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PERIODIC FIELD IN SSC 40mm DIPOLE AND ITS TEMPERATURE GRADIENT EFFECT

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Introduction

The periodic field pattern in dipole magnets which was first observed[1] in HERA magnet has been now observed in other magnets. The explanation for this phenomena is given in a few different ways[2][3][4]. It is interesting to find whether the wave length of the periodic field is determined by the outer coil or inner coil. It is also interesting to make a temperature gradient in the magnet to find whether this effect is a overall current effect or local magnetization effect.

Magnet DSO315 is the last magnet of a series of 40 mm short dipole magnet with vertical split yoke. We have made measurement in this magnet with the purpose of above interest.

Experimental

Because of the good thermal conductivity of copper stabilizer, it is very difficult to make a temperature distribution in a dipole magnet. The magnet DSO315 was hanged vertically in a cryostat. The measurement was started after a ramp up to 6000 A. The cryostat was left without refill of liquid helium for 2 days to let liquid level gradually decrease to below the magnet. The measurement was made by a Rawson-Lush type 789 field meter with vacuum insulated jacket. The probe was moved up and down using gear mechanism by hand. A simple position sensor made of helipot was used to find the vertical position of the probe. The center of the measurement coil was roughly guided to the horizontal center of the warm bore by the physical size of the probe. The analog output of the Rawson-Lush field meter was read into a computer through DVM. The range of measurement in axial position was limited by the length of the probe shaft.

Results

Figure 1 is a typical wave form after a ramp up to 6000 A. The peak in the center of the magnet is due to the magnetization of the gage block[5] which is something else than this periodic field. The peak in the right side of the figure is the effect of the turn around of the coil, where almost entire angle of the cross section is covered by superconductor. The edge of the iron yoke is also determined by the shape of the fourth measurement these positions all agree with the construction drawings. The wave length measured from the peak to peak distance of the first measurement was 80 mm. The measurement right after a ramp was analyzed to give a better definition of the wave length. The fourier components of the wave is shown in Fig.2. The comparison of the wave shape with the reconstructed fit to the sinusoidal wave of wave length 75.3 mm is shown in Fig3. Measured value of strand pitches are 74 mm for outer and 76 mm for inner coil. Unlike 50 mm magnets, there is not large difference of strand pitch between inner and outer coil. The wave length of the periodic field agrees with the strand pitch within the accuracy of the measurement.

The measurements with reduced liquid level were made at the time 24 hours after ramp(1), 26 hours after ramp(2), 32 hours after ramp(3) and 42 hours after ramp(4). These results correspond to the numbers in the Figure 4. From the top to the bottom is the time sequence. Since the liquid level gage only extends 18 inches from the top of the magnet, the liquid level indicated in the figure are the estimation based on the linear extrapolation of the level change. By the time when the measurement(4) was made, the magnet was totally exposed into gas phase. The temperatures indicated in the figure are the reading from the temperature gage attached on the yoke skin. Therefore, it should read considerably higher temperature than the coil temperature.

Discussion

Despite the indication of the temperature gage, the peaks in the top part of the magnet tells that there is some superconducting material at this position in the first three measurements. In the fourth measurement, this part is normal because the field simply follows the remnant field of iron yoke. In the first three measurement (1,2 and 3), the height of the peak decleased significantly with successive measurement i.e. As the temperature increases. This means some part of the superconductor made transition to the normal state or, at least, J_c of the superconductor in this part decreased. The remarkable fact is that the left edge of the figure did not make significant change including periodic patterns in the first three measurements. The normal transition or $J-c$ change in the top of the magnet has no effect to the part of the magnet where the temperature is kept cold.

