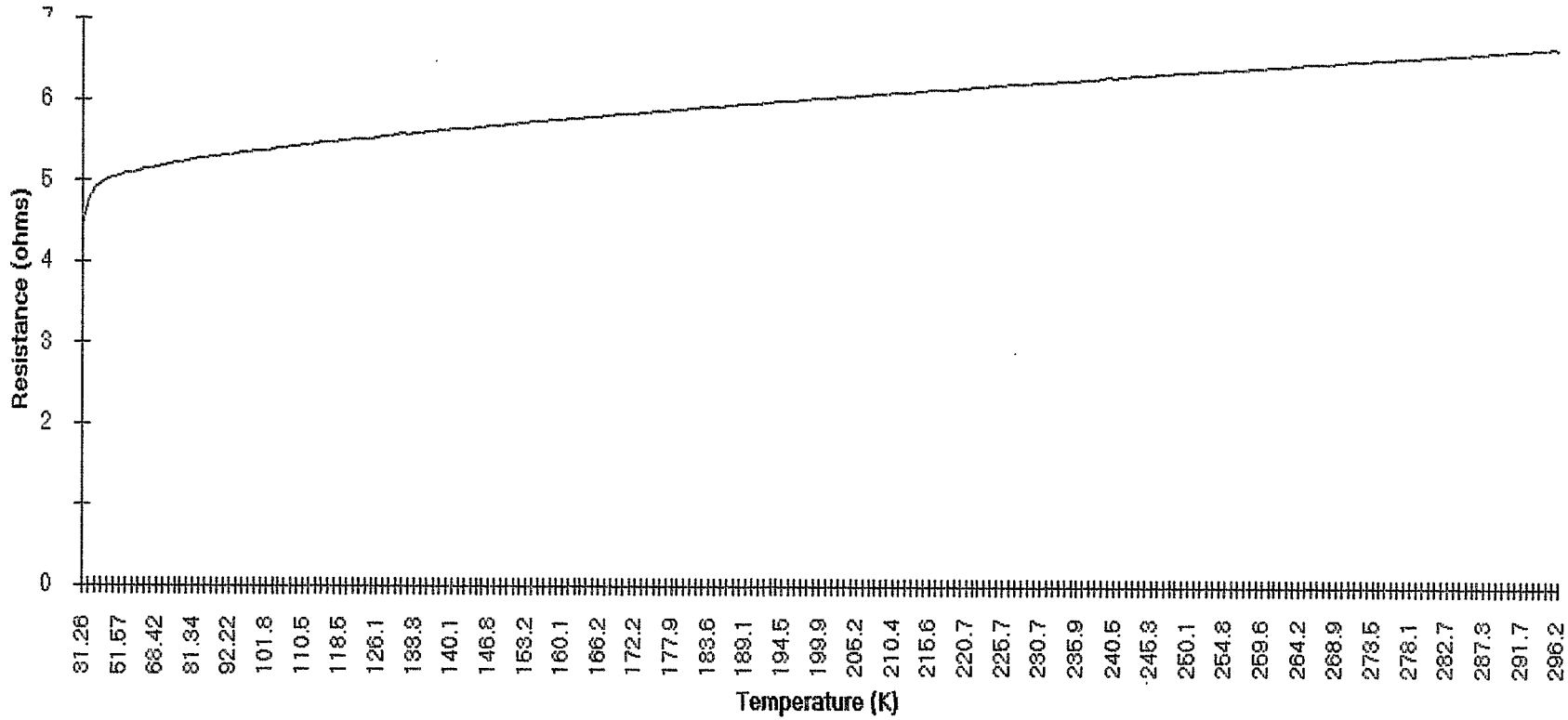

**Figure III. Heater resistivity(Cryo Handbook Data) and calculated