To eliminate the possibility of survival of small J_c superconductivity through entire length of the cable, we measured the resistance of the magnet during the warm up process of other run[6]. This was done by placing 1 Ampare throughout magnet and measuring the voltage across the magnet. This resitance measurement run was done independently of the remnant field data run because the excitation of any transport field might disturb the remnant field. Figure 5 is the temperature and liquid level pattern in both warm up process. Although, the top thermometer of the skin in the measurement run was occasionally cooled by the evapolated gas caused by the insertion of magnetometer, both pattern are pretty much alike. The measurement points and the estimated coresponding points in the reference run are indicated in the figure as arrows. The resistance growth of the magnet is shown in Fig.6. From the plateau at time 64 hours, the normal resistance of the magnet is found to be 7.5 $m\Omega$ which ,in comparison with room temperature resistance of 520 $m\Omega$, gives RRR=70. The first linear part could be the lead cable. The next parabolic or cubic part, which is a two or three dimensional expansion of the normal part, starts at time 40 hours which correspond to the time just before the first measurement. By the time 3rd measurement was done, one can say 3 % length of the cable should have made transition to normal.

This observation is against the theory which is based on the transport current loop through the joint of the cable. The interpretation of the phenomena based on the formation of the pattern due to the mutual inductance coupling between current loops can count for this observation.

References

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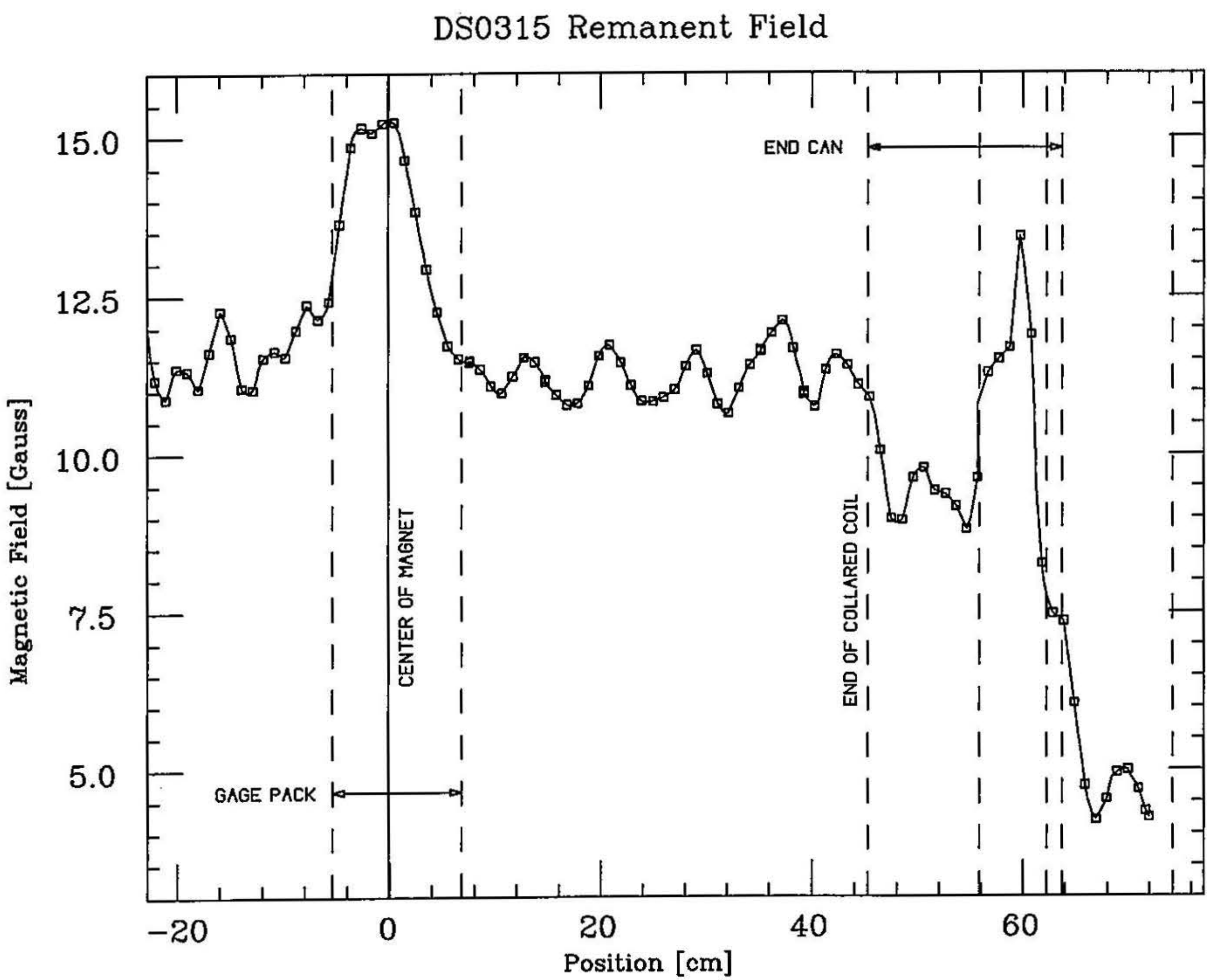
[6] suggestion made by A.Devred, SSCL

Fig. 1



A typical periodic waveform in DS0315 sh
collar, gage pack and lead end clamp lo

Fig. 2

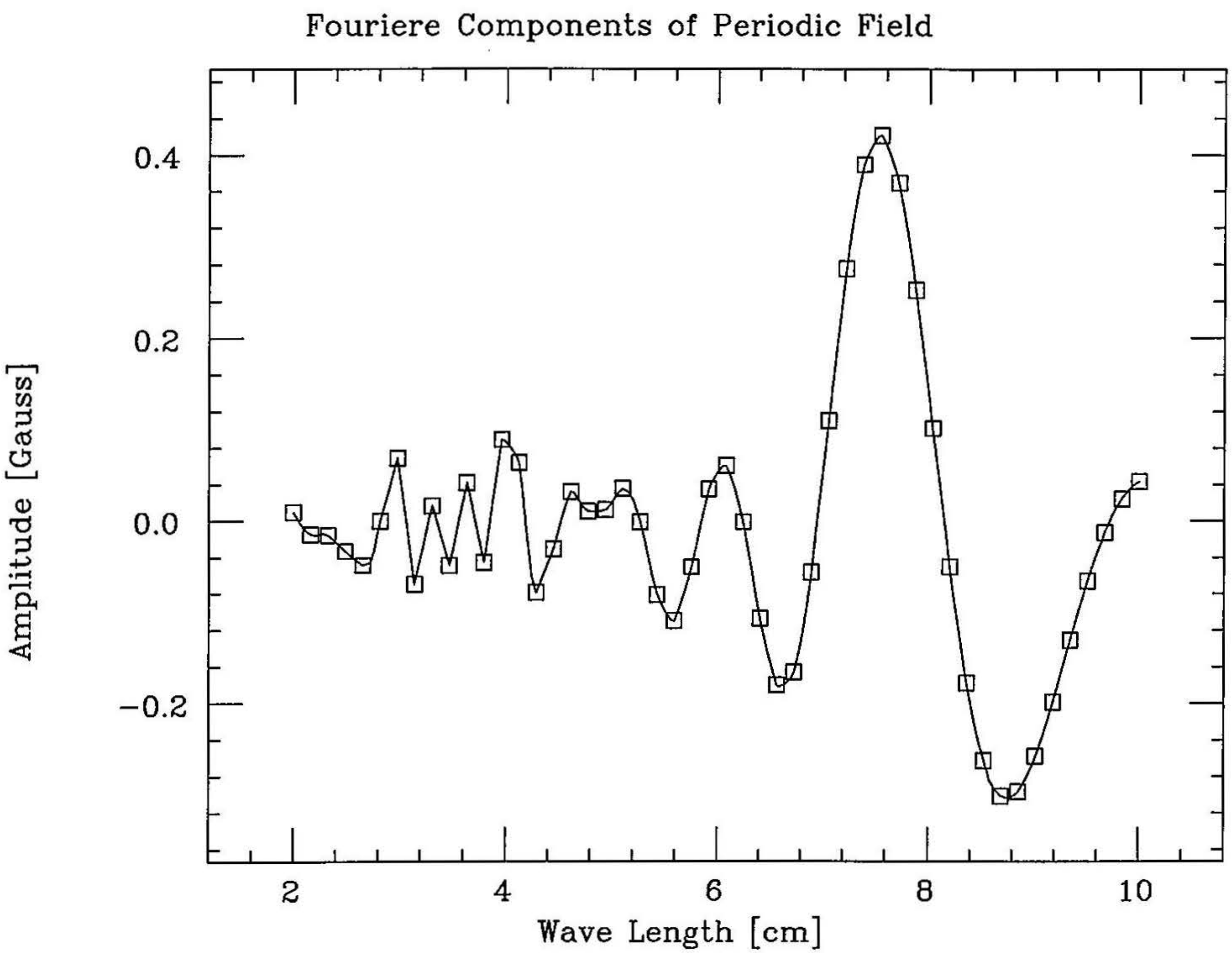
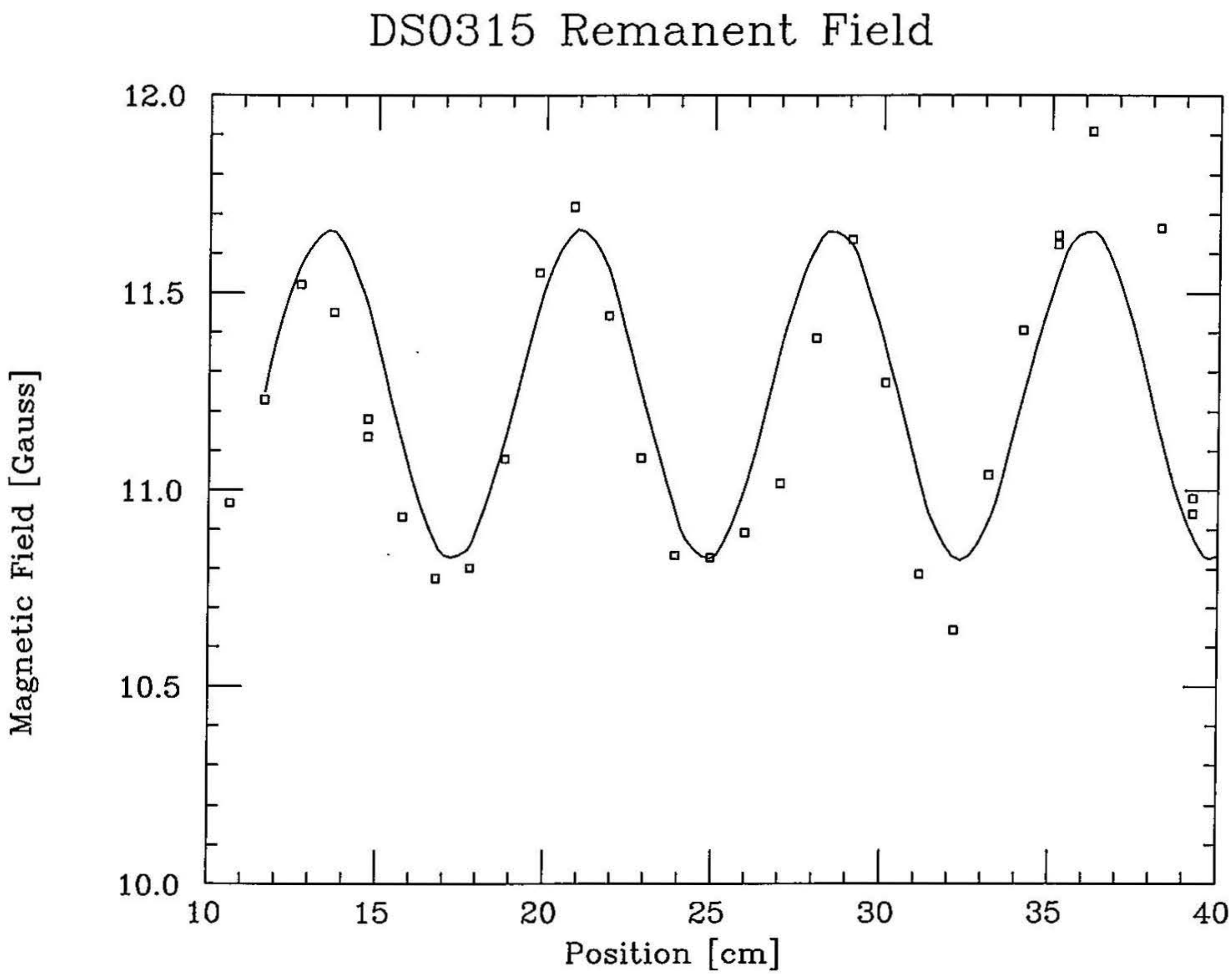