resistance**

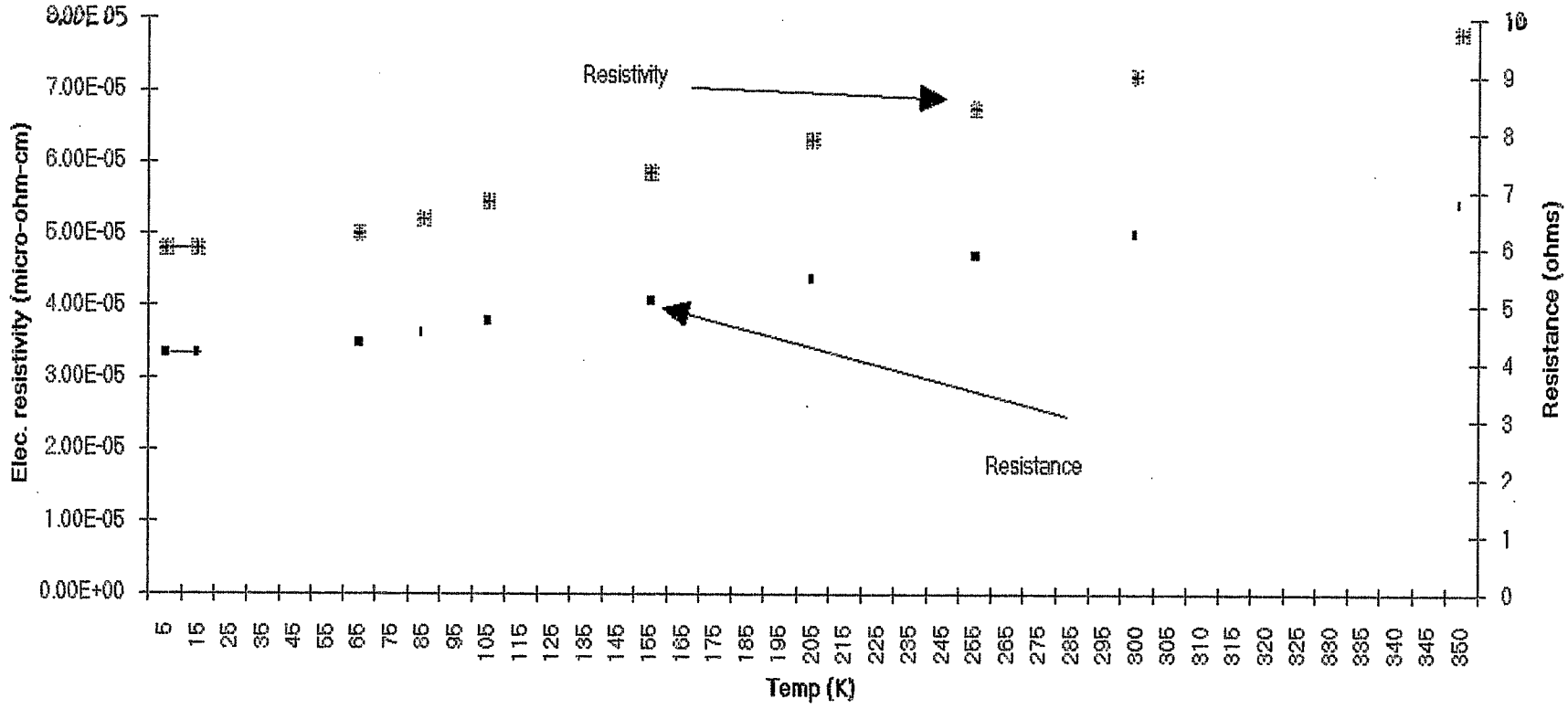

**Figure IV. Heater and Magnet Temperatures with 4kW