Fouriere Components of Periodic Field
Amplitude [Gauss]
Wave Length [cm]
0.4
0.2
0.0
−0.2
2
4
6
8
10

Fig. 3


DS0315 Remanent Field
Magnetic Field [Gauss]
12.0
11.5
11.0
10.5
10.0
10
15
20
25
30
35
40
Position [cm]

9

Fig. 4

DS0315 Remnant Field

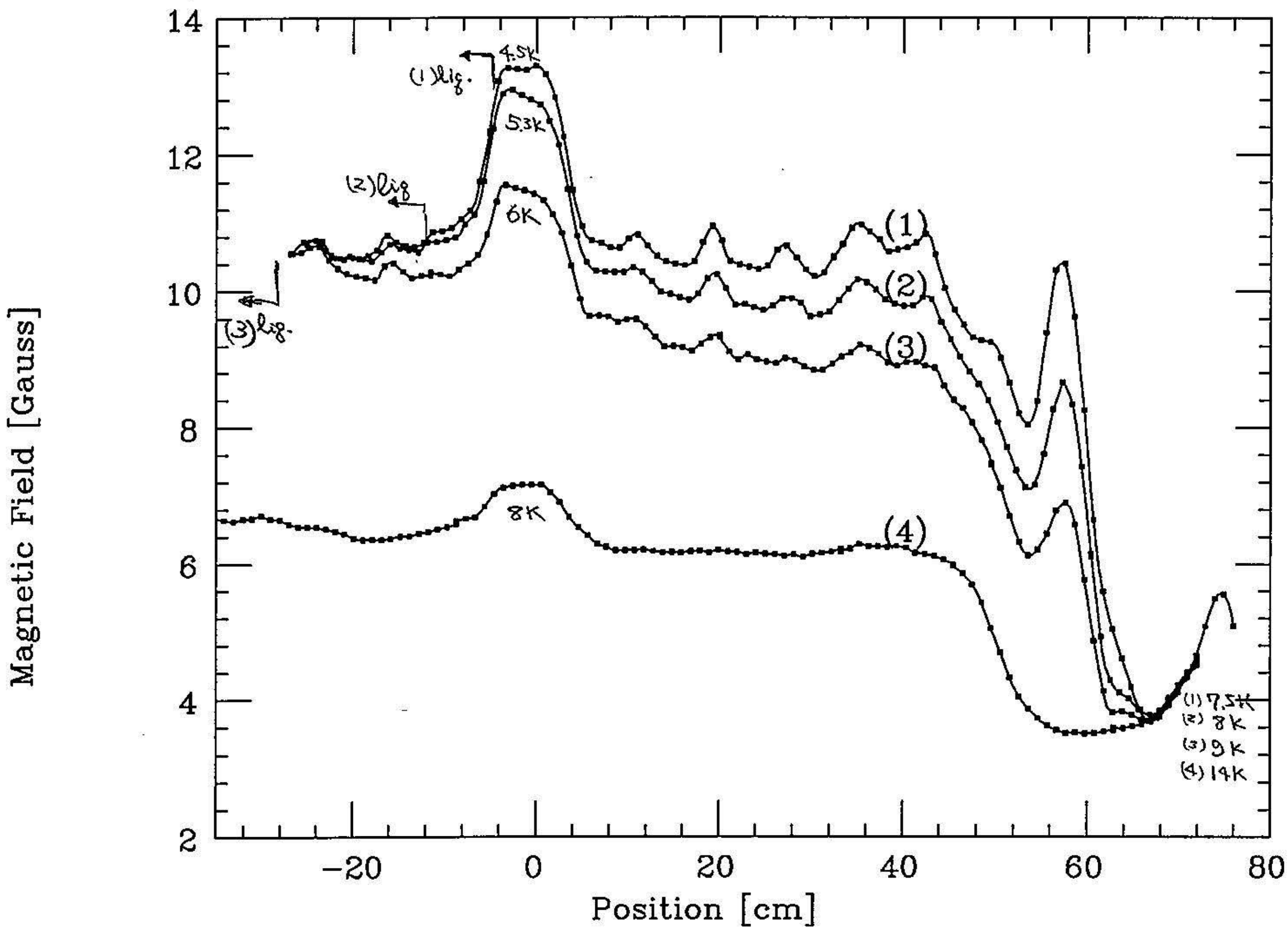
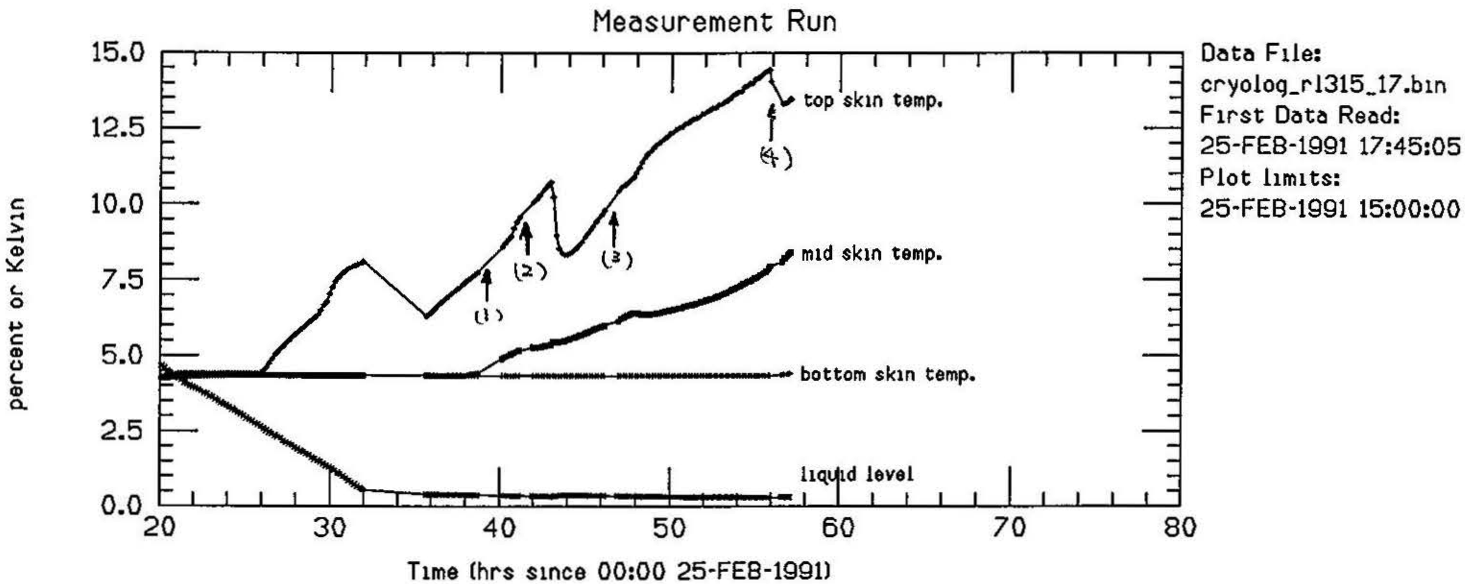
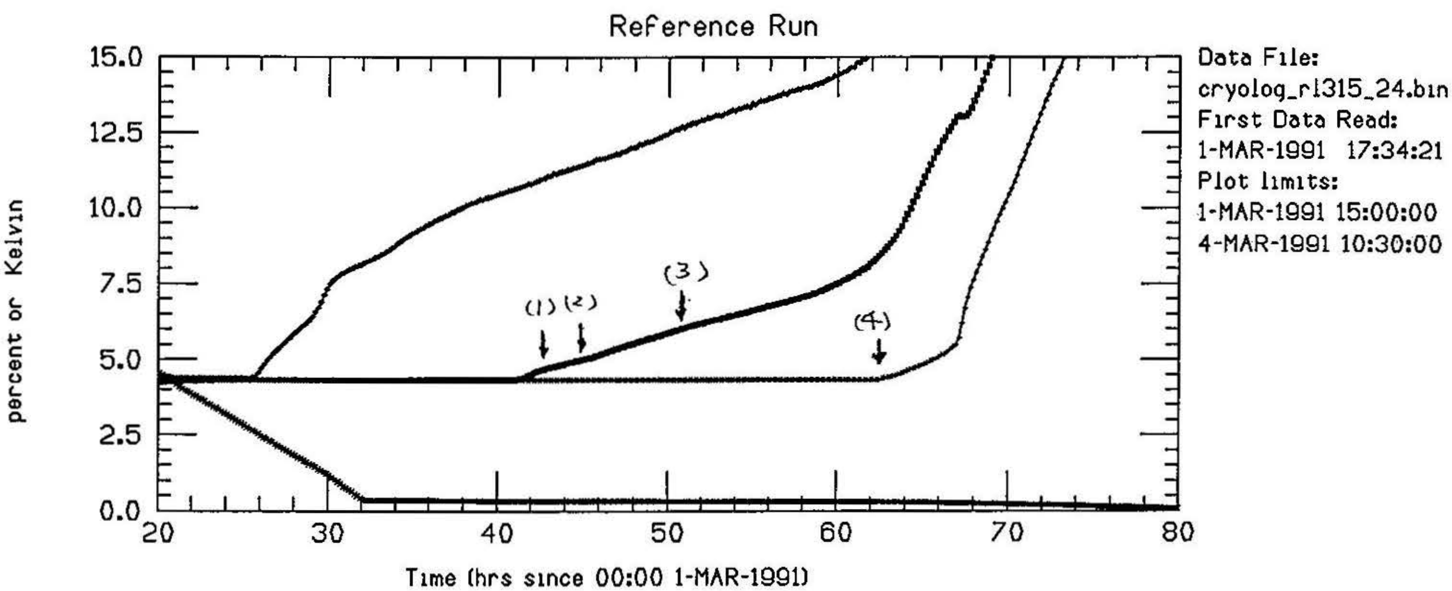