applied**

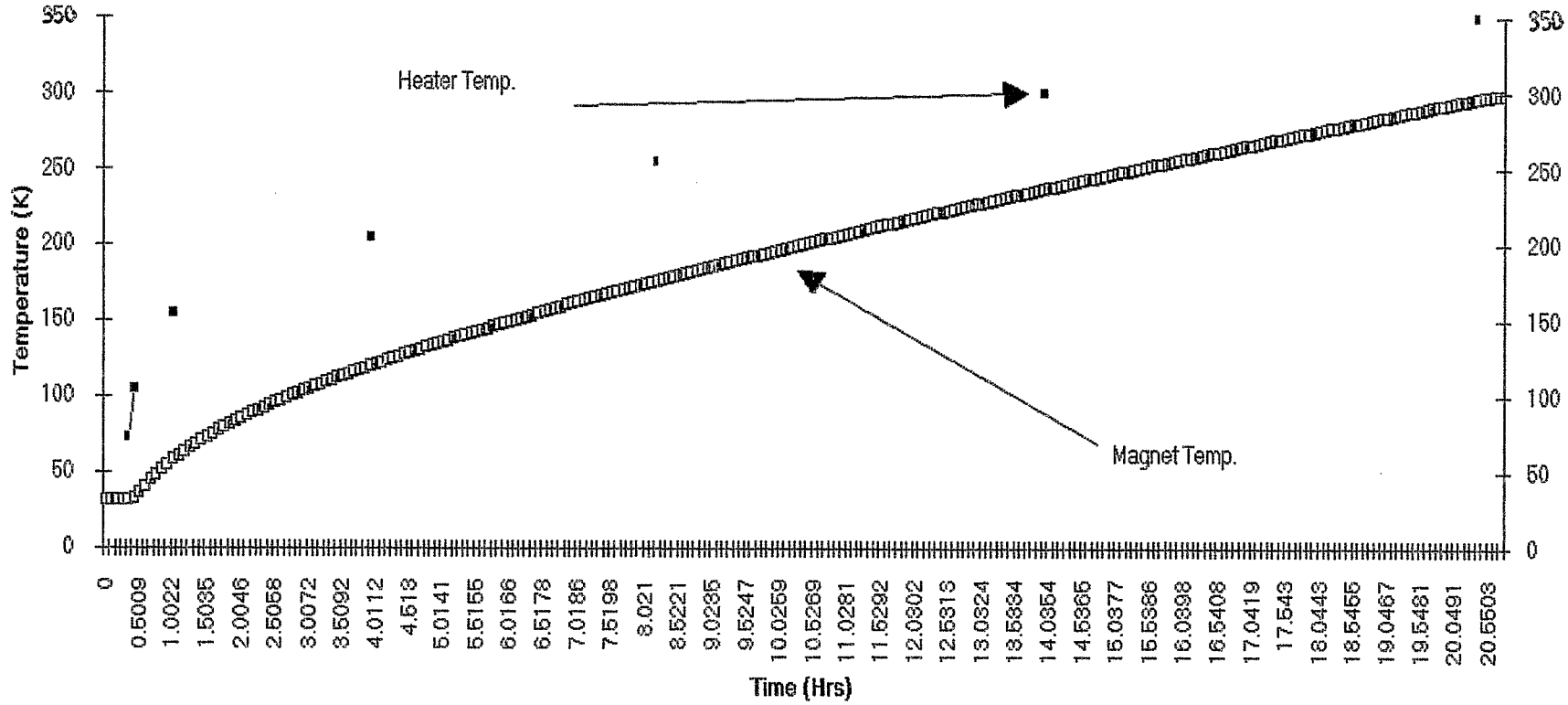

**Figure V. Dipole 012 Warmup**

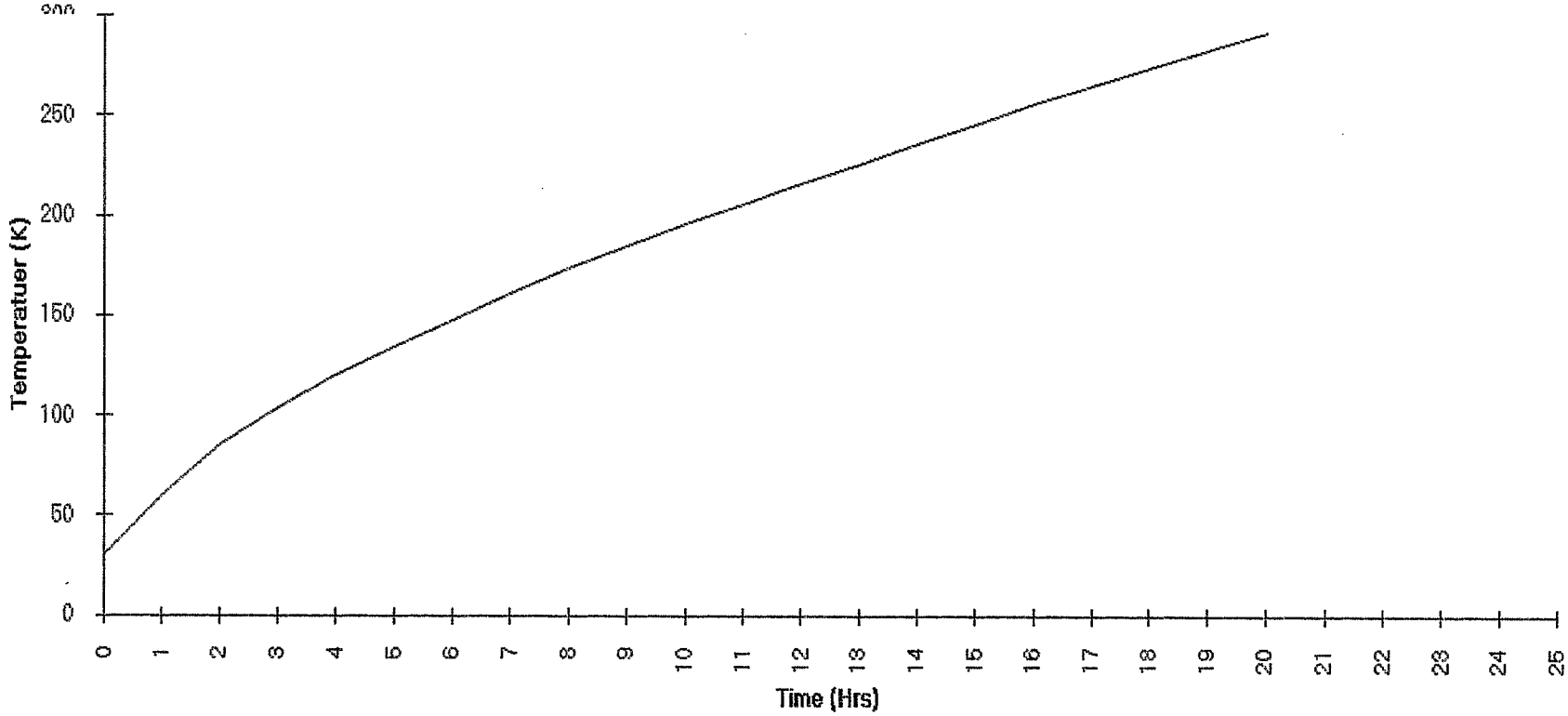