Fig. 5



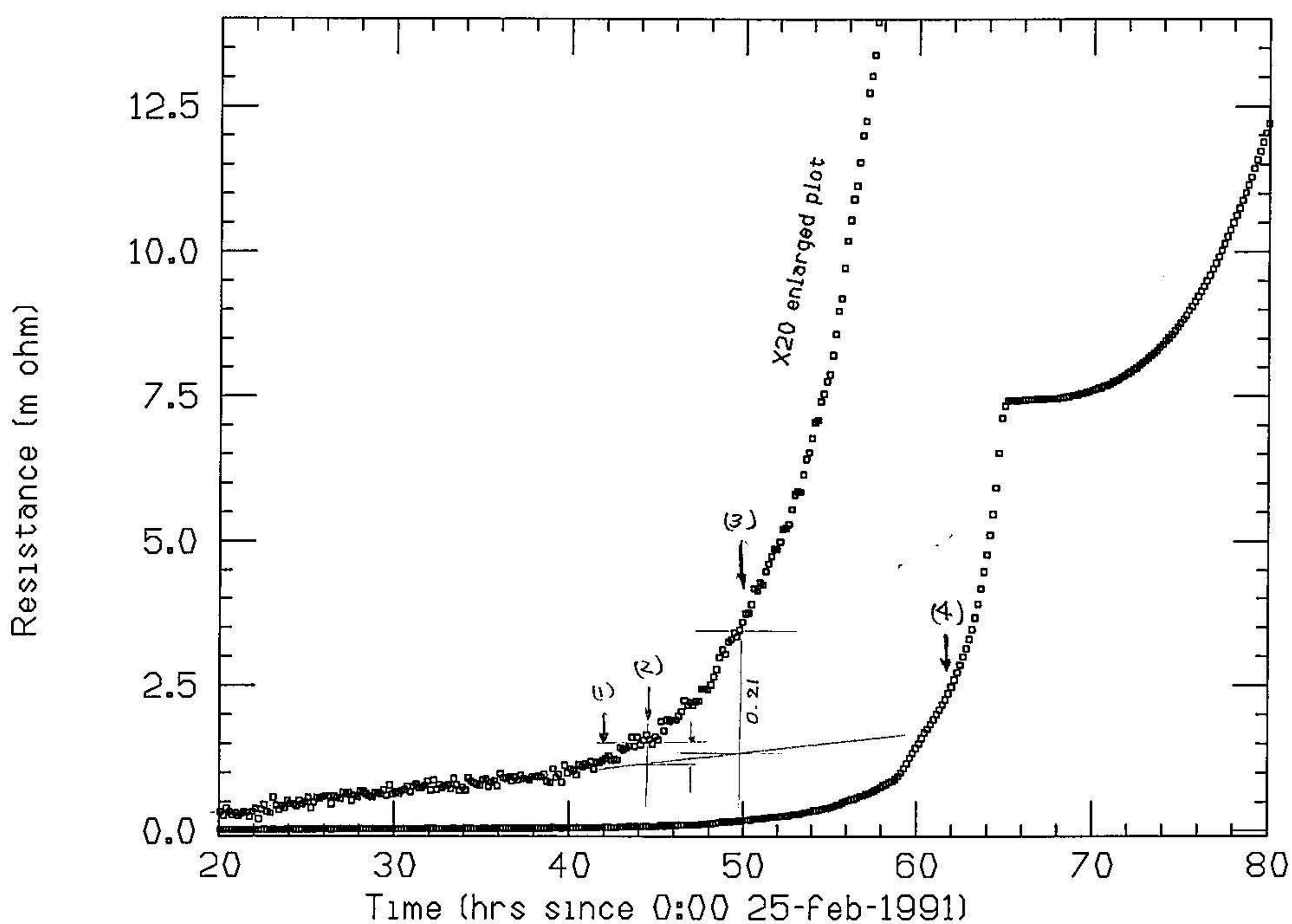
Measurement Run
15.0
12.5
10.0
7.5
5.0
2.5
0.0
percent or Kelvin
20 30 40 50 60 70 80
Time (hrs since 00:00 25-FEB-1991)
top skin temp.
mid skin temp.
bottom skin temp.
liquid level
(1)
(2)
(3)
(4)
Data File:
cryolog_r1315_17.bin
First Data Read:
25-FEB-1991 17:45:05
Plot limits:
25-FEB-1991 15:00:00



Reference Run
15.0
12.5
10.0
7.5
5.0
2.5
0.0
percent or Kelvin
20 30 40 50 60 70 80
Time (hrs since 00:00 1-MAR-1991)
(1)
(2)
(3)
(4)
Data File:
cryolog_r1315_24.bin
First Data Read:
1-MAR-1991 17:34:21
Plot limits:
1-MAR-1991 15:00:00
4-MAR-1991 10:30:00

Fig. 6.

DS0315 resistance change during warm-up



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