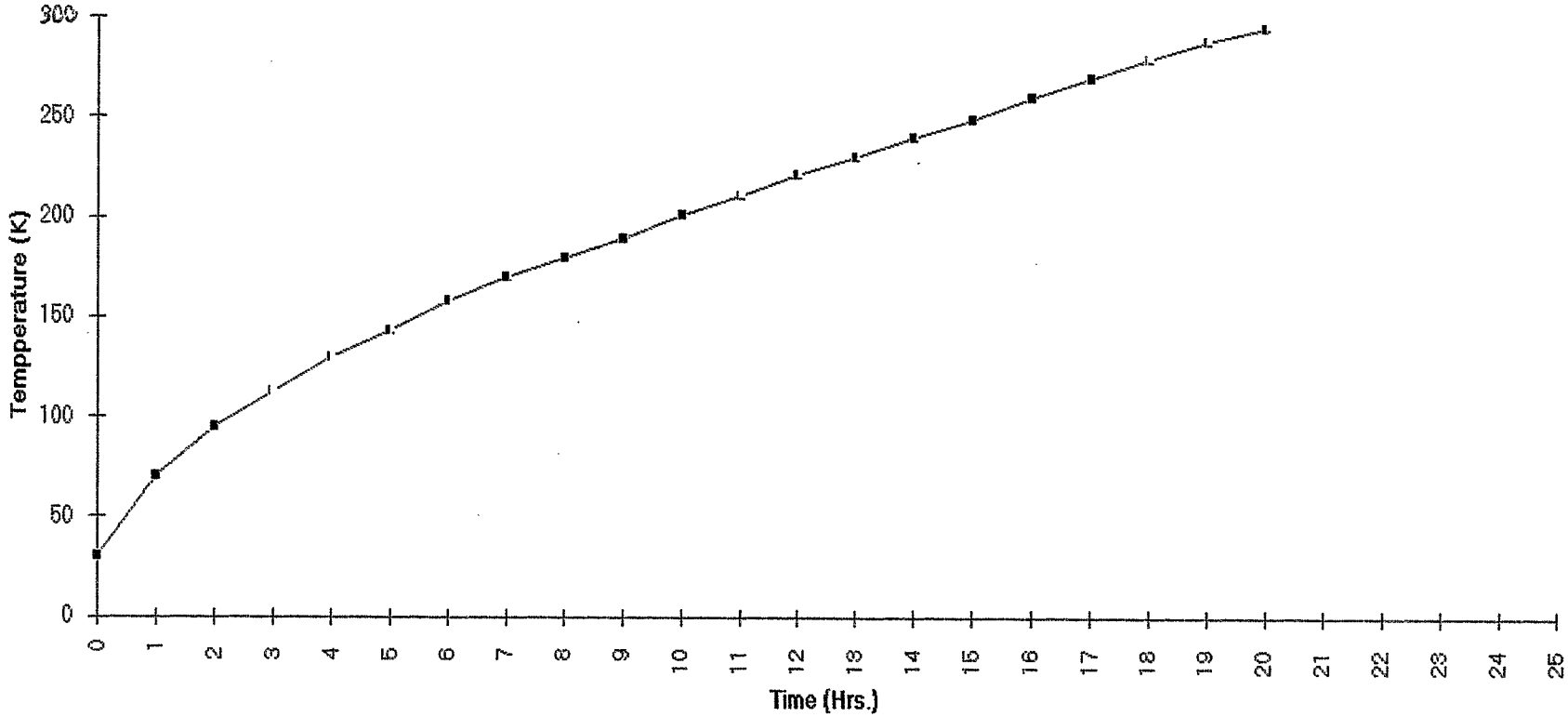
**Figure VI. Calculated Dipole Warmup- 4kW applied**